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Nutrients demand of cactus forage

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A B S T R A C T

The study aimed to evaluate the efficiency of nutrient use in three cactus forage (CF) cultivars (Opuntia stricta and Nopalea cochenillifera), 365 days after planting under different types of fertilizer in two research sites (Condado and Riachão) of the semi-arid region of Paraiba state, Brazil. The experimental design was a randomized block design with treatments in a factorial scheme (3×4), three cultivars of CF (Orelha de elefante Mexicana; Miúda; Bahiana), and four fertilizer treatment (Control; Manure; Manure with Nitrogen; Mineral fertilization) with four replications. The CF cultivars did not differ significantly in nutrient use. That means of physio-logical efficiency by CF cultivars were 1.62, and 2.36 kg of biomass per kg of nutrient applied in Condado and Riachão, respectively. The efficiency of nutrient recovery was 16% for the Condado, according the following order: K> P> Ca> N> C = Mg and 12% for Riachão: K> P> N> C = Ca = Mg. In the two research sites, the treatment with mineral fertilization significantly increased the efficiency use of N, P and K in comparison to the other treatments. The average for efficiency of nutrient utilization was 25% and 19% for Condado and Riachão, respectively, in the following order for Condado: K> P> N> Ca = Mg> C, and Riachão: K> P> N> C> Mg = Ca. In a CF production system aiming to obtain a yearly harvest cycle, it is necessary to replenish of K and P to maintain the nutritional balance between the soil and CF plant.

Keywords: fertilizer, nutrient uptake, semiarid region, forage management, drylands, Dryland cropping

Introduction

Livestock production chains are one of the major social-economic activities in the semi-arid region of Brazil. Consequently, its activity demands a high input of agricultural supplies (e.g. Feed supplementation and maintenance of soil fertility). Currently, it is estimated that the lands of the semi-arid region of Brazil have one of the highest livestock stocking rates in the world, which make the supply of forage the main challenge to assure the production of milk and meat in the region (Dubeux Jr et al. 2017; Souza et al. 2018).

Usually, most of the semi-arid region Brazil has a rainfall pattern marked by 4 to 5 months (350 – 750 mm) while the remaining months of the year are dry with high evapotranspiration (< 210 mm year^{-1}). Such climatic pattern shortens the option of forage resources to be cultivated in this area. Hence, the cactus forage is one of the most successful food sources for the livestock of Brazil, mainly in the semiarid.

Cactus forage has been cultivated in the Brazilian semi-arid lands almost by 100 years, with an estimated total cultivated area about of 600.000 hectares and an average dry matter biomass productivity higher than 25 Mg ha^{-1}.

Besides the large amount of forage produced in a dry land, the cactus forage is an important source of water, energy, and minerals for the animals.

High productivity of this plant also implicates massive nutrient extraction from the soil, which we addressed in part due to in cut-and-carry operations, that moving the nutrients from the land to the stables, especially in cattle dairy systems without doing the reverse path to the field. However, the extraction of nutrients of the cactus forage varies depending on the cultivar, environmental conditions, and management, especially the fertilization (Dubeux Junior et al. 2017).

Nevertheless, there are only a few studies about nutrient reposition in the soil under cactus forage fields. Overall those few studies reported that this plant increases biomass production significantly under adequate fertilization. Such results in biomass production have been encouraging ranchers to fertilize their cactus forage fields. Most of them fertilize with manure, but without soil fertility diagnosis and technical recommendation (Marques et al. 2017).

Determinate the amount of nutrients extracted from the soil by the cactus during their crop cycle is essential to define the correct nutrient refueling to maintain the equilibrium in the soil-plant system. These determinations are basic steps to establish a fertilization program for the cactus forage (Silva et al. 2016; Donato et al. 2016).

Thus, we aim to evaluate the demand and efficiency of nutrient utilization of the different types of fertilization in three cultivars of Cactus forage in the semiarid of Paraiba state, Brazil.

Material e methods

The experiment was conducted on field condition between 2013 and 2015 in two agrarian reform settlements of the semiarid region of Paraiba State-Brazil: Nova Conquista settlement (6°54’40”S e 37°39’44”W) in the municipality of Condado, and Baixio settlement (6°34’0”S and 35°41’9”) in the municipality of Riachão, which on this research we called: Research site of Riachão and research site of Condado. The soils of the research sites were classified as luvisols and planosol, respectively (EMBRAPA 2013). At the research sites of Condado and Riachão, respectively, the long-term average precipitation was 784 mm (CV = 108%) and 568 mm (CV =76%). The monthly average temperature and precipitation during the experimental period is shown in Figure 1.

