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Growth and macronutrient content of Habanero pepper (*Capsicum chinense* Jacq.) subjected to organic fertilization

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Abstract

Studies on the nutritional status of habanero pepper (*Capsicum chinense* Jacq.) in relation to organic fertilization are still incomplete and preliminary. The aim of study were to evaluer the effect of rates of organic fertilizer produced from Family agriculture waste on growth and nutritional status habanero pepper. The experiment was carried out in a greenhouse located at the Federal Rural University of Amazonia, municipality of Belém, State for Pará, Brazil. A completely randomized design (CRD) was used, with five treatments and four replications. Each experimental plot consisted of a pot with a volume of 3.6 dm^3 of soil, in which the seeds were sown. Five doses of organic fertilizer were tested : 0%, 15% (525 g), 30% (1050 g), 45% (1575 g) and 60% (2100 g) of substrate volume, composed of a mixture of chicken manure (10%), duck manure (20%), cassava peel (15%) , cassava leaf (15%), bean straw (15%), rice husk (15%) and corn cob (10%), mixed in volumetric proportions in the substrate. To mix the different amounts of organic fertilizer, a Yellow Latosol with a sandy texture was used, removed from the surface layer (0-20 cm). The best results were achieved at 103 days using a dose of 60% of organic fertilizer. The content and accumulation of macronutrients in leaf tissues showed the following order: N>K≥S>Ca≥Mg>P and N>K>S>Mg>Ca>P. In the fruits, the content and accumulation of macronutrients presented the following order: N>K>S>P>Mg>Ca.

Keywords: habanero pepper; organic fertilization; fruit production.

Crescimento e conteúdo de macronutrientes da pimenta Habanero (*Capsicum chinense* Jacq.) sujeito à fertilização orgânica

Resumo

Os estudos sobre o estado nutricional da pimenta habanero (*Capsicum chinense* Jacq.) em relação à adubação orgânica ainda são incompletos e preliminares. O objetivo do estudo foi avaliar o efeito de doses de adubo orgânico produzido a partir de resíduos da agricultura familiar no crescimento e estado nutricional da pimenta habanero. O experimento foi conduzido em casa de vegetação localizada na Universidade Federal rural da Amazônia, município de Belém, Estado do Pará, Brasil. Foi utilizado o delineamento inteiramente casualizado (DIC), com cinco tratamentos e quatro repetições. Cada parcela experimental foi composta por um vaso com volume de 3,6 dm^3 de solo, no qual foram semeadas as sementes. Foram testadas cinco doses de adubo orgânico: 0%, 15% (525 g), 30% (1050 g), 45% (1575 g) e 60% (2100 g) do volume do substrato, composto pela mistura de esterco de galinha (10%), esterco de pato (20%), casca de mandioca (15%), folha de mandioca (15%), palha de feijão (15%), casca de arroz (15%) e sabugo de milho (10%), misturados em proporções volumétricas no substrato. Para a mistura das diferentes quantidades de adubo orgânico, utilizou-se um Latossolo Amarelo de textura arenosa, retirado da camada superficial (0-20 cm). Os melhores resultados foram alcançados aos 103 dias utilizando a dose de 60% de adubo orgânico. O teor e acúmulo de macronutrientes nos tecidos foliares apresentaram a seguinte ordem: N>K≥S>Ca≥Mg>P e N>K>S>Mg>Ca>P. Nos frutos, o teor e acúmulo de macronutrientes apresentaram a seguinte ordem: N>K>S>P>Mg>Ca.

Palavras- Chaves: pimenta habanero; adubação orgânica; produção de frutos.

Introduction

Originating from the Amazon, the habanero type pepper, belonging to the Solanaceae family, has a thick shape, with fruits produced with different degrees of pungency (COSTA *et al.*, 2015a). This vegetable is a component of the group within the species Capsicum chinense, which presents great diversity in relation to vegetative characteristics, such as leaves, flowers and fruits. The highlight of this pepper, in national and international markets, is due to the numerous biochemical compounds beneficial to human health, such as vitamins and natural antioxidants, including capsaicinoids, carotenoids, ascorbic acid, vitamin A, and tocopherols (MECKELMANN, 2015; PEREIRA, 2016).

Studies focused on fertility and macronutrients required by habanero pepper (Capsicum chinense) are scarce in Brazil, but regarding micronutrients, Silva *et al*. (2018) found that the highest demand for micronutrients by *C. chinense* came from the chemical compounds, in descending order: Fe＜B＜Mn＜Zn＜Cu. Therefore, it is necessary to study the effects of organic fertilization on Habanero crop behavior in order to meet consumer demands, fill gaps in knowledge about the crop, and seek sustainable environmental alternatives for production (JÚNIOR *et al*., 2011).

In the state of Pará there are considerable amounts of poultry manure and plant waste, which allows the production of low-cost organic fertilizers for small farmers and the reuse of this waste, since carbon is a basic energy source of organic molecules that promotes microbial growth, while nitrogen acts in the composition of some essential elements for the growth and functioning of cells, such as proteins, nucleic acids, amino acids, enzymes and coenzymes (COSTA *et al*., 2015b).

Moreover, the chemical composition and accumulation of nutrients in leaves and fruits is essential information to understand the nutritional needs of the plant (VIÉGAS *et al*., 2013), in order to improve the quality (RAHMAN; INDEN, 2012) and productivity of the fruits (DAS *et al*., 2016). In this sense, each nutrient plays a key role in the development of C. chinense, such as nitrogen that acts directly in increasing leaf area and photosynthesis (BARBOSA, 2019); phosphorus in stimulating roots, fortified stem and healthy foliage (OLIVEIRA *et al*., 2011); potassium in the energy state of the crop, transport and storage of nutrients and in water uptake in plant tissues (MARSCHNER, 2012; BARBOSA, 2019).

The aims of study were to evaluer the effect of rates of organic fertilizer produced from Family agriculture waste on growth and nutritional status habanero pepper.

Material and Methods

Experimental area

The experiment was conducted in a greenhouse at the Universidad Federal Rural da Amazonia, municipality of Belém, State for Pará, Brazil (coordinates 01°26'00"S and 48°26'00"W). According to Köeppen's classification, the region's climate is of type Af2, represented by a rainy, hot and humid climate. Average annual precipitation varies from 2,500 to 3,000 mm, with practically no periods of drought or, at most, one or two months of drought. The average annual temperature varies from 27 to 30 °C, with small oscillations of 1 to 3 °C during the year. The light intensities inside and outside the greenhouse during the experimental period were 321 and 694 lux, respectively, measured with a digital luxmeter (Instrutherm, model LD-206).

