

## EFFECTS OF HARVEST MANAGEMENT AND MANURE LEVELS ON CACTUS PEAR PRODUCTIVITY<sup>1</sup>

JOÃO PAULO DE FARIAS RAMOS<sup>2\*</sup>, EDSON MAURO SANTOS<sup>3</sup>, GEORGE RODRIGO BELTRÃO CRUZ<sup>4</sup>,  
RICARDO MARTINS ARAUJO PINHO<sup>5</sup>, POLIANE MEIRE DIAS DE FREITAS<sup>6</sup>

**Abstract** -The aim of this paper was to evaluate the cutting frequency and levels of the manure on cactus forage productivity. The research was conducted at Pendencia Station – The State Agribusiness Research Company of Paraíba, Soledade – PB –Brazil, from August 2008 to August 2010. It was utilized a factorial arrangement 4x5, 4 crop managements (M1= cactus forage harvested at 12 months after establishment; M2= cactus forage harvested at 12 months after the first regrowth; M3= harvested of the accumulated production in 24 months and M4= sum of the first production and regrowth) and five levels of goat manure: 0; 5; 10; 15 e 20 Mg ha<sup>-1</sup>. It was evaluated the fresh matter production (FMP) and dry matter production (DMP), water accumulation, rainfall use efficiency (RUE) and percentage of the water accumulation in the plant. The largest level of organic fertilizer promoted an increase in FMP of 275, 171, 184, 203% and DMP: 305, 175, 223, 218%, respectively, when comparing the highest level of fertilizer with the unfertilized treatment, and an increase in water accumulation 115.60, 102.93, 166.95, 218.53 kg of water ha<sup>-1</sup> when comparing the highest level with the unfertilized treatment. The organic fertilization in M1, M2, M3 and M4 managements, despite of the levels, promoted a linear increase in the RUE. Fertilization increases the cactus forage productivity, and its rainfall use efficiency. The annual cut can be employed as a practice in the management of cactus forage.

**Keywords:** *Opuntiaficus-indica*. Organic fertilization. Rainfall Use Efficiency. Semi-arid.

## EFEITO DO MANEJO DE COLHEITA E DE NÍVEIS DE ESTERCO NA PRODUTIVIDADE DA PALMA FORRAGEIRA

**Resumo** - Objetivou-se avaliar o efeito do manejo de colheita e doses de esterco na produtividade de palma. A pesquisa foi conduzida na Estação Experimental Pendência da Empresa Estadual de Pesquisa Agropecuária da Paraíba, em Soledade - PB, de agosto de 2008 a agosto de 2010. Foi utilizado um delineamento fatorial 4 x 5, sendo 4 manejos de colheita (M1= colheita da palma aos 12 meses no estabelecimento; M2= colheita da palma 12 meses após a primeira colheita na rebrota; M3= colheita da produção de palma acumulada aos 24 meses e M4= somatório da produção da primeira colheita e da rebrota) e cinco doses de esterco caprino: 0; 5; 10; 15 e 20 Mg.ha<sup>-1</sup>. Avaliou-se a produção de massa verde, matéria seca, acúmulo de água, eficiência do uso da chuva e percentual de água acumulada nas plantas. A adubação orgânica com maior dose de esterco promoveu um acréscimo percentual de PMV de 275, 171, 184, 203% e de PMS de 305, 175, 223, 218%, para os manejos M1, M2, M3 e M4, respectivamente, quando se compara a maior dose de adubo com ausência de adubação e um acréscimo no acúmulo de água de 115,60, 102,93, 166,95, 218,53 kg de água ha<sup>-1</sup>, para os manejos M1, M2, M3 e M4, respectivamente, quando se compara a maior dose com ausência de adubação. A adubação orgânica e os M1, M2, M3 e M4, independente das doses, aumentou lineamente a eficiência do uso da chuva (EUC). A adubação incrementa a produtividade e eficiência do uso de água pela palma forrageira. O corte anual pode ser empregado como prática de manejo da palma forrageira.

**Palavras - chave:** *Opuntiaficus-indica*. Adubação orgânica. Eficiência do uso chuva. Semiárido

\*Autor para correspondência

<sup>1</sup>Recebido para publicação em 01/04/2014; aceito em 19/01/2015.

<sup>2</sup>Empresa Estadual de Pesquisa Agropecuária da Paraíba, Caixa Postal 275, 58013-290, João Pessoa-PB, jpemepapb@yahoo.com.br.

<sup>3</sup>Departamento de Zootecnia, Centro de Ciências Agrárias, UFPB, 58397-000, Areia-PB, edsonzootecnista@yahoo.com.br.

<sup>4</sup>Departamento de Agropecuária – Centro de Ciências Humanas Sociais e Agrárias, UFPB, 58220-000, Bananeiras-PB, georgebeltrao@hotmail.com.

<sup>5</sup>Universidade Federal da Paraíba, Centro de Ciências Agrárias, Programa de Doutorado Integrado em Zootecnia, 58397-000, Areia-PB. Areia-PB, ricardo-zootec@hotmail.com.

