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Effect of population and organomineral fertilization on physico-chemical quality of fruits of *Passiflora edulis* cv. Guinezinho

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Abstract

The phyto-technical management of crops, such as the conduction system, spatial arrangement of plants and mineral and organic fertilization are pre-harvest agronomic factors that can alter fruit quality. Therefore, this research was developed to evaluate physico-chemical attributes of yellow passion fruit as a function of population arrangement and organomineral fertilization. The experiment was carried in Entisol with free-sand texture under tropical climate with dry summer. The treatments were obtained from the combination of doses of nitrogen (92, 119, 183, 248 and 275 kg ha^{-1}) and soil organic matter (1.3, 1.8, 2.9, 4.0 and 4.5%), through Central Box Compound, plus four additional treatments to study the effect of the number of plants per pit. The evaluations were carried on seven and ten months after the transplanting of the seedlings. A randomized block design with three replications was used. The fruits were harvested at the beginning of the yellowing of the bark and evaluated in the pulp: pH, total titratable acidity (TTA), total soluble solids (TSS), reducing sugars, non-reducing sugars and total sugars, ascorbic acid, TSS/TTA ratio, electrical conductivity and humidity. The harvesting season changed the physico-chemical properties of the passion fruit pulp and interfered with the effects of plant management and fertilization on the quality of passion fruit. For the production of the best quality passion fruit we may cultivate one, two or three plants per pit. With three plants per pit it is recommended to apply 180 kg ha^{-1} of nitrogen annually and raise the soil organic matter to 4%.

Keywords: *Passiflora edulis*Sims; nitrogen; organic matter; plants per pit; pre-harvest factors.

Introduction

Brazil is the largest consumer and producer of yellow passion fruit, its pulp consumed as juice or processed (Faleiro and Junqueira, 2016), but also takes advantage of fruit peels and seeds in food and pharmaceutical industries (Galisteo et al., 2008; Janebro et al., 2008; Lopes et al., 2010). In 2017, the Brazilian production was 554,598,000 kg, with a higher share of the Northeast region (61%), followed by the Southeast (15%), South (13%), North (8%) and Central West in an area of 41,090 hectares (IBGE, 2017). However, the average yield of the crop was only 13,497 kg ha^{-1} (IBGE, 2017), below the potential yield that may exceed 50,000 kg ha^{-1} (Faleiro e Junqueira, 2016). This way, it is necessary to mitigate environmental adversities and improve crop management to increase productivity, which is linked to the physical and chemical-physical quality of the crop, in accordance with the quality standards demanded by the market.
One of the initial measures is the use of materials adapted to the growing region, seeing that the quality of production is linked to genetic factors (genotypes and plant age), as well as to environmental factors (location and growing season, light and radiation exposure, and temperature) and agronomic (salinity, water management, plant nutrition, biostimulants and microbial inoculants, soil management, and harvest) (Vitorri et al., 2018). In order to improve the nutrient content of the fruits, it is necessary to increase the productivity of the plants (Andrade Junior et al., 2003; Nasser et al., 2011). In this context, Figueiredo et al. (2015) and Weber et al. (2016) conducted an experiment in vertical espalier with populations of one and two plants per pit and did not observe significant variations in the physical and physical-chemical properties in the passion fruit, but concluded that there may be gain in productivity. Changes in the conduction system of passion fruit, such as laying the main stem vertically or diagonally can also change the productivity and quality.
Densified cultivation systems with more than one plant per pit and/or reducing the spacing have been suggested to improve the efficiency of the use of environmental resources (Figueiredo et al., 2015; Weber et al., 2016). These systems need adjustment of the applied inputs. One of the main responsive inputs is the application of organic and mineral fertilizers. Nitrogen, an essential element can change the quality of passion fruit (Rapisarda et al., 2008; Petry et al., 2012; Silva et al., 2015; Dias et al., 2017), and the profitability of the orchard (Miyake et al., 2016, 2018). Nitrogen responses are related to rate of application (Rahimizadeh et al., 2010). Organic fertilization can also alter

the physical-chemical and mineral quality of passion fruit, and even replace mineral fertilization (Pacheco et al., 2016; 2017; 2018).
This research was developed with the objective of evaluating physical-chemical attributes in the passion fruit pulp as a function of organomineral, nitrogen fertilization and organic matter, as well as the effects of the population arrangement, planting density/conduction in two harvest times.

Results and Discussion

The effects of population arrangement and organomineral fertilization were significant on practically all the physical-chemical variables analyzed in the passion fruit pulp, observing also the influence of the harvest season (Table 1).

Conduction/planting density

Hydrogenation potential

The pH in the passion fruit pulp was related to the arrangement of the plants and the interaction of this factor with the harvest season (Table 1). No difference was observed in each arrangement for the pH of the passion fruit pulp (Table 2). Medeiros et al. (2009) reported the similar results. However, the interval between the harvests of these authors was one month. Medeiros et al. (2014) observed higher pH in fruits at the beginning and end of the harvest, interval close to four months. The pH in the passion fruit pulp may increase by 86% depending on the month of harvest (Silva et al., 2016). The meteorological conditions during the formation can alter the growth and the quality of the fruits, as much in the assimilated contribution as in the process of maturation. Vianna-Silva et al. (2008) obtained passion fruit with lower pulp pH under mild air temperature conditions.
In the one- and two-plant-per-hole arrangements, higher pH values were obtained (2.4 to 2.7), while in three and six plants the pH was between 3.0 and 3.2, an average increment of 19% (Table 2). There is a need for greater growth of the main stem in three and six-plants in the pit. It is approximately 2.2 m in passion fruit with vertical growth and 3.3 m when tilted, compared to single- and two-plant crops, with only vertical growth and 2.2 m rod. This probably changes the compositions and the flow rates of the sap with responses in the physical-chemical constitution of the passion fruit. The configurations with three and six plants in the pit probably reduced the translocation of organic acids to the fruit because the pH of the pulp, even with its buffering capacity, is associated with organic acids (Chitarra and Chitarra, 2005), presenting a high correlation (r = -0.79) between the pH and titratable acidity (Medeiros et al., 2009). We obtained r = -0.44 (t = - 4.01; p = 0.002; n = 68) in this research.

