

## ORIGINAL RESEARCH ARTICLE

# Growth, yield and chemical composition of eggplant ‘Ciça’ under potassium fertigation

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### ABSTRACT

The objective of this work was to evaluate the effect of potassium concentrations applied via fertigation on the growth, yield and chemical composition of eggplant ‘Ciça’ in a dystroferic red Latosol. The treatments were composed of five concentrations of K<sub>2</sub>O (0, 36, 72, 108 and 144 kg ha<sup>-1</sup> supplied via fertigation), using potassium chloride as a source, divided into six applications. The irrigation system was of the drip type and irrigation management was done via a “Class A” evaporimeter tank. Harvest started at 62 days after transplanting (DAT) and lasted for five months. The variables evaluated were: plant height, number of leaves, fresh fruit mass, number of fruits per plant, yield per plant, productivity and classification of the fruits according to their length and diameter. At 85 DAT, fruit were collected for characterization as to the percentage of lipids, proteins and fibers. Although the potassium fertigation in cover provided a reduction in the production and productivity, the concentrations of 36 kg ha<sup>-1</sup> and 72 kg ha<sup>-1</sup> of K<sub>2</sub>O applied via fertigation, increased the physical-chemical characteristics of the fruits.

**Keywords:** Nutrition; Fruit Quality; *Solanum melongena* L.

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## 1. Introduction

Eggplant (*Solanum melongena* L.) is demanding in potassium, a nutrient that favors the obtaining of fruits of better quality<sup>[1]</sup>. Thus, optimizing the supply of this nutrient is fundamental to increase productivity and reduce production costs<sup>[2]</sup>.

There is a wide variety of fertilization methods to supply plant nutrients. However, as the efficient use of water and fertilizers is an essential objective in all agricultural systems<sup>[3]</sup>, among the most efficient technologies for nutrient application, fertigation stands out, which has provided good results<sup>[4]</sup>.

Fertigation offers greater versatility in the application of fertilizers, allowing the amounts of nutrients to be rigorously dosed and supplied according to the needs of the plants during their development cycle<sup>[5]</sup>. According to Oliveira *et al.*<sup>[6]</sup>, the major limitations for eggplant cultivation are related to the low availability of water and nutrients in the soil during its development.

However, to provide remunerative harvests with products of good nutritional quality, this work aimed to evaluate the effect of potassium concentrations applied via fertigation on the growth, yield and chemical composition of eggplant ‘Ciça’.

## 2. Materials and methods

### 2.1 Characterization of the experimental area

The experiment was conducted in the period from August 2010 to May 2011 in the Irrigation and Drainage area of the Faculty of Agricultural Sciences (FAS) of the Federal University of Grande Dourados (FUGD), in Dourados-MS, whose geographic coordinates are 22°11'45" S and 54°55'18" W, with an altitude of 446 meters above sea level. The climate is humid mesothermal Cwa, according to Koppen's classification<sup>[7]</sup>. The average annual precipitation is 1,500 mm and the average annual temperature is 22 °C.

The experimental design was in randomized blocks with four repetitions. The experimental unit was composed of 15 'Çiça' eggplant plants, considering the five central plants as useful plants and the spacing used was 1.0 m × 1.0 m.

### 2.2 Soil preparation

The soil was classified as a dystroferic Red Latosol<sup>[8]</sup>, with the following chemical characteristics in the 0–20 cm layer, analyzed according to Embrapa<sup>[9]</sup>: pH (CaCl<sub>2</sub> 0.01 mol L<sup>-1</sup>) 5.20; 40.06 g dm<sup>-3</sup> of MO; 11.75 mg dm<sup>-3</sup> of P; 53.5 mmolc dm<sup>-3</sup> of H + Al; 2.1 mmolc dm<sup>-3</sup> of K; 85.5 mmolc dm<sup>-3</sup> of Ca; 30.6 mmolc dm<sup>-3</sup> of Mg; 118.2 mmolc dm<sup>-3</sup> of SB; 171.7 mmolc dm<sup>-3</sup> of CTC; base saturation (V) of 68.84%.