<sup>6</sup>Universidade Federal da Bahia, Escola de Medicina Veterinária e Zootecnia, Programa de Pós-Graduação em Ciência Animal nos Trópicos, 40170-110, Salvador, Bahia, polianemeire@hotmail.com.

## INTRODUCTION

Animal exploration is one of the most important options for the primary sector of the Brazilian Semiarid region (BS). It is one of the main factors that ensure the food security to rural families, the creation of job opportunities, and income in the region. However, the development of this activity is influenced by the temporal variability of rainfall, due to the seasonality of forage production. Thus, low carrying capacity of cultivated native pastures entails nutrient deficiency in animals, in periods of the year, being one major limitation of livestock. Therefore, it should be considered the use of xerophilous pasture on herd feeding, in most parts of this region.

In this context, the cultivation of cactus pear (*Opuntia ficus-indica*) in the BS region constitutes a potential food source for animals during the dry season in the Semiarid region (TEGEGNE et al., 2007). Furthermore, the high water level in cactus pear represents an important alternative to supply water requirements of animals in arid and semi-arid regions, mainly during the dry season (COSTA et al., 2009).

The cactus pear is a cactaceous with a greater potential for use in the Brazilian Northeast region, becoming an important forage resource during drought periods, due to its high potential for phytomass production in semiarid environmental conditions (SILVA et al., 2014; OLIVEIRA et al., 2007). It stands out for being a high nutritional value culture, persistent under drought conditions, with high water use efficiency and widely incorporated into the production process in the region (SALES et al., 2009).

The cactus pear presents a high potential for phytomass production, however, the extraction of soil nutrients by the crop is high (SANTOS et al., 2006), due to the fact that the whole green mass produced is harvested, and offered to the animals. With the continued use of the soil, without nutrient replacement, the production tends to decrease as a result of soil depletion, either by exporting or by the loss of nutrients by erosion.

Agricultural productivity of the soil is highly correlated to its fertility, defined as the ability of soil to provide nutrients to the plant in balanced and required quantities, in order to promote plant development. If other factors are essential and complementary, such as moisture, light and temperature, they work in conjunction with fertility (SILVA et al., 2010).

The level of fertilization is a determining factor in the production of fresh matter. According to Teles et al. (2002), phosphorus deficiency reduced the total number of cladodes in the spineless cactus plant; which is a limiting factor for this forage productive capacity. On the other hand, it was found that the addition of nitrogen promoted an increase in the total number of cladodes per plant. Data from

Ramos et al. (2011) report to the production of 130 Mg.ha<sup>-1</sup> of fresh matter (FM) in harvests performed in one and a half year after planting, under rainfed conditions in the semi-arid region of Paraíba.

The intensification of goat and bovine milk production systems in Cariri, Paraíba, which feeding basis for these animals is the cactus pear, it is necessary to define a production of this crop in order to increase the productivity, especially on harvest management, usually performed from three to four years after planting.

Thus, the objective of this experiment was to evaluate the effect of harvest frequency, and organic fertilization on yield and rainfall use efficiency by cactus plants.

## MATERIAL AND METHODS

The experiment was conducted under field conditions at Pendencia Experimental station, part of the State Agribusiness Research Company of Paraíba (EMEPA), located in the Agreste region (sub-humid), Paraíba, microregion of the western Curimataú, city of Soledad (7° 8 '18 "S and 36 ° 27 '2 "W), at an altitude of 534 m. The climate type of the region is Bsh, semi-arid hot, with rainfall occurrence from January to April, with average temperatures around 24 °C, relative humidity around 68%, average rainfall of 400 mm per year, with drought almost the whole year (SUDENE, 2003).

Before planting, and at harvest time, soil samples representative of the experimental area at a depth of 0-20 cm for the characterization of soil fertility, were collected. Chemical analysis of soil and goat manure was conducted at the UFPB laboratory, in the city of Areia, using the methodology described by Embrapa (2006). The soil samples presented the following chemical characteristics: pH (H<sub>2</sub>O): 6.24; K: 151.82 (mg.dm<sup>-3</sup>); P: 49.60; Ca: 7.45; Mg: 2.95; H+Al<sup>3+</sup>:4.87; Na: 0.34 (cmol<sub>c</sub>/dm<sup>-3</sup>); CTC: 16.00 e MO: 9.25 (g.kg<sup>-1</sup>).

It was used a randomized blocks experimental design, in 4x5 factorial arrangement, with four harvest managements: M1 = cactus pear harvest at 12 months after planting; M2 = cactus pear harvest at 12 months after the first harvest; M3 = cactus pear harvest at 24 months after planting; M4 = sum of the output of the first harvest and regrowth; and five goat manure levels (0, 5, 10, 15, 20 Mg.ha<sup>-1</sup>), with four replications, totaling 20 experimental unit. The amount of organic matter added in this experiment were 0, 46.25, 92.50, 138.75 and 185.00 kg for the goat manure levels (0, 5, 10, 15, 20 Mg.ha<sup>-1</sup>), respectively.

The experimental unit consisted of four rows with five cactus pear plants each, planted with a 1.5 mx 0.20 m spacing. The useful area was composed of three central plants.

