ISSN 1808-8546 (ONLINE) 1808-3765 (CD-ROM)

ESTADO NUTRICIONAL DO MARACUJAZEIRO AMARELO IRRIGADO E SUBMETIDO A ADUBAÇÃO ORGANOMINERAL

SHERLY APARECIDA DA SILVA MEDEIROS[1]; JOSÉ ADEILSON MEDEIROS DO NASCIMENTO[2]; LOURIVAL FERREIRA CAVALCANTE[3] *(in memoriam)*; MARLENE ALEXANDRINA FERREIRA BEZERRA[4], FRANCISCO THIAGO COELHO BEZERRA[5] E CLEMILTON DA SILVA FERREIRA[6]

[1]Doutora, Programa de Pós-Graduação em Agronomia, Universidade Federal da Paraíba, Rodovia 079 -Km 12 – Caixa Postal 66 – Cep: 58397-000, Areia, Paraíba – Brasil, sherly.agro@hotmail.com
[2]Departamento de Agricultura, Instituto Federal do Ceará, Campus-Tianguá. Avenida Tabelião Luiz Nogueira de Lima SN, Bairro: Santo Antônio, Cep: 62324-079, Tianguá, Ceará – Brasil, adeilson.nascimento@ifce.br
[3]Pós graduação em Agronomia, Universidade Federal da Paraíba, Rodovia 079 - Km 12 – Caixa Postal 66 – Cep: 58397-000, Areia, Paraíba – Brasil, lofeca1946@yahoo.com.br
[4]Doutora, Programa de Pós-Graduação em Agronomia, Universidade Federal da Paraíba, Rodovia 079 -Km 12 – Caixa Postal 66 – Cep: 58397-000, Areia, Paraíba – Brasil, marlene_agro@hotmail.com
[5]Bolsista DCR-Fapesq-CNPq, Programa de Pós-Graduação em Agronomia, Universidade Federal da Paraíba, Rodovia PB 079 - Km 12, CEP: 58.397-000, Areia, Paraíba, Brasil, bezerra_ftc@yahoo.com.br
[6]Departamento de Agricultura, Instituto Federal do Ceará, Campus-Tianguá. Avenida Tabelião Luiz Nogueira de Lima SN, Bairro: Santo Antônio, Cep: 62324-079, Tianguá, Ceará – Brasil, clemil@ifce.edu.br
**Artigo oriundo da Tese de Doutorado de Sherly Aparecida da Silva Medeiros: “Fertilidade do solo, nutrição, fisiologia e produção do maracujazeiro amarelo sob irrigação e adubação organomineral”. UFPB, 2018.*

1 RESUMO

O experimento foi desenvolvido com o objetivo de avaliar a nutrição foliar do maracujazeiro amarelo Sol do Cerrado submetido a lâminas de irrigação, fontes de matéria orgânica e doses de fósforo. O trabalho foi instalado no Instituto Federal do Ceará - *Campus* Tianguá, em um Neossolo Quartzarênico. Os tratamentos foram organizados em parcelas subdivididas obedecendo ao esquema 2 × (3 × 5), com as parcelas principais sendo as lâminas de irrigação (100% e 70% da evapotranspiração da cultura- ETc) e as subparcelas as combinações entre as fontes de matéria orgânica (esterco bovino, cama de frango e não uso de adubação orgânica) e as doses de fósforo aplicadas (0, 40, 80, 120 e 160 kg ha^{-1} de P_2O_5). As doses de fósforo foram aplicadas em dois momentos: no preparo das covas (aplicação de 50% da dose) e no início da floração das plantas (demais 50%). Folhas dos ramos medianos das plantas foram coletadas no início da floração para avaliação de estado nutricional. Após análise dos dados no programa SAS, verificou-se que, independentemente da lâmina de irrigação aplicada, a adubação fosfatada associada à adubação orgânica proporcionou suprimento adequado de nitrogênio e enxofre e deficiência de fósforo, potássio e cálcio.

Palavras-chave: *Passiflora edulis*, nutrição, insumo orgânico.

MEDEIROS, S. A. S.; NASCIMENTO, J. A. M.; CAVALCANTE, L. F.; BEZERRA, M. A. F.; BEZERRA, F. T. C.; FERREIRA, C. S.
NUTRICIONAL STATUS OF IRRIGATED YELLOW PASSION FRUITS UNDER ORAGNOMINERAL FERTILIZATION

Recebido em 20/04/2022 e aprovado para publicação em 09/10/2023
DOI: http://dx.doi.org/10.15809/irriga.2023v28n4p731-744

2 ABSTRACT

The experiment was designed to assess the foliar nutrition of Sol do Cerrado yellow passion fruit subjected to various irrigation depths, organic matter sources, and phosphorus doses. The work was carried out at the Federal Institute of Ceara, Tianguá Campus, on a Quartzarenic Neosol. The treatments were organized into subdivided plots according to a 2 × (3 × 5) scheme, with the main plots being the irrigation depths (100% and 70% of crop evapotranspiration - ETc) and the subplots being the combinations between the sources of organic matter (cattle manure, chicken litter and no use of organic fertilizer) and the doses of phosphorus applied (0, 40, 80, 120 and 160 kg ha $^{-1}$ of P_2O_5). The phosphorus doses were applied at two different times: when the planting holes were prepared (50% of the dose) and at the start of the flowering phase (the other 50%). Leaves from the middle branches of the plants were collected at the beginning of the flowering phase to assess their nutritional status. After the data were analyzed via SAS software, regardless of the irrigation rate applied, phosphate fertilization combined with organic fertilization provided an adequate supply of nitrogen and sulfur and a deficiency in phosphorus, potassium, and calcium.

Keywords: *Passiflora edulis,* nutrition, organic input.