Based on the results of soil analysis and as recommended by Martinez *et al.*<sup>[10]</sup>, 120 kg ha<sup>-1</sup> of P<sub>2</sub>O<sub>5</sub> were applied to the experimental area, using simple superphosphate as a source and 120 kg ha<sup>-1</sup> of nitrogen. The planting fertilization was performed with only 40% of potassium and nitrogen (in the form of urea) recommended ten days before transplanting the seedlings (48 and 40 kg ha<sup>-1</sup>, respectively) together with 100% P<sub>2</sub>O<sub>5</sub> and 20 t. ha<sup>-1</sup> of tanned corral manure.

The chemical characteristics of the applied corral manure, analyzed according to Embrapa<sup>[9]</sup>, were: pH (CaCl<sub>2</sub> 0.01 mol L<sup>-1</sup>) 6.75; 197.70 mg dm<sup>-3</sup> of P; 9.13 mmol dm<sup>-3</sup> of K; 0.0 mmol dm<sup>-3</sup> of Al; 11.36 cmol dm<sup>-3</sup> of Ca; 4.96 cmol dm<sup>-3</sup> of Mg;

2,32 cmol dm<sup>-3</sup> of H + Al; 172.30 mmol dm<sup>-3</sup> of SB; 195.50 mmol dm<sup>-3</sup> of CTC and base saturation (V) of 88.13%. The 60% nitrogen fertilizers and the treatments referring to potassium concentrations were supplied through six fertirrigations, at 16, 25, 31, 39, 45, and 55 days after transplanting (DAT) the seedlings.

### 2.3 Treatments

The treatments consisted of five concentrations of K<sub>2</sub>O: 0, 36, 72, 108 and 144 kg ha<sup>-1</sup> supplied as a cover crop via fertigation, corresponding to percentages of 0.30%, 60%, 90% and 120% of the concentration recommended by Martinez *et al.*<sup>[10]</sup>, using potassium chloride as a source.

### 2.4 Irrigation system

A drip irrigation system was used with a PETRODRIP<sup>®</sup> Manari model drip hose, with 20 cm spacing between emitters, installing a line of hose for each row of plants. Irrigation management was performed using a "Class A" evaporimeter tank, according to the methodology suggested by Bernardo *et al.*<sup>[11]</sup>, using the crop coefficients (Kc) proposed by Doorenbos and Kassam<sup>[12]</sup> for eggplant, to convert reference evapotranspiration into crop evapotranspiration.

Fertirrigation was performed by a pressurized container system, developed at FAS/FUGD, with injection performed by pressure differential. In this container, the necessary amount of fertilizer was inserted according to each treatment.

### 2.5 Evaluations

At 15, 29, 42, 57, 114, 212 DAT, soil samples were collected at a depth of 0–20 cm and from the leaves of the eggplant plants. The soil and leaf K contents were determined respectively, according to Embrapa<sup>[9]</sup> and Malavolta *et al.*<sup>[13]</sup>. The relative chlorophyll index was determined at 13, 20, 28, 42, 56, 61, 84, 106 DAT from leaves located in three positions on the plant: basal, median and apical of five central plants in each plot. The readings were taken using the Chlorophyll Meter SPAD-502, in which the values are calculated by the differential reading of the amount of light transmitted by the leaf, at two wavelengths (650 nm and 940 nm)<sup>[14]</sup>,

obtaining the average for each leaf position.

Harvests were performed starting at 62 DAT and continued for five months. The following variables were evaluated: plant height (measured from the neck to the last young leaves at the time of the first harvest); number of leaves (determined at the time of the first harvest); fresh fruit mass; average fruit length (measured from the base of the fruit to the junction of the peduncle to the calyx); average fruit diameter (measured at a distance of 4.5 cm from the base of the fruit); number of fruits per plant and classification of the fruits according to their size.

