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MORPHOLOGICAL AND PRODUCTIVE CHARACTERIZATION OF FORAGE CACTUS VARIETIES[1]

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ABSTRACT - Cultivars of the genus *Nopalea* are known in Brazil for being tolerant to cochineal carmine attacks, thus making the cultivation of this genus a promising alternative for mitigating the negative effects of this insect on the production of biomass. With the objectives of characterizing morphologically spineless forage cactus varieties and identify morphological characteristics that may be the focus in spineless forage cactus breeding programs, an experiment was conducted in a completely randomized block design with 11 treatments and four replications. The variety Alagoas showed the highest values of weight, area and volume of cladodes. The varieties Negro Michoacan F7 and V7, Tamazunchale V12 showed the highest values of the cladode area index, the total volume of cladodes and total fresh mass production. The varieties Negro Michoacan V7 and F7 presented the highest water use efficiency and dry mass yield. Cladode volume showed the highest correlation coefficients with the fresh weight of cladodes. Aiming the release of varieties for biomass production, varieties Negro Michoacan F7, V7 and Tamazunchale V12 may substitute the Miúda variety. The number and cladode area index may be used as criteria for selection of superior varieties in breeding programs.

Keywords: Cladodes. Correlations. Dry mass yield. *Nopalea cochenillifera*.

CARACTERIZAÇÃO MORFOLÓGICA E PRODUTIVA DE VARIEDADES DE PALMA FORRAGEIRA

RESUMO - Cultivares do gênero *Nopalea* são conhecidos no Brasil por serem tolerantes ao ataque cochonilha carmim, tornando o cultivo desse gênero uma alternativa promissora para mitigar os efeitos negativos deste inseto sobre a produção de biomassa. Com o objetivo de caracterizar morfologicamente variedades de palma forrageira e identificar características morfológicas que podem ser o foco em programas de melhoramento genético, um experimento foi conduzido em delineamento de blocos casualizados com 11 tratamentos e quatro repetições. A variedade Alagoas apresentou os maiores valores de peso, área e volume de cladódios. As variedades Negro Michoacan F7 e V7, Tamazunchale V12 apresentaram os maiores valores de índice de área cladódio, volume total de cladódios e produção total de massa fresca. As variedades Negro Michoacan V7 e F7 apresentaram maior eficiência do uso de água e produção de massa seca. O volume de cladódios apresentou o maior coeficiente de correlação com a massa fresca de cladódios. Visando a liberação de variedades para a produção de biomassa, as variedades Negros Michoacan F7, V7 e V12 Tamazunchale podem substituir a variedade Miúda. O número e cladódios índice de área podem ser utilizados como critério para seleção de variedades superiores em programas de melhoramento.

Palavras-chave: Cladódios. Correlações. Produção de massa seca. *Nopalea cochenillifera.*

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INTRODUCTION

In northeastern Brazil, spineless forage cactus has been used as an important forage resource for feeding ruminants, and most existing plantations in the region are mainly formed with species of the genus *Opuntia*, such as varieties Gigante and Redonda. However, these varieties are susceptible to the attack of carmine cochineal (*Dactylopius coccus*), and, therefore, the introduction of more tolerant genotypes is a viable alternative. Spineless forage cactus, of the genus *Nopalea*, especially Miúda, are recognized in Brazil as varieties with greater tolerance to the carmine cochineal attack (Vasconcelos et al., 2009), thus making the cultivation of this genus a promising alternative to mitigate the negative effects of the insect in the production of biomass.

The introduction of varieties of the genus *Nopalea*, is a palliative measure to overcome the obstacles to the cultivation of varieties of the genus *Opuntia*, and the development of new varieties derived from crosses between genotypes is a more effective action.

The introduction of genotypes necessarily involves the knowledge of morphological and production characteristics, since with the morphology, it is possible to select or discard genotypes with undesirable characteristics in breeding programs, thus facilitating the choice of crosses and increasing the probability of obtaining more productive new genotypes potentially.

For decades, the criterion for selecting spineless forage cactus genotypes in northeastern Brazil was to evaluate solely biomass production. Various morphological and structural characteristics such as number, area, and volume of cladodes, height and width of the plant, assist to a greater or lesser extent the production of plant biomass because they correlate positively with this trait (SANTOS et al., 1994).