Experimental design

The experiment was installed in a completely randomized design (CRD) with five treatments and four replications, making a total of 20 experimental units. The treatments consisted of five doses of organic compost in the proportions of 0%, 15% (525 g), 30% (1050 g), 45% (1575 g) and 60% (2100 g) of the substrate volume (SILVA *et al*., 2018). Each experimental plot consisted of a 3.6 dm^3 pot containing one to two habanero pepper seeds, sown directly into the pot. Soil moisture was maintained between 60% and 80% of total soil porosity by weighing the pots, using demineralized water.

Soil sampling and analysis

The soil used was classified as Yellow Latosol of sandy texture (EMBRAPA, 2018), collected at 0-20 cm, from an area composed of secondary vegetation unexploited for over twenty years, belonging to the Amazon biome, in the city of Moju, Pará state, Brazil. Table 1 illustrates the results of the chemical and physical analysis of the soil used, in which the values were:

Table 1. Chemical and physical analysis of the soil, depth of 0-20 cm.

Depth	P	K	Na	Ca	Ca+Mg	S	Al	H + Al	Zn	Fe	Mn	B	Cu
cm	mg/dm^{-3}	------------------------ cmol$_c$/dm^{-3}----------------------							------------ mg/dm^{-3}--------------				
0-20	1	0.11	0.08	2.7	3.6	4.8	0	2.6	1.50	34.6	16.8	0.39	2.0

SB	t	T	V	MO	Coarse sand	Fine sand	Silt	Clay
---------cmol$_c$/dm^{-3}---------			%	---------------------------------g/kg^{-1}----------------------------------				
3.79	3.79	6.39	59.31	23.0	481	336	103	80

P - Na - K - Fe – Zn - Mn - Cu - Mehlich Extractor $^{-1}$

Ca - Mg - Al - KCL extractor - 1 mol/L

H + Al - 0.5 mol L^{-1} calcium acetate at pH 7.0

B - hot water extractor

S - monocalcium phosphate extractor

SB - sum of interchangeable bases

t - Effective cation exchange capacity

T - Cation exchange capacity at pH 7 (CTC)

V - Base saturation

MO - organic matter

Org. C. - Walkley-Black method

sand - silt - clay - pipette method.

Production of organic Compost

In this study, a compost mixture containing high levels of carbon and nitrogen (ZHU, 2007) was used to produce the organic waste compost, formed by the mixture of chicken manure (10%), duck manure (20%), cassava husk (15%), cassava leaf (15%), bean straw (15%), rice husk (15%) and corn cob (10%). The composting process was carried out for 130 days. The different amounts of organic compost were mixed in volumetric proportions with the soil. The chemical properties of the organic fertilizer showed pH = 6.94; N = 15.2 g kg^{-1}; C = 109.7 g kg^{-1}; Humidity at 65 °C = 41.69%. Further information is shown in Table 2.

Table 2. Analysis of organic residues and final compost after 130 days of composting. Macronutrient and micronutrient values.

Organic Waste	N	P	K	Ca	Mg	S	Zn	Fe	Mn	Cu	B
Composition	--------------------------g/Kg^{-1}------------------------						-------------------mg/Kg^{-1}-----------------------				
Organic Fertilizer	9.1	12.6	6.3	52.1	3.6	7.2	164.0	2546.0	139.0	241.0	19.3
Duck manure	20.8	19.0	10.9	51.2	7.0	10.2	295.0	4012.0	340.5	42.3	39.2
Chicken manure	27.3	21.4	27.9	43.5	8.2	11.7	607.0	15457.0	684.0	297.1	20.9
Cassava Peel	10.3	0.6	7.3	5.0	0.9	2.3	22.8	4639.5	82.6	8.8	30.8
Cassava Leaf	36.6	2.0	12.2	12.0	4.4	15.3	61.5	120.8	52.8	6.5	52.6
Bean Straw	13.4	1.0	12.8	4.2	4.7	2.6	20.0	313.3	42.0	5.1	61.8
Rice husk	6.4	1.5	4.6	2.7	0.8	2.3	34.9	6209.0	145.7	9.7	14.2
Corn cob	7.4	0.3	3.4	0.5	0.5	1.5	40.4	189.1	19.9	2.4	19.5

Determination of Growth and production Parameters

At 103 days after sowing, the vegetative growth assessments were performed: fresh and dry matter (g) and fruit production (g). The fresh and dry masses were obtained by adding the stem, leaves and roots. To obtain dry matter, stem, leaves, and roots were dried at 60 °C in a forced air circulation oven until constant mass was reached (SÁ *et al.*, 2017). After drying, the samples were ground in a Wiley mill (mesh size 20) and subjected to nutritional analysis.

Laboratory analysis of plant material

Leaves and fruits samples were analyzed to determine the macronutrient contents (N, P, K, Ca, Mg, and S) in *C. chinense* (MALAVOLTA, 2006). For determination of P, K, Ca, Mg and S contents, the dried and ground plant material was submitted to nitroperchloric digestion (EMBRAPA, 2009).

Phosphorus was determined by colorimetry by phosphomolybdate reduction, K was determined by flame photometry, Ca and Mg were quantified by atomic absorption spectrophotometry and S was determined by sulfate turbidimetry. For determination of N contents, the plant material was submitted to sulfuric digestion and quantified according to the method described by Bremner (1965).

Macronutrient accumulations (mg leaf^{-1} and mg fruit^{-1}) were calculated by the equation:

$$\mathit{Accummulation} = \frac{[Dry\ Matter\ (mg)\ x\ Nutrient\ Content\ (mg\ kg^{-1})}{1000}$$

Statistical analysis

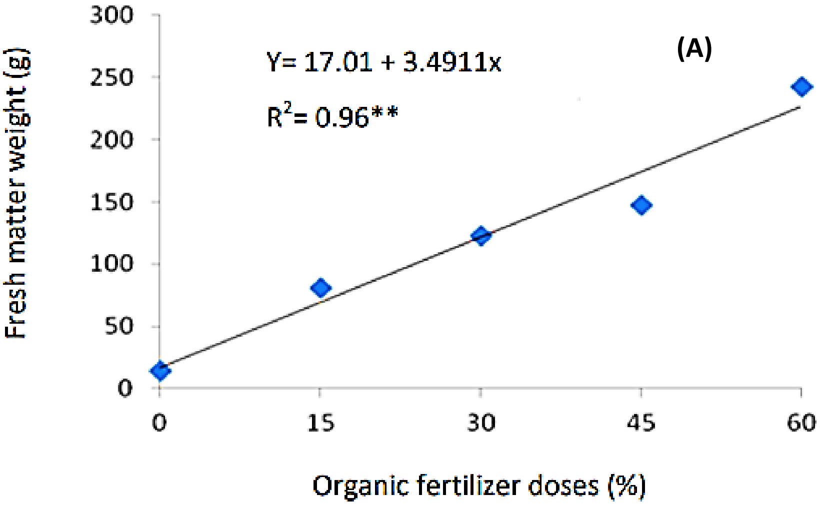
The results were submitted to analysis of variance (F test, $p < 0.05$), adjusting regression models of the variables studied as a function of the doses of organic compound applied, using the ASSISTAT software (SILVA; AZEVEDO, 2016) . The optimal dose for each analyzed variable was calculated based on the derivative of the regression equation in the figure of each equation.

