ISSN: 0975-833X

Available online at http://www.journalcra.com

International Journal of Current Research
Vol. 8, Issue, 11, pp.42003-42009, November, 2016

INTERNATIONAL JOURNAL OF CURRENT RESEARCH

RESEARCH ARTICLE

PRODUCTIVITY AND PHYSICO CHEMICAL QUALITY OF YELLOW PASSION-FRUIT CULTIVATED UNDER DIFFERENT NITROGEN SOURCES THROUGH FERTIGATION

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ARTICLE INFO

Article History:
Received 14th August, 2016
Received in revised form
25th September, 2016
Accepted 20th October, 2016
Published online 30th November, 2016

Key words:

Passiflora edulis,
Nitrogen fertilization,
Fertilizing efficiency,
Sources of N.

ABSTRACT

Nitrogen is the most required and limiting nutrient in the yellow passion-fruit yield. Fertilization through irrigation water provides more rational and efficient use of fertilizers. This study aimed at assessing productive and qualitative parameters of yellow passion-fruit based on different sources and doses of nitrogen through fertigation in Vale do Gurgueia – PI. The experiment was conducted from June 2013 to August 2014 in the city of Cristino Castro – PI. The experimental design was randomized and arranged in a 2 x 5 factorial scheme, with four replicates. Treatments were consisted of combined two nitrogen sources (urea and ammonium sulfate) and five nitrogen levels (100, 200, 300, 400 and 500 kg ha^{-1} $year^{-1}$), each plot had six plants 3.0 x 3.0 m spaced, totaling 1,111 plants ha^{-1}. The fertigation, occurred during the crop cycle, was weekly performed. Yield was evaluated per plant, productivity and mean weight of fruit. In pulp, pH, soluble solids, titratable acidity, (SS/TA) ratio and pulp percentage were evaluated. Increased ratios of N, ammonium sulfate source, cause reduction in fruit pulp percentage of the yellow passion-fruit. Soluble solids and pH of fruit pulp have chemical quality within ranges established by normative instruction of MAPA. To urea source, it is recommended 227.87 kg $ha^{-1}$of N for a productivity of 15.48 t $ha^{-1}$and 309.5 kg $ha^{-1}$of N, as ammonium sulfate, for a productivity of 14.92 t ha^{-1}.

Citation: Regiana Dos Santos Moura, Aureliano de Albuquerque Ribeiro, Marcelo Simeão *et al.* 2016. "Productivity and physico chemical quality of yellow passion-fruit cultivated under different nitrogen sources through fertigation", *International Journal of Current Research*, 8, (11), 42003-42009.

INTRODUCTION

Fruitculture is one of the most dynamic activities of Brazilian agribusiness, with great economic prospects, due to favorable climatic conditions and expanded consumer market. Brazil is the world's foremost producer of passion-fruit, and besides attending to domestic market needs, the country is becoming more popular in the international market (IBGE, 2012). In the 1970's, the economic exploration of passion-fruit in Brazil began and crop has been expanding ever since. In 2013, it was produced about 776,000 tons of passion-fruit (Agrianual, 2014), being the Northeast region the largest producer accounting for 73% of national yield. Consumers have preference for fruits with good external appearance and great taste (sugar content and acidity) (Cavichioli *et al*., 2011). About 60% of Brazilian yellow passion-fruit yield is used for *fresh* consumption as juice and the rest is intended for industrialized products (Claro and Monteiro, 2010). The main consumer markets of passion-fruit juice in Brazil are the states of São Paulo, Rio de Janeiro, Minas Gerais, Bahia and Pernambuco (Araújo Neto *et al*., 2008). Nutrition plays a key role in development and yield of plants, mainly nitrogen fertilization. Nitrogen, which is an essential element for the development of branches and leaves, has amino acids, nucleotides, chlorophyll and others in its composition (Marschner *et al*., 2012). Fertilizers application through irrigation water provides more rational use of fertilizers in irrigated agriculture, increasing its efficiency and decreasing hand labor and energy costs (Embrapa, 2002). The research, with different sources and levels of N in passion-fruit carried out by Borges, Caldas and Lima (2006), showed that passion-fruit field had increasing linear response with increased calcium nitrate levels and maximum productivity with 34.3 t ha^{-1} urea source, and 457 kg ha^{-1} N application. It was even observed that nitrogen fertilization and used sources did not