The planting of cactus pear cv. "Gigante"

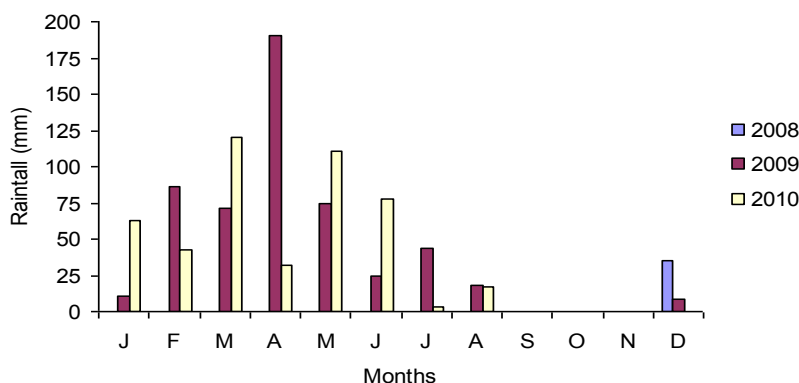
occurred in August 2008, with a cladode per hole, in the vertical position, with the cut side facing the ground, deep enough for half of the cladode to stay buried. The organic fertilization was carried out in coverage, at the time of planting and after the first harvest, with tanned goat manure, according to the pre-established treatments. The weeding was made, when necessary, during the emergence of weeds.

To determine the fresh matter production (FMP), it was performed the cutting of plants at each harvest, preserving the primary cladodes on each plant, in order to maintain the stand. The sectioned cladodes were weighed, obtaining the total weight of each plant. It was considered the average weight of the plants in the plot. That weight was multiplied by the number of plants in the stand in a hectare, result-

ing in the FMP per hectare ( $\text{Mg}\cdot\text{ha}^{-1}$ ). It was determined the dry matter content (DM) through a drying process in an oven at  $65\text{ }^{\circ}\text{C}$  until constant weight was obtained. The dry matter production (DMP) was determined by multiplying the FMP by DM content.

The rainfall use efficiency (RUE) was estimated by dividing the DMP by the amount of rain accumulated during the growth period. The water accumulation was calculated by subtracting the FMP by DMP.

Figure 1 presents the rainfall occurred at Pendencia Experimental Station, from August 2008 to August 2010. A total of 1029.7 mm distributed in 2008 (35 mm), 2009 (528.30), and 2010 (466, 4 mm).



**Figure 1.** Rainfall occurred at Pendencia Experimental Station, Soledade-PB, from August 2008 to August 2010.

The data were subjected to analysis of variance. When there was interaction between the two factors, it was chosen to split the analysis of variance. The mean values of production in different management systems were compared by Tukey test at 5% significance level. The fertilization effect was analyzed by linear regression, adopting as a criterion for models choosing the significance of the regression parameters by Student's *t* test at 5% significance level, as well as the determination coefficients. It was used the system of statistical and genetic analysis (SAEG).

## RESULTS AND DISCUSSION

Data on rainfall from August 2008 to August 2010 (Figure 1), show high variability affecting the monthly water availability for the culture under study. The vegetative growth of cactus pear and other plants are strongly related to soil water content, due to the fact that the main physiological and biochemical processes are dependent on water, such as photosynthesis, respiration, transpiration, and ab-

sorption of nutrients (Sampaio, 2005).

It was found that the effects of harvest management, manure rates, and their interaction were significant ( $P < 0.05$ ) on FMP and DMP. Decomposing the effects of harvesting management in each dosage of organic fertilizer, it was observed that the FMP and DMP increased linearly with the organic fertilizer in the soil, in all crop managements adopted. There were also differences between the collection managements in all manure dosages. It should be noted, based on the high coefficients of determination, that most of the cactus pear forage yield is due to the fertilization (Table 1 and 2).

The organic fertilization with a higher dosage of manure promoted an increase in FMP of 275, 171, 184, 203%, and DMP of 305, 175, 223, 218% for M1, M2, M3, and M4 managements, respectively, when compared to the highest dosage of the unfertilized crop (Table 1 and 2). Possibly, this increase is related to the increase in stocks of organic carbon and total nitrogen, allowing greater root penetration and distribution, increased levels of aggregation, aeration, infiltration capacity, and soil water storage (LEITE et al., 2003).

**Table 1.** Fresh Matter Production (FMP) of pear cactus according to organic manure and crop managements.

	Manure Rates (Mg.ha <sup>-1</sup> )					CV(%)
	0	5	10	15	20	
M <sup>1</sup>	70,45b	99,63b	113,13c	143,54c	194,26b	9,28
M <sup>2</sup>	155,97a	211,8ab	196,71bc	223,58bc	266,92b	8,89
M <sup>3</sup>	216,25a	311,44a	233,07ab	319,96ab	400,27a	17,24
M <sup>4</sup>	226,42a	329,36a	309,85a	367,12a	460,59a	10,19

\* Significant by Student's t test (P < 0.05)

Means followed by same letter in column do not differ significantly by Tukey test at 5% probability

CV= coefficient of variation

M<sup>1</sup> cactus harvested at 12 months after planting

M<sup>2</sup> cactus harvested at 12 months after the first harvest on the regrowth

