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Productive potential and quality of pitaya with nitrogen fertilization

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Abstract – The objective of this work was to determine adequate rates of nitrogen to reach satisfactory yield, fruit quality, and cladode nutrient content in three species of pitaya. The experimental design was carried out in randomized complete blocks, with a 3×4 factorial arrangement. The treatments consisted of the following pitaya species and N rates: *Selenicereus megalanthus*, *Hylocereus undatus*, and *Hylocereus polyrhizus*; and 0, 50, 100, and 200 g N per plant, in the first production cycle (2016/2017 crop season) and 50, 100, 200, and 300 g N per plant, in the second and third production cycles (2017/2018 and 2018/2019 crop seasons). Nitrogen fertilization increased the yield, fruit quality, and cladode nutrient content of the species. In the third production cycle, yield was 1.18 Mg ha^{-1} for *S. megalanthus*, 10.87 Mg ha^{-1} for *H. undatus*, and 10.4 Mg ha^{-1} for *H. polyrhizus* in open pollination. The highest yield is obtained with 300 g N per plant for *S. megalanthus*. For *H. polyrhizus* and *H. undatus* the rates are from 170 to 190 g N per plant, supplemented with P and K.

Index terms: *Hylocereus*, *Selenicereus megalanthus*, dragon fruit, mineral fertilization, orchard management, yield.

Potencial produtivo e qualidade de pitaia com fertilização nitrogenada

Resumo – O objetivo deste trabalho foi determinar doses adequadas de nitrogênio para alcançar produtividade, qualidade das frutas e teor de nutrientes satisfatórios em cladódios de três espécies de pitaia. O delineamento experimental foi feito em blocos ao acaso, com arranjo fatorial 3×4. Os tratamentos consistiram das seguintes espécies de pitaia e doses de N: *Selenicereus megalanthus*, *Hylocereus undatus* e *Hylocereus polyrhizus*; e 0, 50, 100 e 200 g de N por planta, no primeiro ciclo de produção (safra 2016/2017) e 50, 100, 200 e 300 g de N por planta, no segundo e terceiro ciclos de produção (safras 2017/2018 e 2018/2019). A fertilização com N aumentou a produtividade, a qualidade das frutas e o teor de nutrientes nos cladódios das espécies. No terceiro ciclo de produção, a produtividade foi de 1,18 Mg ha^{-1} para *S. megalanthus*, 10,87 Mg ha^{-1} para *H. undatus* e 10,4 Mg ha^{-1} para *H. polyrhizus* em polinização aberta. A maior produtividade é obtida com 300 g de N por planta para *S. megalanthus*. Para *H. polyrhizus* e *H. undatus*, as doses são de 170 a 190 g de N por planta, complementadas com P e K.

Termos para indexação: *Hylocereus*, *Selenicereus megalanthus*, fruta do dragão, fertilização mineral, manejo do pomar, produção.

Introduction

The volume of pitaya marketed in distribution centers in Brazil has been increasing every year, and its high prices in the market attract the interest of producers who are seeking information to start its cultivation. However, information is still incipient on the fertilization management of pitaya orchards in the country, which has caused variations in yield between 2 to 9 tons per hectare (Moreira et al., 2012; Fernandes et al., 2018), values that are still lower than those of other countries, reaching 31.6 tonnes per hectare (Chakma et al., 2014). In this sense, the research on fertilization management is essential for decision making by producers seeking to expand the cultivation area and increase yield.

The pitaya species is considered rustic because of its adaptation to different edaphoclimatic conditions. However, it needs a balanced fertilization in order to receive the nutrients required for its growth and satisfactory yield. This is important especially when annual yields are high, but the exact demand for the various mineral nutrients is still unknown (Mizrahi, 2014). The need for fertilization has been confirmed by Nobel & De La Barrera (2002), Weiss et al. (2009), and Fernandes et al. (2018), who tested the effects of mineral fertilizer application.

Nitrogen is among the main nutrients required by pitaya species (Hernández, 2000) to stimulate the emission of more vigorous roots and cladodes that will sustain a high yield, and it is more demanded by plants from the vegetative growth until the pre-flowering stage (Luders & McMahon, 2006). Nitrogen is among the nutrients most accumulated by pitaya in the period of the greatest cladode growth (Lima et al., 2019; Rabelo et al., 2020b). Pitaya with N deficiency is susceptible to the action of phytopathogens (Valencia Botín et al., 2003) that may lead to a reduced yield.