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affect either to fruit features or juice quality. Silva *et al*. (2015) found no influence of levels and humic substances in fruit chemical and physical attributes of yellow passion-fruit. The nitrogen fertilization through fertigation use promotes increased yield and quality of passion-fruit, because nitrogen s a nutrient required in greatest quantity on crops and in association with fertigation use allows greater efficient in its application. However, in this region, there is little information in nitrogen fertilization literature for passion-fruit. In view of what has been exposed above, the study on nitrogen fertigation and its effects on productivity and quality of yellow passion-fruit in South region of Piauí State, also due to lack of information for this region, assumed primary importance. Thus, this study aimed at assessing productive and qualitative parameters of yellow passion-fruit based on different sources and levels of nitrogen through fertigation in Vale do Gurgueia – PI.

MATERIALS AND METHODS

The experiment was conducted from June 2013 to August 2014 in the city of Cristino Castro in Gurgueia Valley, State of Piauí, located at 08º40'55, 39" south latitude and 44º05'09, 42" west longitude, with average 240 m altitude. The city is located in southern Piaui state. The climate is hot and humid, classified by Köppen as Cwa, with an average rainfall between 900 and 1200 mm year $^{-1}$distributed from October to April and with 26.6º Caverage annual temperature. Chemical and physical soil features of experimental field before experiment are in Table 1. The experiment was conducted in randomized blocks, with four replicates, organized under a 2 x 5 factorial scheme, with two nitrogen sources (urea and ammonium sulfate) and five nitrogen levels (100, 200, 300, 400 and 500 kg ha^{-1} year^{-1}). It was used six plants per plot, totaling 240 plants. The N levels were defined from the great recommended rate of 300 kg ha^{-1}year^{-1} (Embrapa, 2002). Soil preparation consisted of plowing, harrowing, soil correction with dolomitic limestone with 80% effective calcium carbonate equivalent (ECCE). Determining the need for liming was evaluated by neutralization method of Al^{3+} and increased Ca^{2+} + Mg^{2+} contents, aiming at enhancing base saturation to 80% (Fernandes, 1993). The calculation of liming need was measured by mean chemical features on the two (0-20 and 20-40 cm) depth according to the chemical analysis (Table 1). Afterwards, it was installed the vertical support system using wooden pegs spaced at 1.8 m height and 3.0 m away with a smooth wire nº 12. Seeds were grown on the farm, using regional substrates in the ratio of 2: 1: 1 (cattle manure, washed sand and topsoil of native forest). The transplantation was performed when seeds had between 30 and 40 cm height, approximately 45 days after sowing. Pits were opened in 40 x 40 x 40 cm dimensions in 3 x 3 m planting distances, with planting density of 1,111 plants ha $^{-1}$. Irrigation was realized by the located irrigation method, by drip irrigation, using the self - compensating type emitters coupled to polyethylene lines of 16 mm in diameter, with a nominal flow rate of 4 L h^{-1} (one sender per plant). It was daily provided a blade equivalent to daily evapotranspiration corrected in accordance with the crop coefficient (Kc) of passion-fruit, reported by Allen *et al*. (1998). Soil moisture was indirectly measured by tensiometers installed around the plant to 15 cm away from the stem and depths of 20 cm and 40 cm, correlating with soil physical analysis (Table 1). During the crop cycle, fertilization with N, K_2O and S, were applied through fertigation, Ca $^{2+}$ and Mg^{2+} were applied through liming (dolomitic limestone) and micronutrients were twice applied through leaf method in the pre flowering. Fertigation was performed by a Venturi type fertilizer injector at 15 days after transplanting, with weekly sequence throughout crop cycle, as recommended by Embrapa (2002), being distributed as follows: from total N and K, 10% were applied in the first two months; 12% between the 3rd and 4th month; 15% between the 5th and the 6th month; 19% between the 7th and 8th month; and 44% in the last 4 months.