3 INTRODUCTION

The yellow passion fruit (*Passiflora edulis)* Sims.) It is a commercially exploited native tropical fruit tree that is of great economic importance to Brazil and is the largest producer and consumer in the world (FALEIRO *et al.).* ; 2020). In 2022, the Northeast Region of Brazil stood out as the largest national producer, producing 486,893 tons of this fruit, which was equivalent to 69.8% of the total Brazilian production (IBGE, 2023). Located in the Northeast Region, specifically in the state of Ceará, the region known as Serra da Ibiapaba has contributed significantly to Northeast China production. However, this region has low productivity, which unfortunately reflects what occurs in the Northeast Region as a whole, which has a productivity of only 15.30 t ha $^{-1}$ (IBGE, 2023), when the potential yield of the crop can exceed the productivities of 50 t ha $^{-1}$ (FALEIRO *et al*.). ; 2020).

This means that, despite advances in agricultural research and investments in new genotypes, the production chain of this fruit still faces problems. Some of these problems are related to inadequate fertilization and plant nutrition, resulting in low productivity. In addition, it is necessary to consider the importance of irrigation in areas where rainfall is insufficient or where the rainfall distribution is irregular (LIRA *et al*., 2016).

Phosphorus has a positive effect on plant metabolism, playing an important role in energy storage and transfer, respiration and the photosynthetic process (MARSCHNER, 2012). Given the numerous functions of phosphorus in plants, Nascimento *et al.* (2011) reported that mineral nutrition is one of the main factors contributing to increased development, productivity and quality of fruits, especially in soils in tropical regions, which generally have low fertility.

With respect to organic fertilizers, cattle manure is the preferred source for producers to provide organic matter to the soil (NASCIMENTO *et al*., 2016). However, the use of sources rich in nutrients, such as chicken litter, which is abundant in the Ibiapaba region (CE), can increase the productivity of yellow passion fruit. The organic carbon contained in these materials serves as an energy source for soil microbial biomass; improves the physical, chemical and biological properties of the soil; and is an important option for maintaining sustainable agricultural practices (YANG *et al*., 2016).

Therefore, the objective of this study was to evaluate the nutritional composition of yellow passion fruit plants subjected to reduced irrigation depth, phosphate fertilization and organic matter application.

4 MATERIALS AND METHODS

The experiment was developed from March 2016 to March 2017 at the Instituto Federal do Ceará, located in the municipality of Tianguá-CE, in the Serra da Ibiapaba region. The climate in the region is Aw', according to Köppen (ALVAREZ *et al*., 2014), which means tropical with a dry winter season and summer rains. The total precipitation recorded during the experiment was 691.8 mm (Figure 1).

Before the start of the experiment, a sample composed of six simple soil samples was collected from the experimental area, in the 0--40 cm layer, for chemical characterization of fertility and physical analysis (Table 1) via the methodologies described in Embrapa (2017). The soil was classified as Neossolo Quartzarenic.

Table 1. Chemical and physical characterization of soil fertility at depths of 0 - 40 cm before the experiments were conducted

Chemical attributes [1]		**Physical attributes** [2]	
pH H_2O (1:2.5)	5.40	Total sand (g kg^{-1})	746
P (mg dm^{-3})	5.50	Silt (g kg^{-1})	111
K^+ ($cmol_c$ dm^{-3})	0.16	Clay (g kg^{-1})	143
Na^+ ($cmol_c$ dm^{-3})	0.01	Ad (g kg^{-1})	68.30
$Ca2^+$ ($cmol_c$ dm^{-3})	1.30	Degree of flocculation (%)	52.23
$Mg2^+$ ($cmol_c$ dm^{-3})	0.75	Soil density (kg dm^{-3})	1.47
SB ($cmol_c$ dm^{-3})	2.22	Particle density (kg dm^{-3})	2.65
$Al3^+$ ($cmol_c$ dm^{-3})	0.15	Total porosity (m^3 m^{-3})	0.45
H^+ +Al^{3+} ($cmol_c$ dm^{-3})	1.95	Humidity at - 0.033MPa (g kg^{-1})	120
PST	0.24	Humidity at - 1,500 MPa (g kg^{-})	90
CEC ($cmol_c$ dm^{-3})	4.17	Add (g kg^{-1})	30.00
V(%)	53.24	Textural classification :	Sandy loam
MO (g kg^{-1})	19.50		

pH (potential of hydrogen) in water; P (phosphorus), K^+ (potassium) and Na^{2+} (sodium) with Mehlich 1 extract; Ca^{2+} (calcium), Mg^{2+} (magnesium) and $Al^{3+ \text{(aluminum) with 1 M}}$ KCl extractant; H^{++} Al^{3+} (hydrogen plus aluminum) with 0.5 M calcium acetate extractant at pH 7.0; SB (sum of bases) = K^{++} Na^{++} Ca^{2++} $Mg^{2+;}$ CEC (cation exchange capacity) = SB + H^+ + $Al^{3+; \text{V (base saturation) = (SB + H + + Al 3+)}}$; V (base saturation) = (SB/CEC) × 100; PST (percentage of exchangeable sodium) = (Na+/CEC) × 100; m (aluminum saturation) = (Al^{3+}/CEC) × 100; MO (organic matter) = organic carbon × 1.724, Walkley-Black method; Adi = available water; granulometry by the densimeter method, 1 M NaOH dispersant; Ad (clay dispersed in water)

Source: Authors (2017)

Table 2. Characterization chemistry of manure and chicken litter used in organic fertilizer

	Organic inputs	
Variable	**Cattle Manure**	**Chicken bed**
Organic Matter (g kg $^{-1}$)	712.7	705.3
Nitrogen (g kg $^{-1}$)	14.5	14.8
Total phosphorus (g kg $^{-1}$)	6.4	13.6
Potassium (g kg $^{-1}$)	10.4	15
Calcium (g kg $^{-1}$)	1.44	4.5
Magnesium (g kg $^{-1}$)	7.0	2.8
Sulfur (g kg $^{-1}$)	0.0	0.0
Iron (g kg $^{-1}$)	4.6	2.1
Manganese (mg kg)	684.0	168.9
Copper (mg kg)	53.4	0.0
Zinc (mg kg)	71.3	15.2
Boron (mg kg)	100	0.0
Sodium (mg kg)	400	230
Ash (g kg $^{-1}$)	284.3	294.7
Moisture (g kg $^{-1}$)	52.2	39.0
Density (g dm $^{-3}$)	0.5	0.2
Sum of NPK (g kg $^{-1}$)	31.8	40.4
pH	7.7	6.1

Source: Authors (2017).