In general, Brazilian soils need some N supply through fertilizers because of the small amount of N available for absorption by plants. In addition, little is known about the nutritional requirements for the cultivation of pitaya in Brazil. The N amount for fertilization affects the N content in the plant, both in the roots and in the aerial part, influencing CO_2 uptake (Nobel & De La Barrera, 2002), and growth (Lima et al., 2019), as well as number of fruit produced per plant, yield (Turcios & Miranda, 1998; Moreira et al., 2012; Chakma et al., 2014), and quality (Fernandes et al., 2018). Therefore, it is essential to determine the adequate N rate through field research, which can provide a balance of increased yield and commercial quality; this way, more data is available for decision making by producers, in order to achieve a greater yield as in other countries.

Since the pitaya species is perennial, information about proper N fertilization of several production cycles in field conditions are important for orchard management. Its production can increase until the sixth year of cultivation, after which it stabilizes (Nerd et al., 2002), and N availability keeps the plant healthy, vigorous, and productive for up to 25 years (Diaz & Miranda, 2002). However, inadequate fertilization do not allow the plant to express all its productive potential. A proper fertilization management increases yield and reduces production costs. Therefore, it is necessary to use standardized rates to increase the development and production of the pitaya species.

The objective of this work was to determine adequate rates of nitrogen to reach satisfactory yield, fruit quality, and cladode nutrient content in three species of pitaya.

Materials and Methods

The experiment was carried out in an orchard (18°04'42"S, 43°27'27"W, at 726 m altitude), in the state of Minas Gerais, Brazil. According to the Köppen-Geiger's classification, the climate is Aw, tropical altitude, with dry winter and rainy summer. In the hottest month, the average temperature is 24°C, and in the coldest month, 18.4°C. The average annual temperature is 21.5°C, and the average annual rainfall is 1,246 mm. The soil of the experimental area is classified as Latossolo Amarelo distrófico, according to the Brazilian system of soil classification (Santos et al., 2018), i.e., a Ferralsol (IUSS Working Group WRB, 2015).

The experiment was carried out in a randomized complete block design, with 3×4 factorial design. The factors were three pitaya species and four rates of N, with four blocks, and three useful plants per plot. Three production cycles were evaluated from the first harvest after the orchard planting, from 2016/2017 to 2018/2019 crop years.

Before planting the pitaya orchard, a soil sample was collected at 0–20 cm soil depths in the experimental area and analyzed. The soil had the following characteristics: 5.1 pH (H_2O); 1.8 mg dm^{-3} P (Mehlich-1 extractor); 40.7 mg dm^{-3} K; 1.0 $cmol_c$ dm^{-3} Ca; 0.3 $cmol_c$ dm^{-3} Mg; 0.5 $cmol_c$ dm^{-3} Al; 5.1 $cmol_c$ dm^{-3} cation exchange capacity at pH 7.0; 28% base saturation; 0.4 dag kg^{-1} organic matter. The values of the textural analysis of the sample were 270 g kg^{-1} clay, 130 g kg^{-1} silt, and 600 g kg^{-1} sand.

The planting of pitaya orchard was carried out into 0.5×0.5×0.5 m holes, which were prepared with dolomite lime to raise base saturation to 60%, and then with 10 L bovine manure, 54 g P_2O_5, and 50 g FTE BR12 constituted of 9% Zn, 2.1% Mn, 1.8% B, 0.8% Cu, and 0.1% Mo. The source of P used was the single superphosphate, constituted of 18% P_2O_5, 18% Ca and 20% S. The bovine manure source and the amount added to planting of the orchard provided 23.8 g N, 15.1 g P_2O_5, and 47.6 g K_2O per hole.

The three ten-month-old pitaya species − *Selenicereus megalanthus*, *Hylocereus undatus*, and *Hylocereus polyrhizus* − obtained from the rooting of cuttings and planted at 3×3 m spacing, at 1,111 plants ha^{-1} density. The plants were conducted over eucalyptus posts, with 1.80 m height from soil surface, that contained a 1 m long beam positioned at the top of the post, forming a T-shaped structure. The lateral shoots were pruned to a height of 1.70 m leaving only the main cladode. From that height, all shoots were left for the canopy formation for production.