Weed control in experimental field was performed with manually weeding as needed, and for disease and pest control was adopted preventive management and chemical products, registered at Ministry of Agriculture, Livestock and Supply (MAPA), according to the recommendations for cropping. Formation and conducting prunings were done eliminating all tendrils and lateral branches, leaving only the most vigorous branch, leading it to about 10 cm above wire. Final bud was eliminated, favoring lateral branches emission, which were conducted on both wire sides. Subsequently, these buds were clipped favoring axillary bud development that formed the productive branches. Throughout harvest period, fruits were counted and weighed to determine the yield per plant (kg plant^{-1}) and productivity (t ha^{-1}). Twice a week, when fruit had 25% of yellow bark area, harvest was done. At harvest peak, five fruits per plot, totaling 20 fruits per treatment for determining physic chemical features (pH, soluble solids (SS) and titratable acidity (TA) and ratio (SS / TA) were collected by IAL method (2008). Results were subjected to variance analysis for the diagnosis of significant effects by Test "F". The mean comparison between the N sources was performed by Turkey Test, and for N levels, polynomial regression. Following Silva and Azevedo (2009) recommendations, the Assistat 7.0 software was used.

RESULTS AND DISCUSSION

Isolated effect was observed for the different N sources only for the number of fruits per plant (NFP) at 1% probability level. For the different levels and the interaction between sources and doses of N, a significant effect was observed on NFP, production per plant (Pp) and productivity (P) at 1% probability. The variable mean fruit weight (MFW) not suffered significant effect of sources and doses of N. The N sources had a higher influence in amounts of fruits per plant (Table 2), compared to the N source applied as ammonium sulfate, with mean values of 58.90 fruits per plant, corresponding to 14.41% higher than urea source with mean of 50.41 fruits per plant. The ammonium sulfate less concentrated (21% N), has some advantages such as low tendency of volatile nitrogen losses, low nitrification rate, increased phosphorus solubility and soil manganese, improving the utilization of these nutrients by plants. Furthermore, the sulfur contained in the fertilizer (Ammonium Sulfate - 24% S) improves the absorption and utilization of nitrogen by cropping due to positive synergy between these nutrients (Collamer *et al*., 2007) which may have favored the greater amount of fruits per plant of yellow passion-fruit. The mean fruit weight was not influenced by sources and doses of N, with means of 245.50 g for ammonium sulfate and 242.50 g for urea, which are higher than the results found by Borges, Caldas and Lima (2006); Cavalcante *et al*. (2007); Maia *et al*. (2009); Santos *et al*. (2014); Silva *et al*. (2015); Vasconcelos *et al*. (2013). These results can be explained by the gap between the release of applied nitrogen and the element absorption in cropping favored by fertigation.

Table 1. Chemical and physical soil features before experiment in the depth of 0-20 and 20-40 cm

Chemical Attributes	Unit	Value		Physical Attributes	Unit	Value	
Prof.	cm	0 – 20	20 – 40	Prof.	Cm	0 – 20	20 – 40
pH	CaCl	5.10	4.80	O.M	g kg^{-1}	11.00	12.00
B	mg dm^{-3}	0.19	0.23	Sand	g kg^{-1}	840.00	860.00
Zn	mg dm^{-3}	2.20	2.40	Silt	g kg^{-1}	50.00	40.00
P	mg dm^{-3}	10.80	37.40	Clay	g kg^{-1}	110.00	100.00
K^+	mg dm^{-3}	59.00	72.00	SD	kg dm^{-3}	1.40	1.60
$H+Al^{3+}$	cmolc dm^{-3}	1.60	1.60	PD	kg dm^{-3}	2.60	2.60
Al^{3+}	cmolc dm^{-3}	0.00	1.00	Total Porosity	%	38.60	46.10
Ca^{2+}	cmolc dm^{-3}	1.30	1.00	Classification		Sandy loam	
Mg^{2+}	cmolc dm^{-3}	0.30	0.30	FC	cm^3cm^{-3}	0.17	0.19
BS	cmolc dm^{-3}	1.75	1.48	PWP	cm^3cm^{-3}	0.11	0.14
CEC	%	3.35	3.08				
V	%	52.24	48.05				
m	%	0.00	6.30				

P, K: Extractors: Melich (HCl+ H_2SO_4); Al, Ca, Mg: Extractor KCl1M; OM = organic matter; BS= Bases sum; V = value of bases saturation; CEC= Cation exchange capacity; SD= Soil density, PD = Particles density, FC = Field Capacity (-10kPa) e PWP = Permanent Wilting Point (-1500 kPa).