Ttitratable total acidity

The titratable total acidity of passion fruit pulp, based on citric acid, was affected by the interaction between plant arrangement and harvesting season (Table 1). Populations with one and six plants per pit did not differ in the titratable acidity of fruits between harvests, but reductions were occurred from the first to the second harvest in the arrangements with two, 4.5 to 3.3% citric acid (-27%), and three plants, from 3.7 to 3.1% citric acid (-16%) (Table 2). The citrus acid is rapidly accumulated after the physiological maturity of the fruit and it is degraded during ripening (Vianna-Silva et al., 2010; Botelho et al., 2019) to meet the respiratory demand of this climacteric fruit (Alves et al., 2013). According to Cavichioli et al. (2008) and Vianna-Silva et al. (2008, 2010) temperature is a preponderant factor in the concentration of citric acid. Under higher temperatures, the degradation of this acid may occur to meet the respiratory demand of the fruit.
It was also observed that the titratable acidity in the fruit pulp decreased with increasing number of plants per pit (Table 2). In the first harvest, the reduction was from 4.5 to 3.7% of citric acid (-18%) of the fruits from the arrangement with two plants for the means of the three and six arrangements. In the second harvest, the reduction was from 4.1 to 3.2% of citric acid (-22%) of the fruits to the average of those coming from the arrangements with two, three and six plants in the pit. Figueiredo et al. (2015) and Weber et al. (2016) did not observe variation in the titratable acidity of the fruits with populations with one and two plants per pit but same conduction. Organic acids are also translocated by plant phloem (Taiz et al., 2017). So, the effect of plant management can be decisive in the translocation and accumulation of citric acid in passion fruit. Dias et al. (2017) found values of 8.17 to 8.81% of titrable total acidity in the fruit of cultivars of yellow passion fruit, higher than the ones of this research.

Soluble solids

The soluble solids in passion fruit pulp were influenced jointly by population arrangement and harvesting season (Table 1), with a higher concentration in the second crop. On average it was 1.4 °Brix more in cultures with one and three plants per pit (Table 2). The soluble solids increase during the growth/maturation of passion fruit (Coelho et al., 2010; Vianna-Silva et al., 2010; Alves et al., 2013), and it is also one of the most influenced physical-chemical atributes by the harvest season. The highest (16.5 °Brix) and lowest (12.6 °Brix) soluble solids values were in the fruits of the second crop in the arrangement with one plant and in the first crop of the crop with six plants per pit, respectively. This is above the standard (11 °Brix) required for commercialization in Brazil (MAPA, 2018).
There is a tendency to decrease soluble solids in passion fruit with increasing plants per pit, with the lowest values in the arrangement with six plants per pit (Table 2). The alteration in cultivation of plants may have possibly led to change of contribution in the composition of these soluble solids to the fruits. Figueiredo et al. (2015) and Weber et al. (2016) did not observe variation in soluble solids in passion fruit between populations with one and two plants per pit. Carbohydrates, predominantly sucrose, are the soluble elements with the highest concentration in the phloem (Taiz et al., 2017). In yellow passion fruit, about 70% of soluble solids are soluble sugars, of which 96% are reducing sugars (Santos et al., 2013). However, in the present research glucose and sucrose (soluble sugars) represented an average of 36% of the soluble solids and they are in the same proportion (Table 1).

Sugars

Reducing sugars in passion fruit pulp, expressed as glucose, were influenced only by the harvesting season, whereas for non-reducing (sucrose) and total sugars the interaction between harvesting season and plant arrangement was significant (Table 1). Reducing sugars increased from 2.27 to 2.58 g of glucose $100g^{-1}$ (14%) from the first to the second crop, respectively (Table 2). Also, an increase of the first to second harvest in the fruit pulp was observed in the non-reducing sugars from the arrangements with one (57%) and two (53%) plants per hole, and of the total sugars harvested in the populations with one (43%) and three (19%) plants in the pit. The physico-chemical composition of fruits are related both to the season of the year. The temperature is one of the most important meteorological factors, as the age of the plant (Vitorri et al., 2018). However, Medeiros et al. (2014) observed no variation in the sugars of passion fruit harvested at the beginning and end of the harvest, even though the soluble solids were reduced in the second season.

The effects of plant arrangements on non-reducing and total sugars in passion fruit were directly related to the harvest season (Table 2). In the first harvest, the increase from one to six passion fruit per pit increased the non-reducing sugars to the respective values of 1.71 and 2.50 g $100g^{-1}$, an increase of 46%. The total was increased from 3.70 to 4.91 g $100g^{-1}$, which showed a 33% increase. In the second harvest, the lowest value (2.44 g $100g^{-1}$) of non-reducing sugars was the fruit in the arrangement with three plants and the largest (3.16 g 100 g^{-1}) under two plants, while for the total sugars no differences were observed between arrangements, with average of 5.29 g $100g^{-1}$.

Ascorbic acid

The concentration of ascorbic acid (vitamin C) in passion fruit pulp was influenced by the interaction between plant arrangement and harvesting season (Table 1). A higher concentration of vitamin C was observed in fruits of the second crop, with a minimum elevation of 5 (31%) and maximum value of 10.5 mg $100g^{-1}$ (63%) between crops under the same arrangement (Table 2). Genetic material, climatic conditions and cultural practices are pre-harvest factors that affect fruit quality (Lee and Kader, 2000; Vitorri et al., 2018). At higher temperatures, there is less synthesis of vitamin C (Lee and Kader, 2000), justifying the variations between the crops not found by Medeiros et al. (2014).