In the first production cycle (2016/2017 crop season), the N rates were 0, 50, 100, and 200 g per plant, associated with 100 g K_2O per plant. At the last fertilization split, 17 g P_2O_5 were applied per plant, using the Yoorin Master source (17.5% P_2O_5, 18.0% Ca, 7.0% Mg, 0.1% B, 0.08% Cu, 0.3% Mn, 10% Si, and 0.55% Zn). In the second production cycle (2017/2018 crop season), N rates were 50, 100, 200, and 300 g per plant, associated with 200 g K_2O and 35 g P_2O_5 per plant. In the third production cycle (2018/2019 crop season), N rates were 50, 100, 200, and 300 g per plant, associated with 300 g K_2O and 90 g P_2O_5 per plant.

In the three production cycles, the N source was urea constituted of 44% N; K_2O source was potassium chloride constituted of 58% K_2O; and the P_2O_5 source was single superphosphate constituted of 18% P_2O_5, 18% Ca, and 20% S. Nitrogen and K_2O were split in three applications, one in the pre-flowering, in November, and the others at 60 and 150 days after the first application. P_2O_5 was split in two applications, one in the pre-flowering, and the other 150 days after the first application. After the last split of fertilization in each cycle, 5 L of bovine manure were applied per plant that provided 11.9 g N, 7.5 g P_2O_5, and 23.8 g K_2O per plant. The fertilizers were applied superficially to the soil, in the projection of the canopy of the plants.

Irrigation was performed weekly, providing 20 L of water per plant during the dry months. Weed control was conducted by hand up to 40 cm from the plant, and the rest of the area was mowed. Cleaning pruning was performed to eliminate shoots attacked by pests and pathogens, especially in plants that did not receive N fertilization.

Fruit were harvested when they presented the skin with red coloration for *H. undatus* and *H. polyrhizus*, and yellow skin for *S. megalanthus*. Fruit were counted and weighed right after harvest, to determine the productive performance for the number of fruit per plant, yield per plant (kg per plant), and yield (kg ha^{-1}) in open pollination.

The physicochemical characteristics of pitaya were measured in samples of ten fruit taken from each experimental plot, to determine soluble solids (ºBrix), titratable acidity (% malic acid equivalent), soluble solids/titratable acidity ratio (Zenebon et al., 2008), and the average fruit mass (g); transverse and longitudinal diameters were measured in all harvested fruit.

Cladode samples were collected with pruning shears, in the pre-flowering of each productive cycle, which in the region of the present study is in early spring, in September, and the analysis was performed for nutrient level at dry mass. The cladodes that were removed to compose the samples were one year old, formed in the previous spring, with 0.3 m average size and healthy appearance. Cladodes were selected from the ends of the plant, and which had not produced. Each sample was composed of three cladodes per plot, which were collected from three useful plants. The N, P, K, Ca, and Mg contents in the dry mass was determined (Malavolta et al., 1997).

Data were subjected to the analysis of variance, and the N rates were subjected to a polynomial regression analysis, at 1% and 5% probabilities, using the program R 3.6.1. Regression analysis was performed for the rate unfolding within the species (Rabelo et al., 2020b). The species were analyzed separately, and there was no comparison between them, since each species has its different growth and production characteristics (Turcios & Miranda, 1998).

Results and Discussion

In the first production cycle (2016/2017 crop season), there was no difference between the N rates for the evaluated variables in the species *S. megalanthus*, which showed low yield of 94.81 kg ha^{-1} (Table 1). However, *H. undatus* showed an increase of 454.89% yield, 30.7% fruit mass and 47.86% in longitudinal diameter, with an estimated rate of 126.3 g, 102.1 g, and 137.1 g N per plant, respectively, in relation to fruit of plants that were not fertilized with nitrogen. In turn, *H. polyrhizus* species increased 214.88% for the number of fruit per plant, and 150.59% for the yield in plants fertilized with 200 g N, in comparison with plants that did not receive N fertilization.

In the second production cycle (2017/2018 crop season), the species *S. megalanthus* showed increasing values for the number of fruit per plant from 4.45 to 13.67, yield per plant from 0.59 to 1.67 kg, and yield from 656.26 to 1,851.63 kg ha^{-1}, with the fertilization of 300 g N per plant, in comparison with fruit from plants fertilized at 50 g N (Table 1).

In the comparison with plants fertilized with 50 g N, *H. undatus* showed increasing values for the following variables and fertilization rates: number of fruit per plant by 22.83%, with fertilization at 208.1 g N; yield by 28.37%, with 250.7 g N; mass increased by 33.35%, transverse diameter by 9.15%, and longitudinal diameter by 8.36% with 300 g N.