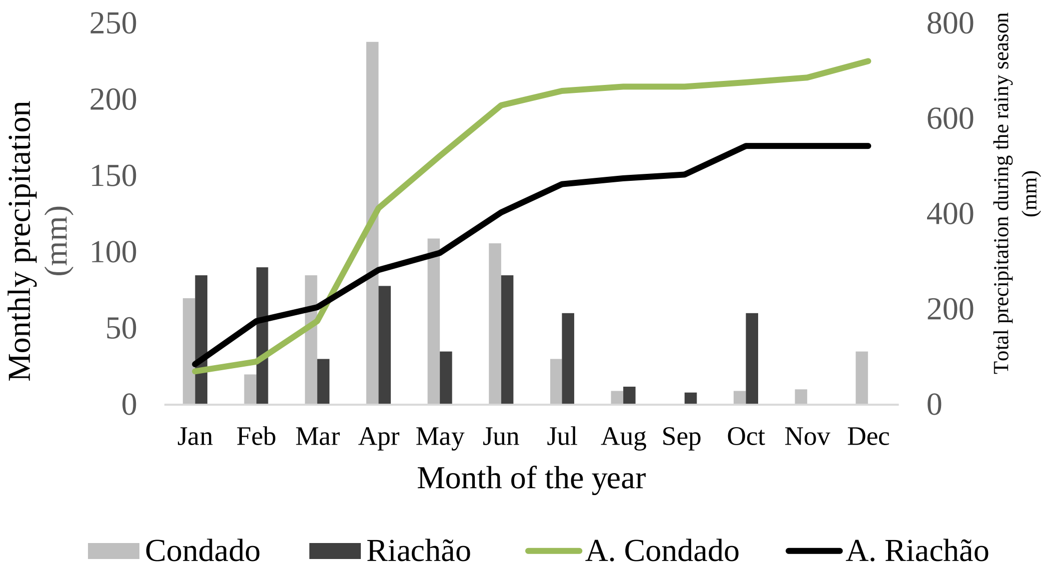

Figure 1. Monthly and accumulated rainfall during the experimental period (one year) in two research sites (Condado and Riacho) at Paraiba state – Brazil which evaluated different sources of fertilizers in three cultivars of opuntia forage (Míuda, bahiana and orelha de elefante).
*The bars represent the monthly rainfall ** The lines represent the rainfall accumulated during the experimental period

The soils were chemically characterized in both researched sites (Table 1) through the collection of 144 soil samples (0-20 cm depth) from each research site. All soil samples were joined forming a composite soil sample of each research site. In the laboratory the soil collected were air-dried (55ºC), crushed and passed through a 2 mm mesh sieve, and then analyzed to determinate the Total Carbon Organic, N, Ca, P, K, and Na according to the methodology described by EMBRAPA (2011).

Each research site consisted of 1 hectare. The experimental design was in randomized blocks with the treatments in a factorial scheme (3 x 4), with four replications. The treatments consisted of the 3 cultivars of cactus forage (*Opuntia stricta* - cultivar Orelha de Elefante Mexicana (POE); *Nopalea cochenillifera* with the cultivars Miuda (PM) and Alagoas (PA)); and four fertilizer treatments (Control = without fertilization; Manure = application of 20 Mg ha^{-1} cow manure, Organic-mineral = application of 10 Mg ha^{-1} cow manure and 40 kg ha^{-1} of Nitrogen; and Mineral fertilization = which followed the recommendation of soil analysis to NPK. The fertilization doses followed the recommendation of the agricultural technical assistance used in the region. As a source of N, P, K were used ammonium sulfate, calcium superphosphate, and potassium chloride, respectively.

The chemical characteristics of the manure used in Condado and Riachão sites were 2,03 e 1,86 of N; 20,92 and 21,95 of C; 1,08 and 1,11 of P; 4,42 and 4,90 of K; 5,09 and 5,27 of Ca and; 2,38 and 2,47 of Mg, respectively. The experiment was divided into four blocks with 3266,3 m^2 each (100,5 × 32,5 m). Each block was subdivided into 12 plots of 260 m2 (35,5 × 8 m), corresponding to 12 treatments (cultivar x fertilizer). The soil preparation consisted of cutting the vegetation, followed by harrowing and then the cactuses were planted burying 1/3 of the cladode mother (± 12 cm). After planting, fertilizers were applied around the cladode mother, and the amount is shown on Table 2.