Table 2. Analysis of variance for the number of fruits per plant, mean fruit weight (MFW), production per plant (Pp) and productivity (P) of yellow passion-fruit based under different sources and doses of N applied through fertigation

Variation Sources	NFP	MFW	Pp	P
		g	kg $planta^{-1}$	t ha^{-1}
N Sources	720.37^{**}	84.10^{ns}	0.84^{ns}	1.04^{ns}
N Levels	728.67^{**}	2007.35^{ns}	25.11^{**}	31.00^{**}
F x D	352.29^{**}	4120.35^{ns}	10.82^{**}	13.35^{**}
		Mean (N Sources)		
Urea	50.38	242.50	11.90	13.22
Ammonium Sulfate	58.87	245.50	11.61	12.91
Overall average	54.63	243.95	11.75	13.06
MSD	5.25	42.58	0.62	1.30
C.V(%)	14.81	27.02	8.19	8.19

** = significant at 1% probability level ($p \leq 0.01$); MSD =minimal significant difference; CV = coefficient of variation, U – Urea; AS = Ammonium Sulfate.

Table 3. Analysis of variance of pulp percentage (PP), pH, soluble solids (SS), titratable acidity (TA) and ratio of fruits of yellow passion-fruit based on different sources and doses of nitrogen applied through fertigation

Variable Sources	PP	pH	SS	TA	Ratio
	%	in H_2O	ºBrix	%	SS/TA
N Sources	176.40^{*}	0.002^{ns}	25.60^{**}	0.16^{ns}	12.13^{**}
N Levels	35.71^{ns}	0.001^{ns}	5.21^{ns}	0.17^{ns}	2.60^{ns}
F x D	149.33^{**}	0.006^{ns}	6.16^{ns}	0.01^{ns}	1.39^{ns}
Mean (N Sources)					
U	52.75	2.89	12.05	2.20	5.55
AS	48.55	2.88	13.65	2.07	6,65
Overall average	50.65	2.88	12.85	2.13	6.10
MSD	8.09	0.03	1.09	0.16	0.65
CV	11.00	2.11	13.18	12.27	16.67

**;* = Significant at 1 and 5% probability level ($p < 0.01$; $p < 0.05$), respectively. MSD = minimal significant difference; CV = coefficient of variation; U – Urea; AS = Ammonium sulfate.

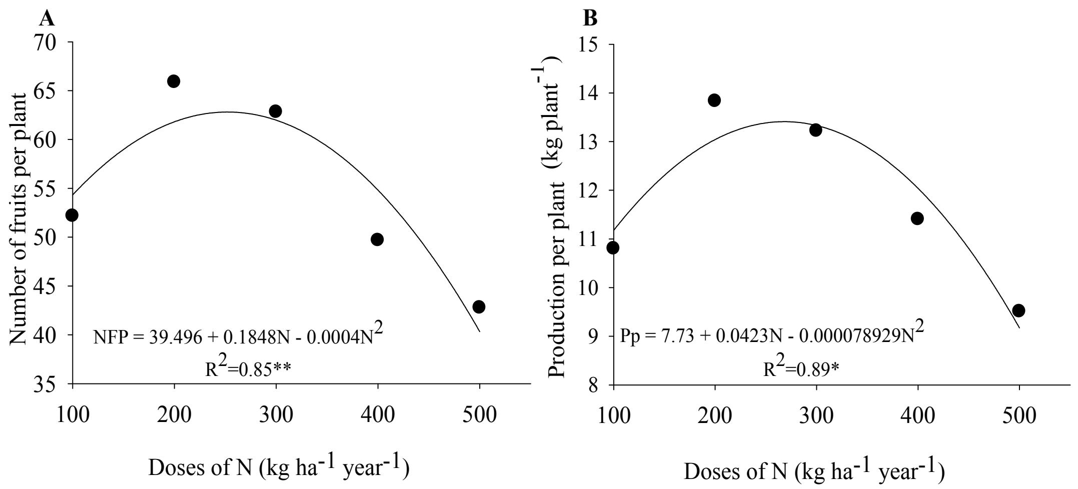

Figure 1. Number of fruits per plant (A) and production per plant (kg $plant^{-1}$) (B) of yellow passion-fruit under different doses of N through fertigation

