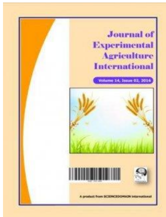

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Qualitative Assessment of Early Palm Cladodes of *Opuntia tuna* L. (Mill) Grown with Organic Manures

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Authors' contributions

This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.

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ABSTRACT

Objective: The objective was to evaluate the physical and chemical quality of young palm cladodes produced with different sources and concentrations of organic fertilisation.
Experimental Design: The experiment was conducted in a randomized block design, corresponding to five doses and three sources of organic fertilisation.
Place and Duration of the Study: The experiment was conducted in the Experimental Area of the Center for Agro-Food Science and Technology of the Universidade Federal de Campina Grande,

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Pombal campus, Paraíba, Brazil, between November 2016 through January 2017.
Methodology: The experiment was conducted in a 3 x 5 factorial block design, using 3 fertilisation sources (avian, bovine and caprine manure) and 5 doses (0, 5, 10, 15 and 20%). The seedlings were obtained from fully mature palm cladodes of the 'Elephant ear Prickly pear' (*Opuntia tuna* (L.) Mill.) cultivar.
Results: The fertilisation with bovine and caprine manure favoured the increase of fresh mass, thickness and transverse diameter characteristics of young palm cladodes. The application of avian manure promoted improvements in chemical attributes.
Conclusion: The fertilisation with organic sources promoted improvements in the physical-chemical attributes of the young palm cladodes. The 10% dose promoted improvements in the physical parameters of shoots and palm. While the chemical attributes showed better with the dose of 5%.

Keywords: Opuntia tuna (L.) Mill.; cactacea; post-harvest quality.

1. INTRODUCTION

The palm (*Opuntia* spp.) is a species belonging to the Cactaceae family, originating in Mexico it is currently cultivated around the world, except Antarctica, being exploited for the purpose of producing fruits and fodder for animal feed. Possessing still great potential for diverse uses as the production of biofuels, cosmetics, adhesives, glues, dyes and their medicinal use [1]. Besides being important in animal feed, palm has great potential to be used in human food, being exploited for this purpose in several countries [2].

It is considered a species that presents high adaptability to the soil and climatic conditions of the Brazilian semi-arid region, adapting the environmental peculiarities of the region that presents high rates of atmospheric evapotranspiration and low levels of water in the soil. Due to its anatomical and morpho-physiological characteristics, the palm has been widely cultivated in the Northeast region, with the largest cultivated areas distributed in the states of Alagoas, Bahia, Pernambuco, Paraíba and Sergipe [3].

Although a plant that adapts well to semi-arid conditions, palm as any other crop needs management, among the factors, fertilisation is essential to achieve high yields. The use of organic fertilisers contributes decisively to the improvement of soil characteristics, as well as to crop nutrition and productivity, promoting a reduction of production costs [4]. Organic fertilisation not only increases crop productivity but also generates plants with better qualitative and sensorial characteristics compared to plants produced with mineral fertilisation [5].

Despite the great importance of palm cultivation, especially for the Northeast region, research on the physical and chemical quality of young palm cladodes destined for human consumption, cultivated with organic fertilisation, is still incipient and it is necessary to develop a larger number of studies.

Therefore, this research aimed to evaluate the physical and chemical quality of young palm cladodes produced by different organic substrates (avian, bovine and caprine manure), as well as the different doses tested.

2. MATERIALS AND METHODS

The present work was developed in the experimental area of the Experimental Area of the Center for Agro-Food Science and Technology of the Universidade Federal de Campina Grande (CCTA/UFCG), Pombal campus, Paraíba, Brazil. Located at 6º46'13" south latitude and 37º48'06" west longitude, at an altitude of 184 m [6]. The predominant climate in the region according to the Köppen classification is BSh, ie hot semiarid, with annual rainfall of 750 mm and rainfall concentrated in the months of December to April [7].

2.1 Plant Material and Experience Management

The production of young cladodes was carried out in vessels with a capacity of 18 dm^3, with a spacing of 1.5 m between rows and 0.5 m between plants. The seedlings were obtained from fully mature palm cladodes of Elephant ear Prickly pear' (*Opuntia tuna* (L.) Mill.) cultivar planted at a depth of 0.20 cm.

The cladodes were obtained from a commercial crop located in the Center of Environmental Agrarian Sciences (CCAA) of the Campus II of the Universidade Estadual da Paraíba (UEPB), in the municipality of Lagoa Seca, which is about 260 km from the city of Pombal, Paraíba, where they were harvested and transported in a cardboard box on 11/11/2016 and taken to the Center of Agri-Food Sciences CCTA/UFCG. Prior to planting, the cladodes were left in the shade for 6 days to heal the wounds that occurred in the cut.

The experimental design used in the production of young cladodes in the field was randomized blocks arranged in a 3 x 5 factorial scheme, with three sources of fertilisation (avian, bovine and caprine manure) and five doses of organic fertilisation (0, 5, 10, 15 and 20% of the vessel), with 3 replicates per treatment.

The chemical characterisation of organic fertiliser and soil sources used in the test is given in Table 1.

The plants were manually irrigated twice a week, with an approximate volume of 1.5 L of water per plant in the months of November 2016 to January 2017.

The young cladodes were harvested 60 days after planting (DAP), and they were harvested manually between 9:00 AM and 9:30 AM. Ten young cladodes were collected per treatment, totaling 150 young cladodes, 16 to 20 cm long.

