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Article

Nutritional status of yellow passion fruit submitted to nitrogen sources by fertigation

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Abstract

Yellow passion fruit is the most cultivated species in Brazil and requires high amounts of nitrogen and an adequate nutritional status to express its entire productive potential. In this sense, this study aimed to evaluate the effect of different sources and doses of nitrogen via fertigation on nutritional status and leaf chlorophyll of yellow passion fruit. The experiment was conducted from June 2013 to August 2014 in Gurgueia Valley, Cristino Castro county, Piaui State, Brazil. The experimental design was randomized blocks with four replications, in a 2 x 5 factorial design related to the application of two nitrogen sources (urea and ammonium sulfate) and five N levels (100, 200, 300, 400 and 500 kg ha^{-1} $year^{-1}$). Six plants per replication were considered, totaling 240 plants, spaced 3 m between rows and 3 m between plants, and covering an area of 2,160 m^2. At pre-flourishing, it was evaluated leaf chlorophyll index and leaf nitrogen, phosphorus, potassium, calcium, magnesium and sulfur contents. Urea increases Ca and Mg leaf contents and reduces leaf S content in relation to ammonium sulfate. The increase in nitrogen fertilizing levels enhances leaf N and Mg concentrations. For Ca, the optimal ammonium sulfate dose is 296.30 kg ha^{-1}.

Keywords: nitrogen fertilization, plant nutrition, macronutrients, *Passiflora edulis*

Introduction

The economic exploitation of yellow passion fruit (*Passiflora edulis* Sims *f. Flovicarpa* Deg) began in the 1970s, and it is still expanding in Brazil, which is the largest global producer and consumer of this fruit. This species represents approximately 95 % of the national production of passion fruit. Only in 2013, Brazil produced approximately 776.000 t of passion fruit (Agrianual, 2014). The Northeast region is the largest producer, accounting for 73 % of the national production, especially in Bahia state , which leads the ranking of area harvested, with 29.938 hectares and producing 320.945 t.

Passion fruit plants need a high amount of nitrogen in its structure. It is the most required nutrient for the fruiting period, making it necessary to complement nutrition with other nutrients, as it has alternate fluxes of vegetation and production (Rebequi et al., 2011). For a greater economic exploitation of this crop, there is a need to develop technologies that contribute to increase fruit yield, especially for fertigation and nutrient management areas. Therefore, the knowledge on nutritional status is a basic requirement for a proper mineral nutrition, essential to achieve a high fruit yield.

The use of chemical plant analyses to evaluate the nutritional status is based on the assumption that there is a causal relation

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between growth rate or production rate and nutrient content in dry or fresh matter, or nutrient concentration, in the solution of the plant tissue (Marschner, 2005).

However, studies studying the nutritional status of passion fruit as a function of nitrogen fertilization by fertigation are scarce in the scientific literature. Similarly, studies on the main sources of N applied by fertigation for fruit cultivation still require further scientific relevance. Thus, there is a need for further research on nutrition of passion fruit. There from emerge some hypotheses to be tested: (a) nitrogen fertilization with balanced amounts of N increases the absorption of this element and its use efficiency, reflecting on nutritional quality of plants; (b) different sources of N applied via fertigation influence leaf macronutrient contents of passion fruit.

Thus, this study aimed to evaluate the effect of different sources and doses of nitrogen via fertigation on nutritional status and leaf chlorophyll of yellow passionfruit in Gurgueia Valley, Piaui State, Brazil.

Material and Methods

Location of the experimental area

The experiment was developed in Cristino Castro county, southern Piauí state (08°40'55.39'' S, 44°05'09.42'' W, altitude 240 m), in the Gurgueia River valley from June 2013 to August 2014. This region has a hot and humid climate, classified by Köppen as Cwa, with an average rainfall between 900 and 1.200 mm year^{-1} distributed from October to April, and an average annual temperature of 26.6 °C.

Seeds and seedling production

Yellow passion fruit seeds of IAC 273 cultivar were used. To produce seedlings, the seeds were sown at a depth of approximately 1.0 cm in polypropylene bags (10 x 20 cm) filled with substrate composed by dried cattle manure, washed sand and plant substrate (2:1:1). Manual irrigation was performed twice daily according to the plant water requirement.

The transplanting was made when seedlings showed the first tendrils, at 30-40 cm height, approximately at 45 days after sowing.