Typically, the N availability decreases over time, while cropping demand increases, thus nitrogen fertilizer should be applied at the time and exact quantity that plant needs (Embrapa, 2002). The production per plant (Table 2) was not affected by N sources (urea and ammonium sulfate) with 11.90 and 11.61 kg plant $^{-1}$, respectively. Silva *et al*. (2015) also found no difference in production per plant of yellow passion-fruit fertigated with nitrogen fertilization, although he had found values higher than those (12.28 kg plant $^{-1}$ in absence and 13.64 kg plant $^{-1}$ in humic substances presence) and Rodrigues *et al*. (2009) with mean of 15.66 kg plant $^{-1}$. Sources of N did not affect the productivity of yellow passion-fruit plants. Urea source promoted mean value of 13.22 t ha $^{-1}$and ammonium sulfate source, 12.91 t ha $^{-1}$ (Table 2). However these results corroborate those found by Borges, Caldas and Lima (2006) and Silva *et al*. (2015) where evaluated different N sources and were not influenced by them, though they have obtained higher productivity than found in this study. This low productivity can be explained by the fact that the soil is sandy (84% sand) which favors leaching of some N applied through fertigation, to a higher depth than the root system or volatilization.

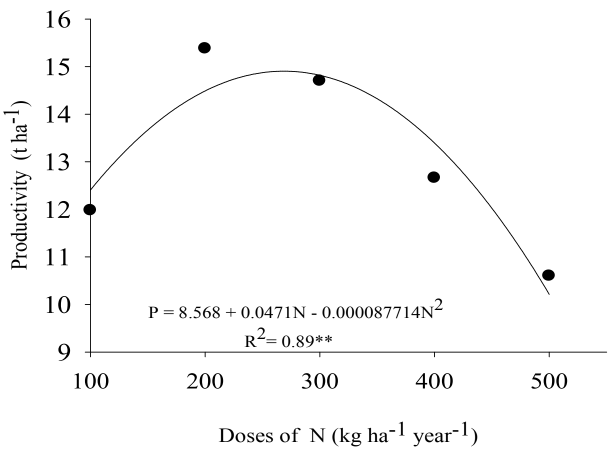

Figure 2. Productivity of yellow passion-fruit under different doses of N through fertigation

For N doses studied, regardless the nitrogen sources used, the number of fruits per plant and productivity per plant obtained a quadratic regression response due to increasing application of N levels (Figure 1A) with a maximum of 60.84 fruits corresponding to a 231 kg ha $^{-1}$ N rate. These results were lower than those found by Venancio *et al*. (2013) where 147 fruits per plant with 70 kg ha $^{-1}$ N were obtained and Borges, Caldas and Lima (2006) where 80 fruits per plant with 100 kg ha $^{-1}$ N were recorded. This result can be attributed to the initial conditions of soil fertility where the experiment was developed and for being the first cropping year, a low production in relation to the second cropping year is expected. The passion-fruit plants reached maximum yield of 13.40 kg plant $^{-1}$ with estimated rate of 268.06 kg ha $^{-1}$ year $^{-1}$ of N (Figure 1B). The result was lower than that found by Silva *et al*. (2015) who obtained 14.4 kg plant $^{-1}$, with the rate of 290 kg ha $^{-1}$ of N. Cavalcante *et al*. (2012), recorded a yield of 17.81 kg plant $^{-1}$, with NPK application on fieldat first cropping. For the passion-fruit productivity, which was fertigated with different doses of N, the best arrangement was quadratic regression (Figure 2), the estimated maximum yield was 14.89 t ha $^{-1}$ for the rate of 268.48 kg ha $^{-1}$ of N. These results, even for the first cropping year, are above the national average of 13.42 t ha $^{-1}$ year $^{-1}$ (Agrianual, 2014). However, they are lower than those recorded by Silva *et al*. (2015) which reached 17.5 t ha $^{-1}$ with the rate of 350 kg ha $^{-1}$ of N. However, the efficiency of nitrogen fertilization of this study was 55.46 kg/kg of N, higher than the result of Silva *et al*. (2015) who has obtained an efficiency of 50 kg/kg of N.