The young cladodes were selected for the absence of physical damage, with fresh appearance and characteristic colour. Afterwards, they were packed in plastic bags, duly identified and taken to the Laboratory of Chemistry, Biochemistry and Food Analysis, of CCTA/UFCG, Pombal campus, PB.

In order to perform the physical and chemical characterisation of the young palm cladodes, a completely randomized experimental design was used in a 3x5 factorial scheme, where the first factor corresponds to the fertilisation sources F1 = avian manure, F2 = bovine manure and F3 = caprine manure, the second factor was the organic fertilisation rates (0, 5, 10, 15 and 20%), with 5 replicates per treatment. The development stage of the young cladodes chosen was stage 4, where the young cladodes present size between 16 to 20 cm.

2.2 Physical Characterisation of Young Cladodes

To obtain the physical characterisation of young palm cladodes, the following parameters were measured:

- Fresh mass of young cladodes: determined by weighing the young cladodes in a semianalitic scale with a precision of 0.01 g expressed in grams (g).
- Thickness: obtained with the aid of a digital caliper, measuring the thickness in the medial part of the shoot, the results being expressed in mm.
- Longitudinal and transverse diameter: established with the help of a graduated ruler, measuring the longitudinal diameter taking into account the length of the shoot and the transverse length taking into account the width. The results were expressed in cm.

Table 1. Chemical characteristics of manure and soil used in palm production (*Opuntia ficus-indica*)

Manure	Doses	[1] O.M.	C.E.	N	Ca^{2+}	Mg^{2+}	K^+	Na^+	BS	CEC	P	pH
	%	g kg^{-1}	dS m^{-1}	%	-------------------		cmol$_c$ dm^{-3}			-------------------	mg dm^{-3}	
Bovine	5	8.0	0.14	0.05	4.40	2.50	0.46	0.13	7.50	7.50	24	7.2
	10	8.0	0.19	0.05	3.50	3.50	0.60	0.22	7.80	7.80	18	7.4
	15	9.0	0.34	0.09	3.40	4.00	1.04	0.37	8.80	8.80	19	7.2
	20	9.0	0.29	0.10	4.20	2.80	1.04	0.42	8.50	8.50	19	7.5
Caprine	5	7.0	0.24	0.08	3.50	3.10	0.91	0.29	7.80	7.80	17	7.6
	10	5.0	0.29	0.08	3.10	3.50	0.91	0.33	7.80	7.80	19	7.3
	15	8.0	0.48	0.06	3.00	3.60	1.69	0.62	8.90	8.90	20	7.6
	20	16.0	0.67	0.11	2.60	3.60	1.30	0.66	8.20	8.20	24	7.6
Avian	5	7.0	0.29	0.07	3.00	1.50	0.65	0.42	5.60	5.60	17	7.2
	10	13.0	0.41	0.04	2.60	3.60	1.04	0.73	7.90	7.90	18	7.7
	15	3.0	0.25	0.07	2.90	3.50	0.65	0.40	7.40	7.40	15	7.8
	20	9.0	0.33	0.06	2.40	3.90	0.91	0.97	8.20	8.20	23	7.8
Soil	-	0.0	0.04	0.10	3.30	2.90	0.27	0.04	6.50	6.50	12	7.6

[1] M.O – Organic material; BS - base sum (Ca^{2+}+Mg^{2+}+Na^++K^+); CTC - cation exchange capacity - [Ca^{2+} + Mg^{2+} + Na^++ K^+ + (H^+ + Al^{3+})]; the pH was measured in aqueous extract (1:2.5). [2]

2.3 Chemical Analyses of Young Cladodes

To accomplish the chemical analyses, it was necessary to obtain the cellular extract of the young palm cladodes. For this, the young cladodes were sanitised in running water and then the manual removal of the spines was carried out with the aid of a knife. Afterwards, the blender was processed with 1:1 water (mass:volume) and the obtained extract was stored in a plastic container protected from light for further analysis. The following chemical parameters were evaluated:

- Hydrogen potential (pH): determined from the cellular extract of young palm cladodes, using a digital bench potentiometer (Digimed brand) according to the recommendations of the [8].
- Titratable acidity: was measured in 1 g of the cellular extract of the young palm cladodes, homogenised in 50 mL of distilled water. The solution containing the sample was titrated with 0.1 N NaOH until reaching the turning point of the phenolphthalein indicator, confirmed by the indicator pH range of 8.2. The titratable total acidity was expressed as a percentage of malic acid, abundant in the palm equivalent to the amount of 0.1 N NaOH spent in the [9].
- Soluble solids were determined through the cellular extract of the young palm cladodes, being read in digital refractometer with automatic temperature compensation (Digital brand refractometer), expressed as a percentage [8].
- The soluble solids/titratable acidity ratio was obtained by dividing the soluble solids values by the values of the titratable acidity.
- Ascorbic acid: estimated by titration using 1 g cell extract of the young palm cladodes, plus 49 mL of oxalic acid 0.5% and titrated with Tillmans solution until reaching a pink colour, as described by the [8].
- Total chlorophyll and total carotenoids: determined according to Lichtenthaler [10] with adaptations. The cell extract of the young palm cladodes was macerated in a mortar with 0.2 g of calcium carbonate ($CaCO_3$) and 5 ml of acetone (80%) in a dark environment. The samples were then centrifuged at 10°C and 3,000 rpm for 10 minutes in a refrigerated centrifuge (Cientec brand), the supernatants were read in spectrophotometer (Spectrum brand) at wavelengths of 470, 646 and 663 nm.