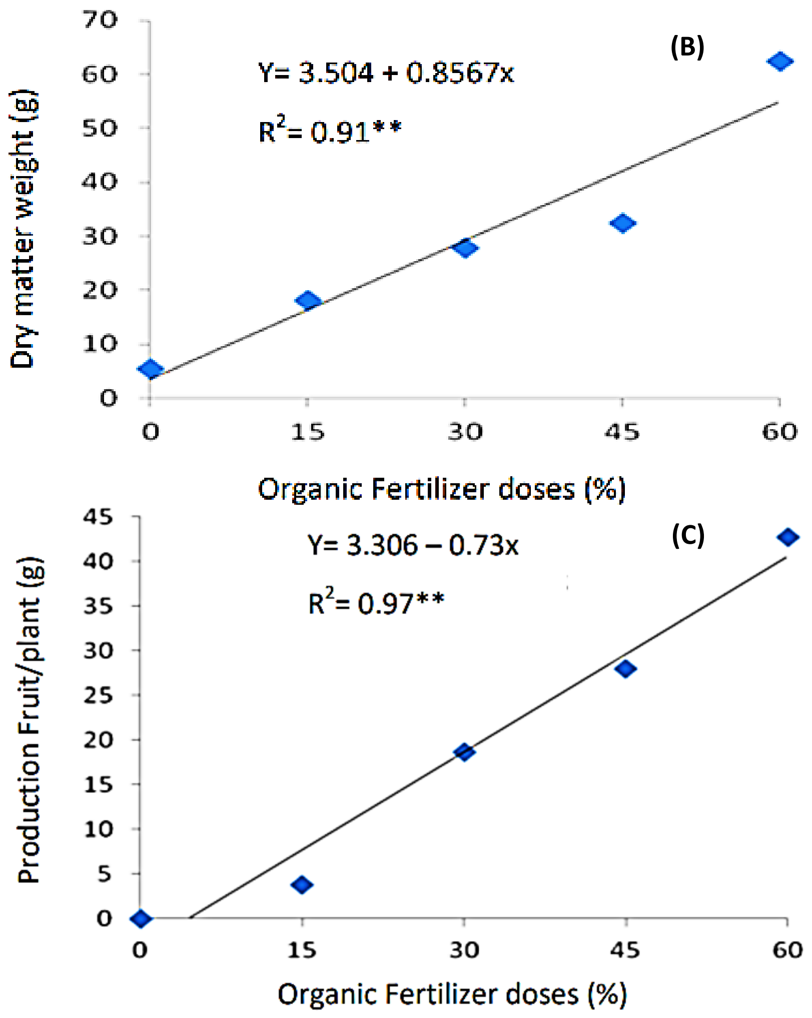
Results and Discussion

Biometric and production characteristics

The results obtained in the present study showed that the application of increasing doses of organic fertilizer promoted a linear increase in plant fresh weight (Figure 1A), plant dry weight (Figure 1B) and fruit production per plant (Figure 1C).

Figure 1. Fresh matter weight (A), dry matter weight (B) and fruit production, per plant (C) of habanero pepper subjected to different doses of organic fertilizer at 103 days after sowing.





Thus, it was verified the importance of fertilization in the culture of habanero pepper, since the control treatment did not produce fruits at 103 days (Figure 1), where the highest dose treatment (60%) had a production of 100% compared to the control. The values observed at the highest dose of compost (60%) for dry material weight, fresh material weight and fruit/plant production weight were 226.476 g plant-1 (Figure 1A), 54.906 g plant-1 (Figure 1B) and 40.49 g plant-1 (Figure 1C), respectively.

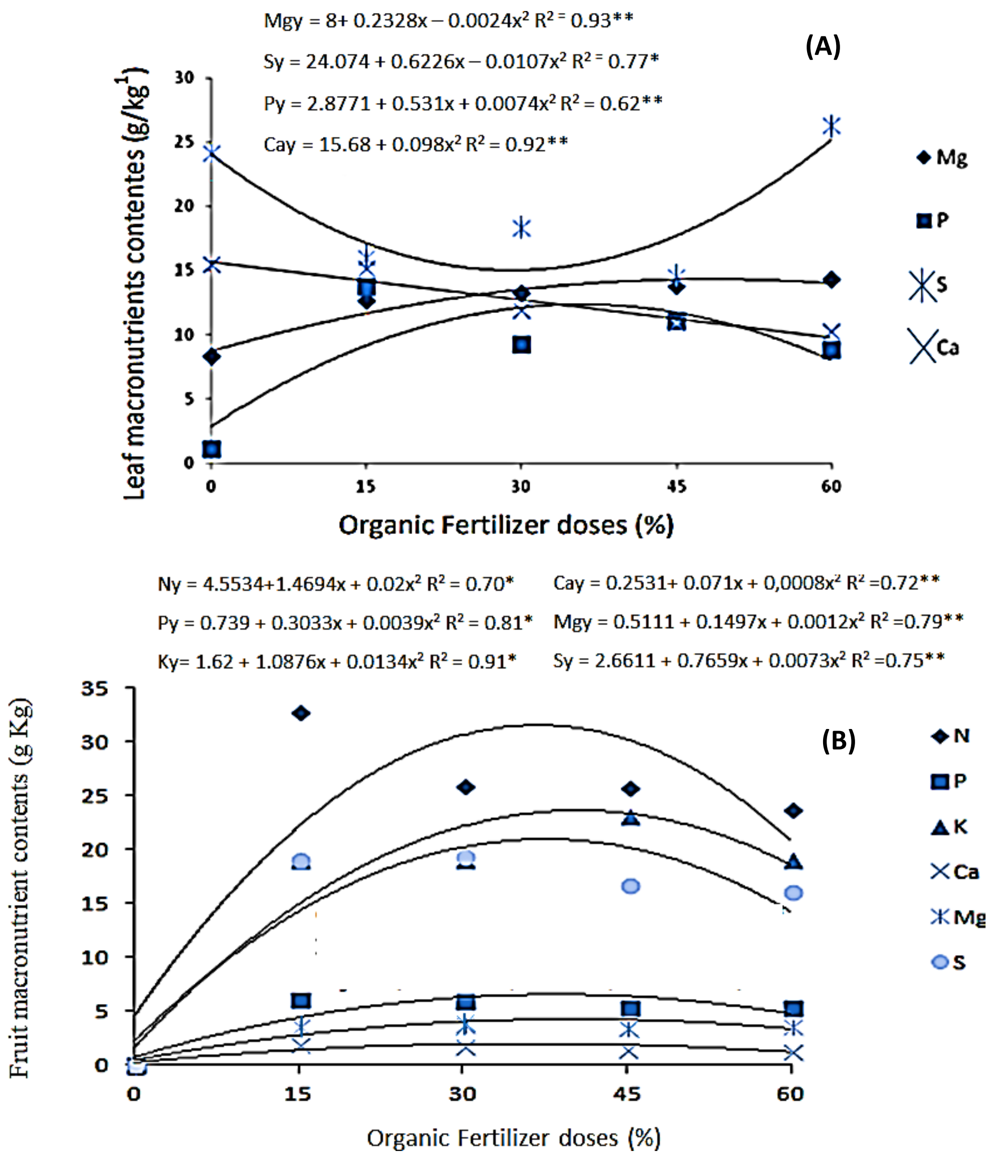
Possibly the low values were promoted by the shorter planting time, genetic characteristics and/or planting conditions. Malavolta *et al*. (1991) obtained values of fresh matter of 386 g plant^{-1}, and dry matter of 119 g plant^{-1} pepper.