Plants of *H. polyrhizus* species showed increased values for the number of fruit per plant by 29.94% with 197.2 g N, and its yield increased by 31.27% with 214.6 g N per plant, in comparison to plants fertilized with 50 g N.

In the third production cycle (2018/2019 crop season), there was no significant difference between N rates for the evaluated variables of *S. megalanthus* species, whose yield reached 1.18 Mg ha^{-1} (Table 1). In comparison with plants fertilized with 50 g N, the species *H. undatus* showed increased values for the variables and fertilization rates as follows: number of fruit per plant by 22.57%, with 203 g N; yield per plant by 18.37% with 188.6 g N; and yield by 18.33%, with 188.9 g N.

Still, in comparison to plants fertilized with 50 g N per plant, *H. polyrhizus* showed increased values for the variables and applied fertilization rates as follows: number of fruit per plant by 26.3%, with the estimated dose of 185 g N; yield per plant by 15.25%, with 167.4 g N; and yield by 19.66%, with 173.4 g N.

The results observed for *S. megalanthus* can be attributed to the low vegetative vigor of this species, which has delayed the beginning of orchard production and low yield. In the first production cycle, the plants had few productive cladodes still, especially those that were fertilized with the lowest N rates. Plants that were not fertilized had generalized chlorosis and could neither emit cladodes nor produce fruit. The second production cycle highlights the importance of N to produce this species, since this nutrient application increased the yield from 94.81 to 1,851.63 kg ha^{-1} in comparison to first productive cycle. Therefore, during the vegetative growth, the N availability is essential to ensure the development of the root system, for the absorption of water and nutrients, and to stimulate the vigor of cladodes for fruit production.

Unlike *S. megalanthus*, the species *H. undatus* showed rapid vegetative growth, with the emission of large number of cladodes, using part of the N available for vegetative growth, as observed in plants in the first production cycle that could compete with fruit yield.

Pitaya species similarly increased fruit yield as a function of increasing N rates; however, the results differ according to the genetic traits of each species (Turcios & Miranda, 1998), which show differences for growth and, consequently, for yield. In the same soil conditions, climate and management, *S. megalanthus* produced less fruit of lower mass than *H. undatus* and *H. polyrhizus* (Table 1).

Besides showing low vegetative vigor, *S. megalanthus* flowering season does not coincide with the that of the other species cultivated in the experimental area (Rabelo et al., 2020a). This fact may affect size and yield, since even being a self-compatible species, pollen viability is reduced because *S. megalanthus* is a tetraploid plant (2n=44), with irregular meiosis occurring in anaphase I (Lichtenzveig et al., 2000). Thus, if there is a greater

Table 1. Regression equations, coefficient of variation (CV), coefficient of determination (R^2), and maximum value of number of fruit per plant, production per plant, yield, mass, transverse diameter, longitudinal diameter of *Selenicereus megalanthus*, *Hylocereus undatus*, and *Hylocereus polyrhizus*, as a function of the N rates applied to the soil, in the 2016/2017, 2017/2018, and 2018/2019 production cycles.