The pits were prepared with dimensions of 40 × 40 × 40 cm, maintaining planting distances of 2.5 m between rows and 3.0 mbetween plants. Owing to its low calcium content and pH below 5.5, dolomitic limestone with a PRNT of 91%, containing CaO = 32% and MgO = 15%, was provided according to the recommendation of Cavalcanti *et al*. (2008), being applied 30 days before the preparation of the pits.

The cattle manure and chicken litter were chemically characterized according to the methodology of Embrapa (2017). These fertilizers were applied to increase the organic matter content in the soil from 1.9 to 4%. Half of the recommended amount was applied during the preparation of the holes, together with the limestone, and the remainder was applied at the beginning of the flowering of the plants, simultaneously with the second application of the phosphorus doses.

The seeds of the Sol do Cerrado hybrid were purchased from Agrocinco. The seedlings were produced in a screened greenhouse in 162-cell trays with vermiculite and washed coconut fiber as the substrate. Transplanting was carried out in the first week of March 2016, when the seedlings reached an average height of 25 cm, and all the treatments achieved 100% success. The plants were trained in a simple vertical espalier system consisting of smooth wire No. 12 installed on top of 2.20 m high stakes. The calculation of organic inputs, chicken litter and cattle manure, was performed with percentages of 2.27% and 1.66%, respectively, in the first application and 1.14% and 1.04%, respectively, in the second application, with the aim of increasing the soil organic matter content from 1.9% to 4%. For this purpose, the expression suggested by Nascimento *et al.* (2016), Equation (1), was used.

DFO = (NMOA-NMOE) × Vc × Ds × Ui/TMOi (1)

where:
DFO = Dosage of the organic source to be applied in the holes (kg per hole)
NMOA = Level of organic matter to be achieved (g kg $^{-1}$)
NMES = Level of organic matter in the soil (g kg $^{-1}$)
Vc = volume of the pit (cm $^{-3}$)
Ds = Soil density (g cm $^{-3}$)
Ui = Input moisture (%)
TMOi = Organic matter content in the input.

The phosphorus rates of 0, 40, 80, 120, and 160 kg ha $^{-1}$ P_2O_5 were based on the recommendation of 80 kg ha $^{-1}$ P_2O_5 suggested by Cavalcanti (2008) for yellow passion fruit cultivation in the state of Pernambuco. This recommendation was adjusted for rates of 80, 40, and 0 and increased to 120 and 160. The corresponding rates were applied in the form of simple superphosphate, which contained 18% P_2O_5, 12% S, and 20% Ca. The application was divided into two stages: 50% of the rates were used in the preparation of the holes, while the other half were applied at the beginning of flowering of the plants.

As with the phosphorus doses, the procedure for applying organic fertilizers, cattle manure (CDM) and chicken litter (PCM) (Table 2), occurred in two stages: the first half during the preparation of the holes and the second half at the beginning of the flowering of the plants. As mentioned, organic inputs were used to increase the soil organic matter content from 1.9% to 4%. The doses corresponding to 100% of the cattle manure and chicken litter were 2.4 kg and 3.0 kg, respectively, with the applications composed of 50% of each organic source.

Topdressing with N and K followed the recommendation of Cavalcanti *et al.* (2008) for passion fruit crops in the state of Pernambuco. Both nutrients were supplied in the form of urea (45% N) and potassium chloride (60% K_2O) at 30 and 60 days after transplanting, respectively, in the amounts of 15 g of N and 7.5 K_2O per plant. During the flowering period and at 90 days after transplanting, 22.5 g of N and 11.25 g of K_2O were supplied per plant.

Irrigation was performed via the drip method, with two self-compensating iDrop drippers with a hydraulic load and a flow rate of 7.8 L h $^{-1}$ per plant spaced 20 cm from the stem. The irrigation frequency adopted was every two days, with water layers corresponding to the replacement of 100% and 70% of the crop evapotranspiration (ETc), which was calculated from the reference evapotranspiration (ETo). The ETo was estimated by multiplying the evaporation of the class 'A' tank by a factor of 0.75, as described by Souza *et al. (2009) for the* Curu Valley Region in Pentecoste, CE. The cultivation coefficients (kc) adopted varied according to the phenological phases of the crop: 0.69 in the initial phase up to 70 days after planting (DAP), 0.92 in the vegetative phase from 71 to 110 DAP and 1.08 in the reproductive phase, from 111 DAP until the end of the harvest. The water used for irrigation came from a tubular well close to the experimental area, whose quality was evaluated according to the methodology of Richards (1954), and a characterization of the risk of soil salinity and sodicity was performed, as indicated in Table 3.

Table 3. Chemical characterization of the irrigation water used during the experiment

pH	EC	Ca2 $^{+}$	Mg $^{2+}$	In $^{+}$	K $^{+}$	SO_4^{-2}	CO_3^{-2}	HCO^{-}_3	Cl^{-}	RAS	Class
	dS m^{-1}	----------------------------- mmol $_c$ L^{-1} ---------------- ---------------									
4.9	0.62	0.12	0.32	5.00	0.62	1.33	0.00	0.00	5.75	10.67	C_2S_2

Source: Authors (2017).
EC = electrical conductivity
RAS = Sodium adsorption ratio
RAS = $Na^{+} / [(Ca^{2+} + Mg^{2+})/2]^{1/}$