2.4 Statistical Analysis

The obtained data were submitted to a variance analysis when a significant effect was detected for the F test, Tukey's test was applied at a 5% probability level using Sisvar® *software* 5.6 [11]. To evaluate the influence of one parameter on the other, the Pearson correlation coefficients were determined with the aid of the AgroEstat® statistical package [12].

3. RESULTS AND DISCUSSION

3.1 Physical Analysis of Young Cladodes

Table 2 shows the results obtained for the physical parameters evaluated in the young palm cladodes as a function of the different sources of fertilisation. It was observed that there was a significant effect for the fresh mass, thickness and transverse diameter of young palm cladodes.

Table 2. Fresh mass (FM), thickness (T), longitudinal diameter (LD) and transverse diameter (TD) in young palm cladodes (*Opuntia ficus-indica*) submitted to different sources of organic fertilization

Fertilisation	Variables			
sources	FM (g)	T (mm)	LD (cm)	TD (cm)
Avian	63.78 b	0.78 b	18.2 a	10.1 b
Bovine	71.13 a	0.87 a	18.3 a	10.9 a
Caprine	71.08 a	0.83 ab	18.5 a	10.9 a
Mean	68.6	0.82	18.3	10.6
CV%	11.8	12.8	5.0	6.89

Means followed by the same letter do not differ significantly by the Tukey test at the 5% probability level

For the fresh mass of the young cladodes, it is observed that the source of organic fertilisation and caprine presented the highest gains with 71.13 and 71.08 g becoming superior to the source of avian fertilisation, which obtained an estimated average of 63.78 g. The values obtained are in agreement with those found by Farias [7], who found in young cladodes in the middle development around 10.53 and 127.48 g in the 'Round' palm, evidencing an increase of the mass with the course of development stage.

The thickness of young cladodes presented the highest values obtained in plants fertilised with bovine and caprine manure, presenting values of 0.87 and 0.83 mm, respectively. However, it is observed that the thickness of the young cladodes fertilised with avian and caprine manure did not differ statistically. These values are lower than those obtained by Lima [13], which obtained an average of 16 mm, and those obtained by Farias [7] estimating averages of thickness between 38 and 55 mm in the 'Giant' cultivar and 47 to 64 mm in the 'Round' cultivar.

According to Donato [14], the increase in the thickness of young cladodes is related to their age, primary cladodes are thicker, due to their function of support and transport of nutrients and organic substances, followed by secondary, tertiary and other cladodes present. Thus, the organic matter supply allows better conditions for the development of the plants, due to the improvements in the substrate characteristics [15], favouring the increase in the physical parameters of young palm cladodes.

Regarding the diameters of the young cladodes of palm evaluated (Table 2), it can be seen that for the longitudinal diameter, the source of fertilisation did not promote significant differences, being the longitudinal diameter rather superior to the transversal, fact due to the characteristic palm shape. The values obtained for the longitudinal diameter were 18.2, 18.3 and 18.5 cm for the source of avian, bovine and caprine fertilisation, respectively, are lower values when compared to the average of 21.97 cm obtained by Silva et al. [16].

The values obtained for the transverse diameter (Table 2) show that the sources of bovine and caprine fertilisation promoted greater responses when compared to the source of avian fertilisation, presenting averages of 10.9, 10.9 and 10.1 cm. The values obtained are lower than those determined by Silva et al. [16], Lima [13] who, when working with different clones of forage palm (*Opuntia* and *Nopalea*), obtained the same averages of 16.5 cm. It can be observed that the sources of bovine and caprine fertilisation were emphasised on the avian source in all the physical parameters evaluated, since they allowed the production of larger, heavier, thicker young cladodes.

The effect of doses of organic fertiliser on the fresh mass of the young cladodes was adjusted to the quadratic model obtaining the largest increment of biomass accumulation in the dose 0% with 81.8 g, with loss with increase of the dose (Fig. 1A).

The values obtained for the thickness, longitudinal and transverse diameter with the results were adjusted to the quadratic model, with the highest additions obtained at the 0% fertilisation dose, with 0.87 mm, 19.7 cm and 11.3 cm, respectively (Fig. 1B, 1C and 1D). The fresh mass and transverse diameter presented their lowest doses of organic fertilisation at 5% dose with averages of 62.39 g and 10.14 cm, while the thickness and longitudinal diameter at dose 10% with respective values 0.74 mm and 17.1 cm, respectively. The mass gain obtained by young palm cladodes can be explained by the increase in diameters and thickness. In young cladodes of 'Giant' and 'Round' palm between 8 and 20 cm in length was found variation from 7.22 to 54.51 g in 'Gigante' cultivar and 12.60 to 132.70 g in 'Round' [7].

The interaction between sources and doses of organic fertilisation presented significance for fresh mass, a longitudinal and transverse diameter of young palm cladodes (Fig. 2A). For the accumulation of fresh biomass and longitudinal diameter of the young cladodes, the results obtained for the sources were adjusted to the quadratic model, with the largest increments in young cladodes produced at dose 0 of each fertilisation source (Fig. 2B). This behaviour may have been due to organic fertilisation not having promoted a greater supply of reserves for young cladodes. In addition to the young cladodes being constituted of great amount of water, thus possibly the fertilisation promoted a greater retention of water in the soil and less translocation by the plant.

For the transverse diameter, the young cladodes submitted to a dose of 6% bovine manure (F2), were the ones that promoted the largest increment with the diameter of 11.5 mm. The young cladodes submitted to avian and caprine sources were superior in plants submitted to dose 0, reduction occurring with increasing doses (Fig. 2C).