Treatments and experimental design

The experimental design used was randomized blocks with four replications, in a 2 x 5 factorial design related to the application of two nitrogen sources (urea and ammonium sulfate) and 5 N doses (100, 200, 300, 400 and 500 kg ha^{-1} year^{-1}). Six plants per replication were considered, totaling 240 plants, spaced 3 m between rows and 3 m between plants, and covering an area of 2.160 m^2. The N doses were 33, 67, 100, 133 and 167 % of the optimal dose (300 kg ha^{-1} year^{-1}) recommended for passion fruit plants (Embrapa, 2002).

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

Chemical Attributes	Unit	Value		Physical Attributes	Unit	Value	
Depth	Cm	0 - 20	20 - 40	Depth	cm	0 – 20	20 – 40
pH	CaCl	5.10	4.80	OM	g kg $^{-1}$	11.00	12.00
B	mg dm^{-3}	0.19	0.23	Sand	g kg $^{-1}$	840.00	86.00
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^3 cm^{-3}	0.17	0.19
BS	cmolc dm^{-3}	1.75	1.48	PWP	cm^3 cm^{-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: Puller KCl1M; OM = organic matter; BS = base sum; V = base saturation; CEC = cation exchange capacity; SD = Soil density, PD = particle density, FC = Field capacity (-10 kPa) and PWP = Permanent Wilting Point (-1,500 kPa).

Characterization of the experimental area and experiment conduction

The chemical and physical characteristics of the soil of the experimental area are shown in Table 1. Data on climatic variables (air temperature, relative humidity and precipitation) collected at the weather station of the CPCE/UFPI during the execution of the experiment, are shown in Figure 1.

Soil preparation consisted of plowing and then harrowing. At this moment, soil correction was made by incorporating dolomitic limestone with a full neutralization relative power of 80 % at 60 days before transplanting using a disc harrow attached to a tractor. The liming demand was determined by the Al^{3+} neutralization method and by the increase of Ca^{2+} + Mg^{2+} aiming to increase base saturation to 80 %, corresponding to 2.58 t ha^{-1}. The liming calculation demand was made with the averages of soil chemical characteristics in the two sampling depths (0-20 and 20-40 cm) (Table 1).

For the guiding of plants, a vertical support system was installed using wooden stacks at 1.8 m height, spaced 3 x 3 m, with a flat wire nº12 tensioned at the top of the stacks in each cultivation row.

The holes were opened with 40 x 30 x 30 cm dimensions in a rectangular system with 12 liters of cattle manure.

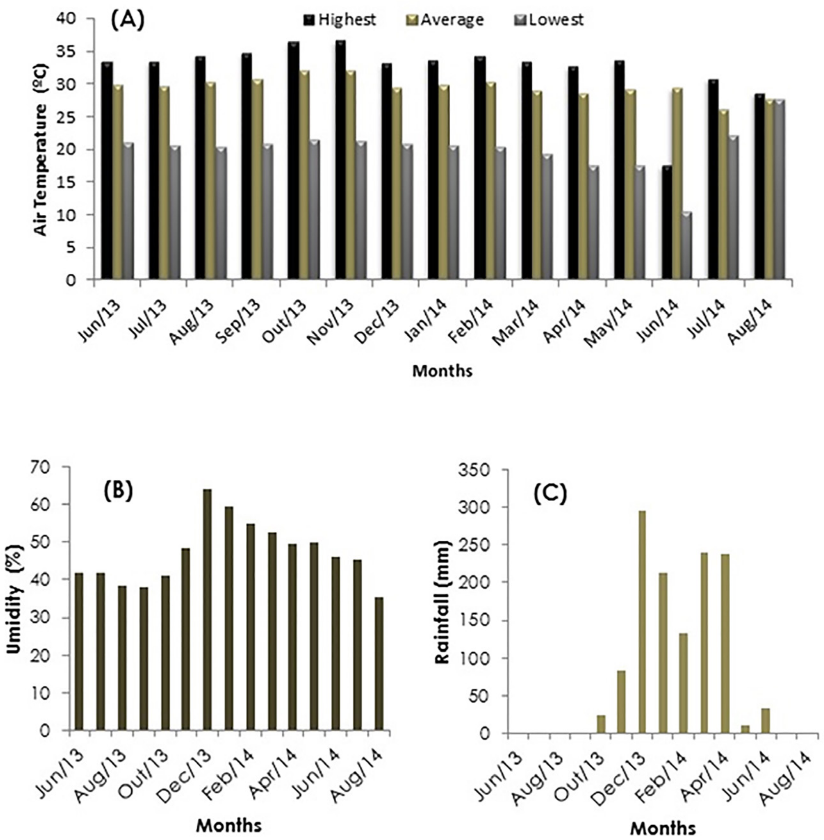

Figure 1. Monthly air temperature (A), relative humidity (B) and rainfall (C) during the execution of the experiment.