Vencovsky & Barriga (1992) reported that the study of the nature and magnitude of the relationships among characteristics is important, since breeding generally aims to improve the genotype for a set of characteristics simultaneously, and not only for isolated characteristics.

This research, therefore, had as objectives the morphological characterization of spineless forage cactus varieties of the genus *Nopalea* to indicate those that may substitute the existing ones, as well as to identify morphological characteristics that may be the focus in spineless forage cactus breeding programs.

MATERIAL AND METHODS

The experiment was conducted at the Center for Agricultural Sciences, Federal University of Alagoas, Rio Largo, Alagoas, Brazil (latitude 9 ° 27'S, 35 ° 27'W longitude and an average elevation of 127 m).

The climate of the region is of the As type according to the climate classification by Köppen, with a dry season from September to May. The soil of the experimental area is classified as Oxisol (EMBRAPA, 2006) and presented the following chemical characteristics: pH (H_2O, 1;2.5) – 5,45; P (mg dm^{-3}) – 4.26 (Mehlich-1); K (mg dm^{-3}) – 28; Ca ($cmol_c\ dm^{-3}$) – 2.2; T ($cmol_c\ dm^{-3}$) – 5.92; V (%) – 49.28. Based on the results of the soil chemical properties, the need for liming was calculated by the method of increase in base saturation so that the base saturation was increased to 80%. Two tons of dolomitic lime was used per hectare applied on the whole area with the implement attached to the tractor, to achieve this result.

Rainfall (mm), maximum, mean and minimum temperatures (expressed in °C) during the experimental period was 3687, 29.6, 24.7 and 20.6, respectively.

The experiment was conducted in a completely randomized block design with 11 varieties of spineless forage cactus (*Nopalea cochenillifera* (L.) SD., Cact. Hort. Dyck. 1849) and four replications. The varieties used in the study were: Miúda, Blanco San Pedro F24, Blanco Michoacan F8, Blanco Valtierrilla V18, Blanco San Pedro V19, Alagoas, Negro Michoacan V7, Negro Michoacan F7, Nopalea Aleman, Tamazunchale V12, Texas Nopalera V13. The cladodes of varieties used in planting were fully expanded and were harvested from plants approximately three years old, from the *ex situ in vivo* germplasm bank of the Secretary of Agriculture of the State of Alagoas in the county of Santana do Ipanema, Alagoas, Brazil (9° 21' 49" South, 37° 14' 54" West).

After cutting, the cladodes were left for seven days under shade for the healing of the cuts. Cladodes were planted in November 2009, with one cladode per burrow, in the vertical position, with the cut side faced down, in the depth sufficient so that one-third of the cladode was covered by the soil.

The experimental plots consisted of three lines three meters long (9 m^2), each line having seven plants. The cladodes were distributed in the experimental plots in a planting density of 20,000 plants per hectare, equivalent to a plant spacing of 1 x 0.50 m. The center line of each experimental unit was composed of cladodes of the evaluated varieties, and for the adjacent lines (borders), the variety Miúda was used.

Fertilization consisted of 200, 130, 100 kg/ha nitrogen (urea), P_2O_5 (simple superphosphate) and K_2O (potassium chloride), respectively, applied 90 days after planting. Whenever necessary, plots were hand weeded.

Before the harvest, the height and width of the plants were measured. Plant height was measured from the soil level to the highest cladode, and mean width of the plants was measured from the furthest point between the ends of the plant, both with the aid of a metric tape.

At 600 days after planting, three plants of the central row of each plot were harvested whole, preserving only the cladodes that had been planted. The plants were sectioned, and their cladodes were weighed on a digital scale.

The following characteristics were estimated: weight (g), area (cm^2), mean volume (cm^3), total number of cladodes, total production of fresh and dry mass ($t\ ha^{-1}$), total volume (cm^3), cladode area index and water use efficiency (kg of dry mass per millimeters of water). The mean weight of the cladodes was estimated by dividing the mean weight per plant by the total number of cladodes of each plant. The mean cladode area was estimated by using the mathematical formula for calculating the area of the ellipse: Ellipse Area = {(C/2) x (L/2)} x π, in which: C = Cladode length in centimeters, L = Cladode width in centimeters, π = 3,141592, $(L/2)^2$= equivalent to the radius in centimeters. The number of cladodes was obtained by counting. The production of total fresh weight (t/ha) was calculated by multiplying the mean total weight per plant by the density of plants per hectare. Cladode area index was obtained by dividing the total area of cladodes and the area occupied by the plant. Total volume was estimated (cm^3) by multiplying the value of the total area of the cladode per plant by the mean thickness of the cladodes. Average volume of cladodes was obtained by the ratio between the total volume and the total number of cladodes per plant. Water use efficiency was estimated by dividing the total dry mass in kilograms by total rainfall during the experimental period, and values were expressed in kg dry mass/mm of water.