Variable	CV (%)	*S. megalanthus*	R^2	Maximum value	*H. undatus*	R^2	Maximum value	*H. polyrhizus*	R^2	Maximum value
First production cycle (2016/2017 crop season)										
Number of fruit per plant	48.9	$\hat{Y}=1.3^{ns}$		1.30	$\hat{Y}=3.15^{ns}$		3.15	$\hat{Y}=3.722 + 0.03999x^{**}$	87.5	11.72
Production (kg per plant)	43.8	$\hat{Y}=0.085^{ns}$		0.085	$\hat{Y}=0.1998 + 0.0148x - 0.00006x^{2**}$	91.3	1.11	$\hat{Y}=0.8915 + 0.00673x^{**}$	84.5	2.24
Yield (kg ha^{-1})	43.7	$\hat{Y}=94.81^{ns}$		94.81	$\hat{Y}=226.49 + 16.31x - 0.06455x^{2**}$	91.4	1,256.76	$\hat{Y}=991.59 + 7.4663x^{**}$	84.4	2,484.85
Mass (g)	29.8	$\hat{Y}=56.43^{ns}$		56.43	$\hat{Y}=207.1 + 1.2455x - 0.0061x^{2*}$	96.1	270.68	$\hat{Y}=217.01^{ns}$		217.01
Transverse diameter (mm)	15.8	$\hat{Y}=36.55^{ns}$		36.55	$\hat{Y}=75.9^{ns}$		75.90	$\hat{Y}=68.25^{ns}$		68.25
Longitudinal diameter (mm)	18.4	$\hat{Y}=57.99^{ns}$		57.99	$\hat{Y}=62.8 + 0.4386x - 0.0016x^{2*}$	93.4	92.86	$\hat{Y}=70.46^{ns}$		70.46
Second production cycle (2017/2018 crop season)										
Number of fruit per plant	22.7	$\hat{Y}=2.61 + 0.03688x^{**}$	99.1	13.67	$\hat{Y}=20.16 + 0.092x - 0.000221x^{2**}$	88.9	29.73	$\hat{Y}=19.86 + 0.142x - 0.00036x^{2**}$	99.5	33.86
Production (kg per plant)	23.4	$\hat{Y}=0.375 + 0.0043x^{*}$	98.1	1.67	$\hat{Y}=3.74 + 0.015x - 0.000035x^{2*}$	92.3	5.35	$\hat{Y}=3.72 + 0.023x - 0.000046x^{2**}$	99.8	6.60
Yield (kg ha^{-1})	20.2	$\hat{Y}=417.18 + 4.7815x^{**}$	98.1	1,851.63	$\hat{Y}=4157.12 + 17.45x - 0.0348x^{2**}$	94.9	6,344.64	$\hat{Y}=4128.21 + 26.18x - 0.061x^{2**}$	99.8	6,937.20
Mass (g)	25.3	$\hat{Y}=127.89^{ns}$		127.89	$\hat{Y}=171.01 + 0.2444x^{*}$	84.7	244.33	$\hat{Y}=189.72^{ns}$		189.72
Transverse diameter (mm)	7.5	$\hat{Y}=48.29^{ns}$		48.29	$\hat{Y}=62.22 + 0.0232x^{*}$	71.3	69.18	$\hat{Y}=66.39^{ns}$		66.39
Longitudinal diameter (mm)	7.6	$\hat{Y}=87.87^{ns}$		87.87	$\hat{Y}=72.88 + 0.0248x^{*}$	77.4	80.32	$\hat{Y}=68.57^{ns}$		68.57
Third production cycle (2018/2019 crop season)										
Number of fruits per plant	13.8	$\hat{Y}=12.61^{ns}$		12.61	$\hat{Y}=34.68 + 0.164x - 0.000404x^{2*}$	99.1	51.32	$\hat{Y}=36.53 + 0.2535x - 0.000685x^{2*}$	99.5	59.98
Production (kg per plant)	15.5	$\hat{Y}=1.06^{ns}$		1.06	$\hat{Y}=6.97 + 0.0298x - 0.000079x^{2**}$	78.6	9.78	$\hat{Y}=6.78 + 0.0298x - 0.000089x^{2**}$	96.4	9.27
Yield (kg ha^{-1})	11.2	$\hat{Y}=1,184.09^{ns}$		1,184.09	$\hat{Y}=7759.4 + 32.984x - 0.0873x^{2**}$	78.3	10,874.93	$\hat{Y}=7025.01 + 38.925x - 0.11226x^{2**}$	95.5	10,399.22
Mass (g)	9.9	$\hat{Y}=86.84^{ns}$		86.84	$\hat{Y}=196.24^{ns}$		196.24	$\hat{Y}=160.24^{ns}$		160.24
Transverse diameter (mm)	5.6	$\hat{Y}=43.49^{ns}$		43.49	$\hat{Y}=64.2^{ns}$		64.20	$\hat{Y}=62.34^{ns}$		62.34
Longitudinal diameter (mm)	5.2	$\hat{Y}=74.34^{ns}$		74.34	$\hat{Y}=72.9^{ns}$		72.90	$\hat{Y}=65.43^{ns}$		65.43

^{ns}Nonsignificant. *, **Different at 5% and 1% probability, by the t-test.

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amount of pollen by manual pollination or by plants of different clones, the production of larger mass fruit is possible due to the greater number of seed (Dag & Mizrahi, 2005). In addition, *S. megalanthus* shows high demands for soil organic matter (Kondo et al., 2013), which is low (0.4 dag kg^{-1}) in the soil of the experimental area; even with the addition of 5 L of bovine manure, in each production cycle, no higher yield were achieved. A 2.5-year-old *S. megalanthus* orchard in Peru has been showing promising results with a high soil organic matter contents (4.31%), associated with 78 g N per plant, achieved 3 Mg ha^{-1} yield, with 11 fruit per plant, 253.55 g average mass, 92.7 mm longitudinal diameter, and 71.5 mm transverse diameter (Sanchéz Herrera, 2017). According to Kondo et al. (2013) it is recommended to alternate mineral fertilization with organic sources every two months.