Eggplant fruits were sorted into three classes, according to the length and largest transverse diameter of the fruit: a) large class: fruits with length equal to or greater than 190 mm and transverse diameter equal to or greater than 70 mm; b) medium class: fruits with length of 160 mm and less than 190 mm and transverse diameter greater than or equal to 60 mm; c) small class: fruits with length ranging from 140 mm to 160 mm and transverse diameter greater than or equal to 50 mm<sup>[15]</sup>.

The second part of the experiment aimed to determine the chemical composition of the eggplant fruits produced with the different concentrations of K as to the contents of lipids, proteins and fibers. The fruits were harvested at 85 DAT, being crushed and homogenized. The lipids were quantified in a Soxhlet extractor using hexane as solvent. The nitrogen content was evaluated by the Micro-Kjedahl method and converted to crude protein using a factor of 6.25<sup>[16]</sup>. Crude fiber content was quantified by acid and basic digestions according to AOAC<sup>[17]</sup>.

## 2.6 Statistical analysis

The data obtained were submitted to variance analysis and, subsequently, when significant at 5% probability level by the F test, regression analysis was performed for the potassium concentration factor.

## 3. Results

The potassium concentrations applied via fertigation did not influence the 'Çiça' eggplant plants with respect to the number of leaves per plant, plant

height, average fruit mass, fruit length and diameter (**Table 1**).

On average, the plants had 110 leaves, height of 66.2 cm, average fruit mass of 265.6 g, fruit length of 14.6 cm, and diameter of 67.68 cm.

**Table 1.** Summary of variance analysis with F test, coefficient of variation and averages of morphological characteristics of eggplant 'Çiça'

	AP	NF	MMF	CF	DF
Blocks	1.00 <sup>ns</sup>	0.85 <sup>ns</sup>	2.14 <sup>ns</sup>	2.40 <sup>ns</sup>	1.62 <sup>ns</sup>
Doses	1.20 <sup>ns</sup>	0.94 <sup>ns</sup>	0.89 <sup>ns</sup>	0.94 <sup>ns</sup>	0.41 <sup>ns</sup>
Averages	65.22	110.20	167.91	9.26	40.63
CV(%)	7.23	17.69	20.34	18.92	30.55

<sup>ns</sup>: not significant at the 5% probability level; CV: coefficient of variation; AP: plant height at first harvest; NF: number of leaves at first harvest; MMF: average fruit mass; CF: fruit length; DF: fruit diameter.

Significant effects were observed ( $p < 0.05$ ) for the following variables analyzed: number of fruits, production per plant (kg plant<sup>-1</sup>), crop yield (t ha<sup>-1</sup>) and fiber, lipid and protein contents.

The regression analysis showed that the number of fruits per plant presented a quadratic response in relation to the concentrations applied (**Figure 1**). Deriving the regression equation presented in **Figure 1**, with a calculated dose of 9.55 kg ha<sup>-1</sup>, a maximum number of 8.98 fruits is obtained.

The yield per plant (**Figure 2**) also showed a decreasing quadratic response in relation to the concentrations applied. Only the treatments in which no potassium (K) was applied in cover and the one that received 36 kg ha<sup>-1</sup> of K (2.36 and 2.39 kg plant<sup>-1</sup> respectively) showed higher production.

It can be seen in **Figure 3** that the total amount of harvested fruit oscillated in each harvesting operation, showing, however, a tendency to increase with each harvest.