A drip irrigation was adopted using auto-compensating emitters coupled to polyethylene lines 16 mm in diameter, with a nominal flow rate of 4 L h^{-1}, which were previously evaluated under normal operating conditions. Water uniformity distribution (CUD) was verified at 98.4 %, considered optimal for this purpose (Araquam et al., 2012). A water blade equivalent to the daily corrected evapotranspiration was daily provided according to the passion fruit crop coefficient (Kc) reported by FAO 56. Soil moisture was indirectly verified with a tensiometer, correlating with the soil water retention curve (Figure 2).

The irrigation system consisted of 240 transmitters, with one emitter per plant. Irrigation management was made based on data obtained indirectly with the tensiometer installed 15 cm away from the base of the plants at 20

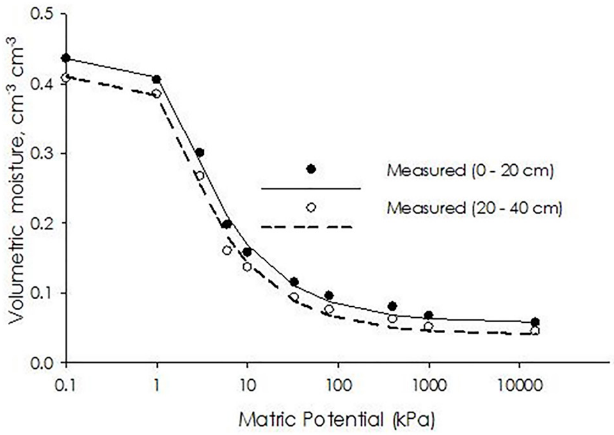

Figure 2. Soil water retention curve in the depths 0-20 and 20-40 cm.

and 40 cm soil depths. Tensiometer readings were performed daily around 08:00 a.m., considering an exploited layer of 40 cm. The irrigation was made when the water pressure in the soil reached a critical moisture point according to the soil water retention curve. The water source (water pH = 5.95) used in the experiment flowed through a tube well near the experimental area. A disc filter was placed at the head control.

The N, K_2O and S fertilizations were applied by fertigation. The nutrient sources used were urea, potassium chloride and ammonium sulfate, respectively. The first fertigation was performed at 15 days after transplanting, in a week interval sequence, throughout the crop cycle, as recommended by Embrapa (2002). It was 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 6th month; 19 % between the 7th and 8th month; and 44 % in the last 4 months. The fertilizer application was performed through a Venturi injector installed on the control head of the irrigation system. B and Zn micronutrients (Borax and zinc sulphate) were leaf sprayed twice during pre-flowering.

The formation and guiding pruning were made by eliminating all tendrils and lateral branches, leaving only the most vigorous branch, guiding it until 10 cm above the wire. At this stage, the terminal bud was eliminated, guiding the two secondary branches to each side of the espalier. Later, the apex of these branches were pruned to induce the growth of the tertiary or productive branches.

Variables studied and statistical analysis

The following evaluations were performed in plants: leaf chlorophyll index (LCI) readings in intermediate and healthy leaves in the pre-flowering, corresponding to 120 days after transplanting, using a Falker® chlorophyll meter. In each plot, two leaves were chosen. Three readings were performed on each leaf: at the base, in the middle part and at the apex.

To determine the plant nutritional status , i.e., the concentration of macronutrients, two leaves per plant were collected. The 3rd or 4th leaf of the mid branches were collected according to the methodology described by Malavolta et al. (1997), and the contents of N, P, K, Mg, Ca and S were determined according to Battaglia et al. (1983) methodology. The N was determined in solutions prepared from extracts obtained by sulfuric acid digestion using the semi-micro-Kjeldahl method; P and S were determined by spectrophotometry; K, Ca and Mg were determined by atomic absorption spectrophotometry.

The results were submitted to analysis of variance by F test, N sources were compared by Tukey test using the software Assistat 7.7. The N levels were analyzed by polynomial regression using the software Sigmaplot 10.0, considering the highest degree equation and the highest coefficient of determination.