The difference for yield observed between the three production cycles can be attributed mainly to the age of the plants, since plants were in formation at the fertilization period in the first production cycle, therefore most of the fertilizer was used for their growth. In the second and third production cycles, plants had already a higher number of cladodes, using most of the fertilizers in reproductive organs (Sabino López, 2010), which evidences that the fertilization management should be planned according to the orchard age, considering the years of formation of the orchard, and the beginning of the production that demands greater amount of nutrients. Yield can increase up to the 6^{th} year of cultivation, when, generally, pitaya orchards reach the yield stability (Nerd et al., 2002).

The species *H. undatus* and *H. polyrhizus* responded satisfactorily to nitrogen fertilization, reaching respectively 10.87 Mg ha^{-1} and 10.4 Mg ha^{-1} yield in open pollination (Table 1). In Brazil, yield data are variable, depending on the management performed in the orchards. In an *H. undatus* orchard fertilized with organic sources, the yield ranged from 2.57 Mg ha^{-1} to 2.93 Mg ha^{-1} (Marques et al., 2012; Moreira et al., 2012); and *H. undatus* and *H. polyrhizus* species fertilized with 100 g N, associated with 200 g K_2O, produced 8.72 Mg ha^{-1} and 7.02 Mg ha^{-1}, respectively, in the third production cycle (Fernandes et al., 2018). In Nicaragua, in a four-year-old orchard, the yield achieved was 5.17 Mg ha^{-1}, using 108 g N per plant, associated with 36 g P_2O_5 and 9 g K_2O (Turcios & Miranda, 1998), which evidences that the fertilization management of the orchard interferes with the yield of the pitaya species.

There was no difference between the N rates applied to the soil for the chemical characteristics of fruit in the three production cycles (Table 2). The results regarding the chemical characteristics observed in fruit of *H. undatus* and *H. polyrhizus*, which achieved higher yield, are like the results already reported for fruit of these species under similar edaphoclimatic conditions, which were 17.35 and 21.03 °Brix, 0.51 and 0.23% of acidity for *H. undatus* and *H. polyrhizus*, respectively (Fernandes et al., 2018). In the present study, the increasing amount of N fertilizer for the plants did not affect the fruit flavor of the three species; which differs from the work by Chakma et al. (2014), who reported that the increasing N amount supplied to the plants reduces the content of soluble solid of the fruit, which is not desirable. Thus, it is possible to indicate all fruit for natural consumption, according to the present study.

Pitaya with soluble solids greater than 12 °Brix have better acceptance for natural consumption (Wanitchang

Table 2. Soluble solids (SS), titratable acidity (TA), and soluble solids/titratable acidity ratio (RAT) of *Selenicereus megalanthus*, *Hylocereus undatus*, and *Hylocereus polyrhizus* fruit, as a function of the N rates applied to the soil, in the first, second, and third production cycles.

Variables	*S. megalanthus*	*H. undatus*	*H. polyrhizus*
	First production cycle (2016/2017 crop season)		
SS (°Brix)	16.89^{ns}	16.13^{ns}	18.46^{ns}
TA (%)	0.18^{ns}	0.23^{ns}	0.16^{ns}
RAT	90.66^{ns}	70.43^{ns}	119.44^{ns}
	Second production cycle (2017/2018 crop season)		
SS (°Brix)	21.15^{ns}	13.66^{ns}	17.49^{ns}
TA (%)	0.55^{ns}	0.38^{ns}	0.32^{ns}
RAT	42.03^{ns}	36.77^{ns}	55.88^{ns}
	Third production cycle (2018/2019 crop season)		
SS (°Brix)	20.17^{ns}	16.79^{ns}	20.07^{ns}
TA (%)	0.37^{ns}	0.31^{ns}	0.34^{ns}
RAT	56.33^{ns}	57.61^{ns}	57.21^{ns}

^{ns}Nonsignificant.

et al., 2010). In the industry, the processing cost is reduced by dispensing or reducing the incorporation of sugar (Sato et al., 2014). The titratable acidity of less than 1% explains the sweet taste of pitaya (Nerd & Mizrahi, 1999).