For the number of fruits per plant (Figure 3A), there is a quadratic regression response due to the increasing application of N doses as ammonium sulfate, with a maximum value of 73 fruits corresponding to a rate of 342.62 kg ha $^{-1}$ of N. For the application of N as urea, there was also a quadratic regression response to the number of fruits per plant, reaching a maximum of 60.52 with the application of 159.83 kg ha $^{-1}$of N. The production per plant (Figure 3B) suffered a quadratic regression response due to the increasing application of N levels as ammonium sulfate, with maximum values of 13.42 kg per plant, corresponding to a rate of 308.95 kg of N ha $^{-1,}$ and efficiency of 43.43 g / kg of N. And for the N application as urea, there was also a quadratic regression response to production per plant, reaching a maximum value of 13.75 kg per plant with 214.42 kg ha^{-1} N application and efficiency of 64.12 g/ kg of N. Values were lower than those found by Silva *et al*.(2015), who has observed a 14.27 kg production per plant, corresponding to the maximum rate of 350 kg ha^{-1} of N. However the efficiency of Silva *et al*. (2015) nitrogen fertilizer was 40.77 g/kg of N, lower than the present work. It can be concluded from this study that, excess nitrogen may have stimulated plant to vegetate, affecting the yield. For productivity of yellow passion-fruit (Figure 4), the application of N through fertigation, provided a quadratic regression response due to the increasing application of N levels as ammonium sulfate, with maximum values of 14.92 t h $^{-1}$,corresponding to a rate of 309.5 kg ha $^{-1}$ of N, which corresponds to 13.43 kg plant $^{-1}$. For the application of N as urea, there was also a quadratic regression response to productivity, reaching a maximum value of 15.48 t ha $^{-1}$ with a dose of 227.87 kg ha $^{-1}$ of N, corresponding to a yield of 13.93 kg plant $^{-1}$.

A productivity of 35.6 t ha^{-1} corresponding to a rate of 100 kg ha^{-1}of N, with a density of 2,666 plants ha $^{-1}$, and production per plant of 13 35 kg plant $^{-1}$, was obtained in study conducted by Borges, Caldas and Lima (2006), being the results lower than those of this study. Thus, it is evident that levels above 300 kg ha $^{-1}$of N stimulates vegetative plant growth and inhibit flowering, affecting the yield. Isolated effect for the different sources of N on the pulp percentage (PP) at 5% probability, soluble solids (SS) and ratio (SS/TA) at 1% probability is observed. For the different levels of N, there was no significant effect for the analyzed variables. The interaction between studied sources and doses of N had a significant effect only for the pulp percentage (PP) at 5% probability level, while pH and titratable acidity (TA) variables suffered no significant effect of sources and doses of N (Table 3). The pulp percentage presented mean values of 52.75% for urea source with 7.89% of superiority related to ammonium sulfate source with 48.55% (Table 3). These values are higher than those found by Silva *et al*. (2015) that observed 40.31% and 36.51% of pulp in presence and absence of humic substances, respectively; and Borges, Caldas and Lima (2006) that found 29.8% for urea source and 30% of pulp for calcium nitrate. The pH of the passion fruit pulp presented mean values of 2.89 and 2.88 for urea and ammonium sulfate sources, respectively, not being