Samples of cladodes used for the determination of the levels of partial dry mass were collected shortly after completion of the assessments of plants in each plot. For this, cladodes of different orders in each plot were randomly removed, washed with distilled water and then dried with an absorbent paper towel and chopped lengthwise. Samples of approximately 800 grams were then taken and dried in an air forced drier where they were subjected to a temperature of 55 °C until constant weight. Total dry mass was obtained by multiplying the fresh mass by the dry mass percentage.

The concentrations of dry mass (DM), organic matter (OM), mineral matter (MM), crude protein (CP), and neutral detergent fiber corrected for ash and protein (NDFcp) were quantified according to the methodologies compiled and described by Detmann et al. (2012). The non-fiber carbohydrates (NFC) were calculated according to the methodology described by Detmann & Valadares Filho (2010). The variety Negro Michoacan V7 was excluded from the chemical composition evaluations, due to deterioration of the samples.

Correlation analysis between the variables production of fresh and dry mass, total number of cladodes, total volume, height and width of the plants, cladode area index and water use efficiency was done. The Pearson correlation coefficients (r) were generated from data of 93 plants, calculated with the aid of the statistical package PROC CORR of SAS Software 9.2.

Data was analyzed using the statistical package PROC MIXED of SAS Software 9.2, considering "varieties" as fixed effect and "blocks" as random effects. To calculate the degrees of freedom of the residue the Kenward-Roger approximation was used. Means were tested by the Dunnett test (α = 0.05 for the type I error), adopting the Miúda variety as a control treatment.

RESULTS AND DISCUSSION

For weight, area and average volume of cladodes (Table 1) it may be observed that the varieties Alagoas, Negro Michoacan F7 (Weight) and Blanco San Pedro F24 (Area) presented higher value than the control variety ($P < 0.05$). Leite (2009) in studies of competition between varieties of spineless forage cactus observed similar results for the characteristic weight of cladodes, in which the Alagoas variety always showed the highest mean value compared with the Miúda variety. Despite variety Alagoas being classified as a species of the genus *Nopalea*, it presented similar morphological characteristics as varieties of the genus *Opuntia*, with a smaller number of cladodes, however with larger dimensions. Indeed, it may be observed in Table 1, that the Alagoas variety despite having fewer cladodes (8.41 cladodes per plant) showed 125, 66 and 130% higher weight, area and cladode volume than the mean of the varieties.

Varieties Negro Michoacan F7 and V7, Nopalea Aleman, Tamazunchale V12 and Nopalera Texas V13, presented higher mean values for the trait number of total cladodes (Table 1).

The number of both total and by order cladodes has not only morphophysiological relevance in a rural property, but also relevance to some practical aspects. In this scenario, due to the fact that spineless forage cactus is usually propagated by vegetative parts (whole cladodes), varieties that have greater number of cladodes (Nopalea Aleman and Tamazunchale V12, for example), would be easier to be multiplied in the process of multiplication of seedlings of varieties and/or clones generated by breeding programs.

Table 1.Weight (MWC), area (MAC), mean volume (MVC), the total number of cladodes (TNC) and coefficients of variation of spineless forage cactus varieties.

Variety	MWC (g)	MAC (cm^2)	MVC (cm^3)	TNC
Miúda	207.37	134.28	244.21	21.33
Blanco Michoacan F8	246.25	165.54	295.03	28.70
Blanco San Pedro F24	237.60	198.82 *	268.16	30.00
Blanco San Pedro V19	181.11	137.95	210.12	24.33
Blanco Valtierrilla V18	260.51	197.65	310.68	20.62
Negro Michoacan F7	275.17 *	190.01	321.04	34.62 *
Negro Michoacan V7	200.22	131.04	226.75	32.50 *
Nopalea Aleman	193.18	158.66	227.91	34.66 *
Alagoas	516.52 *	278.93 *	605.04 *	8.41
Tamazunchale V12	226.35	191.02	249.17	35.75 *
Texas Nopalera V13	251.43	174.75	277.47	32.16 *
CV (%)	34.09	25.12	37.10	32.37

*differs significantly from the control treatment (Miúda) by Dunnett's test (P <0.05).