The cladodes planted were derived from healthy and productive plants from the 3 cultivars of cactus forage, Orelha de elefante (*Opuntia stricta*), Miúda and Bahiana (*Nopalea cocheniliferra*). After harvested, the cladodes were stored under a shaded place for 8 days, allowing the cuts to heal.

After this period, the cladodes were planted in transversal lines to the moderate slope observed in the research field. Such design aims to protect the soil and reduce soil erosion. The planting density was the same for the two sites, double-row with 150 cm between rows and 50 x 50 cm between plants, corresponding to 20.000 plants ha^{-1}. During the experimental period, two manual weedings were allowed, one in the beginning and the other at the end of the rainy season.

365 days after planting (DAP), all cladodes (except the mother cladode) were cut and weighed to determine the green biomass production per hectare. At the same time, a biomass sample of each fertilizer and cultivar experimental plot was taken and weighted. The samples were dried at 57°C until reach constant weight to determine the dry matter biomass (A.O.A.C.,1995). Such results were also reported as kg of dry matter biomass/ha (kg DM ha^{-1}). Samples from dry matter biomass were grounded through a 1-mm diameter screen in a Wiley mill and the levels of C, N, P, K, Ca, and Mg were determinate.

The levels of total C and total N were determined using an elementary analyzer from a subsample 0,1 g of biomass (LECO TRUSPEC-CHN-628). The levels of P, K, Ca and Mg were quantified by X-ray fluorescence using the semi-quantitative EQUA OXIDES method (Kelly et al. 1994). After this, the results of the nutrient analysis were extrapolated to dg per hectare.

With the analysis results and quantity of nutrients applied to the soil, we calculated the physiological efficiency (Dry matter production per unit of nutrient applied. The recuperation efficiency (Amount of nutrient accumulated in the plant per unit of nutrient applied) and utilization efficiency (Amount of nutrient accumulated per unit of nutrient applied) in accordance to the with the protocol described by (Fageria, 1998) which is described in the equation 1, 2 and 3, respectively.

$$PE = \frac{PMSca - PMSsa}{ANca - ANsa} \quad (01)$$

Where:
PE – Physiological efficiency
PMSca – Total dry matter biomass accumulated (Kg) in plots under fertilization
PMSsa - Total dry matter biomass accumulated (Kg) in plots without fertilization
ANca – Total nutrients accumulated (Kg) under fertilization
ANca - Total nutrients accumulated (Kg) without fertilization

$$\Re = \frac{ANca - ANsa}{QNA} \quad (02)$$

where:
RE – Recuperation efficiency
ANca – Amount of nutrients accumulated in plots under fertilization (kg)
ANca - Amount of nutrients accumulated in plots without fertilization (kg)
QNA – Total amount of the nutrient applied

$$UE = PE \times ER \quad (03)$$

Where:
EU – Efficiency of utilization
EF -Physiological efficiency
ER – Efficiency of recuperation

The data for each research site were analyzed separately by ANOVA, and the means were compared by Scott-Knott ($\alpha<0.05$).

Results and discussion

Concentration of nutrients- The concentration of N, C, and P were statistically different in the cactus forage for the research site of Condado (Table 3). Still on this site, overall, the concentration of nutrients in the cultivar Bahiana was on average 15% higher than the observed in the Orelha de elefante and Miúda cultivars. The concentration of C in the cactus forage cultivars decreased in the following order Miúda > Orelha de elefante > Bahiana. In the cultivars, Bahiana and Miúda the concentration of P were 30% higher than Orelha de elefante. The levels of K, Ca, and Mg did not show statistical differences among the cultivars of cactus forage studied (p>0,05).

In the Riachão site, the highest concentration of C was observed in the cultivar Miúda. Inversely, the Ca and Mg levels were higher in the Orelha de elefante and Bahiana cultivars than in Miuda. Still on Riachão site, the concentration of N, P and K did not show statistical differences among cultivars.

Based on the results, we could affirm that the nutrients contained in the Cactus forage varied according to cultivars and location.

Concerning to the type of fertilization, the concentration of C in the treatments with manure + N and, the mineral fertilization were higher than the values observed in the other fertilizer treatments (Table 3). Nitrogen content was, on average, 15% higher in the plots with mineral fertilization when compared to the other fertilizer treatments.