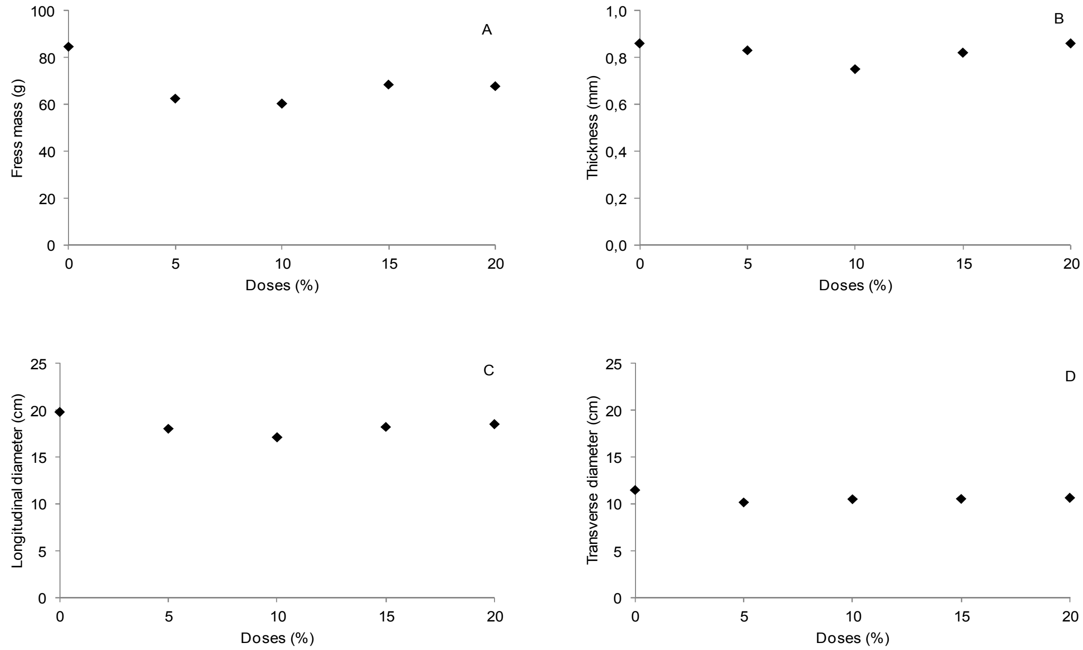

Fig. 1. Fresh mass (A), longitudinal (B) and transverse (C) diameter of young palm cladodes (Opuntia ficus-indica) submitted to different and doses of organic fertilization
**P<0.05*

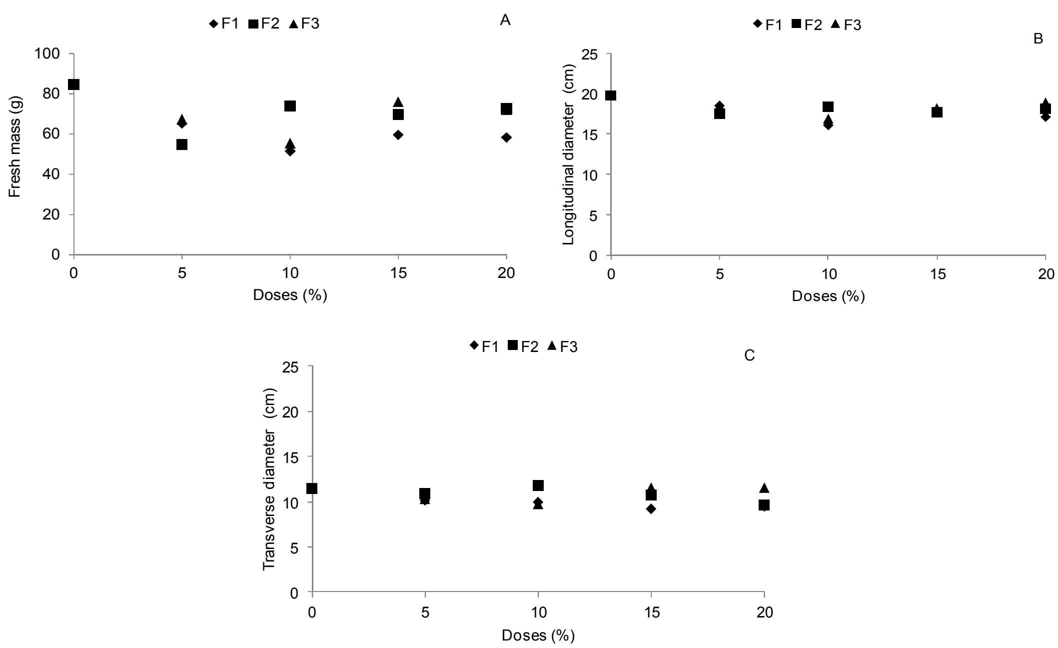

Fig. 2. Fresh mass (A), longitudinal (B) and transverse (C) diameter of young palm cladodes (*Opuntia ficus-indica*) submitted to different sources and doses of organic fertilisation
**P<0.05*

In general, it can be seen that for all the physical characteristics evaluated, the increase in the fertilisation dose promoted a reduction in its values, independently of the source of fertilisation. This effect may be related to the fact of the possible non-mineralisation of the manure, resulting in the non-release of nutrient and consequent absorption.

The results obtained for the Pearson correlation coefficients between the physical characteristics of young "Mexican elephant ear" palm cladodes are presented in Table 3.