Regarding fruit production, the average value for habanero pepper was 23.24 g plant^{-1} (Figure 1C). Poltronieri *et al*. (2006) evaluated cultural management in smell pepper, founded that organic fertilization (1kg plant^{-1} of manure) in combination with pruning and irrigation obtained best results in fruit production. This same event can be observed by Araújo *et al*. (2009), where a maximum production of fruits per harvest was verified with different applications of organic fertilizers rich in nitrogen.

Macronutrient content in leaves and fruits of habanero pepper

The macronutrient levels in leaves and fruits of habanero pepper were best fitted by the quadratic model, except for the Ca content in leaves, which was explained by the negative linear model (Figure 2). The variations in the contents could have occurred due to nutrient availability in the soil (FERNANDES *et al*., 2015), rate of uptake and interaction with plant growth rate (ALMEIDA *et al*., 2014). In addition, the release of nutrients from organic fertilizer is slow compared to soluble mineral fertilizers (PEREIRA *et al*., 2015) due to the mineralization of organic matter, which justifies the results obtained in the present study.

Figure 2. Macronutrient content in leaves (A) and fruits (B) of habanero pepper subjected to different doses of organic fertilizer, at 103 days after sowing.



The following decreasing orders of macronutrients in leaf tissue and fruits were N>K≥S>Ca≥Mg>P and N>K>S>P>Mg>Ca, respectively (Figure 2). Malavolta *et al.* (1991) evaluated the macronutrient content in the plant (leaf and fruit) and found the highest requirements for Malagueta pepper in decreasing order of N>K>Ca>P=Mg=S, while Flores *et al.* (2012) observed that the most determinant nutrients for the growth of chili peppers were N, Ca and K, where Ca was the most demanded nutrient.

According to the individual analysis of each nutrient, the N content in leaf tissue was found to range from 24.2 to 30.6 g kg^{-1} and the N content in fruits obtained an estimated maximum level of 31.54g kg^{-1} with a dose of 36.73% organic fertilizer. Malavolta *et al.* (1991), among the macronutrients, N has a high content in pepper fruits, with an average value of 19 g kg^{-1}.

Due to soil modifications and the fact that nitrogen is a dynamic macronutrient, it is necessary to fertilize the soil at the appropriate time to allow for greater uptake and utilization (KAPPES *et al.*, 2014). In addition, by adding nitrogen doses to the plantation, there is a linear increase in photosynthesis in the flowering phase of the crop, since this nutrient acts directly in the production of proteins and chlorophylls (KAPPES *et al.*, 2014), due to the nutritional needs of the crop in the V11 development phase.

The contents of phosphorus in leaves ranged from 1.1 (control) to 13.7 g kg^{-1} (60 % of organic fertilizer), with an average value of 8.78 g kg^{-1}. The highest technical efficiency was 12.39 g kg^{-1}, obtained at a dose of 35.87 % of the organic fertilizer (Figure 2A). The results of the present study exceeded the values presented by Alves *et al.* (2009) in sweet pepper (4.367 g kg -1 of P) and those described by Flores *et al*. (2012) and Malavolta *et al*. (1991) in the cultivation of Malagueta pepper, which were 4.40 and 5.37 g kg-1 of P, respectively.

In the present study, the maximum P content in fruits was 6.63 g kg-1 obtained, with the application of the organic fertilizer at a dose of 38.88%, with a mean value of 5.64 g kg-1 (Figure 2B). This value was higher than that observed by Malavolta *et al*. (1991) in malagueta pepper fruits (3.46 gkg-1).

Regarding the contents of K in leaves, the values ranged from 17.6 to 23.2 g kg^{-1}, with an average value of 20.08 g kg^{-1} (Figure 2A), which were higher than those described by Flores *et al*. (2012) and Malavolta *et al*. (1991), who observed contents of K of 9.8 and 12.4 g kg^{-1}, respectively, in Malagueta pepper. Nevertheless, the K contents in the present study were lower than those obtained by Souza *et al*. (2005) in eggplant (55.4 to 60.7 g kg^{-1}) and by Fontes *et al*. (2005) in sweet pepper (51.5 and 76.2 g kg^{-1}). On the other hand, for habanero pepper fruits, in the present study, the estimated maximum K content was 23.69 g kg^{-1}, obtained at a dose of 40.5% of the organic fertilizer. The contents ranged from 19.15 to 23.13 g kg^{-1} of K, with an average value of 20.16 g kg^{-1} (Figure 2B). This value is higher than that found by Malavolta *et al.* (1991) in Malagueta pepper fruits (6.0 g kg^{-1} of K). Although K is not an organic element, it plays important roles in plants subjected to stress conditions, such as osmotic properties, stomata opening and closing, photosynthesis, enzymatic activation, protein synthesis and carbohydrate transport (TAIZ *et al*., 2017).

From the average N and K contents, the N/K ratio was calculated, obtaining the values of 1.38 in leaves and 1.34 in fruits, indicating that there was an increased requirement for K, where biomass deposition in the fruit is necessarily accompanied by K accumulation. Potassium plays a major role regarding grain formation, from its action in relation to the transport of photoassimilates in the phloem (MARSCHNER, 2012), and in the activation of several enzymes essential for the synthesis of compounds, such as proteins and starch (COSKUN *et al.,* 2017).

Calcium was one of the nutrients least required by studied culture (Figure 2A), which was equivalent to the requirement for magnesium, with leaf contents ranging from 10.2 to 15.5 g kg^{-1}, and an average value of 12.72g kg^{-1}. Different results were found by Flores *et al*. (2012) when studying Malagueta pepper grown in nutrient solution. The authors found that Ca was the most required nutrient, with an average shoot content of 89.7 g kg^{-1} 56 days after transplantation. Malavolta *et al*. (1991) obtained an average Ca content of 15.5 g kg^{-1} in Malagueta pepper leaves, identifying that it was the third nutrient most demanded by the crop. Although the crops belong to the same botanical family, the cultivation conditions, genotypes and different parts of the leaves collected might have influenced the results of the comparative studies. In fruits, the contents of Ca ranged from 1.4 to 1.91 g kg^{-1}, with an average value of 1.67 g kg^{-1}.