Vitamin C in passion fruit pulp was also more concentrated in the populations with the highest number of plants per pit. They were increased from 6.0 to 18.2 mg 100^{-1} (14%) in the first harvest, and 21.0 to 26.3 mg 100^{-1} (25%) in the second crop, in arrangement with 1, 2, 3 and 6 plant per pit configurations, respectively. The highest concentration of vitamin C in fruits may be related to the conversion of glucose-6-phosphate, precursor of ascorbic acid (Chitarra and Chitarra, 2005). Meteorological factors such as lower temperature and increased availability of light and water may raise vitamin C in passion fruit (Lee and Kader, 2000).

Relationship between soluble solids and total titratable acidity

The relationship between soluble solids and total titratable acidity (TSS/TTA) was independently influenced by the harvest season and the number of plants per pit (Table 1). This ratio increased from 3.56 to 3.94 (11%) from the first to the second crop (Table 2). Regarding the population arrangements, the highest value of the TSS/TTA ratio (4.3) was observed in the fruits harvested from the three-per-plant cultivation, which did not differ from the one and two-plant arrangements, but exceeded the population of six plants per pit. Sugars and organic acids contribute appreciably to the fruit's taste (Chitarra and Chitarra, 2005).

Electrical conductivity

The electrical conductivity in the passion fruit pulp was affected only by the harvest season (Table 1), whereas it was reduced from 4.5 to 4.3 dS m^{-1} from the first to the second, respectively (Table 2). The electrical conductivity expressed the total concentration of material dissolved in the pulp (Medeiros et al., 2014). In this work, we observed that the increase of the electrical conductivity of the pulp is related to the increase of humidity (r = 0.32; = 2.66, p = 0.0099, n = 66).

As for moisture in the fruit pulp, the interaction effect between harvest season and arrangement was significant (Table 1). In relation to the harvesting period, a difference in moisture was observed only under the arrangement of three plants per pit, with a reduction from 89.6 to 87.6% from the first to the second crop, respectively (Table 2). In the two harvest periods, the differences among the arrangements were not significant on values of humidity in the passion fruit pulp, varying from 87.6% of the fruits of the arrangement with three plants in the second crop, to 89.9%, in the population with six plants per pit in the first harvest.

Organomineral fertilization

Hydrogenation potential

The effect of organomineral fertilization on the passion fruit pH was independent from the harvest season (Table 1). The highest pH in the passion fruit pulp was obtained under the lowest nitrogen dose (3.22) (Fig 1). The pH was reduced with the application of nitrogen with a higher rate of reduction up to the dose of 193 kg ha^{-1}, representing a decrease of 4% compared to the dose of 92 kg ha^{-1}.The nutritional status of the plants is a decisive agronomic factor in fruit quality (Vitorri et al., 2018), and the application of nitrogen can alter the titratable acidity (Silva et al., 2015, Dias et al., 2017), interfering in the pH of the pulp (Chitarra and Chitarra, 2005).

The effect of organomineral fertilization on titratable acidity was related to the harvest season (Table 1). The fruit acidity in the first harvest was influenced jointly by nitrogen and organic fertilization, observing an increase of 16 and 28% with increase of nitrogen from 92 to 275 kg ha^{-1}, 1.3% of organic matter, and matter organic matter from 1.3 to 4.5%, under the lowest nitrogen dose (Fig 2A).

Table 1. Values of the F-test of the likelihood analysis for the hydrogen ionic potential (pH), vitamin C (Vit C), total soluble solids (TSS), total titratable acidity (ATT), soluble solids and acidity ratio (TSS/ATT) (NR), non-reducing (NR) and total (NR) sugars in passion fruit pulp at harvest, and the factorial between doses of nitrogen and organic matter in the central compost (CCB) and the number of plants per pit.

FV	GL	pH	ATT	SST	AR	ANR
Crop (C)	1	0.01^{ns}	121.83**	1.39^{ns}	16.84*	132.92**
Treatment (T)	(11)	11.05**	4.79**	6.41**	5.57**	7.98**
CCB	8	1.36^{ns}	5.06**	2.55*	7.46**	9.73**
Additional items (A)	3	242.24**	6.52**	12.99**	0.26^{ns}	4.55**
C x T	(11)	1.58^{ns}	5.59**	0.93^{ns}	4.40**	7.09**
C x CCB	8	1.27^{ns}	4.20**	1.42^{ns}	10.52**	15.93**
C x A	3	13.19**	3.25*	4.02*	1.80^{ns}	3.15*
CV (%)		4.57	6.74	5.72	10.90	11.60
Average		3.03	3.68% citric acid	13.67 °Brix	2.43 g 100g^{-1}	2.51 g 100g^{-1}
FV	GL	AT	Vit. C	SST/ATT	CE	HUMIDITY
Crop (C)	1	117.58**	1.194.49**	22.28**	10.43*	4.67^{ns}
Treatment (T)	(11)	5.34**	9.36**	3.49**	1.15^{ns}	1.44^{ns}
CCB	8	6.52**	8.50**	4.36**	1.35^{ns}	1.16^{ns}
Additional items (A)	3	2.56^{ns}	13.39**	3.52*	1.52^{ns}	2.27^{ns}
C x T	(11)	3.39**	7.31**	3.97**	0.69^{ns}	1.20^{ns}
C x CCB	8	9.13**	4.14**	2.44*	1.31^{ns}	0.97^{ns}
C x A	3	3.60*	4.20*	1.14^{ns}	1.39^{ns}	2.91*
CV (%)		8.48	6.02	9.16	5.10	0.89
Average		4.94 g 100g^{-1}	21.08 mg 100g^{-1}	3.75	4.39 dS m^{-1}	88.84%

^{ns}, * e **: not significant and significant at 5 and 1% probability by the F test, respectively.

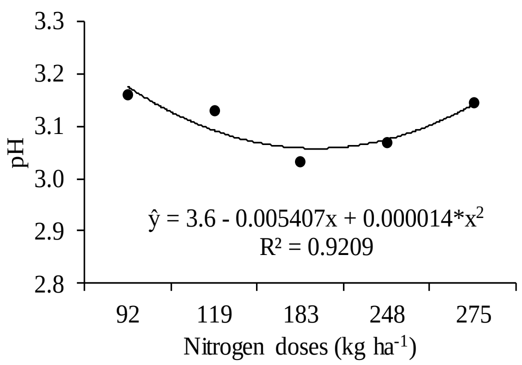

Fig 1. Hydrogen ionic potential in passion fruit pulp as a function of nitrogen. *significant at 5% probability by the F test.