Results and Discussion

Individual effects of different nitrogen sources were observed for Ca ($P < 0.05$), Mg and S ($p < 0.01$) contents in passion fruit leaves. In relation to different N doses, there was significant effect for N and Mg ($p < 0.01$). The interaction between sources and N doses studied had a significant effect only on leaf Ca concentration at 1% probability.

The leaf chlorophyll index (LCF) was not affected by the nitrogen sources and doses studied (Table 2), similarly to the variation of leaf chlorophyll in yellow passion fruit studied by Silva Junior et al. (2013), who evaluated the nutritional status and leaf chlorophyll of yellow passion fruit as a function of biofertilizers, liming and fertilization with N and K in Bom Jesus, Piauí, Brazil and also found no significant effect on this photosynthetic pigment with soil nitrogen levels increasing.

Table 2. Summary of the variance analysis for leaf chlorophyll index (LCI), N, P, K, Ca, Mg and S concentrations in yellow passion fruit leaves as a function of different sources and doses of nitrogen applied via fertigation.

Sources of N (F)	LCI	N	P	K	Ca	Mg	S
		------------------- $g\ kg^{-1}$ -------------------					
Urea	66.39	36.07	1.68	22.20	11.24	1.45	0.78
Ammonium sulfate	67.07	36.85	1.63	23.47	9.97	1.30	1.24
MSD	3.16	2.14	0.17	2.14	1.25	0.10	0.19
N doses							
100 $kg\ ha^{-1}$	68.36	28.60	1.70	23.20	12.13	1.20	0.78
200 $kg\ ha^{-1}$	66.57	34.15	1.53	23.33	11.18	1.25	1.10
300 $kg\ ha^{-1}$	56.75	36.45	1.61	22.33	9.85	1.41	0.90
400 $kg\ ha^{-1}$	67.23	41.16	1.66	22.55	10.43	1.48	1.13
500 $kg\ ha^{-1}$	65.71	41.95	1.76	22.76	9.45	1.53	1.15
	------------------- F Value -------------------						
F	4.62^{ns}	6.08^{ns}	0.02^{ns}	16.21^{ns}	16.21^{*}	0.23^{**}	2.17^{**}
D	9.81^{ns}	238.80^{**}	0.06^{ns}	1.43^{ns}	9.20^{ns}	0.16^{**}	0.21^{ns}
F x D	57.07^{ns}	2.57^{ns}	0.18^{ns}	13.45^{ns}	23.50^{**}	0.06^{ns}	0.11^{ns}
General average	66.73	36.46	1.65	22.87	10.61	1.37	1.01
CV (%)	7.34	9.05	15.82	14.44	18.15	11.98	28.44

**; * = significant at 1% and 5% probability error ($p < 0.01$; $p < 0.05$), respectively. LCI = leaf chlorophyll index; MSD = minimum significant difference; CV = coefficient of variation.

On the other hand, Freire et al. (2013), studying chlorophyll contents and leaf mineral composition of yellow passion fruit in Remígio, Paraiba state, Brasil, reported an increase in total leaf chlorophyll for plants grown with enriched biofertilizers and justified this result due to a higher nitrogen content of this fertilizer.

Probably the great divergence in such research results occurred because both were developed in field, where a great edaphoclimatic variability occurs, chlorophyll levels may not follow a tendency of values responsive to nitrogen sources and doses, even if this is the main nutrient responsible for the change of this pigment in leaves (Schlemmera et al., 2013). The function of chlorophyll is to absorb light incident on leaves for the photosynthesis process (Amarante et al., 2008). Jamil et al. (2007), Cavalcante et al. (2009) and Mendonça et al. (2010) observed that photosynthetic pigment levels in plants are reduced by the salinity of soil solution.

Leaf potassium (K) had average values of 22.20 and 23.47 for urea and ammonium sulfate sources, respectively, and they were not influenced by the nitrogen sources and doses studied (Table 2). On the other hand, Rodrigues et al. (2009), evaluating the fruit production and nutrition of yellow passion fruit in soil with "supermagro" and potassium biofertilizers, observed that leaf potassium accumulation was stimulated by both "supermagro" values applied and potassium fertilizing , which is a situation different from the present study.

The sources of N affected calcium contents in leaves of yellow passion fruit (Table 2), with a superiority for N applied as urea, with an average value of 11.24 $g\ kg^{-1}$, thus 11.29 % higher than the average ammonium sulfate (9.97 $g\ kg^{-1}$).