The dry mass of cladodes of the three species, in the pre-flowering stage (September 2016), showed an increase of N content from 4.31 to 8.65 g kg^{-1} in *S. megalanthus*; from 3.92 to 5.95 g kg^{-1} in *H. undatus*; and from 4.07 to 7.89 g kg^{-1} in *H. polyrhizus*, as a function of the N rates, which provided higher yield. The P, K, Ca, and Mg contents decreased in the dry mass of cladodes, as a function of the applied N rates in the soil (Table 3).

In September 2017, the N content increased from 9.1 to 17.12 g kg^{-1}, and the P content decreased from 1.85 to 1.32 g kg^{-1} in the dry mass of the cladodes of *S. megalanthus*, in comparison with plants fertilized with 50 g N. In the species *H. undatus* and *H. polyrhizus*, the N content were not significant. There was an increase of K content in *S. megalanthus* and *H. undatus* species (Table 3).

In September 2018, there was no significant difference for the nutrient content in the three species, as a function of the applied N rates in the soil (Table 3). The nutrient content observed in larger quantities in the dry mass of *S. megalanthus* cladodes occurred in the following order: K>Ca>N>Mg>P, in September 2016 and September 2017; K>N>P>Ca>Mg, in September 2018. For the *H. undatus*, the nutrient order was: Ca>K>N>Mg>P, in September 2016; Ca>K>Mg>N>P, in September 2017; and K>N>P>Ca>Mg, in September 2018. For the *H. polyrhizus*, the nutrient order was: K>Ca>N>Mg>P, Ca>K>N>Mg>P, and K>N>P>Ca>Mg in September 2016, September 2017, and September 2018, respectively.

The order of nutrient content in the cladodes can be changed depending on the management carried out in the orchard, the soil cultivation, and the yield achieved. However, they serve as an indication for the planning of orchards, in the sense of making available the nutrients that are demanded by the species of pitaya in greater quantities, to ensure a high yield of commercial quality fruit, since the nutrients observed in greater quantity in the dry mass of the cladodes are present in the most exported by fruit (Rabelo et al., 2020b). Therefore, it is essential to provide an adequate fertilization of nutrients, such as N, that is used and exported in large quantities.

The higher N contents, observed in the dry mass of the cladodes of *S. megalanthus* species, can be attributed to the lower yield and lower vegetative growth of this species, while *H. undatus* and *H. polyrhizus* species, due to their vigor, show a higher demand for nutrients with increased yield (Table 3).

The observed N content is lower than that considered satisfactory by Moreira et al. (2012), of 11 to 16 g kg^{-1}, for the yield of 2.93 Mg ha^{-1}, in the second productive cycle, in *H. undatus* at the same planting density. Thus, as there is no standard that can be used to evaluate the nutritional status of pitaya species, the evaluated contents in the present study, in the first productive cycle, may be considered low and may have influenced the yield.

The reduction of nutrient contents and low N contents observed for the dry mass of cladodes can be attributed mainly to the vegetative growth and plant yield. With the high demand for the emission and formation of cladodes, the plants used a larger amount of nutrients for these drains, which led to the nutrient dilution, justifying the lower observed contents. The lower Ca and Mg contents in September 2018 is justified because the Yoorin Master source was not added to the soil in the previous production cycle.

The observed contents of P, K, Ca, and Mg were similar to those reported for *H. undatus* fertilized with organic sources (Moreira et al., 2012; Costa et al., 2015) and considered satisfactory contents for the species.

In the management of pitaya orchards, the correct amount of nutrients should be supplied annually to obtain satisfactory results in relation to vegetative growth and yield, which makes it possible to plan the production costs of the orchards and is essential for the producer who aims to obtain high yield and commercial standard fruit. It is important to consider that the excess application of fertilizers contributes to higher production costs, thus reducing profit.

The results of this work show the importance of studies focused on nitrogen fertilization, since the definition of the N rates performed in several production cycles evidences that an appropriate management is possible for the pitaya in commercial production.

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Table 3. Regression equations, coefficient of variation (CV), coefficient of determination (R^2), and value that provided the highest plant yield for N, P, K, Ca and Mg (g kg^{-1}) contents in the cladodes of *Selenicereus megalanthus*, *Hylocereus undatus*, and *Hylocereus polyrhizus*, in September 2016, September 2017, and September 2018, as a function of the N rates applied to the soil.