M<sup>3</sup> harvest of the accumulated production at 24 months

M<sup>4</sup> sum of the output of the first harvest and regrowth

Regression

R<sup>2</sup>

$${}^1\hat{Y} = 65,8996 + 5,8307 * X \quad 0,95$$

$${}^2\hat{Y} = 164,3828 + 4,6498 * X \quad 0,84$$

$${}^3\hat{Y} = 228,0590 + 7,1730 * X \quad 0,57$$

$${}^4\hat{Y} = 230,2824 + 10,4805 * X \quad 0,92$$

Considering the organic fertilizer into the soil management, it was observed that the addition of manure at a dosage of 5 Mg.ha<sup>-1</sup> in M1, and M2 increased significantly the FMP and DMP in 70, and 73%, respectively. However, the FMP and DMP achieved, in the absence of organic fertilization in all harvest managements were very low, showing, among other factors, the importance of correcting soil nutrients in order to increase the rate of forage accumulation in cactus pear (Table 1 and 2).

Menezes et al. (2002), evaluating the cactus pear productivity in various locations in Pernambuco and Paraíba, observed the FMP values of 204 Mg.ha<sup>-1</sup>, considering, the average production in 33 months. These values of productivity correspond to any biomass produced by the cactus, including all primary cladodes, unlike the results found in the present paper, which, at the time of cutting and harvesting of shoots to obtain FMP, preserved the primary cladodes on each plant, reducing the average productivity of treatments.

The average results found in this study for DMP was 22,30 Mg.ha<sup>-1</sup> (Table 2), at the highest

dosage of manure, regardless of harvesting management, are higher than those related by Silva et al. (2010), who studied the productivity of two-year cactus pear clones, with 30 Mg.ha<sup>-1</sup> of bovine manure, obtained DMP of 7.1 Mg.ha<sup>-1</sup>. Dubeux Jr. e Santos (2005) stated that the use of manure increases the productivity of cactus pear, especially when applied in conjunction with chemical fertilizers.

It can be seen in Table 2 an increase in DMP of 140, 135, 179, 137% at 5 Mg.ha<sup>-1</sup> of manure on M1, M2, M3 and M4 crop managements, respectively, compared to DMP of the cactus without the compost. Possibly, this increase in DMP with the dosage 5 Mg.ha<sup>-1</sup> of manure fertilization demonstrated that it significantly influences the nutrient content of the cactus shoots, as well as increases in the DM content.

Santos et al. (2005), in a research concerning organic and mineral fertilization in cactus pear cv. "Gigante", observed an increase of 81% in DM yield with 10 Mg.ha<sup>-1</sup> of bovine manure and 29% with 50 Mg.ha<sup>-1</sup> of N, and P<sub>2</sub>O<sub>5</sub> when compared to the unfertilized crop.

**Table 2.** Dry Matter Production (DMP) of cactus pear, according to the organic fertilization and crop management.

	Manure Rates (Mg.ha <sup>-1</sup> )					CV(%)
	0	5	10	15	20	
M <sup>1</sup>	3,99b	5,61c	6,16b	8,53b	12,20b	14,22
M <sup>2</sup>	9,86a	13,38bc	13,04ab	14,42b	17,28b	7,76
M <sup>3</sup>	13,18a	23,68ab	14,27ab	21,97a	29,49ab	26,28
M <sup>4</sup>	13,85a	19,00a	19,20a	22,96a	30,26a	9,75

\* Significant by Student's t test (P < 0.05)

Means followed by same letter in column do not differ significantly by Tukey test at 5% probability

CV= coefficient of variation

M<sup>1</sup> cactus harvested at 12 months after planting

M<sup>2</sup> cactus harvested at 12 months after the first harvest on the regrowth

M<sup>3</sup> harvest of the accumulated production at 24 months

M<sup>4</sup> sum of the output of the first harvest and regrowth

Regression

R<sup>2</sup>

$${}^1\hat{Y} = 3,4340 + 0,3879 * X \quad 0,92$$

$${}^2\hat{Y} = 10,4234 + 0,3177 * X \quad 0,88$$

$${}^3\hat{Y} = 14,1873 + 0,6489 * X \quad 0,53$$

$${}^4\hat{Y} = 13,8574 + 0,7048 * X \quad 0,92$$

According to the fertilizer recommendations for the cactus pear in the State of Pernambuco, the dosages vary depending on the spacing, levels of available nutrients in the soil, as well as the phase of the crop (planting and maintenance). In general, the nitrogen is located between 60 and 130 kg N.ha<sup>-1</sup> for populations of 5,000 and 40,000 plants/ha, respectively. Concerning the organic fertilization, the rec-

ommendation is to apply 25 m<sup>3</sup> of bovine manure per hectare after each harvest (IPA, 2001).

As illustrated by the data presented in Tables 1 and 2, it is verified that the FMP and DMP of regrowth (M2) were higher in relation to the ones which occurred at the harvest of M1 crop (Table 1 and 2). The production of regrowth in the cactus pear increases with the number of cuts. This behavior

may be related to the morphology and physiology of the cactus, which can be influenced by climatic conditions and also by the root system already established, facilitating the absorption of water and soil nutrients.