It was observed that the applied dose of fertilizer had a limit for the calcium content in the fruits, which began to decrease as the dose was increased (Figure 2B).In the present study, it was verified a low redistribution of leaf Ca to fruits (Figure 2A and Figure 2B), justified by the Ca in the aerial part of the plant supplied by the transpiratory current, via xylem, transporting the nutrient directly from the soil solution. Low Ca concentration in the xylem sap causes competition for the nutrient, which is preferably transported to the leaves compared to the fruits, since the leaves have a higher transpiration rate (KUMAR *et al*., 2015). Moreover, Ca redistribution from leaves to fruits is generally physiologically insignificant (MARSCHNER, 2012), resulting in low Ca levels in the fruits of *C. chinense.* The maximum estimated Ca content was 1.49 g kg^{-1}, obtained at the dose of 46.87% of the organic fertilizer (Figure 2B).

The contents of Mg in leaves ranged from 8.3 to 14.3 g kg^{-1}, with an average of 12.44 g kg^{-1}. The maximum estimated content of 14.35 g kg^{-1} was obtained at the dose of 48.5% of the organic fertilizer (Figure 2A). The values obtained in the present study were higher than those described in the literature for sweet pepper (ALVES *et al*., 2009) and Malagueta pepper (MALAVOLTA *et al*., 1991), which were 2.5 and 7.4 g kg^{-1}, respectively. Probably the high concentration of magnesium in the leaf tissue corresponds to the high consumption provided by the organic fertilizer. In fruits, the average magnesium content was 3.71 g kg^{-1}, with the maximum estimated content of 3.78g kg^{-1}, obtained at the dose of 59.87% of the organic fertilizer (Figure 2B). This value is much higher than those described by Malavolta *et al*. (1991) in Malagueta pepper fruits, which was 1.13 g kg^{-1} of Mg.

Some particularities in the requirement of macronutrients for the formation of leaves and fruits, especially in relation to the requirement of S, were verified (Figure 2A and Figure 2B). The contents of S ranged from 14.5 to 26.3 g kg^{-1} in leaves, demonstrating the requirement of S by the pepper. Therefore, it is important that the substrate presents adequate contents of the nutrient to not limit the growth and the production of fruits. Leaf tissue S values were higher than 4 g kg^{-1} (MALAVOLTA *et al*., 1997) and 6.93 g kg^{-1} (ALVES *et al*., 2009) for sweet pepper and 12.7 g kg^{-1} in Malagueta pepper (FLORES *et al*., 2012).

It was found that the higher fertilizer dosage (60%) caused a higher sulfur content in the leaves (figure 2A), however, in the fruits, there was a decreasing curve in the sulfur content , from the increase of the dosage (figure 2B). The higher sulfur content observed in the present study also suggests that there may be a relationship between sulfur and the presence of capsaicin, a substance that gives the characteristic pungency of the pepper fruit. Capsaicin is an alkaloid (NAVES *et al*., 2019), and alkaloids are heterocyclic compounds that, in addition to carbon, hydrogen and nitrogen, can contain oxygen and sulfur (PAGARE *et al*., 2015). Kumari *et al*. (2017), studying doses and sources of sulfur in pepper (*Capsicum annum* L.), found that capsaicin levels were higher compared to the control treatment, regardless of the source or dose of sulfur. In addition, Poornima *et al*. (2015) found an increase in the synthesis of volatile sulfur compounds and an increase in the pungency of onions subjected to sulfur application.

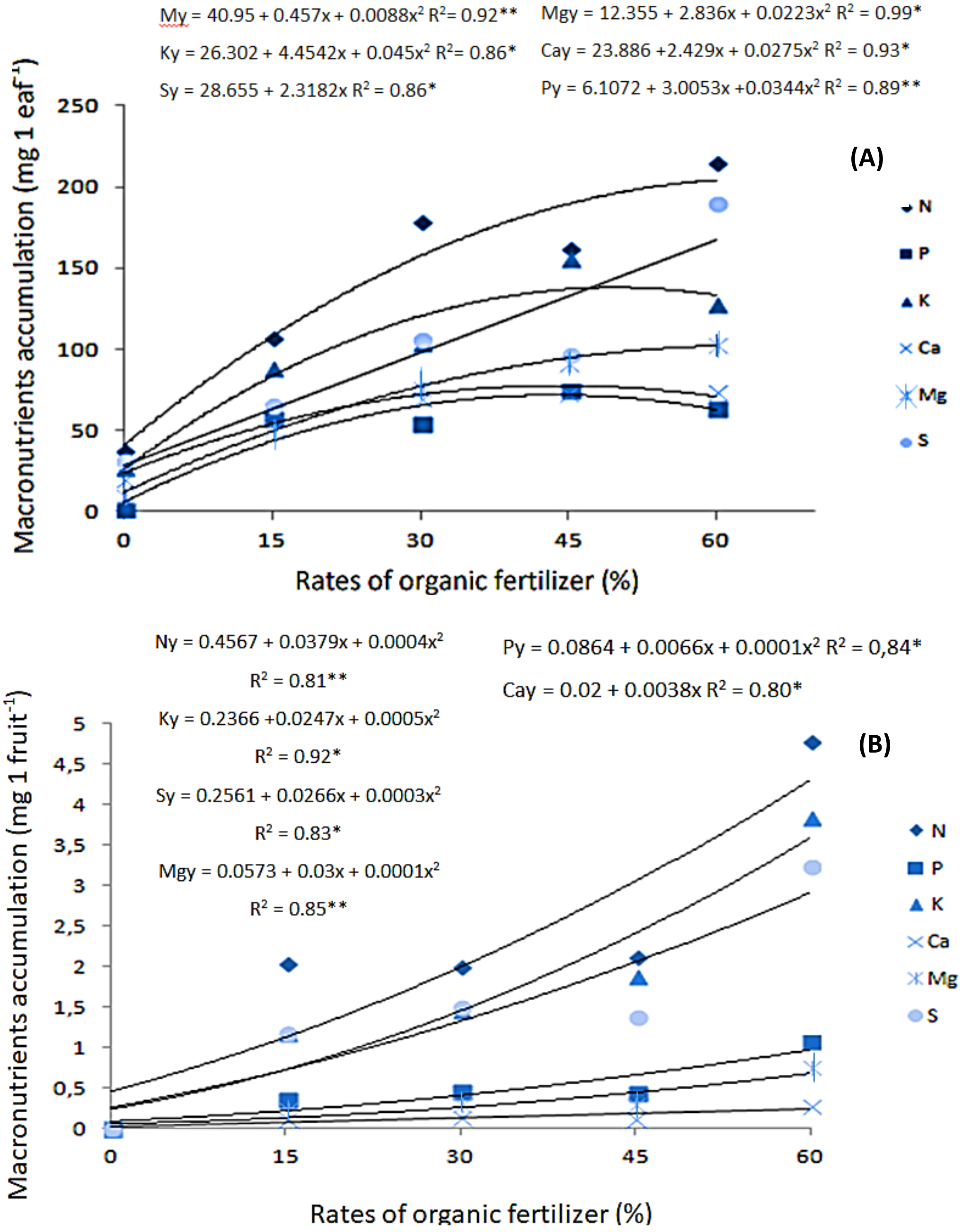
It is important to note that the contents of S in leaves (14.5 to 26.3 g kg^{-1}) observed in the present study are considered very high compared to other macronutrients. Due to the presence of humic compounds in decomposing organic matter, a high content of sulfur was observed, since this element has a direct effect on the metabolic development of plants, from ionic absorption to cell differentiation (CHAVES, 2017). Another possible explanation would be the importance of sulfur in the synthesis of volatile compounds and capsaicin for *C. chinense.* In addition, it presents a luxury consumption, tolerating high concentrations of nutrients in the leaf tissue. However, from the present study, the information could not be obtained, highlighting the need for further research focusing on the importance of S for *C. chinense*.