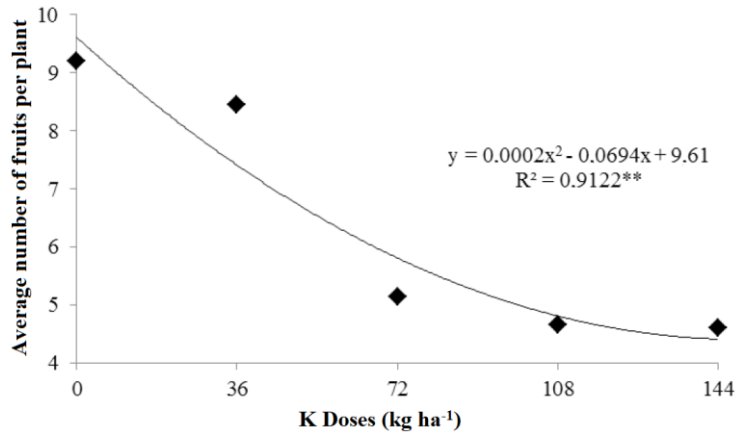
The fruits were classified in three classes, 9.0% were considered large, 33.6% medium and 57.4% were classified as small fruits (length between 140 mm and 160 mm and transversal diameter bigger or equal to 50 mm). The number of medium fruits was higher until the fifth harvest, and in the three remaining harvests, fruits classified as small prevailed.

Following the same trend as the other variables, yield (t ha<sup>-1</sup>) showed a negative response to overhead fertigation (**Figure 4**), since with increasing

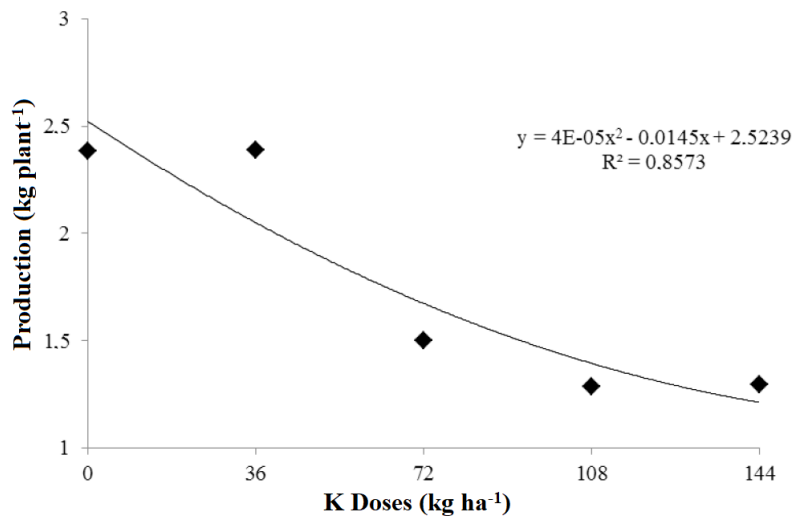
potassium concentrations, there was a reduction in crop yield.

Through the derivative of the equation in **Figure 4**, a maximum of 24.97 t ha<sup>-1</sup> is found through the calculated dose 21.62 kg ha<sup>-1</sup> of K<sub>2</sub>O.

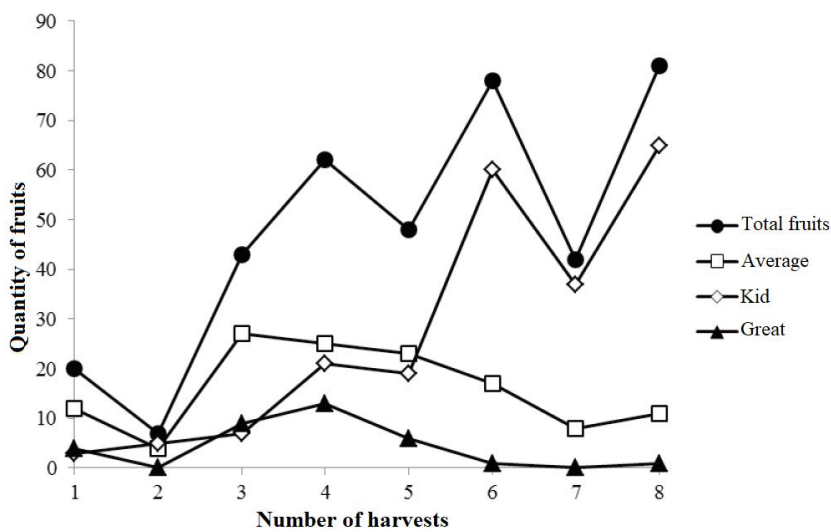
The highest foliar potassium content found was in treatment 1 (0 kg ha<sup>-1</sup> of K<sub>2</sub>O) with 4.56 mmol dm<sup>-3</sup>. While the highest average soil potassium content was found in treatment 5 (144 kg ha<sup>-1</sup> of K<sub>2</sub>O) with 5.81 mmol dm<sup>-3</sup>.