Table 2. Mean values of hydrogenation potential pH, total soluble solids (SST), reducing sugars (RA), non-reducing sugars (ANR) and total (AT), vitamin C (Vit C), soluble solids and acidity (SST / ATT), electrical conductivity (EC) and humidity (UMID) in passion fruit pulp in terms of harvest and number of plants per pit/conduction.

	Plants per pit/conduction					Plants per pit/conduction				
Crop	1*	2*	3**	6**	Average	1*	2*	3**	6**	Average
	pH					TTA (g citric acid 100g^{-1})				
1	2.40bA	2.55bA	2.97aA	3.19aA	2.78	3.86abA	4.52aA	3.72bA	3.65bA	3.94
2	2.47bA	2.69abA	3.02aA	3.07aA	2.81	4.07aA	3.26bB	3.07bB	3.39bA	3.45
Average	2.44	2.62	3.00	3.13	2.80	3.97	3.89	3.40	3.52	3.69
	TSS (°Brix)					AR (g glucose 100g^{-1})				
1	15.0aB	14.8aA	13.7abB	12.6bA	14.0	2.00	2.56	2.21	2.41	2.29B
2	16.5aA	15.0aA	15.1aA	13.0bA	14.9	2.60	2.27	2.65	2.36	2.47A
Average	15.8	14.9	14.4	12.8	14.5	2.30a	2.41a	2.43a	2.38a	2.38
	ANR (g sucrose 100g^{-1})					AT (g 100g^{-1})				
1	1.71aB	2.07abB	2.07abA	2.50aA	2.09	3.70bB	4.63aA	4.28abB	4.91aA	4.38
2	2.69abA	3.16aA	2.44bA	2.96aA	2.81	5.29aA	5.43aA	5.09aA	5.33aA	5.29
Average	2.20	2.62	2.25	2.73	2.45	4.50	5.03	4.69	5.12	4.83
	Vit. C (mg 100^{-1})					TSS/TTA				
1	16.0bB	16.8abB	18.9aB	19.0aB	17.7	3.92	3.26	3.69	3.46	3.59B
2	21.0bA	27.3aA	25.8aA	25.7aA	24.9	4.05	4.55	4.91	3.85	4.34A
Average	18.5	22.1	22.4	22.3	21.3	3.99ab	3.91ab	4.30a	3.66b	3.96
	CE (dS m^{-1})					Humidity (%)				
1	4.37	4.37	4.26	4.62	4.41A	88.1aA	87.7aA	89.6aA	89.9aA	88.8
2	4.23	4.24	4.08	4.26	4.20B	87.9aA	89.1aA	87.6aB	88.8aA	88.4
Average	4.30a	4.31a	4.17a	4.44a	4.30	88.0	88.4	88.6	89.4	88.6

*Plants conducted only with main stem vertically.**Leaded plants with main stem vertically and diagonally.Means followed by the same letter, upper case between crops and lowercase between plants per pit, do not differ among themselves by the F (p ≤ 0.05) and Tukey (p ≤ 0.05) tests, respectively.

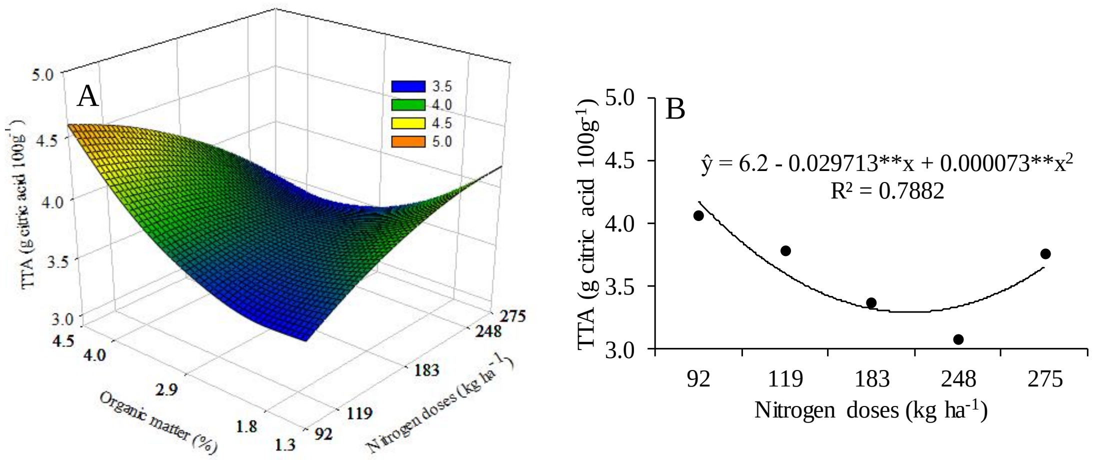

Fig 2. Titratable total acidity in passion fruit pulp as a function of nitrogen and organic matter in the first (A) and nitrogen in the second crop (B). ŷ (A) = 2.9 + 0.012756°N - 0.000016*N^2 - 0.163007MO + 0.127386**MO^2 - 0.002868**N*x*MO, R^2 = 0.7189. °, * and **: significant at 10, 5 and 1% of probability by the F test, respectively.

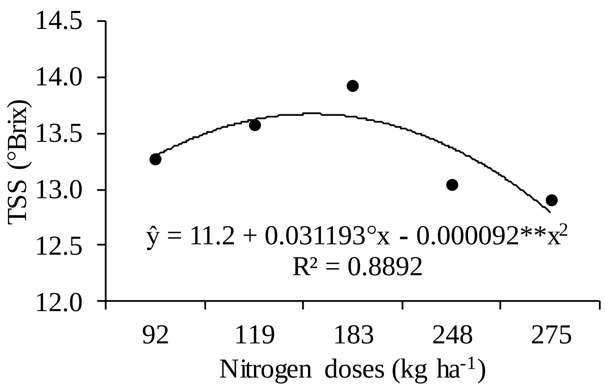

Fig 3. Soluble solids in passion fruit pulp as a function of nitrogen. ° and **: significant at 10 and 5% probability by the F test, respectively.