In a simulation of the support capacity (SC) of cactus pear in 1 ha to confine sheep, for a period of 100 days, using the cactus in 70% of the diet, it was contacted a support capacity of 85, 135, 150, 194, and 247 adult sheeps at dosages of 0, 5, 10, 20 10 Mg.ha<sup>-1</sup> of organic manure, respectively (RAMOS et al. 2010). The organic fertilizer boosts the production of the cactus pear, favors the carrying capacity of the area, providing sharp increase in the production per hectare. In Brazilian Semiarid, which presents small farms, this increasing is very important.

Considering data of DMP in corn, sorghum and cactus pear in Pernambuco, Ferreira (2005) points out that this cactus produces more energy per unit area than these two other grasses, with 6.43 Mg.ha<sup>-1</sup>NDT/year, and, respectively, 4.32 and 5.16 for corn and sorghum.

The data found in this study demonstrate the feasibility of application of organic fertilizer in the form of animal manure in the cultivation of cactus pear, most of the time the fertilizer being available in agrarian units of SB. It should be noted, moreover, that because it is perennial forage, with high yield potential, fertilizer use becomes feasible, even in larger doses.

The results show that the cactus can be harvested one or two years after planting, the farmer can choose the cutoff frequency to be adopted in accordance with the need of his herd, which is strongly influenced by the duration and intensity of drought in SB.

It is verified that the accumulation of water increased (P<0.05) linearly with the management of harvest and manure rates (Table 3). The greater availability of nutrients in the soil caused a greater

accumulation of water in the cladodes, possibly resulting in increase in organic reserves and greater persistence conditions to prolonged water deficit. These larger accumulations of water promoted by organic manure can be explained due to the higher growth of the cactus root system associated with a greater number of cladodes presented by the fertilized plants.

The organic fertilization with a higher dosage of manure promoted an increase in the accumulation of water 115.60, 102.93, 166.95, 218.53 kg.ha<sup>-1</sup> of water for the managements M1, M2, M3, and M4, respectively, when comparing the highest dosage with unfertilized crop (Table 3).

A significant amount of water in crop management (average of 308.40 kg.ha<sup>-1</sup>) was stored by the crop at the highest dosage of manure, which could be used as water for animal consumption. Results higher than these ones were found by Leite (2009) for *cv.Italiana*, with chemical and organic fertilization, in Cariri, Paraiba, which accumulated 259,180 kg.ha<sup>-1</sup> of water. This result may be justified by the greater intensity and amount of rainfall that occurred during the experiment.

There was a significant increase (P<0.05) in the accumulation of water with addition of 5 Mg ha<sup>-1</sup> manure in M1 and M2 of 104.41 kg of water per hectare (Table 3).

The presence of the cactus in the diet of ruminants during the dry season help the animals to supply a great amount of the water needed by the body, and it is, often, the only food available during the dry season. Considering the results found in this study, with an average of 308.40 Mg.ha<sup>-1</sup> of water stored by the cactus, fertilized with 20 Mg.ha<sup>-1</sup> of manure, one hectare with this forage would supply the water needs of 168 adult sheeps per year. Santos et al. (2006) defends the fact that the cactus has a high water content represents valuable contribution to its supply to the animals in the SB.

**Table 3.** Accumulation of water (Mg.ha<sup>-1</sup>) in the cactus pear according to the organic manure and crop management.

	Manure rates (Mg ha <sup>-1</sup> )					CV(%)
	0	5	10	15	20	
M <sup>1</sup>	66,45b	94,01b	106,97b	135,00b	182,05b	8,98
M <sup>2</sup>	146,10a	198,42ab	183,61ab	209,16b	249,03b	8,95
M <sup>3</sup>	203,06a	292,4a	218,80ab	297,99ab	370,01a	17,03
M <sup>4</sup>	212,56a	305,68a	290,64a	344,16a	431,09a	9,76

\*Significant by Student's t test (P < 0.05)

Means followed by same letter in column do not differ significantly by Tukey test at 5% probability

CV= coefficient of variation

M<sup>1</sup> cactus harvested at 12 months after planting

M<sup>2</sup> cactus harvested at 12 months after the first harvest on the regrowth

M<sup>3</sup> harvest of the accumulated production at 24 months

M<sup>4</sup> sum of the output of the first harvest and regrowth

Regression

<sup>1</sup>Ŷ= 62,4653 + 5,4443\*X

<sup>2</sup>Ŷ= 153,9594 + 4,3321\*X

<sup>3</sup>Ŷ= 213,8716 + 6,5240\*X

<sup>4</sup>Ŷ= 216,4219 + 9,1747\*X

R<sup>2</sup>

0,96

0,84

0,58

0,92

According to Menezes et al. (2005), another important characteristic of the cactus pear is that it can be stored in the same field, only being taken when necessary, without significant loss of nutrition-

al value.

Nobel (2001) affirms that during the first weeks of the dry season little change is observed in the cactus, reflecting the ability to store water in the

cladodes and the low water requirements inherent in the plants that have the path of crassulacean acid metabolism (CAM). Only after two months it can be seen a small daily loss of CO<sub>2</sub>, because of currently breathing becoming greater than the net photosynthesis. When compared to plants with C3 and C4 metabolism it is observed the wide adaptation of CAM species. It is undeniable that the water content in soil is the main limiting factor for absorption of CO<sub>2</sub> by *Opuntiaficus-indica*.