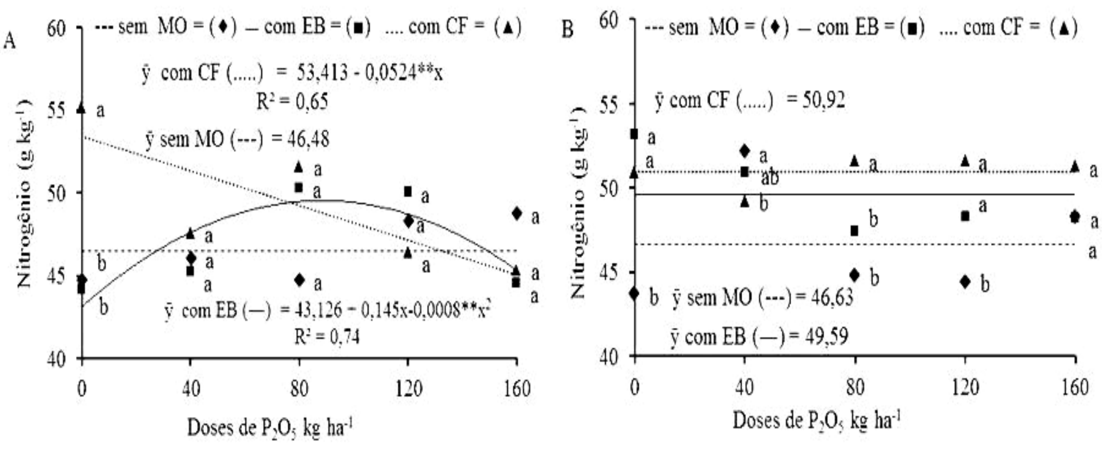
During the beginning of flowering, leaf samples were collected from the middle branches of the plants (4th leaf from the tip) in each plot, with the aim of evaluating the nutritional status of the plants. These samples were subjected to the methodology described by Malavolta, Vitti and Oliveira (1997) and sent for analysis at the Agronomic Laboratory of Campinas-São Paulo (LAGRO) to determine the nutritional status of the plants.

The data obtained were analyzed by analysis of variance via the F test ($p \leq 0.05$) to verify the effects of the factors alone and their interactions. The comparison between the sources of organic matter and the irrigation depths was performed via the Tukey test ($p \leq 0.05$), whereas the phosphorus doses were analyzed via regression via SAS® software. University (CODY, 2015).

5 RESULTS AND DISCUSSION

The passion fruit plants irrigated with the highest water availability, fertilized with phosphorus and without the application of organic inputs (Figure 1A), presented nitrogen values in leaf dry matter that did not fit any regression model, being represented by an average of 46.49 g kg^{-1}. Although there was no significant difference between the inputs from the dose of 40 kg ha^{-1}, the treatment with cattle manure resulted in a maximum leaf nitrogen value of 49.7 g kg^{-1}, which was obtained with the maximum estimated dose of 91 kg ha^{-1} of P_2O_5. In contrast, the use of poultry litter as an organic source led to a reduction in the nitrogen content of the leaf dry matter as the phosphorus dose increased.

Figure 1. Nitrogen content in dry matter of yellow passion fruit plants subjected to irrigation levels of 100% (A) and 70% of ETc (B) and to doses of P_2O_5 in soil without organic matter (- - -), with cattle manure (—) and with chicken litter (....)



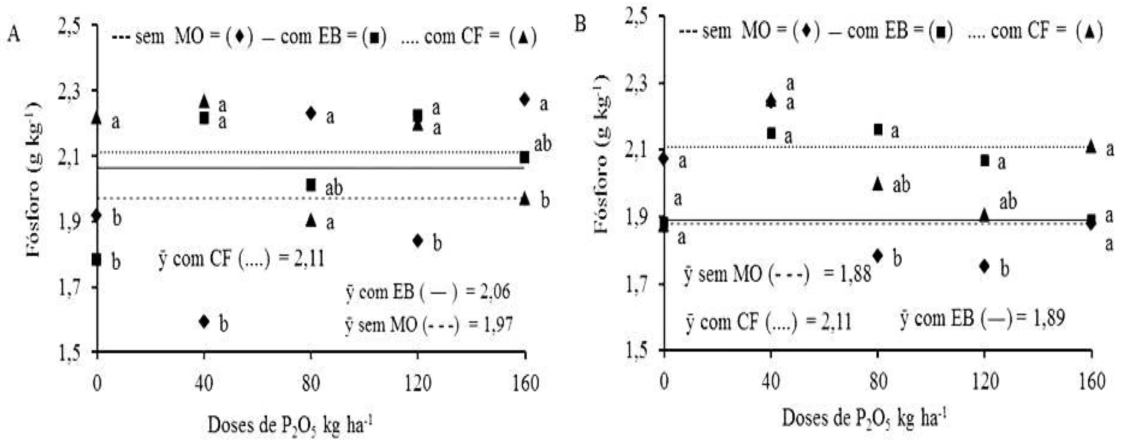
Source: Authors (2023).

When the plants were irrigated with a water depth corresponding to 70% of the ETc (Figure 1B), the values resulting from the application of phosphorus doses associated with the supply of organic sources did not fit any regression model and were represented by average values of 46.63, 49.59, and 50.92 g kg $^{-1}$ for the soil without organic matter, with cattle manure and with chicken litter, respectively. Even without adjustment for regression, it was possible to verify the superiority of chicken litter when the plants were fertilized with a dose of 80 kg ha^{-1}.

The values recorded were above the range considered adequate for the crop, which varies between 40 and 50 g kg $^{-1}$ (MALAVOLTA; VITTI; OLIVEIRA, 1997). Organic matter has the capacity to retain water in the soil, which contributes to obtaining results within adequate levels, even with a reduction in the applied water level (ERNANI *et al*., 2007; KLEIN; KLEIN, 2015). In addition, organic matter also provides essential nutrients for plants (Table 2). The data corroborate those recorded by Santos *et al*. (2018), who reported that the supply of P_2O_5 increased the N content in passion fruit plants to a maximum value of 47.0 g kg $^{-1}$. Similar results were reported by Silva *et al*. (2015), who reported an increase in nitrogen content in wild passion fruit plants. Thus, adequate doses of these nutrients increase the absorption of these elements; however, an excess of one of these elements can inhibit the absorption of the other (CERUTTI; DELATORRE, 2013).