The Ca contents presented in this study (9.97-11.24 g $plant^{-1}$) are higher than the range 3.28-4.40 $g\ kg^{-1}$ reported by Silva Júnior et al. (2013) and Freire et al. (2013), with an average value of 7.00 $g\ kg^{-1}$ of Ca. Santos et al. (2011), evaluated different sources of N and found that Ca in passion fruit plants fertilized with cattle manure plus ammonium sulfate was superior to other treatments, obtaining 16.27 $g\ kg^{-1}$. Malavolta et al. (1997) consider that for a proper calcium nutrition, yellow passion fruit should present average Ca levels of 15-20 g kg^{-1}.

For magnesium, another nutrient affected by N sources, urea increased the Mg content in leaves, averaging 1.45 g kg^{-1}, corresponding to a 10.35 % superiority in relation to the 1.30 g kg^{-1} average promoted by ammonium sulfate (Table 2). Thus, it is observed that, like Ca, Mg is also influenced by the N source applied to the soil due to chemical changes, especially the reduction of soil pH, more intensified by ammonium sulfate, which alters the dynamics of cationic elements, thus reducing its absorption even by reducing the root system.

Whether compared the magnesium contents found in the present study with those recorded by other authors, it is possible to identify that the range 1.3-1.45 g kg^{-1} is inferior to the interval 2.62-3.08 g kg^{-1} reported by Freire et al. (2013) and to the average of 1.5 g kg^{-1} registered by Silva Júnior et al. (2013). Moraes et al. (2011) presented results that were also superior to the range of leaf Mg presented in this study, with an average range 2.55-3.55 g kg^{-1}. On the other hand, Malavolta et al. (1997) consider the Mg range 3-4 g kg^{-1} as optimal for yellow passion fruit, therefore higher than the values found in this study.

The treatment with urea promoted lower sulfur levels (Table 2), with an average value of 0.78 g kg^{-1} in leaves. On the other hand, when plants were fertilized with ammonium sulfate, the average S content was 1.24 g kg^{-1}, evidencing a 37.09 % difference between the amount of sulfur in leaves as a function of the N source applied via fertigation. According to Jamal et al. (2010), high nitrogen doses in the soil may reduce the availability of soil sulfur, thus affecting plants. The superiority of ammonium sulfate in relation to urea, for sulfur levels, is due to the presence of 24 % of S in this nitrogen source $(NH_4)_2SO_4$, which favored a higher absorption of this element by passion fruit plants.

For the N doses studied, independently of the nitrogen source used, the leaf N concentrations were linearly increased with N doses enhancement via fertigation, with a maximum value of 42.9 g kg^{-1} of N for its highest dose (500 kg ha^{-1}), i.e., an increase of 31.27 % when only 100 kg ha^{-1} of N was applied (Figure 3a).

In a study about production, fruit quality and leaf nitrogen content of yellow passion fruit plants fertilized with nitrogen in Aquidauana, Mato Grosso do Sul state, Brazil, Venâncio et al. (2013) reported that leaf nitrogen was affected by different doses of nitrogen applied to the soil, fitting the linear regression model. The N doses increase enhanced leaf N contents, reaching N levels of 40.49 g kg^{-1} at the maximum dose applied to the soil (315 g $plant^{-1}$ of N). In this study, a 42.9 g kg^{-1} of N was obtained for the maximum dose, with 450 g $plant^{-1}$ of N. Similar results were also reported by Silva Júnior et al. (2013) for passion fruit crop.

Specifically for studies with nitrogen fertilizer via fertigation in passion fruit crop, there were few manuscripts in the scientific literature. Studies with other fruit crops such as papaya 'pawpaw' (Santos et al., 2014), vine (Brunetto et al., 2008), guava (Neto et al., 2013), in which the leaf N concentration increased with the increase

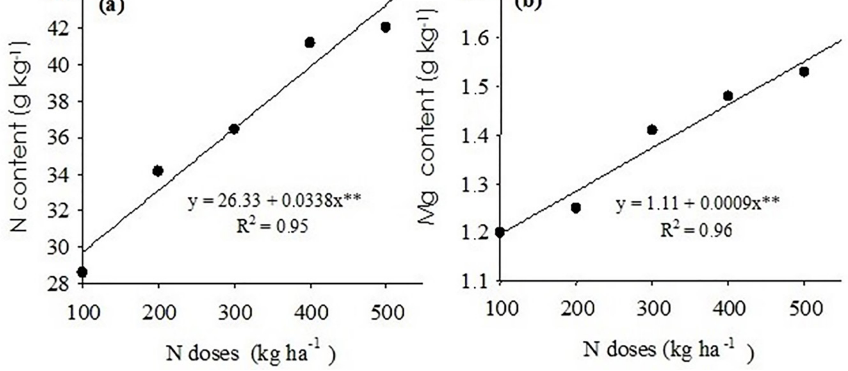

Figure 3. Leaf nitrogen (a) and magnesium (b) contents of yellow passion fruit cultivated with different doses of nitrogen.

in N doses, may be cited, corroborating the results of this study.