The increase in seedling production with increasing number of plant cladodes guarantees to some extent the increased scope of the program of distribution of seedlings among ranchers. In this scenario, the proportion of palm plantations for sale and use in animal nutrition in the property could be increased, since smaller areas would be aimed to form new plantations.

Leaf area index (LAI), which corresponds, in the spineless forage cactus to the cladode area index (CAI) directly influences the use of photosynthetically active radiation and as a consequence, photosynthesis and dry mass production (SANTOS, 2009). Spineless forage cactus presents a low cladode area index compared to grasses and forage legumes, which results mainly in lower biomass production per unit area, as these characteristics have a close relationship (MARTUSCELLO et al., 2005; MARTUSCELLO et al., 2006; OLIVEIRA et al., 2007).

By having a low cladode area index, spineless forage cactus is a crop which is sensitive to competition for abiotic resources (light, nutrients and water) with invasive plants, since the crop does not cover the ground so efficiently, thus needing regular weeding more frequently.

In this context the varieties Blanco Michoacan F8, Blanco San Pedro F24, Negro Michoacan F7 and V7, Nopalea Aleman, Tamazunchale V12 and Texas Nopalera V13 presented higher mean values for cladode area index, significantly different (P<0.05) from the standard variety, which may be an indication that these varieties have higher photosynthetic rates.

Table 2. Cladode area index (CAI), total volume of cladodes (TVC), water use efficiency (WUE) and coefficients of variation in varieties of forage cactus.

Variety	CAI	TVC (cm^3)	WUE (kg mm^{-1})
Miúda	0.57	5239.45	1.99
Blanco Michoacan F8	0.95 *	8145.14 *	3.19 *
Blanco San Pedro F24	1.16 *	8088.01 *	2.87
Blanco San Pedro V19	0.89	6803.67	2.40
Blanco Valtierrilla V18	0.80	6367.59	2.31
Negro Michoacan F7	1.33 *	11189.49 *	3.84 *
Negro Michoacan V7	1.10 *	9485.66 a*	3.61 *
Nopalea Aleman	1.08 *	7759.11	2.86
Alagoas	0.46	5027.23	1.71
Tamazunchale V12	1.36 *	8963.04 *	4.36 *
Texas Nopalera V13	1.11 *	8679.49 *	3.02
CV (%)	33.44	28.85	32.99

*differs significantly from the control treatment (Miúda) by Dunnett's test (P <0.05).

Varieties Blanco Michoacan F8, Blanco San Pedro F24, Negro Michoacan F7 and V7, Tamazunchale V12, and Texas Nopalera V13 presented higher mean values of total volume of cladodes (Table 2), differing significantly (P<0,05) from the control variety. Unlike grasses and forage legumes, the organs responsible for photosynthesis of spineless forage cactus (cladodes), have a considerable thickness, by presenting the parenchymal tissue and marrow formed by succulent tissues (HILLS, 2001).

The volume of cladodes is a trait that is under direct influence of the mean thickness of the cladodes, thickness being affected by genetic factors or a possible representation of both the state of turgidity and the accumulation of organic compounds in the parenchyma of the cladodes. In this sense, when comparing plants with similar or superior cladode area indices, these may present distinct total volumes, due to differences in the average thickness of the cladodes of each variety, as can be observed between the varieties Negro Michoacan and F7 Tamazunchale V12 (Table 2).

Significant differences (P<0.05) for the characteristic water use efficiency were observed, and the varieties Blanco Michoacan F8, Negro Michoacan V7, F7 and Tamazunchale V12 differed (P<0.05) from the control variety (Table 2). Water use efficiency is influenced by many intrinsic and extrinsic factors to the plant. Dubeux et al. (2006) reported that agronomic practices such as minimum tillage, proper use of fertilizers, control of weeds, diseases and insects are some practices that increase water use efficiency.