Although the phosphorus contents in leaf dry matter responded to variations in the sources studied, which were associated with the greater irrigation depth and the supply of phosphorus and organic matter, no regression model was fit (Figure 2A). The average values of 1.97, 2.06 and 2.11 g kg $^{-1}$ phosphorus indicate the advantages of 7.1 and 4.6% of the treatments with chicken litter and cattle manure, respectively, compared with those with no organic source. The superiority of chicken litter is due to the high phosphorus content in its chemical composition (Table 2).

Figure 2. Phosphorus content in dry matter of yellow passion fruit plants subjected to irrigation levels of 100% (A) and 70% of ETc (B) and to doses of P_2O_5 in soil without organic matter (- - -), with cattle manure (—) and with chicken litter (....)



Source: Authors (2023).

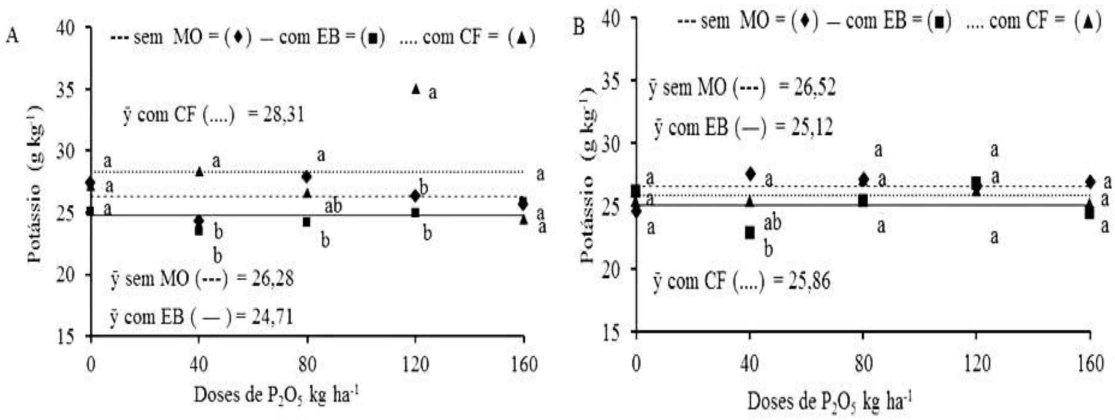
When the plants received the irrigation depth corresponding to 70% of the crop evapotranspiration (Figure 2B), the values resulting from the application of organic matter did not fit any regression model, being represented by averages of

1.88, 1.89, and 2.11 g kg $^{-1}$, respectively, for the soils without organic matter, with cattle manure and with chicken litter. Considering the indications of Malavolta, Vitti and Oliveira (1997), the maximum levels obtained in this experiment are below the critical level for yellow passion fruit crops, which ranges from 4.0 to 5.0 g kg $^{-1}$. The higher phosphorus levels in the soil with phosphate fertilization did not translate into higher levels of this element in the dry matter of the plants. The lower phosphorus levels in the plants fertilized with phosphorus and organic matter must be linked to the more vigorous vegetative growth of these plants, resulting in greater dry matter production.

According to Barrett *et al.* (2008), a greater production of dry matter may cause a dilution effect of nutrients in the tissue, or it may even be related to the fact that phosphorus was supplied in a partial manner, both in the preparation of the holes and at the beginning of flowering. The data presented in this research differ from those obtained by Santos *et al*. (2018), who found that plants were adequately supplied with phosphorus after the application of nutrients.

The values of potassium accumulation in the passion fruit leaf dry matter, obtained with the application of the depth corresponding to 100% of the crop evapotranspiration, phosphate fertilization and application of organic matter, did not fit any regression model. The average results were 26.28 g kg $^{-1}$ for the soil treated without organic matter, 24.71 g kg $^{-1}$ for the soil fertilized with cattle manure and 28.31 g kg $^{-1}$ for the soil fertilized with chicken litter (Figure 3A).

Figure 3. Potassium contents in dry matter of yellow passion fruit plants subjected to irrigation depths of 100% (A) and 70% of ETc (B) and to doses of P_2O_5 in soil without organic matter (- - -), with cattle manure (—) and with chicken litter (....)

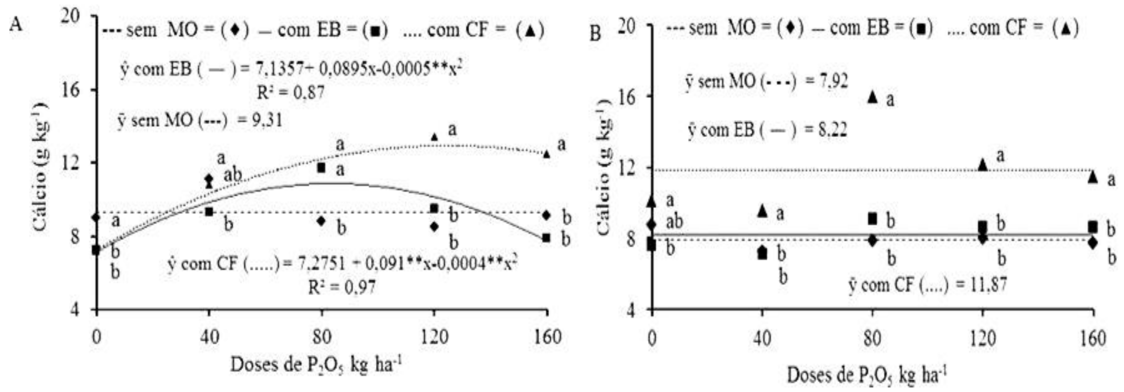


Source: (Authors, 2023).