Of all the physical characteristics evaluated, an intense positive correlation was observed between the fresh mass and the longitudinal and transverse diameter, showing that the fresh mass is influenced by the diameters, especially by the longitudinal one, a fact that can be observed clearly in the evaluated palm format. The thickness did not present a significant correlation with the other physical characteristics evaluated, showing that its behaviour in relation to the different doses and sources of organic fertilisation does not have similarity with the other characteristics.

3.3 Chemical Analyses of Young Cladodes

The results obtained for pH, titratable acidity, soluble solids, soluble solids/titratable acidity and ascorbic acid for young palm cladodes produced with different sources of organic fertilisation are described in Table 4.

It is verified that the young cladodes produced in the different sources of fertilisation used presented acid pH, with an average of 4.12, 4.45 and 4.17 for avian, bovine and caprine fertilisation, respectively. These values corroborate the results obtained by Pereira et al. [17] who, working with different sources of organic fertilisation at different levels, obtained a pH of 4.57 for young palm cladodes at the 75% level when using bovine manure and 4.49 at the concentration of 100% caprine manure.

There was no significant difference in the sources of organic fertilisation studied for titratable acidity (Table 4), which presented averages 2.01, 2.08 and 2.08% for avian, bovine and caprine sources, respectively. These values were higher than those found by Sáenz et al. [18] that in studies with 10 palm cultivars found values of 0.28 to 0.76% in young cladodes of 30 days of age and 20 cm in length. According to Chitarra and Chitarra [19], the acidity variation in the palm is related to its CAM photosynthetic metabolism, which tends to have a greater variation in acidity during the day, a characteristic that must be taken into account to determine the ideal moment for the harvesting.

There was also no significant difference between the solubility of the three sources of fertilisation, with averages of 4.97, 4.85 and 4.87% for avian, bovine and caprine sources, respectively. Results higher than those found by Pereira et al. [17] in young palm cladodes obtained values of 3.27 and 3.68% in the concentrations of 75% of caprine manure and 12.5% of bovine manure, respectively.

In relation to the SS/TA ratio, it was observed that fertilisation provided with avian manure promoted a higher ratio with 2.52, followed by caprine fertilisation with 2.36 and finally with bovine fertilisation with a mean of 2.33. The SS/TA ratio is of paramount importance in evaluating fruit maturation, taste evaluation and is more representative than the isolated measurement of sugars or acidity. This relationship gives a good idea of the balance between these two components [20,21].

The ascorbic acid levels were higher in young cladodes submitted to fertilisation with aivan and caprine manure with 7.04 and 6.69 mg/100 g, respectively. Young cladodes fertilised with bovine manure presented an average of 5.86 mg/100 g. The difference in ascorbic acid content

Table 3. Pearson correlation coefficients (r) among physical parameters analysed in young 'Mexican Elephant Ear' cladodes

Parameters	Fresh mass	Thickness	Longitudinal D.	Transversal D.
Thickness	0.12781^{ns}	–	–	–
Longitudinal D.	0.80253**	0.11989^{ns}	–	–
Transversal D.	0.73192**	0.11255^{ns}	0.40467**	–

*^{ns} not significant; ** significant at the 5% probability level*

Table 4. pH, titratable acidity (TA), soluble solids (SS), titratable acidity soluble solids (SS/TA) ratio and ascorbic acid (AA) in young palm cladodes (*Opuntia ficus-indica*) submitted to different sources of organic fertilization

Fertilisation	Variables				
sources	pH	TA (%)	SS (%)	SS/TA	AA (mg/100 g)
Avian	4.12 b	2.01 a	4.97 a	2.52 a	7.04 a
Bovine	4.45 a	2.08 a	4.85 a	2.33 b	5.86 b
Caprine	4.17 b	2.08 a	4.87 a	2.36 ab	6.69 a
Mean	4.24	2.06	4.89	2.40	6.53
CV%	6.30	8.77	6.96	11.4	9.17

Means followed by the same letter do not differ significantly by the Tukey test at the 5% probability level