Similar results were reported by Donato et al. (2016) in the *Opuntia ficus-indica* (Cultivar Gigante), suggesting that in the cactus forage, the response for type of fertilization is similar among species. But different from those reported to Mayer and Cushman (2019) that found that in field-grown tissue of O*puntia ficus indic*a the calcium was the most abundant macronutrient at 50 g/kg of dry matter, followed by Mg and N.

Extraction of nutrients

In the Condado research site, the cultivar Miuda demanded more nitrogen and phosphorus, while Orelha de elefante was less demanding of all nutrients analyzed. In the research site of Riachão, the cultivars Orelha de elefante and Bahiana extracted more calcium and magnesium from the soil. Overall, however, the Orelha de elefante was the cultivar which demanded fewer nutrients among the cultivars studied.

The fertilizer treatments did not promote statistical differences among the cultivar of cactus forage in the Condado site. However, the Riachão had differences between fertilization treatments for N, C, and Ca.

In the Condado site the extraction of N, Ca and Mg were different among cultivars (Table 4). The N and Ca were similar between Orelha de elefante and Bahiana but higher than Miúda. Besides that, Orelha de elefante also had the highest Mg extration among all cultivars studied. In the Riachão site the cultivars had differences for exration only for Ca and Mg, where the cultivars Orelha de elefante and Bahiana had higher values than Miúda.

In the Riachão site, the average nutrient extraction of N, C, P, and K were 16.94, 509,8 and 173 Kg ha^{-1}, respectively. Such values correspond to 47 and 62% of the Total N, total C, P available and K exchange in the soil. Overall the values in the Riachão site were lower than those observed in the research site of Condado, probably due to lower biomass accumulated in Riachão.

Previous studies with Cactus forage that evaluated planting density and type of fertilization reported a dry matter biomass accumulation of 10 Mg ha^{-1} in the species *Opuntia ficus-ìndica* cultivar 'Gigante' 600 days after planting (DAP), and the values of extraction varied between 90 and 177 Kg ha^{-1} to N, 11 to 19 kg ha^{-1} to P and 247 to 714 kg ha^{-1} to K (Silva et al. 2016; Donato et al. 2016)

Considering level of extraction of Cactus forage, it is worth to mentioning that to cultivate this forage source without nutrient replacement could increase the chances of drastic and rapid reduction of nutrients in the soil, especially for P and K that do not have a natural replenishment mechanism.

For N and P replacement in the soil can be reached through the use of intercropping cultivation with legumes, we believe that is an alternative to mitigate the deficit of this element in the soil-plant system through biological nitrogen fixation.

Miranda et al. (2019) stated that the intercropping association of cactus forage with tree legumes contributes to an increase in production and nutrient concentration of the *Nopalea cochenilifera* Cultivar Bahiana

Physiological (PE) and Recovery (RE) efficiencies

The variable PE did not differ significantly between the cultivars of cactus forage studied in the two research sites (Table 5). The PE average in the three cultivars was 1.62 and 2.36 kg kg^{-1} of biomass per unit of nutrient accumulated, respectively to the research sites of Condado and Riachão. The RE average was 8% and 4% for N, 5% and 3% for C, 23% and 16% for P, 43% and 42% for K, 9% and

3% for Ca and 5% and 3% for Mg, respectively to the Condado and Riachão sites.

We observed a significant heterogeneity among nutrient recovery between research sites that we addressed in part for the differences between sites in terms of timing and duration of the dry season.

The fertilizer type did not promote a significant effect on PE in both researched sites. However, the RE for the nutrients N and P in the Condado site were 220% and 1272% higher in plants that receive mineral fertilization. In the Riachão site, these results were, even more, staggering for N and P in the plants that receive mineral fertilization, being the values observed 1100 % and 4300% higher than manure + N and manure treatments, respectively.

Still on the Riachão site, the RE of the K nutrient was 38 times higher in the treatment with mineral fertilization in comparison with other fertilizer treatments studied. In contrast, the results of RE for C were higher in the treatments with manure in both researched sites. To the other nutrients studied, Ca and Mg exhibited low RE in both research sites, and they did not show statistical differences among the treatments.

The PE and RE observed in the cactus forage in our study were at least 20 times less efficient than the values reported to C4 forage grass (Junior, 2017). However, for compare this result, we should consider the environmental conditions in which the biomass was produced. Cactus forage is able to provide forage under dry environments.