Water plays a key role in the plant, participating in most biochemical processes essential to life and constituting 80 to 95% of the plant tissue mass. In plants, the water is continuously lost to the atmosphere and absorbed into the soil. For each gram of organic matter produced by the plant, approximately 500 g of water are absorbed by the roots, transported through the plant body, and lost to the atmosphere (TAIZ; ZEIGER, 2004).

The organic fertilization, regardless of the dosage, increased linearly the RUE, with a greater amount of cactus biomass produced per unit of rain precipitated (Table 4). It should be noted also that the water loss through the evapotranspiration process, runoff, and deep drainage, was not taken into

account, contributing to the underestimate of the RUE value.

The organic fertilization with higher dosage of manure promoted an increase in RUE (kg of DM/ha/mm rainfall) of 305, 223, 218, and 255% for the M1, M2, M3, and M4 managements, respectively, when the highest dosage is compared with the no fertilized area, and overall average of 250% (Table 4).

Leite (2009), reports that the greater use of rain water by the cactus pear is due to its anatomical, morphological, and physiological adaptations to the arid and semiarid environments.

Ben Salem and Nefzaoui (2002) reported that the great importance of cactus in arid and semiarid regions is its high RUE to convert water into dry matter, based on its specialized photosynthetic mechanism and the ability of remaining juicy during the dry season, continually producing herbage.

Increments of the RUE, in response to fertilization of cactus pear, are reported in the literature. Dubeux et al. (2006) estimated the average cactus RUE (*Opuntiaficusindica*) cv. IPA20.18 kg of DM/ha/mm of rainfall in the Semiarid region of Pernambuco.

**Table 4.** Rain use efficiency (kg of DM/ha/mm rainfall) for the cactus pear according to the organic manure and crop

	Manure rates (Mg.ha <sup>-1</sup> )					CV(%)
	0	5	10	15	20	
M <sup>1</sup>	7,69b	10,82b	11,87b	16,45b	23,52b	14,22
M <sup>2</sup>	13,13ab	18,92ab	14,22b	21,88ab	29,37ab	20,22
M <sup>3</sup>	13,80ab	23,58a	19,13ab	22,88ab	30,14ab	17,22
M <sup>4</sup>	20,82a	29,44a	26,89a	38,33a	52,52 <sup>a</sup>	15,69

\* Significant by Student's t test (P < 0.05)

Means followed by same letter in column do not differ significantly by Tukey test at 5% probability

CV = coefficient of variation

M<sup>1</sup> cactus harvested at 12 months after planting

M<sup>2</sup> cactus harvested at 12 months after the first harvest on the regrowth

M<sup>3</sup> harvest of the accumulated production at 24 months

M<sup>4</sup> sum of the output of the first harvest and regrowth

Regression

R<sup>2</sup>

$${}^1\hat{Y} = 6,6165 + 0,7458 * X \quad 0,92$$

$${}^2\hat{Y} = 21,4900 + 0,6552 * X \quad 0,88$$

$${}^3\hat{Y} = 14,1315 + 0,6463 * X \quad 0,53$$

$${}^4\hat{Y} = 13,8026 + 0,7018 * X \quad 0,92$$

When the plant is subjected to drought stress, it occurs in its inside, a series of biochemical reactions trying to overcome the situation. Nobel and Zutta (2008) reported that there is evidence of chemical signals from the roots of cactus that act directly on the dynamic behavior of the stomata, under conditions of water deficit in the soil. In addition, the water deficit stimulates the expansion of the root system to deeper and wet areas of the soil profile.

It can be seen in Table 5, that, there has been an increasing in the percentage of water accumulated by the cactus in relation to the total of rainwater when increased the manure levels, and intensified the harvesting management.

The organic fertilization with a higher manure dosage promoted a higher percentage of water accumulated by the cactus of 270, 179, 182, and 201, for the management M1, M2, M3, and M4, respectively,

when comparing the highest dosage with the unfertilized one. The highest percentage obtained was 270 in the M1 harvest (Table 5). These data corroborate with the proposition of Inglese (1995), who stated that in high density planting, the cactus should be harvested annually to avoid self shading and also to reduce the infestation by the carmine cochineal *Dactylopius sp.*

The evolutionary process of CAM plant photosynthesis results in greater efficiency in water use compared to C3 plants, which can be measured as the ratio between the mass of water transpired, and the fixed mass of CO<sub>2</sub> in short-term measures. This greater efficiency allows, in denser farming systems, with the use of fertilizer, a decrease in the cutting frequency of the crop, which also stimulates the regrowth production and may assist in better planning of forage resource use.

**Table 5.** Ratio between the amounts of water accumulated in the plants, and the amounts of rainwater according to the dosages of goat manure and harvesting management.