When the plants were irrigated with 70% crop evapotranspiration, the values related to phosphorus application and organic matter supply did not significantly change. The average potassium values remained at 26.52, 25.52, and 25.86 g kg $^{-1,}$ respectively, for the plants treated without organic matter supply, with cattle manure fertilization and with chicken litter fertilization (Figure 3B). The values recorded are similar to those verified by Nascimento *et al.* (2011), who reported values between 20.66 and 27.18 g kg $^{-1}$ potassium in the dry matter of yellow passion fruit with increasing doses of organic input. The potassium levels obtained in this experiment are insufficient for an adequate supply of yellow passion fruit, considering that adequate values are between 35 and 30 45 gg kg $^{-1}$ (MALAVOLTA, E.; VITTI, GC; OLIVEIRA, SA, 1997). On the other hand, the results are in agreement with those of Oliveira (2002), who considered a sufficient range of 20--30 g kg^{-1} potassium, which would classify the values obtained as adequate for the crop, even with the reduction in the volume of water applied. The data are also in agreement with those verified by Sousa *et al*. (2008) when evaluating the effects of irrigation levels and potassium doses on the nutrient levels of yellow passion fruit.

The calcium values when the soil was irrigated at the greatest water depth and treated with phosphorus doses associated with chicken litter reached the maximum estimated value of 12.5 kg $^{-1}$, with an application of 113.75 kg $^{-1}$ $_{P_2O_5}$. In the soil treated with cattle manure, the calcium level increased to the maximum value of 11.1 kg $^{-1}$, corresponding to a maximum estimated dose of 90 kg $^{-1}$. In the soil that did not receive any type of organic fertilizer, the values did not fit any applied regression model and thus were represented by an average of 9.31 kg $^{-1}$ (Figure 4A).

Figure 4. Calcium contents in dry matter of yellow passion fruit plants subjected to irrigation depths of 100% (A) and 70% of ETc (B) and to doses of P_2O_5 in soil without organic matter (- - -), with cattle manure (—) and with chicken litter (....)



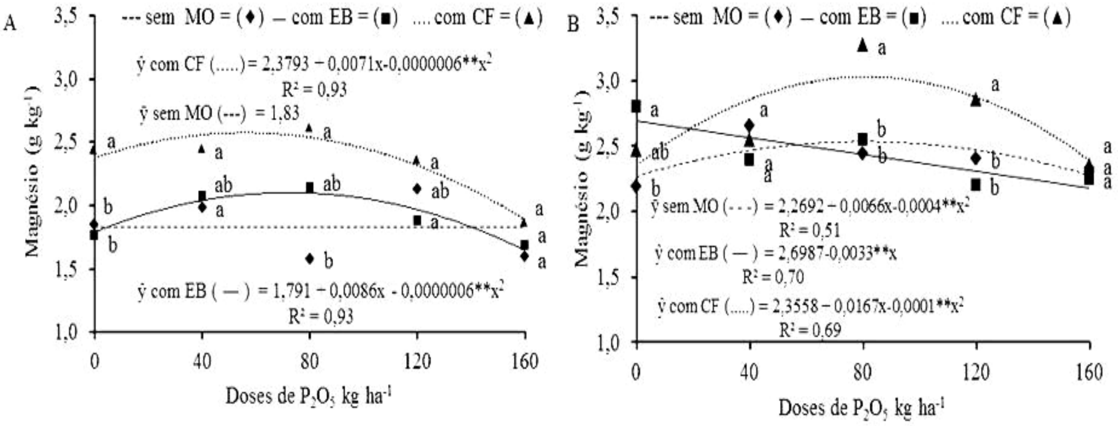
Source: Authors (2023)

When the plants were irrigated to a depth of 70% of the ETc and fertilized with organic matter, the values did not fit any applied regression model and were represented by averages of 7.92, 8.22 and 11.87 g kg $^{-1}$ of calcium, respectively, for the soil without organic matter, with cattle manure and with chicken litter, once again demonstrating the superiority of chicken litter in terms of nutrient absorption (Figure 4B).

Although the values are outside the recommended range for yellow passion fruit, chicken litter is superior to cattle manure at both irrigation depths because of the greater concentration of nutrients in its chemical composition (Table 2). Considering that the adequate calcium levels for passion fruit vary between 15 and 20 g kg $^{-1}$ (MALAVOLTA; VITTI; OLIVEIRA, 1997), the plants were not adequately supplied with this nutrient (Figure 4).

In terms of the magnesium content in leaf dry matter, the maximum estimated dose of 71 g kg $^{-1}$ P_2O_5 was responsible for the maximum value of 2.90 g kg $^{-1}$ magnesium when the plants were irrigated with 100% evapotranspiration from the crop and fertilized with chicken manure. Under the same irrigation conditions, when the plants were fertilized with cattle manure, the maximum nutrient value obtained was 2.50 g kg $^{-1}$, with an estimated dose of 80 kg ha $^{-1}$ (Figure 5A).

Figure 5. Magnesium contents in dry matter of yellow passion fruit plants subjected to irrigation levels of 100% (A) and 70% of ETc (B) and to doses of P_2O_5 in soil without organic matter (- - -), with cattle manure (—) and with chicken litter (....)

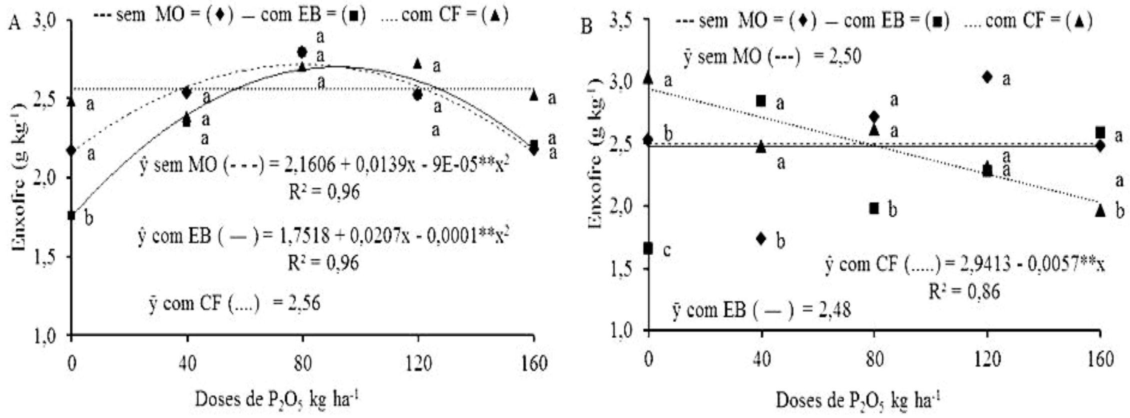


Source: Authors (2023).