In this scenario, evaluating the effects of plant spacing, nitrogen, phosphorus and location, the authors observed values ranging from 5 to 34.9 kg DM mm^{-1} of rainfall. Snyman (2005) considering the evapotranspiration in the calculations of water use efficiency observed similar values of water use efficiency for *Opuntia ficus-indica* and *Opuntia robusta*, 1.57, and 1.19 kg DM mm^{-1} of rainfall, respectively. Water use efficiency could be a feature that could guide the decision on selection of varieties, especially if these varieties are aimed at the Brazilian semiarid areas that have the lowest rainfall. In this scenario, varieties Tamazunchale V12, Negro Michoacan F7 and V7 could be pre-selected. However, this characteristic should not be evaluated in isolation.

Observing the mean values obtained for the characteristic production of total fresh mass (Table 4) it is shown that varieties Blanco Michoacan F8, Blanco San Pedro F24, Negro Michoacan F7 and V7, Tamazunchale V12, Texas Nopalera V13, differed (P<0.05) from the standard variety. The mean values varied from 86.45 to 190.90 t ha^{-1}, with the lowest values being presented by the standard variety (Miúda) and the highest by the variety Negro Michocan F7, respectively. The varieties Blanco Michoacan F8, Negro Michoacan V7, F7 and Tamazunchale V12 differed (P<0.05) from the standard variety for the characteristic total dry mass production (Table 3). The highest and lowest values were observed in the varieties Tamazunchale V12 (16.08 t ha^{-1}) and Alagoas (6.31 t ha^{-1}), respectively.

Table 3. Production of total fresh weight (FW), total dry mass (TDM) and coefficients of variation of the characteristics in spineless forage cactus varieties.

Variety	TFW (t ha^{-1})	TDM (t ha^{-1})
Miúda	86.45	7.35
Blanco Michoacan F8	144.17 *	11.78 *
Blanco San Pedro F24	141.25 *	10.58
Blanco San Pedro V19	118.96	8.86
Blanco Valtierrilla V18	106.90	8.54
Negro Michoacan F7	190.31 *	14.17 *
Negro Michoacan V7	168.22 *	13.33 *
Nopalea Aleman	132.72	10.58
Alagoas	86.78	6.31
Tamazunchale V12	157.87 *	16.08 *
Texas Nopalera V13	163.63 *	11.14
CV (%)	29.19	32.44

*differs significantly from the control treatment (Miúda) by Dunnett's test (P <0.05).

In studies with spineless forage cactus, the importance of fresh mass production is often sidelined and sometimes disregarded when compared to dry mass production. In environments where the spineless forage cactus is cultivated (arid and semiarid areas), the availability of water resources for livestock production is limited and thus spineless forage cactus may also be used as a source of water to be ingested by animals. Moreover, this feature is of great importance regarding the practical and economic aspects of the rural property. Since it is a characteristic of easy visualization and measurement, fresh mass production in the Brazilian semiarid region is mainly used as the basis to calculate the number and flow of animals on the farm during the dry periods of the year.

Comparatively, the variety Tamazunchale V12 was superior to the variety Miúda in approximately 118% in dry mass production, which makes this variety an alternative promising variety, since the objective of most breeding programs is the increase in biomass production. From the scientific point of view, the production of dry mass can be seen as a product of interactions between morphological and structural characteristics, and the process of selection of genotypes should guide the results. In fact, varieties Negro Michocan F7, V7 and Tamazunchale V12, presented the highest values for total number of cladodes (Table 1), which resulted in highest values of cladode area index (Table 2), thereby increasing the production of dry mass (Table 3) indicating that there are strong correlations among these traits.

Differences (P<0.05) among varieties for plant height were observed, and varieties Negro Michoacan F7, Nopalea Aleman, Tamazunchale V12 and Texas Nopalera V13 differed (P<0.05) from the standard variety (Table 4). No differences were observed (P>0.05) for the width of the plant among the evaluated varieties and the standard (Table 4).

The varieties of the genus *Nopalea*, are smaller than those from the genus *Opuntia* (Amorim, 2011), either due to genetic factors and/or to plant architecture. Shorter plants (as Alagoas and Blanco Valtierrilla V18, for example) have less ability to compete with weeds because of growth factors, mainly light, which can cause negative effects on the profitability of the system, being necessary in this case, more frequent weeding.