	Manure Rates (Mg.ha <sup>-1</sup> )					CV(%)
	0	5	10	15	20	
M <sup>1</sup>	12,88b	18,11b	20,61b	26,01b	35,95b	10,28
M <sup>2</sup>	30,12a	40,91a	37,87a	43,12a	51,35a	8,94
M <sup>3</sup>	20,22ab	30,44a	21,79b	29,69b	36,85b	18,56
M <sup>4</sup>	21,17ab	29,12ab	28,95ab	34,27ab	42,93ab	8,27

\* Significant by Student's t test (P < 0.05)

Means followed by same letter in column do not differ significantly by Tukey test at 5% probability

CV= coefficient of variation

M<sup>1</sup> cactus harvested at 12 months after planting

M<sup>2</sup> cactus harvested at 12 months after the first harvest on the regrowth

M<sup>3</sup> harvest of the accumulated production at 24 months

M<sup>4</sup> sum of the output of the first harvest and regrowth

Regression

R<sup>2</sup>

$${}^1\hat{Y} = 11,8635 + 1,0835 * X \quad 0,95$$

$${}^2\hat{Y} = 31,7455 + 0,8931 * X \quad 0,85$$

$${}^3\hat{Y} = 21,3035 + 0,6496 * X \quad 0,57$$

$${}^4\hat{Y} = 21,5570 + 0,9736 * X \quad 0,92$$

## CONCLUSIONS

The organic fertilization increases biomass productivity and rainfall use efficiency by the cactus plant. The linear responses suggest that it is possible to increase the production at higher levels than those shown in this study.

The annual cut can be employed as a management practice for the cactus pear, since the sum of fresh matter production, and dry matter production was greater when adopted the annual harvested.

## REFERENCES

BEN SALEM, H.; NEFZAOU, A. *Opuntia* ssp. – a strategic fodder and efficient tool to combat desertification in the Wana Region. In: MONDRAGON-JACOBO, C.; PÉREZ-GONZALÉZ, S. E. (Ed.) **Cactus (*Opuntia* spp.) as forage**. n. 169. Roma: FAO, 2002. p. 73-90.

COSTA, R. G. et al. Effects of increasing levels of cactus pear (*Opuntia ficus-indica* L. Miller) in the diet of dairy goats and its contribution as a source of water. **Small Ruminant Research**, Amsterdam, v. 82, n. 1, p. 62-65, 2009.

DUBEUX JUNIOR, J. C. B. et al. Adubação mineral no crescimento e composição mineral da palma forrageira—Clone IPA-20. **Revista Brasileira de Ciências Agrárias**, Recife, v. 5, n. 1, p. 129-135, 2010.

DUBEUX JÚNIOR, J. C. B. et al. Productivity of *Opuntia ficus-indica* (L.) Miller under different N and P fertilization and plant population in north-east Brazil. **Journal of Arid Environments**, Amsterdam, v. 67, n. 3, p. 357-372, 2006.

DUBEUX JR., J. C. B.; SANTOS, M. V. F. Exigên-

cias nutricionais da palma forrageira. In: MENEZES, R. S. C.; SIMÕES, D. A.; SAMPAIO, E. V. S. B. **A palma no Nordeste do Brasil: conhecimento atual e novas perspectivas de uso**. Recife: Ed. Universitária da UFPE, 2005. 258 p.

EMPRESA BRASILEIRA DE PESQUISA AGROPECUÁRIA: Solos. Recife: UEP, 2006. Disponível em <<http://www.uep.cnps.embrapa.br/solos/index.html>>. Acesso em: 11 jul. 2011.

FERREIRA, M. A. **Palma forrageira na alimentação de bovinos leiteiros**. Recife: UFRPE, Imprensa Universitária, 2005. 68 p.

IPA. **Racionalização do Cultivo da Palma Forrageira (*Opuntia e Nopalea*) para a Agricultura Familiar do Semi-Árido**. Recife, 2001.

INGLESE, P.; BARBERA, G.; MANTIA, T. L. Research strategies for the improvement of cactus pear (*Opuntia ficus-indica*) fruit quality and production. **Journal of Arid Environments**, Amsterdam, v. 29, n. 4, p. 455-468, 1995.

LEITE, L. F. C. et al. Estoques totais de carbono orgânico e seus compartimentos em argissolo sob floresta e sob milho cultivado com adubação mineral eorgânica. **Revista Brasileira de Ciência do Solo**, Viçosa, v. 27, n. 5, p. 821-832, 2003.

LEITE, M. L. M. V. **Avaliação de clones de palma forrageira submetidos a adubações e sistematização de informações em propriedades do semiárido paraibano**. 2009. 209 p. Tese (Doutorado em Zootecnia) - Centro de Ciências Agrárias, Universidade Federal da Paraíba. Areia, 2009.