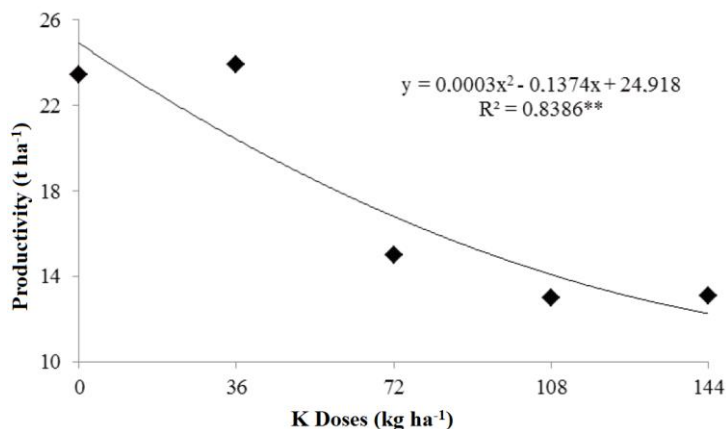
**Figure 1.** Average number of fruits of *Solanum melongena* L. as a function of potassium concentrations applied via fertigation.



**Figure 2.** Production (kg plant<sup>-1</sup>) by plants of *Solanum melongena* L. as a function of potassium concentrations applied via fertigation.