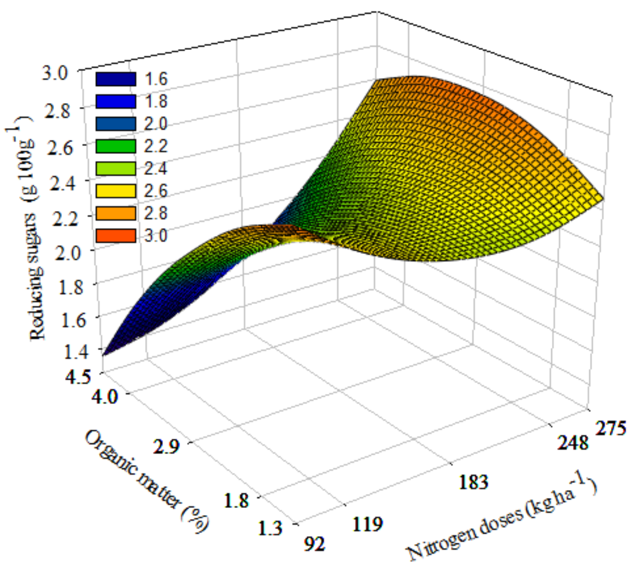

Fig 4. Reducing sugars in passion fruit as a function of nitrogen and organic matter, first harvest. ŷ = 4.1 - 0.01626**N + 0.00003**N^2 - 0.187853**MO - 0.087197**MO^2 + 0.002672*N*x*MO, R^2 = 0.5139. * and **: significant at 5 and 1% of probability by the F test, respectively.

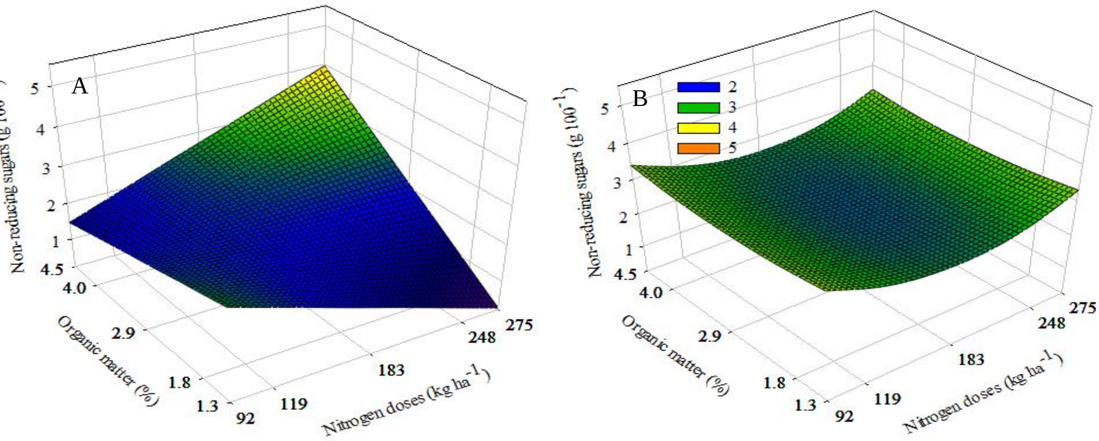

Fig 5. Non-reducing sugars in the first (A) and second (B) harvest as a function of nitrogen and organic matter doses. ŷ (A) = 5.4 - 0.0242N - 1.1516**MO + 0.0084**N*x*MO, R^2 = 0.8537; ŷ (B) = 6.2 - 0.033954N + 0.000091**N^2 - 0.446029MO + 0.076829°MO^2, R^2 = 0.7712. ° and **: significant at 10 and 1% of probability by the F test, respectively.

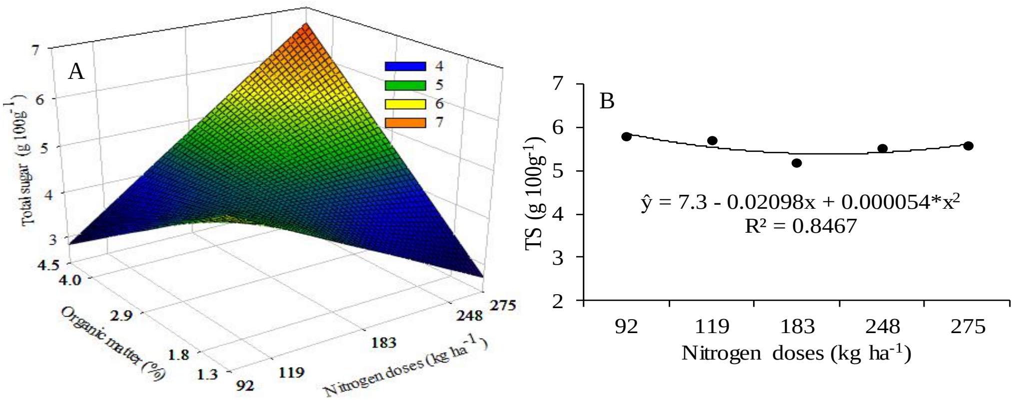

Fig 6. Total sugar in passion fruit pulp as a function of nitrogen and organic matter in the first (A) and nitrogen in the second crop (B). ŷ (A) = 9.2 - 0.0294*N - 1.8453*MO + 0.0112**N*x*MO, R^2 = 0.7469. * and **: significant at 5 and 1% probability by the F test, respectively