In fruits, the contents of S ranged from 16.11 to 19.29 g kg^{-1}, with an average value of 17.78 g kg^{-1}. The maximum content of 17.38 g kg^{-1} was obtained at the dose of 54.7% of the organic fertilizer (Figure 2B). This value is up to 11 times higher than the values reported by Malavolta *et al*. (1991) in Malagueta pepper fruits (up to 1.56 g kg^{-1}). In the control treatments and at the dose of 15% of the organic fertilizer a value of zero was considered for the nutrients due to no fruit production (0%) and the lack of material for analysis.

Macronutrient accumulation in leaves and fruits of habanero pepper

Macronutrient accumulation in leaves showed the following decreasing order N>K>S>Mg>Ca>P. Sulfur presented the best fit for the quadratic equation (Figure 3A), with the estimated maximum accumulation for P (71.74 mg $leaf^{-1}$), K (138.0 mg $leaf^{-1}$) and Ca (77.53 mg $leaf^{-1}$) at a dose of 45%, of the organic fertilizer.

Figure 3. Accumulation of macronutrients in leaves (A) and fruits (B) of habanero pepper submitted to different doses of organic fertilizer, at 103 days after sowing.

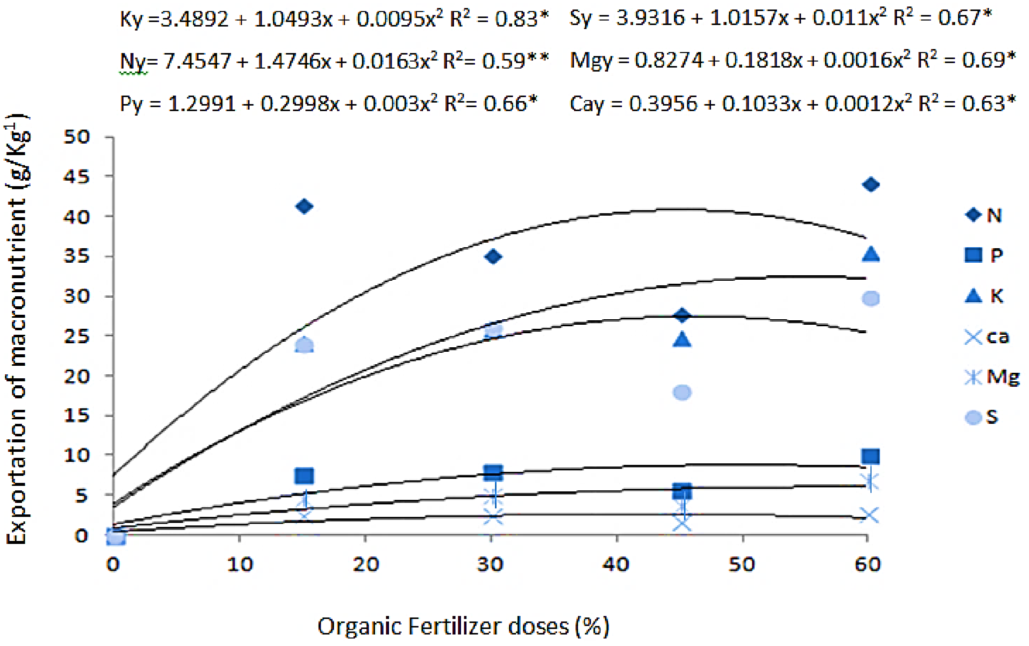


In figure 3B, the accumulation of macronutrients in habanero pepper fruits presented the following decreasing order: N>K>S>P>Mg>Ca, with values of 2.18, 1.67, 1.45, 0.46, 0.31, 0.13 mg fruits^{-1}, respectively . In general, the accumulation of macronutrients was better explained by quadratic models, except for Ca (Figure 3B).

Export of macronutrients by fruits of habanero pepper

The macronutrient contents of habanero pepper fruits were explained by quadratic models, with average quantities of N, P, K, Ca, Mg and S of 37.11, 7.80, 27.65, 2.28, 5.15 and 24.49 kg ha^{-1}, respectively (Figure 4). From the obtained results, it was observed the following nutrient extraction, in decreasing order: N>K>S>P>Mg>Ca. Albuquerque *et al.* (2012) identified that the order of export of nutrients in the fruits of irrigated peppers was K>N>Cl>P>Ca>Mg>S>Na.

Figure 4. Export of macronutrients in habanero pepper with fruits submitted to different doses of the organic fertilizer, at 103 days after sowing.



The exported quantities of macronutrients per tonne of habanero pepper fruits shown in table 3, allowed identify that the rate of 60% of organic fertilizer promoted the highest export of macronutrients N, P, K, Ca, Mg and S, in which for the macronutrient calcium, both the 30% and 60% doses had the same value of 0.25 kg/t-3.

Table 3. Exported quantity of N, P, K, Ca, Mg and S per ton habanero pepper fruits submitted to rates of of organic fertilizer.

Doses of organic fertilizer	N	P	K	Ca	Mg	S
%	--Kg/t^{-3}--					
0*	-	-	-	-	-	-
15	4.14	0.75	2.42	0.24	0.47	2.40
30	3.50	0.80	2.59	0.25	0.51	2.60
45	2.78	0.56	2.49	.16	0.38	1.80
60	4.40	0.99	3.55	0.25	0.69	2.98
Average	3.71	0.78	2.76	0.22	0.51	2.44

*There was no fruit production in the treatment.