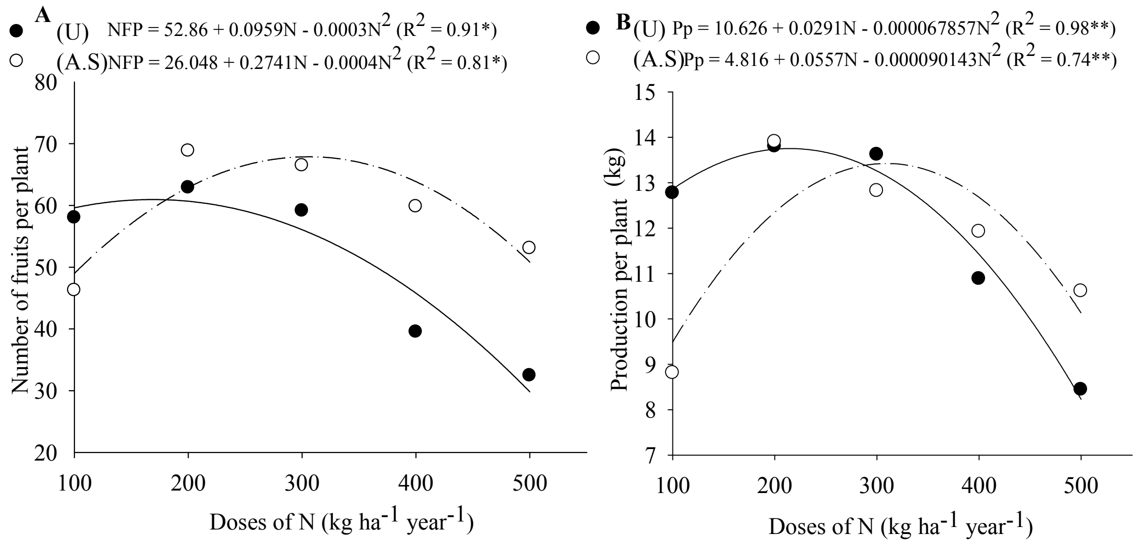

Figure 3. Number of fruits per plant (A) and production per plant (kg) (B) of yellow passion-fruit cultivated under different doses of N as urea (U) and ammonium sulfate (AS)

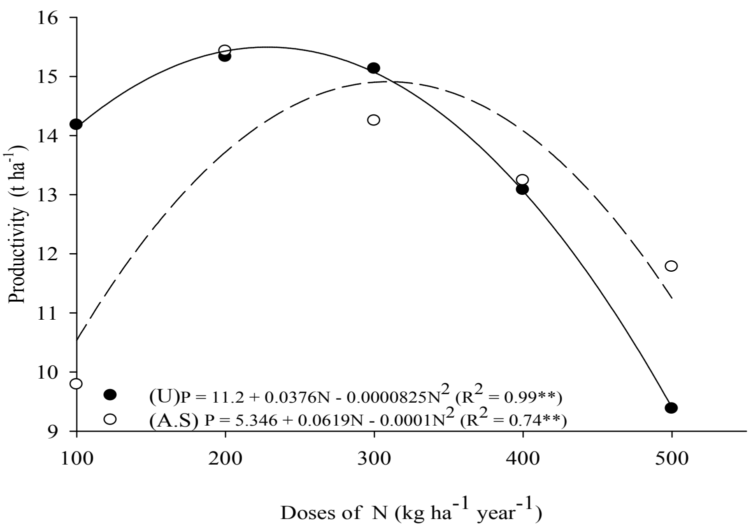

Figure 4. Productivity of yellow passion-fruit cultivated under different doses of N as urea (U) and ammonium sulfate (AS)

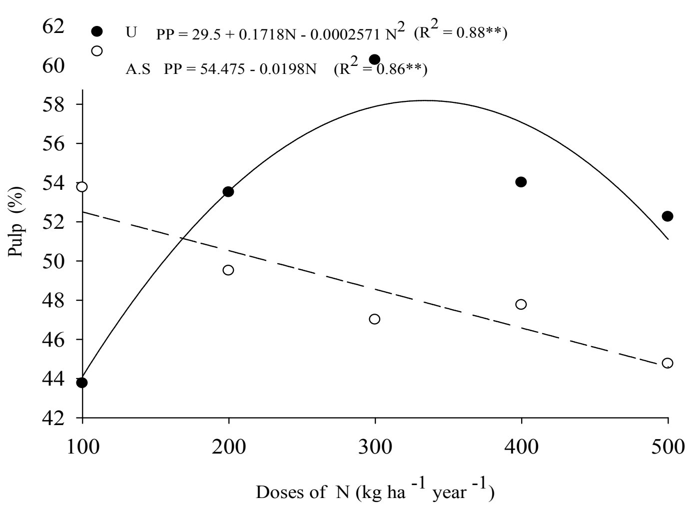

Figura 5. Yellow passion-fruit pulp percentage cultivated under different doses of N as urea (U) e ammonium sulfate (AS)