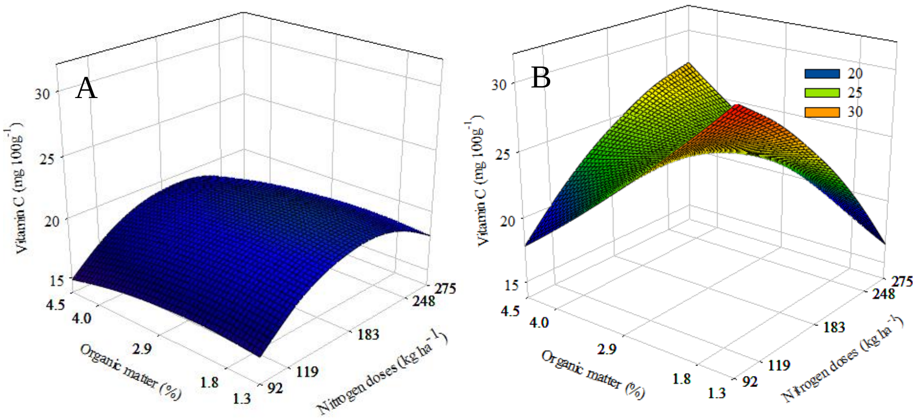

Fig 7. Vitamin C in passion fruit pulp as a function of nitrogen and organic matter in the first (A) and second (B) harvest. ŷ (A) = 3.3 + 0.1585N - 0.0004**N^2 + 1.4092MO - 0.2998*MO^2, R^2 = 0.8939; ŷ (B) = 47.0 - 0.0674N - 0.0002*N - 9.6206*MO + 0.2094*MO + 0.0429*N*x*MO, R^2 = 0.8402. * and **: significant at 5 and 1% of probability by the F test, respectively.

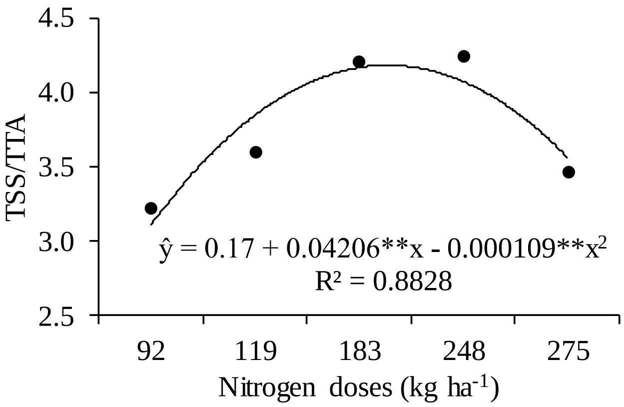

Fig 8. Relation between total soluble solids and titratable total acidity (TSS/TTA) in passion fruit pulp as a function of nitrogen. **: significant at 1% probability by F test.

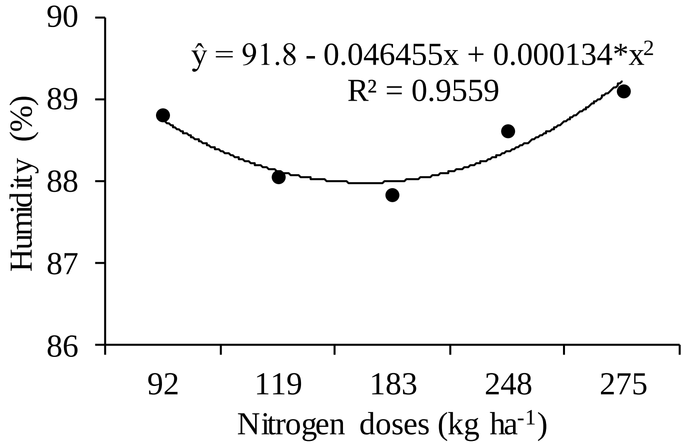

Fig 9. Humidity in passion fruit pulp as a function of nitrogen. **: significant at 1% probability by F test.

However, the concomitant increase of the fertilizers reduced the titratable acidity from 3.60 to 3.49% citric acid, with the highest concentration (4.60% citric acid) obtained under the combination of 92 kg ha^{-1} of N and 4.5% of organic matter in soil. In the second harvest, the acidity in the pulp was decreased with the nitrogen doses, with a lower value of 3.18% citric acid under 206 kg ha^{-1} of N, a 22% reduction compared to the 92 kg ha^{-1} dose (Figure 2B).

Titratable total acidity

Nitrogen fertilization may alter the titratable acidity and the effect is related to organic fertilization (Silva et al., 2015). These authors observed a reduction in the titratable acidity with increase in nitrogen doses to passion fruit tree. When plants also received humic substances and nitrogen fertilization the acidity was increased. Thi is opposite to the results of this research, when the association between organic matter and nitrogen reduced the passion fruit acidity. Dias et al. (2017) did not find an answer to the passion fruit acidity with increased fertilization with nitrogen and potassium.

Solids soluble

Harvest time did not interfere with the effect of organomineral fertilization on solids soluble in passion fruit pulp (Table 1). In general, the total soluble solids decreased in the passion fruit pulp with nitrogen application (Fig 3). This reduction was registered in the comparison between the lowest and highest nitrogen doses, reducing soluble solids by 4% (13.3 to 12.8 °Brix). However, increase of nitrogen dose from 92 to 164 kg ha^{-1} increased the soluble solids by 4% in the passion fruit pulp, reaching 13.8 °Brix. Nitrogen plays an important role in the biosynthesis of sugars in the leaf, which is translocated to fruits (Taiz et al., 2017). On the other hand, the excess of nitrogen fertilization may lead to a reduction in the solubility of soluble solids due to competition due to bigger fruit production (Spironello et al., 2004; Duarte et al., 2008).