**Figure 3.** Quantity of *Solanum melongena* L. fruits at each harvest.

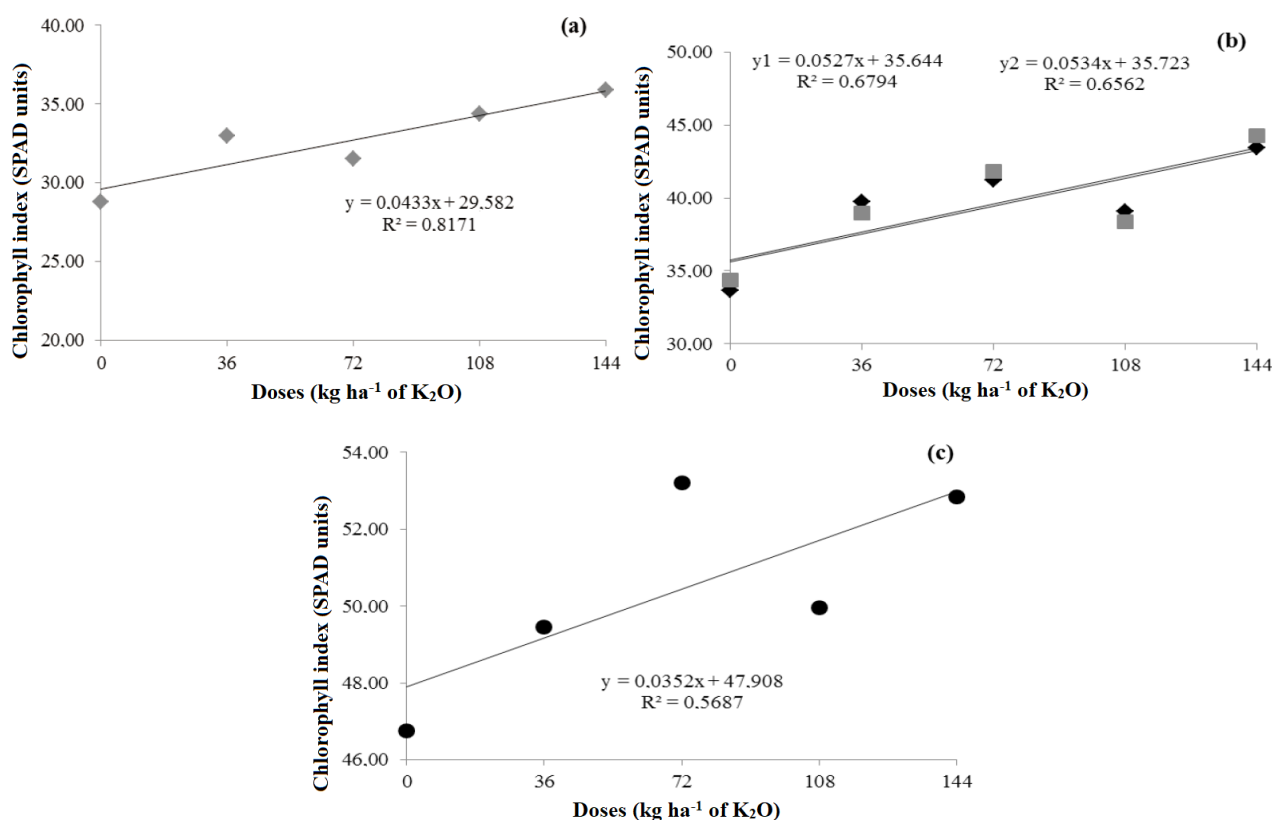


**Figure 4.** Yield of *Solanum melongena* L. as a function of potassium concentrations applied via fertigation.

By regression analysis, the applied concentrations showed significant effect on the chlorophyll content in the leaves for the basal leaf at 13 and 42 DAT, for the apical and median leaves at 20 DAT. An increasing linear response was found for the chlorophyll index with increasing K<sub>2</sub>O content at the concentrations applied via fertigation (**Figure**

**5).**

The chemical composition of eggplant fruits harvested at 85 DAT regarding the contents of lipids, proteins and fibers are presented in **Figure 5**, in which the means followed by the same letter do not differ at 5% probability by Tukey's test.



**Figure 5.** Chlorophyll index (SPAD units) established at 13 (a), 20 (b) and 42 (c) DAT in leaves of *Solanum melongena* L. submitted to five doses of potassium supplied via fertigation.

## 4. Discussion

The average number of leaves, height, average mass, length and diameter of the fruits were higher

than those found by Antonini *et al.*<sup>[18]</sup>. When evaluating the productive capacity of several varieties of eggplant under irrigation, they verified that the cultivar Çiça presented an average mass of 249.5 g for

fruits with length between 13 and 17 cm. It is possible that characteristics such as plant height and number of leaves were not influenced by K, since this is considered a quality nutrient.

Especially for vegetables and fruits, the visual variables are of extreme importance in the commercialization of the products. The fruits produced in this study are in accordance with the commercial standards for the state of São Paulo, according to which, the fruits should have a diameter between 70 and 80 mm, length between 14 and 16 cm and weight between 200 and 250 g.

Although the number of fruits observed was lower than those found by Antonini *et al.*<sup>[18]</sup>, who obtained, for the cultivar Ciça, an average of 12 fruits per plant, the production was very close to that found by Antonini *et al.*<sup>[18]</sup>, who reached an average production of 2.68 kg/plant.

Filgueira<sup>[19]</sup> stated that the K applied to the soil via fertilizer is well used by the plant, with relatively slow K uptake in the initial stages of plant development. In view of this, it is possible that only the planting fertilization was already sufficient for the management of the crop (40% of the K recommendation was applied at planting), with no need for complementary fertigation in covering (the remaining 60% of the recommendation). The yield was superior to that found by Antonini *et al.*<sup>[18]</sup>, who obtained a yield of 17.87 t ha<sup>-1</sup>, but the spacing between plants used was 1.5 × 1.0 m, different from that used in this study.