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Nutrient use efficiency (NUE) - According to Brounder and Volenec (2017) nutrient use efficiency is an integrated indicator of the soil ability to match nutrient supply within the root zone of the plants.

Following the same pattern of PE, in both researched sites the NUE for N, C, P, K, Ca and Mg did not exhibit statistical differences among the cultivars of cactus forage studied (Table 6). The NUE averages were 15% and 9% to N, 7% and 6% to C, 48% and 27% to P, 61% and 63% to K, and 10% and 3% Mg in the researched sites of Condado and Riachão, respectively.

The NUE observed in the cactus forage were higher than the reported for other species of Cactus. For Nitrogen, the NUE found in *Rhipsalis baccifera*, *R. paradoxa* and *Hatiora salicornioides* were 0.2, 0.15 and 0.75 kg kg^{-1}. Respectively. But lower than the average of C4 forage species (0.35 kg kg^{-1}) (Silva, 2017).

For the fertilizer treatments, the NUE values observed for N, P and K were higher with the mineral fertilizer treatment when compared with the others studied. In the Condado site the treatments with mineral fertilizer, exhibited high values to N, P and K in comparison to the other fertilizer treatments studied. The research site of Riachão showed the same tendency for the NUE. withe no statistical differences for the nutrients C, Ca and Mg among the fertilizer treatments evaluated.

Cactus forage differs the NUE according to type of fertilizer. Thus, our results suggest that the type of fertilizer and the amount of nutrient applied influences the NUE. The mineral fertilization treatment promoted a better NUE among the fertilizer treatments evaluated.

As reported for grass forages species by Druille et al. (2019), mineral fertilization increased NUE. This state is well known in grasses where the magnitude of this response was positively correlated with N and P doses. A positive effect of N fertilization on NUE enhance the partitioning to shoots rather than roots.

In Cactus forage the fertilization often increases the N content in the cladodes (Dubeux Junior et al., (2017). Currently has a lack of response of NUE in forage species under dry environments conditions, the few reports existing suggests that limited in water availability imposes a less nutrient use efficiency in the plants. Under water stress, the plants closure their stomatal, reducing the water loss via transpiration, consequently a downregulation of photoassimilation rates.

In terms of NUE, the fertilization with manure showed to be less efficient than the mineral fertilizer. According to Miranda (2019), soils with low water availability often occur a stagnation in the process of mineralization of the organic matter, becoming less available the nutrients for the plant. This phenomenon can causes a desynchronization between the nutritional demand of the plant and its growth cycle, affecting the NUE.

Conclusion

The cultivars of cactus forage commonly cultivated in the semi-arid areas of Brazil do not differ in nutrient use. Overall, the physiological efficiency in the three cultivars was on average 1.99 kg of biomass per kg of nutrient applied in the soil, and the recovery efficiency of nutrient was on average 14 %, following the order of demand K>P>Ca>N>C=Mg. Thus, in a cultivation system aiming to harvest the biomass in the first year it is necessary to replenish of K and P to maintain the nutritional balance of the soil-plant system.

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Table 1. Chemical attributes of the luvisols (Condado site) and plansoils (Riacão site) at-0-20 cm depth, cultivated with cactus forage.

Municipality	COT	pH	P	Ca^{+2}	Mg^{+2}	K^{+}	Na^{+}	Al^{+3}	H+Al	V
	g kg^{-1}	H_2O	mg dm^{-3}		---------------------	$cmo_c dm^{-3}$	--------------------			%
Riachão	1.03	6.60	10.12	6.10	0.00	0.36	0.05	0.74	0.78	89.3
Condado	2.05	6.50	8.98	8.98	0.00	0.27	0.05	0.00	1.27	88.0

Table 2. Amount of nutrients applied in the soil to each treatment (fertilization) and research sites (Condado and Riacho) in the semiarid of Paraiba state – Brazil.

Treatments	Amount applied (kg ha^{-1})					
	N	C	P	K	Ca	Mg
Manure – Condado	405.8	4183.2	216.0	884.0	1018.0	476.0
Manure – Riachão	371.2	4389.6	222.0	980.0	1054.0	494.0
Manure and Nitrogen – Condado	242.8	2091.6	108.0	442.0	509.0	238.0
Manure and Nitrogen – Riachão	225.5	2194.8	111.0	490.0	527.0	247.0
Mineral fertlization (NPK)	100.0	0	8.7	82.9	0	0

Table 3**.** Concentration (g $^{kg-1}$) of nitrogen (N), carbon (C), phosphorus (P), potassium (K), calcium (Ca) and magnesium (Mg) in plants of three cultivars of cactus forage (Míuda, bahiana and orelha de elefante) under different sources of fertilizers in two research sites (Condado and Riacho) in the semiarid of Paraiba state – Brazil.