Sugars

Reduction of non-reducing and total sugars in the passion fruit pulp was influenced by organomineral fertilization, and the effects were related to the harvesting season (Table 1). Reducing sugars in the fruits of the first harvest were affected by nitrogen and organic matter (Fig 4). The highest concentration of reducing sugars (2.8 g $100g^{-1}$) was obtained using combination of 92 kg ha^{-1} of N and 1.3% of organic matter. The increase in nitrogen or organic matter decreased the reducing sugars when only one of these fertilizers was increased. However, the concomitant increase from 190 kg ha^{-1} of N to 1.8% of organic matter reverses the

isolated effect of this fertilization. In the second harvest, the variations in reducing sugars were not justifiable due to organomineral fertilization.
The non-reducing sugars in the passion fruit pulp in the first harvest were affected by organomineral fertilization (Fig 9A). The increase of nitrogen or organic matter reduced the non-reducing sugars, but the concomitant increase of these fertilizers raised the sugars from 2.7 to 4.0 g $100g^{-1}$ which obtained in the combinations between the lower and higher levels of nitrogen and organic matter, respectively. In the second harvest, there was no interaction between nitrogen and organic matter, with isolated effects (Fig 9B). Nitrogen fertilization reduced the non-reducing sugars in the passion fruit pulp, with the greatest reduction at 187 kg ha^{-1} N, reflecting a loss of 25%, compared to 3.2 g $100g^{-1}$ under the lowest nitrogen dose. Organic matter also resulted in a decrease in sugars, observed only up to the level of 2.9%.
Total sugars had practically the same trends as non-reducing sugars. In the first harvest, the effects of nitrogen and organic matter were interacted and the isolated increase of these fertilizers reduced the total sugars (Fig 10A). However, the concomitant increase of these fertilizers increased the total sugars from 5.4 to 6.7 g $100g^{-1}$, with an increase of 24%, obtained in the combinations between the lowest and highest levels of nitrogen and organic matter, respectively. Regarding the second harvest, only nitrogen effect was observed on total sugars (Fig 10B). At that time the increase of nitrogen from 92 to 194 kg ha^{-1} reduced the sugars from 5.8 to 5.3 g $100g^{-1}$, loss of 9%.

Ascorbic acid

Vitamin C in passion fruit was influenced by the interaction between organomineral fertilization and harvesting season (Table 1). In the first harvest, the effects of nitrogen and organic matter were independent, with an increase in ascorbic acid of 16.1 to 20.6 mg $100g^{-1}$ (28%) with applications of 92 and 198 kg ha^{-1} of N (Fige 7A). Meanwhile, the increase in soil organic matter from 1.3 to 2.4% increased vitamin C in fruits by only 2% (20.2 and 20.6 mg $100g^{-1}$). In the second harvest, interaction of organomineral fertilization on vitamin C was observed, with reductions of up to 49 and 46% with increase of nitrogen from 92 to 275 kg ha^{-1} and organic matter from 1.3 to 4.5%, respectively. This effect is reversed when the two fertilizers are simultaneously increased (Fig 7B). However, the maximum was under the lowest applications of nitrogen and organic matter (32.1 mg $100g^{-1}$).
The effect of the reduction in vitamin C on fruits is related to the source used, and the synthetic ones are responsible for the reduction (Rapisarda et al., 2008). The reduction of vitamin C with the elevation of the nitrogen dose can lead to a decrease in the synthesis of sugars and ascorbic acid in fruits, in detriment to the stimulus of protein synthesis (Petry et al., 2012).

Relationship between total soluble solids and total titratable acidity

The relationship between total soluble solids and total titratable acidity (TSS/TTA) in relation to organomineral fertilization was related to the harvest period (Table 1). The sweetness (TSS/TTA) in the first harvest was not explained by fertilization. In the second crop, sweetness was increased with nitrogen application, increasing from 3.1 to the maximum of 4.2 at 92 and 193 kg ha^{-1}, respectively (Fig 8). There was also a 13% gain in the sweetness of passion fruit with 275 kg ha^{-1} compared to those who received the lowest fertilization. This increase in sweetness with the elevation of N doses converges with the trends observed in the increase of SST and in the decline of total titratable acidity.

Electrical conductivity

The electrical conductivity in the passion fruit pulp did not adjust to the regression models as a function of organomineral fertilization, with an average of 4.39 dS m^{-1} (Table 1). The variation in pulp moisture was one unit, reducing from 89 to 88 followed by 89% under the doses of 92, 173 and 275 kg $ha^{-1}$of nitrogen, respectively (Fig 9). This behavior converges with that observed in the total soluble solids, since they are inversely proportional to the moisture content. However, high nitrogen applications may result in the decrease of the soluble solids contents caused by the dilution due to the higher productivity of the fruits (Silva et al., 2015).

Materials and Methods

Research location

The research was carried out from May 2017 to July 2018 at the Macaquinhos site (7º 00 '04 "south latitude, 35º 47' 54" longitude west of Greenwich Meridian and 558 m altitude), municipality of Remígio, State of Paraíba, Brazil. The municipality is under the climatic zone, according to classification of Köppen, type As, under tropical climate with dry summer (Alvares et al., 2013). The soil of the experimental area was classified as Entisol, which was analyzed in a composite sample removed in the 0-20 cm layer of the profile according to the methodologies compiled by Teixeira et al. (2017). In the fertility, Entisol has pH of 5.6, phosphorus of 17.85 mg dm^{-3}, potassium, sodium, calcium, magnesium, sum of bases, aluminum, potential acidity and cation exchange capacity of 0.93, 06, 0.39, 0.36, 1.74, 0.05, 0.91 and 2.65 $cmol_c$ dm^{-3}, respectively, 65.7% base saturation and 15.18 g dm^{-3} organic matter. With free-sand texture, the Entisol had 869, 78 and 53 g kg^{-1} of sand, silt and clay, respectively, with the respective soil and particle densities of 1.50 and 2.63 g cm^{-3} and porosity total of 0.43 m^3 m^{-3}.

Treatments and experimental design

The treatments were obtained from the combination of nitrogen rates (92, 119, 183, 248 and 275 kg ha^{-1}) and organic matter concentrations in the soil (1.3, 1.8, 2.9, 4.0 and 4.5%) following the model $2^2 + 2\ x\ 2 + 1$, according to matrix Central Box Compound (Montgomery, 2013). Three plants per pit, plus four additional treatments were cultivated to study the effect of density or number of plants per pit, with evaluations at seven and ten months after the transplanting of the seedlings. The effects of nitrogen and organic matter were studied in the arrangement at the density of three plants per pit. The additional treatments (plants per pit) consisted of one, two and six plants per pit, with a content of 2.9% of organic matter in the soil and the recommended nitrogen for cultivation with a plant (367 kg ha^{-1} or 276 g per pit), with growth of 25% per additional plant in the pit. A randomized block design with three replications was used. The experimental unit consisted of two pits, which was composed of two, four, six or twelve plants under the arrangements/density with one, two, three and six plants per pit, respectively.