When the plants did not receive any type of organic fertilization, the data did not fit any applied regression model and are represented by an average of 1.83 g kg $^{-1}$. When the plants were irrigated with the lowest water level, together with the application of phosphorus and chicken manure, the maximum estimated dose of 84 kg ha^{-1} resulted in values of approximately 3.1 g kg^{-1} magnesium (Figure 5B), which means that it was within the range of 3--4 g kg^{-1}, which is considered adequate for yellow passion fruit crops (MALAVOLTA; VITTI; OLIVEIRA, 1997). In general, these low values can be attributed to the low pH of the soil and the low concentration of this nutrient in the soil, in addition to the high levels of potassium and the presence of calcium from simple superphosphate, which are factors that inhibit the absorption of magnesium (VITTI; LIMA; CICARONE, 2006). Data from Santos *et al*. (2018) reported that passion fruit plants fertilized with simple superphosphate presented values higher than the range of 3--4 g kg^{-1}.

The sulfur contents in the leaf dry matter of yellow passion fruit under the layer with the highest water availability (Figure 6A) revealed that the values related to the application of chicken manure did not fit any regression model, with an average value of 2.56 g kg $^{-1}$. When the plants were fertilized with cattle manure, the maximum estimated dose, which was responsible for the maximum value of 2.8 g kg $^{-1}$, was 104 kg ha $^{-1}$ P_2O_5. In the treatments without organic matter and with cattle manure, under the lowest irrigation layer (Figure 6B), the average results were 2.50 and 2.48 g kg $^{-1}$, respectively, for the treatments without organic matter and with cattle manure, which also did not fit the applied regression model. On the other hand, chicken litter promoted a linear reduction in sulfur levels, decreasing from 2.94 g kg $^{-1}$ to 1.97 g kg $^{-1}$ from the lowest to the highest phosphorus doses.

Figure 6. Sulfur content in dry matter of yellow passion fruit plants subjected to irrigation levels of 100% (A) and 70% of ETc (B) and to doses of P_2O_5 in soil without organic matter (- - -), with cattle manure (—) and with chicken litter (....)



Source: Authors (2023).

The sulfur levels were lower when the plants received the irrigation depth corresponding to the lowest water availability (Figure 6). This can be explained by the fact that the flow of water absorbed by the plant is an important route for transporting dissolved nutrients from the soil to the root surface, where absorption occurs (TAIZ *et al*., 2017). This dynamic is especially significant for sulfur, as this nutrient is absorbed mainly by mass flow.

In general, the maximum sulfur levels obtained in this study exceeded the range of 2--3 g kg^{-1}, indicating that the plants were sufficiently supplied with this nutrient according to the recommendations of MALAVOLTA; VITTI; OLIVEIRA, 1997. This is due, in part, to the presence of 12% sulfur in the simple superphosphate, which contributed to an adequate supply to the plants. These results are in line with those reported by Santos *et al*. (2018), who also reported similar levels when simple superphosphate was applied to yellow passion fruit plants.

6 CONCLUSION

Phosphate fertilization combined with organic fertilization provided adequate nutrition to passion fruit plants in terms of nitrogen and sulfur, regardless of the water depth provided. Although the plants were well supplied with nitrogen, magnesium and sulfur, the levels of phosphorus, potassium and calcium did not meet the needs of yellow passion fruit crops.

7 REFERENCES

ALVARES, CA; STAPE, JL; SENTELHAS, PC; GONÇALVES, JLM; Sparovek , G. Köppen's climate classification map for Brazil . **Meteorologische Zeitschrift** , Stuttgard , vol. 22, no. 6, p. 711-728, 2014. DOI: 10.1127/0941-2948/2013/0507 . Available at: https://www.schweizerbart.de/papers/metz/detail/22/82078/Koppen_s_climate_classification_map_for_Brazil . Accessed July 22, 2018.

BARRETI, PB; SOUZA, RM; POZZA, AAA; POZZA, EA; CARVALHO, JG; SOUZA, JT Increased nutritional efficiency of tomato plants inoculated with growth-promoting endophytic bacteria. **Brazilian Journal of Soil Science** , Viçosa, v. 32, p. 1541-1548, 2008. DOI: https://doi.org/10.1590/S0100-06832008000400018 . Available at: https://www.scielo.br/j/rbcs/a/WpJ9RLKtDFVkHt8GGDXBrMR/?lang=pt . Accessed on July 24, 2018.

CERUTTI, T.; DELATORRE, CA Nitrogen and phosphorus interaction and cytokinin: Responses of the primary root of *Arabidopsis thaliana* and the *pdr1* mutant. **Plant Science** , Limerick , v. 198, p. 91-97, 2013. DOI: https://doi.org/10.1016/j.plantsci.2012.10.007 . Available at: https://www.sciencedirect.com/science/article/abs /pii/S016894521200218X . Accessed on: May 20, 2021.

CAVALCANTI, JCP **Fertilization recommendations for the state of Pernambuco** (2nd approximation). 3rd ed. Recife: Agronomic Institute of Pernambuco, 2008.

CODY, R. **An Introduction to SAS University Edition** . Cary: SAS Institute, 2015.

EMBRAPA. **Soil analysis methodology manual .** 3rd ed. revised and expanded. Brasília, DF: Embrapa, 2017.

ERNANI, PR; ROSCOE, R.; KURIHARA, CH; PEREIRA, NF Potassium In.: NOVAIS, RF; ALVAREZ, V., VH; BARROS, NF; FONTES, RLF; CANTARUTTI, RB NEVES, JCL **Soil Fertility** . Viçosa , MG: Brazilian Society of Soil Science, 2007. chap. 9, p. 471-550.