The quantities of macronutrient content by the fruits represent an important component of the exports of nutrients from the soil, which should be restored, considering that if these exported quantities of macronutrients are not supplied to the crop after each harvest, the tendency is that, over time, the habanero pepper will show symptoms of nutritional deficiency, especially in high yields and in soils of low fertility, characteristic of Amazonian soils (JÚNIOR *et al.*, 2011). Moreover, the macronutrients contained in shoot can be incorporated into soil if plant residues are applied.

Conclusions

The dose of 60% (2100g of organic susbtrate volume) was not sufficient to result in maximum production of habanero pepper , suggesting the need to conduct future research from rate of 60% of organic fertilizer.

The increasing dose of fertilizer resulted in a linear increase in shoot weight and pepper productivity.

Content and accumulation of macronutrients in habanero pepper the leaves showed the following descending order: N>K≥S>Ca≥Mg>P.

The content, accumulation and export of macronutrients in habanero pepper fruits presented the following decreasing order: N>K>S>P>Mg>Ca.

References

ALBUQUERQUE, F.S.; SILVA, E.F.F.; BEZERRA N.E.; SOUZA, A.E.R; SANTOS, A.N. Mineral nutrients in fertigated sweet pepper under irrigation depths and potassium doses. **Horticultura Brasileira**, 2012. http://dx.doi.org/10.1590/S0102-05362012000400019

ALMEIDA, M.O.; CRUZ, M.C.; CASTRO, G.D.M.; FAGUNDES, M.C.P. Growth and nutrient uptake by yellow passion fruit seedlings produced in organic and commercial substrates and nitrogen fertilization. **Revista Brasileira de Ciências Agrárias**, 2014. http://dx.doi.org/10.5039/agraria.v9i2a3593

ALVES, G.S.; SANTOS, D.; SILVA, J.A.; NASCIMENTO, J.A. M.; CAVALCANTE, L.F; DANTAS, T.A.G. Nutritional status of sweet pepper cultivated in soils treated with different types of biofertilizer. **Acta Scientiarum Agronomy**, 2009. http://dx.doi.org/10.4025/actasciagron.v31i4.731

ARAÚJO, J.S.; ANDRADE, A.P.; RAMALHO, C.I.; AZEVEDO, C.A.V. Yield of bell pepper cultivated in greenhouse under different doses of nitrogen through fertirrigation. **Revista Brasileira de Engenharia Agrícola e Ambiental**, 2009. https://doi.org/10.1590/S1415-43662009000500008

BARBOSA, C.H. **Eficiência nutricional de diferentes biofertilizantes produzidos a partir de resíduos da Agricultura Familiar no desenvolvimento da pimenta de cheiro**. 2019. Dissertação (Mestrado) - Universidade Federal do Amazonas, Humaitá, 2019.

BREMNER, J.M. **Total nitrogen**. *In*: BLACK, C.A. (org.). Methods of soil analysis. **American Society of Agronomy**, 1965. v.9, p.1179-1237. https://doi.org/10.2134/agronmonogr9.2.c33

COSKUN, D.; BRITTO, D.T.; KRONZUCKER, H.J. The nitrogen-potassium intersection: Membranes, metabolism, and mechanism. **Plant, Cell and Environment**, 2017. https://doi.org/10.1111/pce.12671

COSTA, A.R.S.; XIMENES, T.C.F.; XIMENES, A.F.; BELTRAME, L.T.C. The process of composting and its potential in the recycling of organic waste. **Revista GEAMA**, 2015a. Disponível em: https://journals.ufrpe.br/index.php/geama/article/view/503

COSTA, L.V.; BENTES, J.L.S.; LOPES, M.T.G.; ALVES, S.R.M.; JÚNIOR, J.M.V. Morphological characterization of Amazon pepper accessions. **Horticultura Brasileira**, 2015b. http://dx.doi.org/10.1590/S0102-053620150000300003

CHAVES, C.M.M.B. **Diagnose nutricional de enxofre em eucalipto por análise não destrutiva**. (2017). Dissertação (Mestrado) - Universidade Federal dos Vales do Jequitinhonha e Mucuri, Diamantina, 2017.

DAS, S.; TEJA, K.C.; DUARY, B.; AGRAWAL, P.K.; BHATTACHARYA, S.S. Impact of nutrient management, soil type and location on the accumulation of capsaicin in *Capsicum chinense Jacquin*: One of the hottest chili in the world. **Scientia Horticulturae**, 2016. https://doi.org/10.1016/j.scienta.2016.10.041

EMBRAPA. **Manual de análises químicas de solos, plantas e fertilizantes**. 2. ed. Brasília, 2009. Disponível em: https://www.alice.cnptia.embrapa.br/bitstream/doc/257040/1/PL-Metodos-analises-quimicas-2009.pdf Acesso em: 19 out. 2022.

EMBRAPA. **Sistema brasileiro de classificação de solos**. 5. ed. Brasília: EMBRAPA, 2018. Disponível em: http://livimagens.sct.embrapa.br/amostras/00053080.pdf Acesso em: 19 out. 2022.

FERNANDES, D.M.; GROHSKOPF, M.A.; GOMES, E.R.G.; FERREIRA, N.R.; BÜLL, L.T. Phosphorus in soil solution in response to the application of mineral and organomineral fluid fertilizers. **Irriga**, 2015. http://dx.doi.org/10.15809/irriga.2015v1n1p14

FLORES, R.A.; ALMEIDA, T.B.F.; POLITI, L.S.; PRADO, R.M.; BARBOSA, J.C. Growth and nutritional disorder in chili pepper grown in nutrient solutions with macronutrient omission. **Revista Brasileira de Ciência Agrárias**, 2012. https://doi.org/10.5039/agraria.v7i1a1648

FONTES, P.C. R.; DIAS, E.N; GRAÇA, R.N. Nutrient uptake curves and a method to estimate nitrogen and potassium rates in sweet pepper fertigation. **Horticultura Brasileira**, 2005. http://dx.doi.org/10.1590/s0102-05362005000200022

JÚNIOR, J.F.V.; SOUZA, M.I.L.; NASCIMENTO, P.P.R.R.; CRUZ, D.L.S. Soils of the Amazon: **Etnopedology and sustainable development**, v.5, n.2, p.158-165, 2011. https://doi.org/10.18227/1982-8470ragro.v5i2.562

KAPPES, C.; ARF, O.; DAL BEM, E.A.; PORTUGAL, J.R.; GONZAGA, A.R. Manejo do nitrogênio em cobertura na cultura do milho em sistema plantio direto. **Revista Brasileira de Milho e Sorgo**, 2014. https://doi.org/10.18512/1980-6477/rbms.v13n2p201-217

KUMAR, A.; SINGH, U.M.; MANOHAR, M.; GAUR, V.S. Calcium transport from source to sink: Understanding the mechanism(s) of acquisition, translocation, and accumulation for crop biofortification. **Acta Physiologiae Plantarum**, 2015. https://doi.org/10.1007/s11738-014-1722-6

KUMARI, S.S.; BHARATHI, S.; JYOTHI, K.U.; REDDY, P.V. Efficacy of levels and sources of sulphur on yield attributes, yield and capsaicin content of hot pepper (Capsicum annum L.). **Journal of Research Angrau**, v.45, n.3, p.88-90, 2017. Disponível em: https://www.cabdirect.org/cabdirect/abstract/20183271544 Acesso em: 19 out. 2022.