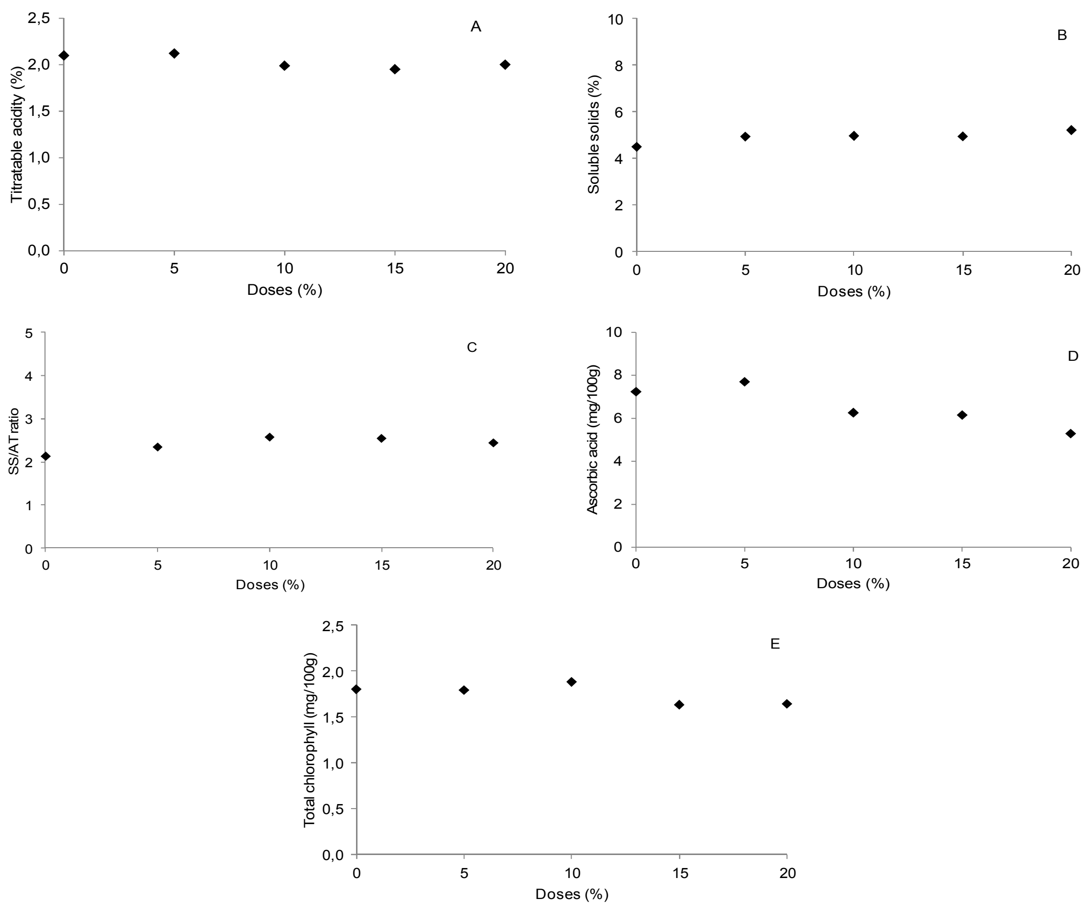

Fig. 3. Titratable acidity (A), soluble solids (B), titratable acidity soluble solids ratio (C), ascorbic acid (D) and total chlorophyll of young palm cladodes (*Opuntia ficus-indica*) submitted to different sources and doses of organic fertilisation
**P<0.05*

may be related to the development of young palm cladodes, since the more advanced the physiological maturity, the greater the resistance to stress conditions, the greater the capacity to induce the synthesis of substances, among them vitamin C (ascorbic acid), carotenoids, flavonols, phenolic compounds and tocopherols [22]. The values found are lower than those found by Pereira et al. [23], who obtained an average ascorbic acid of around 11.4 mg/100 g.

The effect of the doses of organic fertilisation on titratable acidity in young cladodes was observed (Fig. 3A). The dose 5% with a mean of 2.12%

presented higher values when compared to the doses (0, 10, 15 and 20%), respectively. With the increase of the doses of fertilisation tends to promote a reduction in the values of the acidity. It is considered a low value, being extremely acidic, peculiar characteristic of the plants that have CAM metabolism, which carry out their photosynthesis at night.

According to Fig. 3B, it was observed that the dose of organic fertilisation 20 presented higher solids content in young cladodes with an average of 5.2%, respectively, being higher in relation to the other doses evaluated. It can be observed that the increase in the doses of organic fertilisation provided higher solids contents soluble in the young cladodes. Farias [7] states that this variation in the concentration of soluble solids may be related to the increase of the moisture content during the development, and consequently to a greater dilution of the soluble compounds in the aqueous medium. It is important to remember that the soluble solids are constituted predominantly by sugars, being also amino acids, organic acids and pigments dissolved in the cellular juice or vacuoles.

In Fig. 3C, we can see for the doses of organic fertilisation in SS/TA ratio in young cladodes, that the dose 10% with a mean of 2.57% excelled when compared to the other doses evaluated with averages (2.13; 2.34, 2.54, 2.44%), respectively. The relation SS/AT is of paramount importance to evaluate the maturation of the fruits and consequently the flavor of them, thus indicating the degree of sweetness of a particular fruit [21].

It can be observed in Fig. 3D the effect of doses of organic fertilisation, that the ascorbic acid content in young cladodes in the dose 5%, obtained average 7.7 mg/100 g, being superior to the other doses analysed in the present work. The 20% dose was the lowest that presented ascorbic acid content with a mean of 5.24 mg/100 g, respectively. These values found in the respective study are much lower than those found by Pereira et al. [17] that found an even greater value for the concentration of ascorbic acid in young cladodes of 'Giant' palm 21.0 mg/100 g.

The estimated values of organic fertilisation rates for total chlorophyll content in young cladodes are shown in Fig. 3E, where it was verified that the highest values obtained for total chlorophyll contents were at 5% doses with a mean of 1.82 mg/100 g. The value found for chlorophyll is higher than that estimated by Pereira et al. [23] when analysing young cladodes of 'Minimally processed' palm, which estimated an average of 1.76 mg/100 g, being this value lower than that found in the present work for total chlorophyll of 1.88 mg/100 g. When there is a greater contribution of nutrients to the plant, especially nitrogen, there is a tendency of the plant to present a higher photosynthetic rate [24].

Fig. 4 shows the values obtained for the variables titratable acidity, soluble solids/acid titrable ratio and ascorbic acid as a function of the interaction between sources and organic fertilisation rates in young cladodes of 'Mexican elephant ear'.

It can be seen in Fig. 4A that the titratable acidity of young cladodes produced with avian and caprine fertilisation sources presented the highest levels at dose 0, while young cladodes produced under bovine manure presented the maximum increase in dose of 9%, with 2.08. The values found are lower than those found by Lins et al. [25] in young palm cladodes obtained an average of 4.5% of malic acid, and higher than the values found in the work of Farias [7], which obtained values of 0.44 to 1.08% in young palm cladodes. The chemical attributes of the palm, such as the titratable acidity, may vary depending on some factors, such as the time of year, plant age, cultivar, fertilisation management, among others [25].