The foliar analysis of eggplant is an important tool in helping to interpret the nutritional state of the plant, aiming at the evaluation and correction of soil fertility for the best use of the crop's productive potential.

The results of the leaf K content corroborate those found by Marcussi *et al.*<sup>[20]</sup> studying nitrogen and potassium fertigation in bell pepper culture based on the accumulation of nitrogen and potassium by the plant, observed that the relative chlorophyll index also increased according to the dose of nitrogen and potassium applied. The authors stated that the accumulated chlorophyll seems to be sufficient for the maintenance of green tissues, ensuring photosynthetic efficiency for the accumula-

tion of carbon in other chemical forms and the transport of synthesized carbon towards the aerial part.

The plants submitted to concentrations of 36 kg ha<sup>-1</sup> and 72 kg ha<sup>-1</sup> of K<sub>2</sub>O applied via fertigation, showed the best increases in the physicochemical characteristics of eggplant 'Ciça', with the highest levels of fiber (20.20%) and lipids (4.00%) in the fruit. However, the highest protein content, 1.44%, was found in the plants that were not subjected to the potassium concentrations, which means that with these potassium concentrations, they were sufficient to improve the quality of the fruits.

Santos *et al.*<sup>[21]</sup>, by studying the chemical composition of dehydrated eggplant powder, also observed a significant effect for fiber content. Perez and Germani, by analyzing the physical and chemical characteristics of mixed flour of wheat and eggplant, observed that the eggplant flour had a high content of total dietary fiber and high amounts of protein, ash and total sugars.

## 5. Conclusions

Although potassium fertigation in cover caused a reduction in the production and productivity of the eggplant crop with the increase of the concentrations proposed in this work, the concentrations of 36 kg ha<sup>-1</sup> and 72 kg ha<sup>-1</sup> of K<sub>2</sub>O applied via fertigation, increased the physicochemical characteristics of the fruits, presenting the highest contents of fibers (20.20%) and lipids (4.00%). And the highest protein content, 1.44%, was found in fruits that were not subjected to potassium concentrations.

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## Conflict of interest

The authors declare that they have no conflict of interest.