Regarding leaf Mg (Figure 3b) and N contents, there was an increase in its values with the enhancement of N doses via fertigation, regardless of the N sources studied. The highest Mg leaf value was 1.56 g kg^{-1} for the 500 kg ha^{-1} N dose, whilst, regarding the application of only 100 kg ha^{-1}, the Mg content was 1.20 g kg^{-1}. Therefore, the increase of this nutrient was 23.07 %.

The Mg absorption rate may be affected by other cations such as K^+, NH_4^+, Ca^{2+} and Mn^{2+}, as well as H^+ in low soil pH conditions (Heenan & Campbell, 1981). Thus, the increase in leaf Mg with the highest dose of N may be related to the soil availability of N-NH_4^+ . The functions of Mg in plants are mainly related to its ability to interact with nucleophilic ligands, such as phosphoric groups, through ionic bonds, acting as a bonding element or forming complexes with different stabilities. The Mg is part of the chlorophyll component, enzyme activation, and it affects CO_2 assimilation, sugar synthesis, starch synthesis and ATP synthesis (P charger).

For leaf calcium contents (Figure 4), a quadratic regression response due to the decreasing application of N as ammonium sulfate is observed, with maximum values of 13.09 g kg^{-1} of calcium corresponding to a dose of 296.28 kg ha^{-1} of N. As for the application of nitrogen as urea, there was a linear decrease in leaf calcium levels with the N fertilizer dose increase . The application of urea in the maximum dose (500 kg ha^{-1}) reached a minimum value of 9.13 g kg^{-1}, which corresponds to a 37.33 % reduction in leaf calcium content.

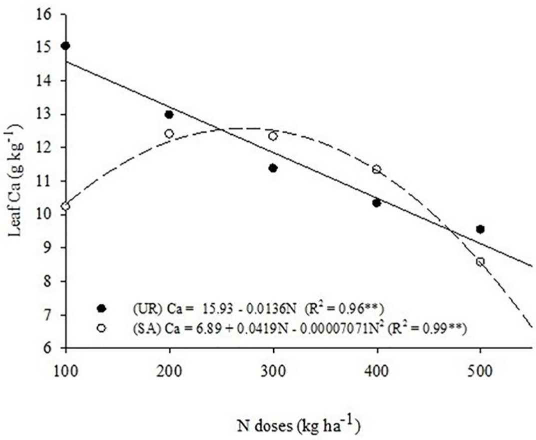

Figure 4. Leaf calcium content of yellow passion fruit cultivated under different doses of N as urea and ammonium sulfate.

In general, the increase of leaf calcium values with the application of N as ammonium sulfate occurred at lower N doses applied by fertigation (296.38 kg ha^{-1}). For urea, the highest leaf calcium value was observed for the lowest N dose applied, 100 kg ha^{-1}.

It is known that the change in the mineral composition of plants by nitrogen fertilization is directly related to the N form used or available in the soil. Thus, in this study, it was found that there was a strong leaf Ca reduction with N fertilizing increase independently of the N source used. This is justified by the acidifying power of both N sources, by the release of H^+ in the transformation of NH_4^+ into NO_3^-, especially ammonium sulfate, which can be detrimental to plant growth because it affects availability and absorption of some nutrients, especially the cationic ones (Marschner, 2005) such as Ca^{2+} (Figure 4) and Mg^+ (Figure 3B), causing a nutritional imbalance.

The calcium absorption inhibition reflected in lower leaf Ca contents due to the application of ammonium nitrogen fertilizers via fertigation in short periods, and it was also reported in research with different crops such as papaya (Santos et al., 2014).

Conclusions

Urea increases Ca and Mg, and reduces leaf S content in relation to ammonium sulfate.

The increase in nitrogen fertilizing levels enhances leaf N and Mg concentrations. For Ca, the best ammonium sulfate dose is 296.30 kg ha^{-1}.

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