For the solid soluble/titratable acidity ratio, it was favoured by the fertilisation in the three sources tested, being the largest increment obtained in young cladodes with 2.82 in the dose of 12%. However, young cladodes submitted to fertilisation with bovine and caprine manure showed the greatest increases in the dose of 15% with 2.37 and 2.52, respectively (Fig. 4B).

The results obtained for the SS/TA ratio showed that the averages for the three fertilisation sources at the different concentrations were low, on average from 2.09 to 2.81 for the avian source; from 2.17 to 2.37 for bovine source and from 2.06 to 2.52 for caprine. Suggesting that the elephant ear palm is not indicated for industrialisation of sweet products since it presented a low SS/AT ratio.

Ascorbic acid content in young cladodes produced under bovine and caprine fertilisation was higher in those submitted to dose 0. The young cladodes submitted to fertilisation with avian manure had the largest increase in young cladodes at the dose of 6% (Fig. 4C). This effect may be due to a greater availability of nutrients contained in avian manure, allowing a nutrient availability to the plant. The use of avian manure favors the development of plants due to the contribution of organic matter to the soil [26], mainly due to its low C:N ratio, allowing the rapid mineralisation and release of the nutrients necessary for the growth and development of plants [27].

It is also verified that ascorbic acid, independent of the fertilisation source, tends to decrease with the increase of the dose of organic fertilisation, decreasing from 7.53 to 4.76 mg/100 g for source of fertilisation; from 7.54 to 4.71 mg/100 g in the bovine source and from 7.22 to 6.26 mg/100 g for caprine source.

Regarding the effect of the different fertilisation sources tested on total chlorophyll content and total carotenoids, it is possible to observe that the source of avian fertilisation promoted a greater increase in the pigments evaluated, but did not differ significantly from the source of caprine fertilisation in the results of total chlorophyll and total carotenoids.

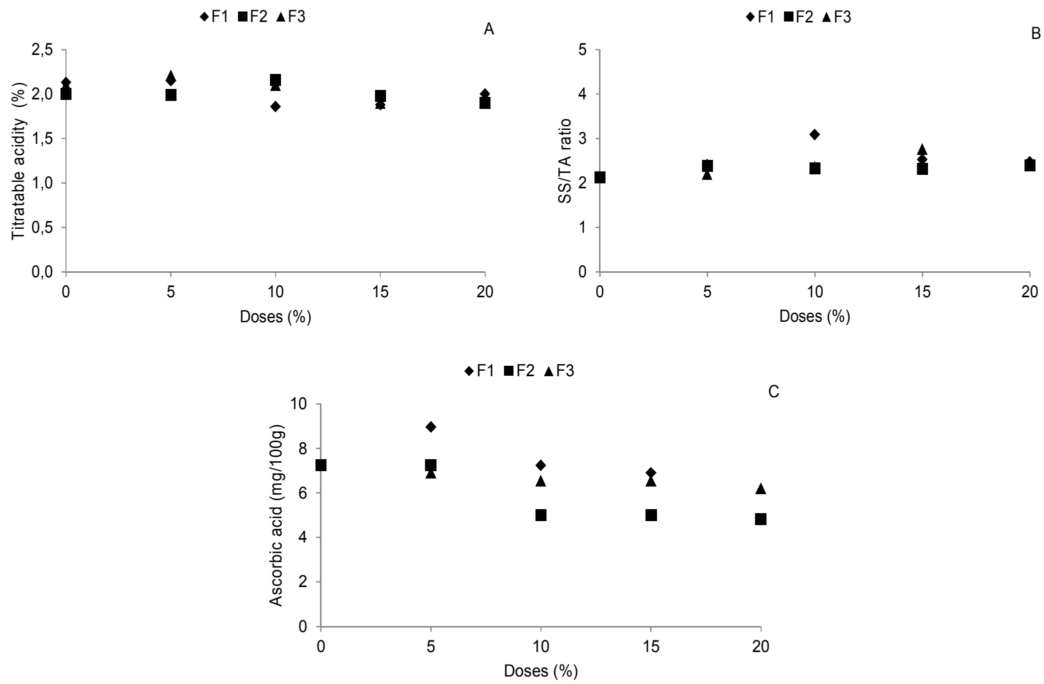

Fig. 4. Titratable acidity (A), SS/TA ratio (B) and ascorbic acid (C) of young palm cladodes (*Opuntia ficus-indica*) submitted to different sources and doses of organic fertilisation
**P<0.05*

Table 5. Total chlorophyll and total carotenoids in young palm cladodes (*Opuntia ficus-indica*) submitted to different sources of organic fertilisation

Fertilisation source	Total chlorophyll (mg/100 g)	Total carotenoids (mg/100 g)
Avian	1.88 a	0.33 a
Bovine	1.54 b	0.28 b
Caprine	1.74 ab	0.31 a
Mean	1.72	0.31
CV%	19.4	19.6

Means followed by the same letter do not differ significantly by the Tukey test at the 5% probability level

In this way, it can be stated that the sources of avian and caprine fertilisation provided greater photosynthetic capacity, since they presented higher values of total chlorophyll, possibly due to the source of fertilisation provided a greater amount of nutrients for the plants. Since, when there is a greater contribution of nutrients to the plant, especially nitrogen, there is a tendency of the plant to present a higher photosynthetic rate [28].