In high-density planting systems, the width of the plants should be considered. In this type of system the spacing between the lines is decreased, so plants with the greatest width would rapidly fill the planting lines in the course of its growth, thereby impeding weed control to be done effectively, resulting in negative reflections on biomass production of the area.

Thus, varieties like Blanco Valtierrilla V18, Negro Michocan V7, and Texas Nopalera V13, which presented smaller heights, but have larger widths, should preferably not be used in high-density planting systems, but in other plant spacings, especially those where larger distances between the lines are employed.

Table 4. Plant height (PH), the width of plants (PW) and coefficients of variation in varieties of spineless forage cactus.

Variety	PH (cm)	PW (cm)
Miúda	61.12	76.25
Blanco Michoacan F8	68.37	82.79
Blanco San Pedro F24	71.04	89.50
Blanco San Pedro V19	65.94	83.05
Blanco Valtierrilla V18	58.00	80.37
Negro Michoacan F7	78.66 *	93.87
Negro Michoacan V7	68.05	90.44
Nopalea Aleman	84.70 *	85.54
Alagoas	57.54	76.70
Tamazunchale V12	83.29 *	94.54
Texas Nopalera V13	73.41 *	95.50
CV (%)	15.05	13.37

*differs significantly from the control treatment (Miúda) by Dunnett's test (P <0.05).

For the characteristics related to chemical composition (Table 5), the following varieties differed (P<0.05) from the control treatment: variety Tamazunchale V12 for dry mass, Blanco San Pedro F24 for mineral matter, Blanco San Pedro V19, Negro Michoacan F7 and Texas Nopalera V13 for crude protein and San Pedro Blanco V19 for neutral detergent fiber. The characteristics organic matter and non-fibrous carbohydrates did not significantly differ (P>0.05) between the control and the other varieties.

The chemical composition of spineless forage cactus is influenced by several factors, among them, genus and species, variety, soil fertility, season (dry or wet), plant age and order of harvested cladodes. However, despite the number of factors, the variation found in the characteristics may be considered small, and inconsistencies are usually not observed. Similar results have been observed for the variety Miúda (Santos et al, 2001), and this similarity can be extended for most varieties (absence of data), except for those that differed from the control treatment. The observed values of the varieties that differed from the control treatment for the characteristics MM (Blanco San Pedro F24) and CP (Blanco San Pedro V19, Negro Michoacan F7 and Tamazunchale V12) were higher than those commonly found in the literature. Because they have different phenological growth cycles, it is possible that at the time of harvest of the plants, they had a greater number of higher order cladodes.

These cladodes have a better chemical composition, which probably contributed to the increase in the values. In this sense, Teixeira et al., (1999) found that the values of CP and MM increase according to the order of the cladodes, and cladodes with higher order (4th and 5th order) showed the highest values.

Table 5. Dry mass (DM), organic matter (OM), mineral matter (MM), crude protein (CP), neutral detergent fiber corrected for ash and protein (NDFap), non-fiber carbohydrates (NFC) and coefficients of variation in varieties of spineless forage cactus.

Variety	DM	OM	MM	CP	NDFap	NFC
	(dag kg^{-1})					
Miúda	8.02	86.65	13.34	4.72	29.89	51.35
Blanco Michoacan F8	6.99	84.37	15.62	5.08	35.93	42.78
Blanco San Pedro F24	6.77	81.13	18.86*	5.79	33.67	41.09
Blanco San Pedro V19	6.66	82.10	17.89	7.37*	40.02*	34.07
Blanco Valtierrilla V18	6.99	84.37	15.62	5.08	35.93	42.78
Negro Michoacan F7	6.70	83.15	16.84	8.99*	31.28	43.34
Nopalea Aleman	7.24	85.17	14.82	4.10	29.04	50.95
Alagoas	6.18	84.53	15.46	5.13	28.42	50.17
Tamazunchale V12	9.49 *	88.54	11.45	3.59	30.62	53.76
Texas Nopalera V13	5.93	82.88	17.11	14.89*	31.24	36.00
CV (%)	15.16	3.45	18.54	52.49	13.28	16.14

*differs significantly from the control treatment (Miúda) by Dunnett's test (P <0.05).

Table 6. Coefficients of correlation of Pearson (n = 93), between structural characteristics of varieties of spineless forage cactus.