Passion Fruit : *Passiflora Edulis Sims* . *In* : CARLOSAMA, AR; FALEIRO, FG; MORERA, MP; COSTA, AM **Passionflowers** : Cultivated Species in the world. Brasília, DF: **Embrapa Cerrados** , 2020. chap. 1, p. 15-28.

IBGE. **Municipal Agricultural Production** . Brasília, DF: IBGE, 2023. Available at https://sidra.ibge.gov.br/Tabela/1613 . Accessed on: July 6, 2024.

KLEIN, C.; KLEIN, A. Strategies to enhance soil water retention and availability. **Electronic Journal of Environmental Management, Education and Technology** , Santa Maria, v. 19, n. 1, p. 21-29, 2015. DOI: http://dx.doi.org/10.5902/2236117014990. Available at: https://periodicos.ufsm.br. Accessed on: January 15, 2018.

LIRA, RM; SANTOS, AN; SILVA, JS; BARNABÉ, JMC; SILVA BARROS, M; RAMALHO, H. The use of lower quality water in irrigated agriculture . **Magazine Geama** , Recife, v. 3, no. 1, p. 62-83, 2016 .

MALAVOLTA, E.; VITTI, GC; OLIVEIRA, SA **Evaluation of the nutritional status of plants: principles and applications** . Piracicaba: Potafós , 1997.

MARSCHNER, P. **Marschner's mineral nutrition of higher plants** . 3rd ed. London: Elsevier, 2012.

NASCIMENTO, JAM; CAVALCANTE, LFC; DANTAS, SAG; SILVA, SA Nutritional status of yellow passion fruit irrigated with saline water and organomineral fertilization. **Brazilian Journal of Fruit Growing** , Jaboticabal, v. 33 , p. 729-735, 2011. DOI: https://doi.org/10.1590/S0100-29452011000500102 . Available at: https://www.scielo.br/j/rbf/a/pjNr4GSxDTGW89SJMsthy4k/ . Accessed on June 20, 2018.

NASCIMENTO, JAM; SOUTO, JS; PERREIRA, WE; MEDEIROS, SAS; CAVALCANTE, LF Macronutrients in waterme long plants fertilized with potassium and cattle manure . **Brazilian Journal of Agricultural and Environmental Engineering** , Campina Grande, v. 20, n. 9, p.836-840, 2016. DOI: https://doi.org/10.1590/1807-1929/agriambi.v20n9p836-840 . Available at: https://www.scielo.br/j/rbeaa/a/pDgTbgPhkfHHwVvJFqsbSJF/ . Accessed on July 20, 2018.

OLIVEIRA, SA Leaf analysis. *In* : SOUZA, DMG; LOBATO, E. (ed.). **Cerrado** : soil correction and fertilization. Planaltina: Embrapa Cerrados, 2002. p. 245-256.

RICHARDS, LA **Diagnosis and improvement of saline and alkaline soils** . Washington: United States Salinity Laboratory Staff, 1954. 160 p. (Agriculture , 60).

SANTOS, GP; CAVALCANTE, LF; NASCIMENTO, JAM; LIMA NETO, AJ; MEDEIROS, SAS; CAVALCANTE, IHL Nutritional status of yellow passion fruit fertilized with phosphorus sources and doses. **Journal of Soil Science and Plant Nutrition** , Temuco, v. 18, n. 2, p. 388-402, 2018. DOI: http ://dx.doi.org/10.4067/S071895162018005001204 . Available at: https://www.scielo.cl/scielo.php?script=sci_arttext&pid=S0718-95162018000200388 . Accessed on July 18, 2020 .

SILVA, EM; MELO, NF; MENDES, AMS; ARAÚJO, FP; MAIA, LC; YANO-MELO, AM Response of *Passionflower setacea* to mycorrhization and phosphate Fertilization in a Semiarid Region of Brazil . **Journal of Plant Nutrition** , New York, v. 38, n. 3, p. 431-442, 2015. DOI: https://doi.org/10.1080/01904167.2014.934472 . Available at: https://www.tandfonline.com/doi/abs/10.1080/01904167.2014.934472 . Accessed on February 14, 2020.

SOUSA, VF; FOLEGGATTI, MV; FRIZZONE, JA; DIAS, TJ; ALBUQUERQUE JUNIOR, B.; BATISTA, ERASMO. C. Irrigation levels and potassium doses on leaf nutrient contents of yellow passion fruit. **Brazilian Journal of Agricultural and Environmental Engineering** , Campina Grande, v. 12, n. 1, p.41-46, 2008. DOI: https://doi.org/10.1590/S1415-43662008000100006 . Available at: https://www.scielo.br. Accessed on July 15, 2018.

SOUZA, MSM; BEZERRA, FM L; VIANA, TV A; TEÓFILO, E. M; CAVALCANTE, Í. HL Evapotranspiration of Passion Fruit in the Curu Valley conditions . **Caatinga Magazine** , Mossoró, v. 22, n. 2, p. 11-16, 2009.

VITTI, GC; LIMA, E.; CICARONE, F. Calcium, magnesium and sulfur. *In.* : FERNANDES, MS **Mineral Nutrition of Plants** . Viçosa, MG: Brazilian Society of Soil Science, 2006. chap. 7, p. 300-322.

TAIZ, L.; ZEIGER, E.; MOLLER, I.; MURPHY, A. **Plant physiology and development** . 6th ed. Porto Alegre: Artmed , 2017.

YANG, R.; MO Y.; LIU, C.; WANG, Y.; MA, J.; ZHANG, Y.; LI, H.; ZHANG, X. The effects of cattle manure and garlic rotation on soil under continuous cropping of watermelon (*Citrulluslanatus* L.). **PLoS ONE** , São Francisco, v. 11, n. 6, p. 1-15, 2016. DOI: https://doi.org/10.1371/journal.pone.0156515 . Available at: https:/

/journals.plos.org/plosone/article?id=10.1371/journal.pone.0156515 . Accessed on July 20 , 2018.