MALAVOLTA, E.; MALAVOLTA, M.L.; CABRAL, C.P.; CARVALHO, M.J.R. Nota sobre as exigências nutricionais da pimenta malagueta (Capsicum frutescens). **Revista de Agricultura**, v. 66, n. 2, p. 193-201, 1991.

MALAVOLTA, E.; VITTI, G.C.; OLIVEIRA, S.A. **Assessment of Nutritional Status of Plants: Principles and Applications.** 2. ed. Piracicaba: POTAFOS, 1997.

MALAVOLTA, E. **Manual de nutrição de plantas**. São Paulo: Agronômica Ceres, 2006.

MARSCHNER, P. **Marschner's mineral nutrition of higher plants**. 3. ed. New York: Academic Press, 2012.

MECKELMANN, S.W.; RIEGEL, D.W.; ZONNEVELD, M.V.; RÍOS, L.; PEÑA, K.; MUELLER-SEITZ, E.; PETZ, M. Capsaicinoids, flavonoids, tocopherols, antioxidant capacity and color attributes in 23 native Peruvian chili peppers (Capsicum spp.) grown in three different locations. **European Food Research and Technology**, 2015. https://doi.org/10.1007/s00217-014-2325-6.

NAVES, E.R.; SILVA, L.A.; SULPICE, R.; ARAÚJO, W.L.; NUNES-NESI, A.; PERES, L.E.P.; ZSÖGÖN, A. Capsaicinoids: Pungency beyond Capsicum. **Trends in Plant Science**, 2019. https://doi.org/10.1016/j.tplants.2018.11.001

OLIVEIRA, F.A.; CAMPOS, M.S.; OLIVEIRA, F.R.A.; OLIVEIRA, M.K.T.; MEDEIROS, J.F.; MELO, T.K. Nitrogen, phosphorus and potassium development and concentration in leaf tissues of eggplant in function of salinity. **Revista Brasileira de Ciências Agrárias**, 2011. http://dx.doi.org/10.5039/agraria.v6i1a807

PAGARE, S.; BHATIA, M.; TRIPATHI, N.; PAGARE, S.; BANSAL, Y.K. Secondary metabolites of plants and their role: Overview**. Current Trends in Biotechnology and Pharmacy**, v.9, n.3, p.293-304, 2015. https://doi.org/10.5958/2249-0035.2015.00016.9

PEREIRA, L.B.; ARF, O.; SANTOS, N.C.B.; OLIVEIRA, A.E.Z.; KOMURO, L.K. Fertilization management in bean crop under organic production system. **Pesquisa Agropecuária Tropical**, 2015. http://dx.doi.org/10.1590/1983-40632015v4528018

PEREIRA, P.F.M.; LEITE, M.A.G.; LIMA, L.C.; STEFANI, R. Evaluation of antioxidant potential of pepper sauce (Capsicum frutescens L.). **Cogent Food & Agriculture**, 2016. https://doi.org/10.1080/23311932.2015.1134381

POORNIMA, K.S.; MAMATHA, N.; RAMESH, H.S. Effect of potassium and sulphur on quality parameters of onion and chilli intercrops in a vertisol. **Advance Research Journal of Crop Improvement**, 2015. http://dx.doi.org/10.15740/HAS/ARJCI/6.2/166-169

POLTRONIERI, M.C.; BOTELHO, S.M.; LEMOS, O.F.; ALBUQUERQUE, A.S.; SILVA JÚNIOR, A.C.; PALHARES, T.C. **Tratos culturais em pimenta de cheiro (*Capsicum chinense* Jac.).** Embrapa, 2006.

RAHMAN, M.J; INDEN, H. Effect of nutrient solution and temperature on capsaicin content and yield contributing characteristics in six sweet pepper (*Capsicum annuumL.*) cultivars. **Journal of Food, Agriculture & Environment**, v.10, n.1 (part. 1), p.524-529, 2012.

SÁ, F.V.S.; SOUTO, L.S.; PAIVA, E.P.; ARAÚJO, E.B.G.; OLIVEIRA, F.A.; MESQUITA, E.F.; FERREIRA, M. N.; DANTAS, J.S. Initial development and tolerance of bell pepper (*Capsicum annuum*) cultivars under salt stress. **Journal of Agricultural Science**, 2017. https://doi.org/10.5539/jas.v9n11p181

SILVA, F.A.S.; AZEVEDO, C.A.V. The Assistat Software Version 7.7 and Its Use in the Analysis of Experimental Data. **African Journal of Agricultural Research**, 2016. https://doi.org/10.5897/AJAR2016.11522

SILVA, S.P.; VIÉGAS, I.J.M.; OKUMURA, R.S.; SILVA, D.A.S.; GALVÃO, J.R.; SILVA JÚNIOR, M.L.; ARAÚJO, F.R.R.; MERA, W.Y.W.L.; SILVA, A.O. Growth and micronutrients contents of smell pepper (*Capsicum chinense*) submitted to organic fertilizer. **Journal of Agricultural Science**, 2018. https://doi.org/10.5539/jas.v10n11p425

SOUZA, V.S.; SOARES, I.; CRISÓSTOMO, L.A.; SILVA, L.A; HERNANDEZ, F.F.F. The influence of electrical conductivity of the nutritive solution on the accumulation of dry matter and nutrients contents in eggplant cultivated in coconut coir fibre. **Revista Ciência Agronômica,** v.36, n.2, p.123-128, 2005.

TAIZ, L.; ZEIGER, E.; MØLLER, I.M.; MURPHY, A. **Fisiologia e desenvolvimento vegetal**. 6. ed. Porto Alegre: Artmed, 2017.

VIÉGAS, I.J.M.; SOUSA, G.O.; SILVA, A.F.; CARVALHO, J.G.; LIMA, M.M. Mineral composition and visual symptoms of nutrients deficiencies in long pepper plants (Piper hispidinervum C. DC.). **Acta Amazonica**, 2013. http://dx.doi.org/10.1590/S0044-59672013000100006

ZHU, N. Effect of low initial C/N ratio on aerobic composting of swine manure with rice straw. **Bioresource Technology**, 2007. http://dx.doi.org/10.1016/j.biortech.2005.12.003