The values obtained for total chlorophyll and total carotenoids of young palm cladodes produced in different sources and doses of organic fertilisation are shown in Fig. 5. The chlorophyll levels were higher in the young cladodes produced with the fertilisation with avian manure at the dose of 20% with 2.44 mg/100 g. The values for young cladodes produced with bovine and caprine manure presented the highest values at doses 0 and 4%, with 1.78 and 1.87 mg/100 g, respectively (Fig. 5A).

The values obtained for chlorophyll in the different sources and doses of organic fertilisation are higher than those found by Farias [7], which obtained 1.03 mg/100 g when evaluating young cladodes of the 'Round' cultivar. In the same study, chlorophyll content was 2.44 mg/100 g in the 'Giant' palm cultivar, which is similar to that found at 20% of the source of avian fertilisation. The variation in chlorophyll content can be attributed to the difference of cultivars, as well as to environmental factors such as light and temperature, which influence the degradation of the same [7].

Similar behaviour to chlorophyll content occurred for carotenoid contents, where the highest increases were obtained in young cladodes from fertilisation with avian manure with 0.38 mg/100 g at the dose of 20%. While the young cladodes produced with bovine and caprine manure presented maximum increments in doses 0 and 6% with 0,32 and 0,35 mg/100 g, respectively (Fig. 5B).

The results obtained are much higher than those found by Sáenz et al. [18], who found levels of total carotenoids of 0.03 mg/100 g in young and fresh cladodes, in relation to the content of carotenoids found in the different sources and doses of organic fertilisation. The difference in results can be attributed to the maturation stage, since, according to Rodrigues-Amaya et al. [29] in some vegetables an increase of the carotenoids occurs with advance of the development; as well as for [7] the variation in the carotenoid contents can be attributed to environmental factors, the cultivar, the conditions of cultivation and even the method of quantification.

The results obtained for the Pearson correlation coefficients between the chemical characteristics of young palm cladodes produced under different sources of organic fertilisation are presented in Table 6.

A high positive correlation between the SS/TA ratio and soluble solids was observed, as the soluble solids have a direct influence on the SS/TA ratio, the higher the soluble solids concentration the higher the SS/TA ratio. For the titratable acidity, a strong negative correlation was observed with the SS/TA ratio, since they are inverse parameters and the higher the acidity the SS/TA ratio.

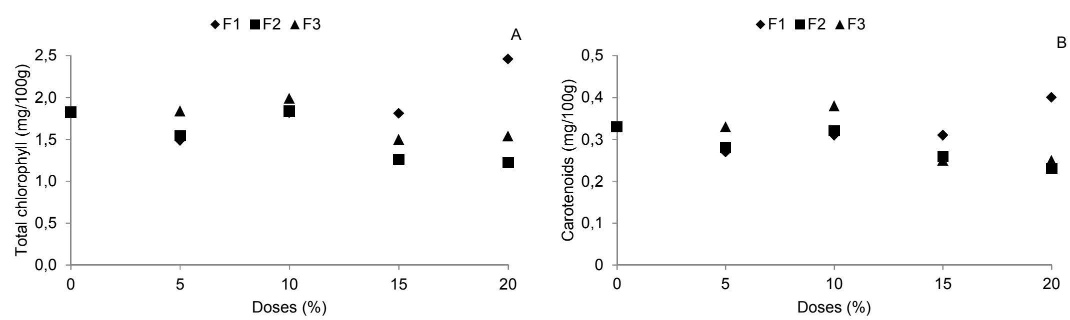

Fig. 5. Total chlorophyll (A) and total carotenoids (B) of young palm cladodes (*Opuntia ficus-indica*) submitted to different sources and doses of organic fertilisation
**P<0.05*

Table 6. Pearson correlation coefficients (r) among chemical parameters analysed in young cladodes of 'Mexican Elephant Ear'

Parameters	pH	AT	SS	SS/AT	AA	CLO
AT	0,080 ^{ns}	–	–	–	–	–
SS	-0,007^{n}	0,089 ^{ns}	–	–	–	–
SS/AT	-0,110 ^{ns}	-0,766 **	0,533 **	–	–	–
AA	-0,279 **	-0,027 ^{ns}	-0,127 ^{ns}	-0,023 ^{ns}	–	–
CLO	0,039 ^{ns}	-0,009 ^{ns}	-0,028 ^{ns}	-0,026 ^{ns}	-0,001^{ns}	–
CARO	0,045 ^{ns}	0,045 ^{ns}	-0,045 ^{ns}	-0,081 ^{ns}	0,030 ^{ns}	0,959 **

TA = titratable acidity; SS = soluble solids; AA = ascorbic acid; CLO = chlorophyll; CARO = carotenoids; ^{ns} not significant;
*** significant at the 5% probability level*

The evaluated pigments had a positive correlation with each other, due to the similar behaviour when submitted to different doses and concentrations of organic fertilisation. The other chemical characteristics did not present a significant correlation.

4. CONCLUSIONS

The sources of bovine and caprine organic fertilisation were superior to the avian source in the physical parameters evaluated.

The chemical attributes of ascorbic acid and the SS/TA ratio of young palm cladodes presented higher increases under fertilisation with the avian source.

The production of the total chlorophyll and total carotenoid pigments is benefited with the fertilisation using avian manure at the dose of 20%.

The 10% dose of organic fertilisation promoted improvements in the physical parameters of shoots and palm. On the other hand, the chemical attributes were better under fertilisation with the dose of 5% manure.

In some variables, organic fertilisation independent of the source was not efficient to boost positive responses, which may be related to non-manure mineralisation, resulting in non-release of nutrients and consequent absorption.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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