Treatments	N	C	P	K	Ca	Mg
	----------------------------------		g kg^{-1}		----------------------------------	
Cultivars			Condado - Luvisols			
Orelha de elefante	15.3 b	353.0 b	4.00 b	98.8 a	140.6 a	41.1 a
Miúda	14.1 b	361.6 a	5.34 a	105.8 a	129.4 a	36.2 a
Bahiana	17.0 a	344.6 c	6.33 a	104.8 a	144.4 a	36.5 a
Fertilizer						
Control	14.2 a	351.5 a	5.01 a	95.4 a	139.9 a	39.4 a
Manure	15.6 a	351.8 a	5.32 a	118.3 a	145.9 a	36.6 a
Manure + N	15.3 a	353.2 a	5.26 a	98.4 a	134.9 a	39.7 a
Mineral fertlization (NPK)	16.7 a	355.7 a	5.47 a	100.4 a	131.8 a	36.1 a
Varieties			Riachão – Planosols			
Orelha de elefante	11.5 a	356.8 b	5.81 a	10.75 a	12.29 a	4.29 a
Miúda	12.7 a	362.3 a	7.45 a	12.90 a	10.99 b	3.47 b
Bahiana	11.9 a	354.3 b	6.42 a	12.12 a	12.61 a	4.04 a
Fertilizer						
Control	12.7 a	356.5 b	6.74 a	12.62 a	13.07 a	3.98 a
Manure	10.6 b	351.9 b	8.23 a	11.61 a	12.38 a	4.31 a
Manure + N	11.7 b	359.7 a	6.41 a	11.56 a	11.73b	3.80 a
Mineral fertlization (NPK)	13.2 a	363.1 a	4.85 a	11.90 a	10.68 b	3.64 a

Means followed by different letters in the column are significantly different according to Scott-Knott.

Table 4. Extraction of nitrogen (N), carbon (C), phosphorus (P), potassium (K), calcium (Ca) and magnesium (Mg) of three cultivars of cactus forage (Míuda, bahiana and orelha de elefante) under different sources of fertilization in two research sites (Condado and Riacho) at Paraiba state – Brazil.

Treatments	MS	N	C	P	K	Ca	Mg
	t ha^{-1}	--- kg ha^{-1}-----------------------------					
Cultivars				Condado - Luvisols			
Orelha de elefante	4.21 a	65.05 a	1490.42 a	17.13 a	421.88 a	588.81 a	172.39 a
Miúda	3.31 a	46.96 b	1197.01 a	17.76 a	351.78 a	429.10 b	119.86 b
Bahiana	3.73 a	64.51 a	1287.18 a	24.67 a	399.99 a	535.65 a	131.05 b
Fertilizer							
Control	3,64 a	54,67 a	1279,44 a	20,10 a	365,05 a	504,53 a	138,12 a
Manure	3,94 a	62,45 a	1386,98 a	21,11 a	464,84 a	570,64 a	142,69 a
Manure + N	3.68 a	56.44 a	1305.33 a	18.61 a	360.75 a	498.95 a	147.69 a
Mineral fertilization (NPK)	3.73 a	61.80 a	1327.73 a	19.60 a	374.23 a	497.29 a	135.89 a
Cultivar				Riachão – Planosols			
Orelha de elefante	1.68 a	18.70 a	599.94 a	10.65 a	182.67 a	206.41 a	67.67 a
Miúda	1.13 a	14.45 a	413.86 a	8.90 a	155.71 a	123.09 b	38.63 b
Bahiana	1.44 a	17.67 a	515.65 a	8.89 a	181.53 a	179.07 a	56.61 a
Fertilizer							
Control	1.08 b	14.11 b	387.17 b	7.92 a	142.55 a	141.00 a	42.29 a
Manure	1.21 b	12.68 b	425.21 b	10.73 a	146.80 a	152.84 a	52.14 a
Manure + N	1.41 b	16.00 b	511.38 b	9.24 a	164.16 a	167.99 a	53.74 a
Mineral fertilization (NPK)	1.96 a	715.50 a	715.50 a	10.03 a	239.71 a	216.26 a	69.03 a

Means followed by different letters in the column are significantly different according to Scott-Knott.