Nutrient	CV (%)	*S. megalanthus*	R^2	$Value^D$	*H. undatus*	R^2	$Value^D$	*H. polyrhizus*	R^2	$Value^D$
					September 2016					
N	12.1	$\hat{Y}=4.31 + 0.0217x^{**}$	93.5	8.65	$\hat{Y}=3.92 + 0.0161x^{**}$	93.2	5.95	$\hat{Y}=4.07 + 0.0191x^{**}$	95.6	7.89
P	45.8	$\hat{Y}=1.51 - 0.0183x + 0.000069x^{2**}$	86.3	0.61	$\hat{Y}=0.59^{ns}$		0.59	$\hat{Y}=0.41^{ns}$		0.41
K	11.2	$\hat{Y}=22.61 - 0.0251x^{**}$	97.8	17.59	$\hat{Y}=19.94^{ns}$		19.94	$\hat{Y}=16.87 - 0.0231x^{**}$	74.8	12.25
Ca	18.6	$\hat{Y}=23.11 - 0.1628x + 0.000485x^{2*}$	83.0	9.95	$\hat{Y}=22.59^{ns}$		22.59	$\hat{Y}=23.97 - 0.068x^{**}$	95.8	10.37
Mg	25.3	$\hat{Y}=7.02 - 0.0702x + 0.000237x^{2**}$	96.9	2.46	$\hat{Y}=3.74^{ns}$		3.74	$\hat{Y}=4.79 - 0.043x + 0.000142x^{2**}$	96.5	1.87
N^D		200			126.3			200		
					September 2017					
N	14.2	$\hat{Y}=7.49 + 0.0321x^{**}$	75.9	17.12	$\hat{Y}=7.48^{ns}$		7.48	$\hat{Y}=13.82^{ns}$		13.82
P	20.8	$\hat{Y}=2.46 - 0.014x + 0.000034x^{2**}$	80.9	1.32	$\hat{Y}=0.78^{ns}$		0.78	$\hat{Y}=0.87^{ns}$		0.87
K	17.6	$\hat{Y}=29.44 + 0.0494x^{**}$	82.8	44.26	$\hat{Y}=25.17 + 0.0297x^{*}$	91.7	32.62	$\hat{Y}=26.4^{ns}$		26.4
Ca	31.5	$\hat{Y}=34.55^{ns}$		34.55	$\hat{Y}=37.67^{ns}$		37.67	$\hat{Y}=37.15^{ns}$		37.15
Mg	15.6	$\hat{Y}=7.57^{ns}$		7.57	$\hat{Y}=7.7^{ns}$		7.7	$\hat{Y}=7.3^{ns}$		7.3
N^D		300			250.7			214.6		
					September 2018					
N	19.8	$\hat{Y}=14.78^{ns}$		14.78	$\hat{Y}=12.1^{ns}$		12.1	$\hat{Y}=9.93^{ns}$		9.93
P	15.7	$\hat{Y}=2.62^{ns}$		2.62	$\hat{Y}=1.93^{ns}$		1.93	$\hat{Y}=1.68^{ns}$		1.68
K	24.1	$\hat{Y}=44.77^{ns}$		44.77	$\hat{Y}=35.72^{ns}$		35.72	$\hat{Y}=27.17^{ns}$		27.17
Ca	18.5	$\hat{Y}=0.29^{ns}$		0.29	$\hat{Y}=0.34^{ns}$		0.34	$\hat{Y}=0.33^{ns}$		0.33
Mg	23.5	$\hat{Y}=0.06^{ns}$		0.06	$\hat{Y}=0.05^{ns}$		0.05	$\hat{Y}=0.04^{ns}$		0.04
N^D		300			188.9			173.4		

$Value^D$, N dose-dependent value for increased yield. N^D, N dose for higher yield. ^{ns}Nonsignificant. *, **, different at 5% and 1% probability, by the t-test.

Conclusions

1. Nitrogen fertilization increases the yield and fruit quality of the *Selenicereus megalanthus, Hylocereus undatus*, and *Hylocereus polyrhizus* pitaya species.

2. Nutrient contents in the cladodes of pitaya species increase to a satisfactory content with nitrogen fertilization.

3. The adequate nitrogen rate for *Selenicereus megalanthus* is 300 g per plant, and for *Hylocereus polyrhizus* and *Hylocereus undatus*, from 170 to 190 g N per plant, as long as plants are supplemented with P and K.

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