influenced by sources and levels of nitrogen in the study (Table 3). Borges, Caldas and Lima (2006) also found no significant difference in passion-fruit study, however, found higher values (3.08) to the present work. On the other hand, Silva *et al.*(2015) observed interaction effect between N levels and humic substances on pH and titratable acidity of the fruits of yellow passion-fruit (in the lack of humic substances pH was 3.10 with the maximum rate estimated of 225 kg ha $^{-1}$of N). The results obtained in this study are within the identity and quality standards for the passion-fruit pulps, established in Normative Instruction nº 1 of January,7, 2000 of MAPA, where legislation establishes pulp pH values for passion-fruit between 2.7 and 3.8. The pulp pH is a fruit feature used to evaluate the fruit acid character and post-harvest useful life period. Fruits with low acidity are most appropriate for *fresh* consumption, while those with more acid characteristics are more required by the food industry (Campos *et al*., 2007). For soluble solids, the ammonium sulfate sources howed mean of 13.65 ° Brix, 11.72% higher than mean of urea source 12.05 ° Brix (Table 3), these values are lower than those found by Borges, Caldas and Lima (2006), who reported 14.1 and 14.3 ° Brix to urea and calcium sulfate respectively. However, the soluble solids contents are within the minimum standard required by MAPA, ranging from 11 to 15 °Brix (Ial, 2008). The titratable acidity showed mean values of 2.20 and 2.07 for urea and ammonium sulfate sources, respectively, not being influenced by sources and doses of nitrogen in the study (Table 3). However, the high acidity content may have occurred due to fruits are in the initial maturation stage (25% of yellow peel) because fruit acidity varies with the maturation degree, and the more mature, less acidity. Venâncio *et al*. (2013) also found no significant difference in titratable acidity of fruit of passion-fruit subjected to nitrogen fertilization. While Silva *et al*. (2015) and Cunha *et al*. (2015) observed an exponential decrease in the value of fruits acidity of the yellow passion-fruit with increased levels of N. Despite little variation, values found are not in accordance with the normative of MAPA, which establishes minimum value of 2.5%.

The ammonium sulfate presented mean ratio (SS/TA) of 6.65 with 16.54% of superiority related to the urea source which had mean of 5.55. Borges *et al*. (2006) found no difference between sources and doses of N, but found SS/TA values lower than the present study (3.1). The SS/AT ratio is one of the best ways to evaluate the fruit taste, which occurs, largely, due to the balance of acids and sugars, being more representative than the measurement of these parameters alone. It is a feature that reflects the sensorial quality of fruits, which should be used as fruit maturation index for others (Brito Neto *et al*., 2011). Thus, when values of this relation are high, it means that the fruit is in a good degree of maturity. There is increase of degree when acidity decreases and TSS content enhances, arising from maturity. The percentage of fruit pulp of yellow passion-fruit set in a decreasing linear regression response due to increased N levels as ammonium sulfate (Figure 5). With application of the maximum rate of 500 kg ha $^{-1}$of N, reached a minimum value of 44.57% pulp yield, which corresponds to a 15.10% reduction, and initially was 52.50 %. And for N application as urea, there was a quadratic regression response reaching maximum of 58.20% with a rate of 334.11 kg ha $^{-1}$ of N. The pulp percentage values in this study were higher than those found by Venancio *et al*. (2013) (51.7%) for urea source with maximum rate of 210 kg ha $^{-1}$of N. While Silva *et al*. (2015) found no influence on the nitrogen and humic substances levels applied to the soil through fertigation in passion-fruit. Since Rocha *et al*. (2013) studied different NK percentages in liming presence, found low percentage of pulp (10%). However, Cavalcante *et al*. (2012) point out that there is not, in the literature, a standard value considered ideal for the percentage of pulp of passion-fruit.

Conclusion

The increased nitrogen levels, ammonium sulfate source, cause a reduction in the percentage of fruit pulp of yellow passion-fruit. The soluble solids and pH fruit pulp present chemical quality within the ranges established by normative instruction of MAPA. It is recommended for urea source 227.87 kg ha^{-1} of N for a yield of 15.48 t ha $^{-1}$ and 309.5 kg ha $^{-1}$ of N as ammonium sulfate for a field of 14.92 t ha^{-1}.

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