Table 5. Physiological (PE) and Recovery (RE) efficiencies of Nitrogen (N), carbon (C), phosphorus (P), potassium (K), calcium (Ca) and magnesium (Mg) contend in three cultivars of opuntia forage (Míuda, bahiana and orelha de elefante) under different sources of fertilization in two research sites (Condado and Riacho) at Paraiba state – Brazil.

Treatments	PE	Recovery efficiency (RE)					
		N	C	P	K	Ca	Mg
	DM kg fertilizer[1] accumulated	---------------------------------kg kg-----------------------					
Cultivars		Condado - Luvisols					
Orelha de elefante	1.39 a	0.07 a	0.05 a	0.11 a	0.32 a	0.10 a	0.05 a
Miúda	2.06 a	0.05 a	0.03 a	0.30 a	0.18 a	0.02 a	0.04 a
Bahiana	1.41 a	0.13 a	0.08 a	0.28 a	0.80 a	0.15 a	0.05 a
Fertilizers							
Manure	1.41 a	0.05 b	0.07 a	0.04 b	0.19 a	0.14 a	0.05 a
Manure + N	1.42 a	0.04 b	0.09 a	0.05 b	0.15 a	0.13 a	0.10 a
Mineral fertilization (NPK)	2.03 a	0.16 a	0.00 b	0.61 a	0.95 a	0.00 b	0.00 a
Cultivars		Riachão – Planosols					
Orelha de elefante	1.39 a	0.03 a	0.03 a	0.25 a	0.40 a	0.03 a	0.04 a
Miúda	1.82 a	0.05 a	0.02 a	0.16 a	0.48 a	0.03 a	0.02 a
Bahiana	3.87 a	0.05 a	0.03 a	0.08 a	0.38 a	0.02 a	0.02 a
Fertilizer							
Manure	4.11 a	0.00 b	0.02 b	0.02 b	0.03 b	0.03 a	0.03 a
Manure + N	1.16 a	0.01 b	0.06 a	0.02 b	0.06 b	0.06 a	0.05 a
Mineral fertilization (NPK)	1.82 a	0.11 a	0.00 b	0.45 a	1.18 a	0.00 a	0.00 a

Means followed by different letters in the column are significantly different according to Scott-Knott.

Table 6. Efficiency of use of Nitrogen (N), carbon (C), phosphorus (P), potassium (K), calcium (Ca) and magnesium (Mg) contend in three cultivars of opuntia forage (Míuda, bahiana and orelha de elefante) under different sources of fertilizers in two researched sites (Condado and Riacho) at Paraiba state – Brazil.

Treatments	N	C	P	K	Ca	Mg
	------------------------------------		kg kg^{-1}		-----------------------------------	
Cultivars			Condado - Luvisols			
Orelha de elefante	0,12 a	0,06 a	0,19 a	0,49 a	0,10 a	0,05 a
Miúda	0,15 a	0,07 a	0,78 a	0,27 a	0,02 a	0,18 a
Bahiana	0,19 a	0,09 a	0,47 a	1,07 a	0,17 a	0,06 a
Fertilizers						
Manure	0,07 b	0,10 a	0,05 b	0,24 b	0,16 a	0,08 b
Manure + N	0,05 b	0,12 a	0,05 b	0,13 b	0,13 a	0,22 a
Mineral fertilization (NPK)	0,34 a	0,00 b	1,33 a	1,46 a	0,00 a	0,00 b
Cultivars			Riachão – Planosols			
Orelha de elefante	0,05 a	0,04 a	0,40 a	0,56 a	0,03 a	0,04 a
Miúda	0,09 a	0,02 a	0,27 a	0,72 a	0,02 a	0,03 a
Bahiana	0,12 a	0,13 a	0,13 a	0,61 a	0,04 a	0,03 a
Fertilizers						
Manure	0,04 b	0,11 a	0,03 b	0,04 b	0,04 a	0,04 a
Manure + N	0,03 b	0,08 a	0,03 b	0,06 b	0,06 a	0,06 a
Mineral fertilization (NPK)	0,19 a	0,00 a	0,75 a	1,79 a	0,00 a	0,00 a

Means followed by different letters in the column are significantly different according to Scott-Knott.