MENEZES, R. S. C. et al. Produtividade de palma em propriedades rurais. In: Rômulo S. C. Menezes,

- Diogo A. Simões, Everardo V. S. B. Sampaio. **A palma no Nordeste do Brasil: conhecimento atual e novas perspectivas de uso.** Recife: Ed. Universitária da UFPE, 2005. 258 p.
- MENEZES, R. S. C. et al. Avaliação da produtividade de palma forrageira agrícola familiar no Agreste e Curimataú da Paraíba. In: SILVEIRA, L. M.; PETERSEN, P.; SABOURIN, E. (org.) **Agricultura familiar e agroecologia no Semi-árido: avanços a partir do Agreste da Paraíba.** Rio de Janeiro, ASPTA, 2002. p. 275-280.
- NOBEL, P. S. Biologia ambiental. In: BARBERA, G; INGLESE, P.; PIMIENTA BARROS, E. **Agroecologia, cultivo e usos da palma forrageira.** João Pessoa: FAO, SEBRAE/PB, 2001. p. 36-48.
- NOBEL, P. S.; ZUTTA, B. R. Temperature tolerances for stems and roots of two cultivated cacti, *Nopalea cochenillifera* and *Opuntia robusta*: Acclimation, light and drought. **Journal of Arid Environments**, Amsterdam, v. 72, n. 5, p. 633-642, 2008.
- OLIVEIRA, V. S. et al. Substituição total do milho e parcial do feno de capim-tifton por palma forrageira em dietas para vacas em lactação. Consumo e digestibilidade. **Revista Brasileira Zootecnia**, Viçosa, v.36, n.5, p.1419-1425, 2007.
- RAMOS, J. P. F. et al. Crescimento vegetativo de *Opuntia ficus-indica* em diferentes espaçamentos de plantio. **Revista Caatinga**, Mossoró, v. 24, n. 3, p. 41-48. 2011.
- SALES, A. T. et al. Adaptation potential of cactus pear to soil and climatic conditions of the Semi-Arid in Paraíba State, Brazil. **Acta Horticulturae**, Leuven, v. 811, p. 395-400, 2009.
- SAMPAIO, E. V. S. B. Fisiologia da palma. In: MENEZES, R.S.C.; SIMÕES, D.A.; SAMPAIO, E.V.S.B. (Eds). **A palma no Nordeste do Brasil conhecimento atual e novas perspectivas de uso.** 2. ed. Recife: Editora universitária da UFPE, 2005. p. 43-63.
- SANTOS, D. C.; LIRA, M. A.; DIAS, F. M. Melhoramento genético da palma forrageira. In: MENEZES, R. S. C.; SIMÕES, D. A.; SAMPAIO, E. V. S. B. **A palma no Nordeste do Brasil: conhecimento atual e novas perspectivas de uso.** Recife: Ed. Universitária da UFPE, 2005. 258 p.
- SANTOS, D. C. et al. **Manejo e utilização da palma forrageira (*Opuntia e Nopalea*) em Pernambuco.** Recife: IPA, 2006. 48 p. (IPA. Documento, 30)
- SANTOS, D. C. et al. Níveis de nitrogênio e fósforo em palma forrageira (*Opuntia ficus-indica*) clone IPA-20 sob dois espaçamentos. In: CONGRESSO NORDESTINO DE PRODUÇÃO ANIMAL, 4., 2006, Petrolina. **Anais...** Petrolina:SNPA, 2006. p. 381-383.
- SILVA, C. P. M. et al. Esterco de gado leiteiro associado à adubação mineral e sua influência na fertilidade de um latossolo sob plantio direto. **Revista Brasileira de Ciência do Solo**, Viçosa, v. 34, n. 2, p. 453-463, 2010.
- SILVA, N. G. M. et al. Relação entre características morfológicas e produtivas de clones de palma-forrageira. **Revista Brasileira de Zootecnia**, Viçosa, v. 39, n. 11, p. 2389-2397, 2010.
- SILVA, D. J.; QUEIROZ, A. C. **Análise de alimentos: métodos químicos e biológicos.** 3.ed.Viçosa: Universidade Federal de Viçosa, 2005. 235 p.
- SILVA, T. G. F. et al. Indicadores de eficiência do uso da água e de nutrientes de clones de palma forrageira em condições de sequeiro no Semiárido brasileiro. **Bragantia**, Campinas, v. 73, n. 2, p. 184-191, 2014.
- Superintendência de Desenvolvimento do Nordeste . **O Nordeste Semi-Árido e o Polígono das Secas.** Recife, 2003. Disponível em: < <http://www.sudene.gov.br/nordeste/index.html>>. Acesso em: 6 ago 2011.
- TELES, M. M. et al. Efeitos da adubação e de nematocida no crescimento e na produção da palma forrageira (*Opuntia ficus-indica* Mill) cv. Gigante. **Revista Brasileira de Zootecnia**, Viçosa, v. 31, n. 1, p. 52-60, 2002.
- TEGEGNE, F.; KIJORA, C.; PETERS, K. J. Study on the optimal level of cactus pear (*Opuntia ficus-indica*) supplementation to sheep and its contribution as source of water. **Small Ruminant Research**, Amsterdam, v. 72, n. 2-3, p. 157-164, 2007.
- TURNER, N. C. Agronomic options for improving rainfall-use efficiency of crops in dryland farming systems. **Journal of Experimental Botany**, Oxford, v. 55, n. 407, p. 2413-2425, 2004.
- TAIZ, L.; ZEIGER, E. **Fisiologia Vegetal.** 3.ed. Porto Alegre: Artmed, 2004. 719 p.
- VAN SOEST, P. J. **Nutritional ecology of the ruminant.** 2. ed. New York: Cornell University Press. 476 p, 1994.