Characteristic	TDM	TVC	WUE	CAI	PH	PW	TNC	TFW
TDM	-	0.81 (<0.0001)	1.00 (<0.0001)	0.81 (<0.0001)	0.42 (<0.0001)	0.29 (0.0038)	0.84 (<0.0001)	0.94 (<0.0001)
TVC	0.81 (<0.0001)	-	0.81 (<0.0001)	0.82 (<0.0001)	0.32 (0.0016)	0.28 (0.0065)	0.75 (<0.0001)	0.87 (<0.0001)
WUE	1.00 (<0.0001)	0.81 (<0.0001)	-	0.81 (<0.0001)	0.42 (<0.0001)	0.29 (<0.0038)	0.84 (<0.0001)	0.94 (<0.0001)
CAI	0.81 (<0.0001)	0.82 (<0.0001)	0.81 (<0.0001)	-	0.49 (<0.0001)	0.37 (0.0003)	0.80 (<0.0001)	0.84 (<0.0001)
PH	0.42 (<0.0001)	0.32 (0.0016)	0.42 (<0.0001)	0.49 (<0.0001)	-	0.43 (<0.0001)	0.50 (<0.0001)	0.39 (<0.0001)
PW	0.29 (0.0038)	0.28 (0.0065)	0.29 (<0.0038)	0.37 (0.0003)	0.43 (<0.0001)	-	0.31 (0.0002)	0.33 (0.0010)
TNC	0.84 (<0.0001)	0.75 (<0.0001)	0.84 (<0.0001)	0.80 (<0.0001)	0.50 (<0.0001)	0.31 (0.0002)	-	0.83 (<0.0001)
TFW	0.94 (<0.0001)	0.87 (<0.0001)	0.94 (<0.0001)	0.84 (<0.0001)	0.39 (<0.0001)	0.33 (0.0010)	0.83 (<0.0001)	-

Total dry mass production (TDM); Total volume of cladodes (TVC); Water use efficiency (WUE); Cladode area index (CAI); Plant height (PH); Plant width (PW); Total number of cladodes (TNC); Total fresh weight production (TFW).

There were significant positive correlations (P <0.05) between all characteristics, with the highest correlation coefficients being observed when the characteristics TDM, CAI, TNC, and TFW were correlated with the others (Table 6). The lowest values were observed when PH and PW were used.

As for tropical grasses under grazing, plant structure and consequently its community is a central and defining characteristic of the dynamics of growth and competition. The only consideration that must be done is that for fresh and, or, dry mass to be a criterion for selection of superior varieties in breeding of spineless forage cactus, may often incur in error in their release, since biomass production is the result of interaction among many structural characteristics of the plant.

Also to the characteristic dry mass production, TNC could also be used as a criterion for selection of superior varieties. Besides being easy to measure (count of cladodes of the plant), it presented high correlation coefficients with CAI and TDM (Table 6).

This pattern of response was because even for cladodes of varieties of similar dimensions, their number would be a key feature for the CAI increase and consequently dry mass production. Varieties with higher CAI could be destined to semi-arid regions where climatic conditions are milder (Agreste region, for example) since these plants would be potentially more efficient in intercepting light energy.

Although numerically the characteristic PH has been lower than CAI and TNC, its importance should not be diminished and therefore discarded as a criterion of selection of varieties. As previously reported, plants of the genus *Nopalea* are smaller than those of the genus *Opuntia*, emphasizing the disadvantages of having plants with this trait. Thus, in a first-moment plants of greater height could be selected, discarding them or not in a second moment after evaluation of their TNC and CAI.

CONCLUSIONS

Aiming the release of varieties for biomass production, varieties Negro Michoacan F7, Negro Michoacan V7 and Tamazunchale V12 may substitute variety Miúda.

The total number and cladode area index may be used as criteria for selection of superior varieties in breeding programs.

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REFERENCES

AMORIM, P. L. **Caracterização morfológica e produtiva em variedades de palma forrageira.** 2011. 54 p. Dissertation (M. Sc. In Animal Science: Concentration area in Forage Crops) – Federal University of Alagoas, AL, Brazil, 2011.

DETMANN, E. et al. **Métodos para analise de alimentos**. 1. Ed. Visconde do Rio Branco, MG: Suprema, 2012. 214 p.