Installation and orchard management

The support stakes was set up in the distances between lines and between plants of 2.5 x 3.0 m, respectively with the wire of support to 2.2 m of height. In one and two plants per pit, the conduction form of the passion fruit main stem was only vertical with growth of 2.2 m to reach the support wire. In three and six plants per pit, one third of the passion fruit were arranged as stem vertical and 2/3 diagonal, to grow at least 3.3 m to reach the support wire in the line adjacent to the planting pit.

The seedlings of the 'guinezinho' passion fruit were transplants with, on average, three pairs of leaves, 25 cm from height and 60 days after sowing us containers. In tretaments with more than one plant per pit, they were spaced by 10 cm apart. The pits with one and three plants after the pruning were conducted two secondary branches per plant, one for each side of the espalier. In the pits with two and six plants, only one secondary branch per plant was conducted in opposite direction. Transplanting took place in May 2017. Eight months after transplanting, pruning cleaning, removing excess branches and dry or attacked gains were arranged.

The management of the fertilization followed the recommendations of Borges and Souza (2010) for cultivation with one plant per pit and 25% for each additional plant per pit. The organic matter to raise the contents according to the treatments was applied in foundation and the equivalent to 50% reapplied after cleaning pruning. In the preparation of the pits also dolomitic limestone was incorporated to meet the demand in Ca^{2+} (Quaggio and Piza Júnior, 1998). Coverage mineral fertilizations were applied monthly using urea (45% N), monoammonium phosphate (11% de N and 44% P_2O_5), potassium sulphate (18% de S and 50% K_2O), and is all supplied until ninety months after transplanting.

Irrigation was performed three times a week, with the crop evapotranspiration (ETc). The based slide was obtained from the reference evapotranspiration (ETo), phenotype (Kc) and coefficient of reduction (kr) of area (ETc = ETo x Kc x Kr). The slide was increased by 50% for each addition of one plant per pit. The reference evapotranspiration was obtained from the evaporation of the class' A tank corrected by the 0.75 tank factor (Allen et al., 2006). The cultivation coefficients were 0.43 in the vegetative phase, 0.94 at flowering, and 1.04 at the fruiting stage. The reduction coefficient was based on the reduction of the wetting area of the localized irrigation (Steduto et al., 2012).

Variables analyzed

The fruits were harvested at the beginning of the yellowing of the bark, with the first harvest at 7 months and the second at 10 months after transplanting of the seedlings, and two fruits were collected from each plant. The physico-chemical analyzes in the passion fruit pulp were carried out at the Biology and Post-Harvest Technology Laboratory of the Agrarian Sciences Center. Pulp extraction was performed manually.

Te following factors were determined in the passion fruit pulp: pH, in digital potentiometer (AOAC 2005); total titratable acidity (TTA), by titration with 0.1N NaOH and 1% phenolphthalein as indicator, the results that are expressed in grams of citric acid per 100g of pulp (AOAC, 2005); total soluble solids (TSS), in Shimadzu table refractometer with °Brix result (AOAC 2005); reducing sugars (AR), in g glucose $100g^{-1}$ of the pulp, non-reducing (RNA), in grams of sucrose $100g^{-1}$, and total sugars (AT) (AOAC, 2005); ascorbic acid (Vitamin C) in 1 g of the sample diluted in 50 ml of 0.5% Oxalic Acid titrating with a solution of DFI (2,6-dichlorophenolindophenol 0.002%) until obtaining clear permanent pink expressed as mg $100g^{-1}$ (Strohecker and Henning, 1967); pulp sweetness, determined by the ratio of TSS to TTA; electrical conductivity, determined in a benchtop conductivity meter at 20 ° C and expressed in dS m^{-1}; humidity in 5 g of the oven sample at 105 ° C expressed as a percentage.

Statistical analysis

The data were initially analyzed for each harvest in order to evaluate the homogeneity of the residual variances. They are considered homogeneous when the ratio between the highest and the lowest is below 4.0 (Pimentel-Gomes, 2009). Once the homogeneity between the harvesting seasons was established, a likelihood analysis was performed (mixed model), and the harvests were considered as a repeated measure in time. The mean values of the results of the plants per hole were compared by the Tukey's test ($p \leq 0.05$). The effect of the harvest season was analyzed by the F test admitted error up to 5% probability and the quantitative factors (nitrogen and organic matter) adjusted for regression using the F-test ($p \leq 0.10$) to validate the models. Statistical analyzes were performed on SAS® University Edition software using PROC Mixed.

Conclusions

The physico-chemical quality of the pulp of the yellow passion fruit is linked to the harvesting season, which may interfere with the effects of organomineral fertilization. The fruits of the second harvest season, at the end of the first crop year, had a higher concentration of soluble solids, sugars, vitamin C and lower titratable acidity. The increase of plants per hole provides passion fruit with higher pH, sugars, vitamin C and soluble solids and lower titratable acidity. Nitrogen fertilizers and organic matter decreased the values of the physical and chemical attributes of passion fruit pulp, with the exception of total soluble solids, vitamin C and sweetness that was increased with the application of nitrogen. The application of nitrogen associated with organic matter in passion fruit yielded in fruits with lower vitamin C content, titratable acidity, reducing sugars and higher concentrations of non-reducing and total sugars. For the production of the best quality passion fruit, with higher soluble solids and sweet taste, we suggest cultivation of one, two or three plants per pit. In the arrangement with three plants per hole, best fruits were harvested from passion fruit fertilized with 180 kg ha^{-1} of nitrogen which also increased the soil organic matter up to 4%

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