## References

1. Filgueira FAR. Solanáceas: Agrotecnologia moderna na produção de tomate, batata, pimentão, pi-

- menta, berinjela, e jiló (Portuguese) [Solanaceae: Modern agrotechnology in the production of tomatoes, potatoes, peppers, eggplant, and eggplant]. Lavras: UFLA; 2003. p. 333.
2. Malavolta E, Pimentel-Gomes F, Alcarde JC. Adubos e adubações (Portuguese) [Fertilizers and fertilizing]. São Paulo: Nobel; 2002. p. 200.
  3. Dinnes DL, Karlen DL, Jaynes DB, *et al.* Nitrogen management strategies to reduce nitrate leaching in tile-drained Midwestern soils. *Agronomy Journal* 2002; 94(1): 153–171. doi:10.2134/agronj2002.0153.
  4. Factor TL, Araújo JAC, Vilella Júnior VE. Pepper production in substrates using fertigation with biological reactor effluent. *Revista Brasileira de Engenharia Agrícola e Ambiental* 2008; 12(2): 143–149. doi: 10.1590/s1415-43662008000200006.
  5. Nannetti DC, Souza RJ, Faquin V. Efeito da aplicação de nitrogênio e potássio via fertirrigação, na cultura do pimentão (Portuguese) [Effect of nitrogen and potassium application via fertigation on sweet pepper crop]. *Horticultura Brasileira* 2000; 18(1): 843–845.
  6. De Oliveira AB, Hernandez FFF, Assis Júnior RN. Green coconut coir fiber, an alternative substrate to eggplant seedling. *Revista Ciencia Agronomica* 2008; 39(1): 39–44.
  7. Koppen W. Climatología: Con un estudio de los climas de la tierra (Spanish) [Climatology: With a study of the climates of the earth]. Mexico: Fondo de Cultura Económica; 1948. p. 478.
  8. Empresa Brasileira de Pesquisa Agropecuária (EMBRAPA). Sistema brasileiro de classificação de solos (Portuguese) [Brazilian system of soil classification]. 2<sup>nd</sup> ed. Rio de Janeiro: Ministério da Agricultura e do Abastecimento; 2006. p. 306.
  9. Empresa Brasileira de Pesquisa Agropecuária (EMBRAPA). Manual de métodos de análises de solo (Spanish) [Solo analysis methods manual]. 2<sup>nd</sup> ed. Rio de Janeiro: Ministério da Agricultura e do Abastecimento; 1997. p. 212.
  10. Martinez EPM, Carvalho JG, Souza RB. Diagnóstico foliar. In: Ribeiro AC, Guimarães PTG, Alvarez VH (editors). *Recomendações para o uso de corretivos e fertilizantes em Minas Gerais: 5ª aproximação* (Portuguese) [Recommendations for the use of correctives and fertilizers in Minas Gerais: 5<sup>th</sup> approach]. Viçosa: CFSEMG; 1999. p. 143–168.
  11. Bernardo S, Soares AA, Mantovani EC. *Manual de Irrigação* (Portuguese) [Irrigation manual]. 7<sup>th</sup> ed. Viçosa: Editora UFV; 2005. p. 611.
  12. Doorenbos J, Kassam AH. *Yields response to water*. Rome: FAO; 1979. p. 306.
  13. Malavolta E. *ABC da adubação* (Portuguese) [ABC of fertilization]. 5<sup>th</sup> ed. São Paulo: Agronômica Ceres; 1989. p. 292.
  14. Swiader JM, Moore A. SPAD-chlorophyll response to nitrogen fertilization and evaluation of nitrogen status in dryland and irrigated pumpkins. *Journal of Plant Nutrition* 2002; 25(5): 1089–1100. doi:10.1081/pln-120003941.
  15. Luengo RFA, Calbo AG, Lana MM, *et al.* *Classificação de hortaliças* (Portuguese) [Classification of vegetables]. Brasília: Embrapa Hortaliças; 1999. p. 27–33.
  16. Adolfo Lutz Institute. *Normas analíticas do Instituto Adolfo Lutz: Métodos químicos e físicos para análises de alimentos* (Portuguese) [Analytical standards of the Adolfo Lutz Institute: Chemical and physical methods for food analysis]. 4<sup>th</sup> ed. São Paulo: Instituto Adolfo Lutz; 2008. p. 1020.
  17. Association of Official Analytical Chemists. *Official methods of analysis of AOAC international*. 16. Rockville: Gaithersburg ed. AOAC international; 1997. p. 1141.
  18. Antonini ACC, Robles WGR, Tessarioli Neto J, *et al.* Yield potential of eggplant cultivars. *Horticultura Brasileira* 2002; 20(4): 646–648. doi: 10.1590/s0102-05362002000400027.
  19. Filgueira FAR. *Novo manual de olericultura: Agrotecnologia moderna na produção e comercialização de hortaliças* (Portuguese) [New horticulture manual: Modern agrotechnology in the production and marketing of vegetables]. Viçosa: EditoraUFV; 2008. p. 421.
  20. Marcussi FFN, Godoy LJG, Bóas RL. Nitrogen and potassium fertilization in sweet pepper culture based on N and K accumulation by plants. *Brazilian Journal of Irrigation and Drainage* 2004; 9(1): 41–51.
  21. Santos KA, Karam LM, Freitas RJS, *et al.* *Composição química da berinjela* (*Solanum melongena* L.) (Portuguese) [Chemical composition of eggplant (*Solanum melongena* L.)]. *BCEPPA* 2002; 20(2): 247–256. doi:10.5380/cep.v20i2.1250.