DETMANN, E.; VALADARES FILHO, S. C. On the estimation of non carbohydrates in feed and diets. **Arquivo Brasileiro de Medicina Veterinária e Zootecnia**, Belo Horizonte, v. 62, n.4, p. 980-984, 2010.

DUBEUX JR, 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**, v. 67, n.3, p. 357–372, 2006.

EMBRAPA. Centro Nacional de Pesquisa de Solos. **Sistema Brasileiro de classificação de solos**. 2ª ed. Rio de Janeiro, EMBRAPA-SPI, 2006. 306 p.

HILLS, F. S. Anatomia e morfologia. In: INGLESE, P.; BARBERA, G.; PIMIENTA BARRIOS, E. (Ed.) **Agroecologia, cultivo e usos da palma forrageira**. Paraíba: SEBRAE, 2006, p. 28-35.

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. Tesis (P.h.D in Animal Sciences: Concentration area in Forage Crops) – Federal University of Paraíba, PB, Brazil, 2009.

MARTUSCELLO, J. A. et al. Características morfogênicas e estruturais do capim-massai submetido a adubação nitrogenada e desfolhação. **Revista Brasileira de Zootecnia**, Viçosa, v. 35, n. 3, p. 665-671, 2006.

MARTUSCELLO, J. A. et al. Características morfogênicas e estruturais do capim-xaraés submetido à adubação nitrogenada e desfolhação. **Revista Brasileira de Zootecnia**, Viçosa, v. 34, n. 5, p. 1475-1482, 2006.

MONDRAGON-JACOBO, C. Caracterización genética de uma coleccion de Nopal (*Opuntia* spp.) de la región centro de México. **Agricultura Técnica en México**, Texoco, v. 28, n. 1, p. 3-14, 2006.

OLIVEIRA, R. A. et al. Área foliar em três cultivares de cana-de-açúcar e sua Correlação com a produção de biomassa. **Pesquisa Agropecuária Tropical**, Goiânia, v. 37, n.2, p. 71-76, 2007.

SANTOS, D. C. et al. Desempenho Produtivo de Vacas 5/8 Holando/Zebu Alimentadas com Diferentes Cultivares de Palma Forrageira (*Opuntia* e *Nopalea*). **Revista Brasileira de Zootecnia**, Viçosa, v. 30, n. 1 p. 12-17, 2001.

SANTOS, D.C. et al. Estimativas de parâmetros genéticos em clones de palma forrageira *Opuntia ficus-indica* Mill e *Nopalea cochenillifera* Salm-Dyck.. **Pesquisa Agropecuária Brasileira**, Brasília, v. 29, n. 12, p. 1947-1957, 1994.

SANTOS, N. L. **Avaliação do capim-tanzânia manejado com Diferentes IAF residuais sob lotação Rotacionada por cabras bôer x saanen**. **Dissertação de mestrado em Zootecnia.** 2009. 89 p. Dissertation (M. Sc. in Animal Sciences: Concentration area in Forage Crops) – São Paulo State University "Julio de Mesquita Filho", Faculty of Agriculture and Veterinary Sciences, Jaboticabal, 2009.

SAS Institute. **SAS/STAT**: user's Guide. Version 9.2. Cary: SAS Institute, 2009. 7869 p.

SNYMAN, H. A. A case on *in situ* rooting profile and water use-efficiency of cactus pear *Opuntia ficus -indica* and *O. robusta*. **Journal of Professional Association of Cactus Development**, Chapingo, v.7, n.1, p. 1-21, 2005.

TEIXEIRA, J. C. et al. Cinética da digestão ruminal da palma forrageira (*Nopalea cochenillifera* (L.) Lyons-Cactaceae) em bovinos e caprinos. **Ciência e Agrotecnologia**, Lavras, v. 23, n. 1, p. 179-186, jan./mar, 1999.

VASCONCELOS, A. G. V. et al. Seleção de clones de palma forrageira resistentes à cochonilha-do-carmim (*Dactylopius* sp). **Revista Brasileira de Zootecnia**, Viçosa, v. 38, n. 5, p. 827-831, 2009.

VENCOVSKY, R.; BARRIGA, P. **Genética biométrica no fitomelhoramento**. 1. Ed. Ribeirão Preto, SP: Sociedade Brasileira de Genética, 1992. 496 p.