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Accumulation of nutrients in sweet peppers cultivated in coconut fiber

Hamilton César de O Charlo[1]; Sueyde F de Oliveira[2]; Pablo F Vargas[2]; Renata Castoldi[2]; José Carlos Barbosa[2]; Leila T Braz[2]

[1]IFTM, R. João Batista Ribeiro 4000, Mercês, 38045-000 Uberaba-MG; hamiltoncharlo@iftm.edu.br; [2]UNESP-FCAV, Rodov. Prof. Paulo Donato Castellane s/n, 14884-900 Jaboticabal-SP

ABSTRACT

The production of sweet peppers in greenhouse has been severely affected by soil pathogens. With this, producers are adopting new cultivation techniques, such as cultivation in substrates, but information about this type of cultivation are still scarce. The aim of the present work was to evaluate nutrient accumulation in sweet peppers cultivated in coconut fiber with fertirrigation in greenhouse. Initially, 160 plants (Eppo cultivar) were divided into four blocks, where two plants per block were analyzed every 21 days after transplanting. The sweet peppers were cultivated in plastic pots of 13 L, containing coconut fiber, and placed in double rows with spacing of 0.5 x 0.8 m between single rows and 1.10 m between double rows. The commercial production of the mature fruits was estimated to be 97.3 t ha^{-1}, where all the production was classified as Extra (maximum quality). The accumulation of the various determined nutrients were: 8.22 g $plant^{-1}$ of N, 1.14 g $plant^{-1}$ of P, 7.84 g $plant^{-1}$ of K, 3.25 g $plant^{-1}$ of Ca, 1.34 g $plant^{-1}$ of Mg, 2.24 g $plant^{-1}$ of S, 16.65 mg $plant^{-1}$ of B, 3.36 mg $plant^{-1}$ of Cu, 45.98 mg $plant^{-1}$ of Fe, 34.78 mg $plant^{-1}$ of Mn and 22.28 mg $plant^{-1}$ of Zn.

Keywords: *Capsicum annuum*, coconut fiber, fertirrigation.

RESUMO

Acúmulo de nutrientes na cultura do pimentão cultivado em fibra de coco

A produção de pimentões em ambiente protegido tem sido severamente afetada por fitopatógenos de solo, fazendo com que produtores adotem novas técnicas de cultivo, como por exemplo o cultivo em substratos, mas informações sobre este tipo de cultivo ainda são escassas. Diante disto, o objetivo deste trabalho foi determinar o acúmulo de nutrientes de pimentão cultivado em fibra da casca de coco como substrato, em casa-de-vegetação. Foram plantadas 160 plântulas (‘Eppo’), sendo divididas em quatro blocos. Foram analisadas duas plantas por bloco a cada 21 dias após o transplante. O cultivo do pimentão foi realizado em vasos plásticos de 13 L, contendo fibra da casca de coco, e dispostos em fileiras duplas nos espaçamentos 0,5 x 0,8 m entre fileiras simples e 1,10 m entre fileiras duplas. A produção comercial de frutos maduros estimada foi de 97,3 t ha^{-1}, sendo toda a produção classificada como Extra (qualidade máxima). Foi verificado acúmulo de 8,22 g $planta^{-1}$ de N, 1,14 g planta-^{1} de P, 7,84 g $planta^{-1}$ de K, 3,25 g planta-^{1} de Ca, 1,34 g $planta^{-1}$ de Mg, 2,24 g $planta^{-1}$ de S, 16,65 mg $planta^{-1}$ de B, 3,36 mg $planta^{-1}$ de Cu, 45,98 mg $planta^{-1}$ de Fe, 34,78 mg $planta^{-1}$ de Mn e 22,28 mg $planta^{-1}$ de Zn.

Palavras-chave: *Capsicum annuum*, fibra de coco, fertirrigação.

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Sweet pepper is one of the species of vegetables that are the most widespread and popular. It is considered one of the ten species of greatest economic importance in the Brazilian vegetable market. Sweet peppers are grown mainly in greenhouses, and the practice of two or three or more successive plantings along with the accumulation of crop residues has increased the incidence of pests and phytopathogens such as nematodes, due to their continuous multiplication (Charlo *et al.,* 2009).

Sweet pepper growing areas in the state of São Paulo have had many problems with root-knot nematodes (*Meloidogyne* spp.), especially *Meloidogyne incognita* and *M. mayaguensis* which reduce productivity. Currently, there are no sweet pepper cultivars that are resistant to *M. incognita* and *M. mayaguensis*, which means frequent change in cultivation areas or the need for soil treatment, resulting in marked environmental impacts. One possible solution to this problem is cultivation in pots or bags filled with substrate. The production of sweet pepper in pots is a recent technique, and therefore there are only a few published studies presenting data that can be used for appropriate technical recommendations, which makes sweet pepper cultivation difficult in areas contaminated with *Meloidogyne incognita* and *M. mayaguensis.*

The monitoring of nutrients is a tool in fertilizer management of crops, mainly when they are grown in substrates, which in the majority of cases, all nutrients that the plants absorb come from fertirrigation. The obtained curves express the quantity of each nutrient absorbed according to the age of the plants.

The mineral composition and the level of nutrients in leaf tissues depend of various factors, such as plant (species, cultivar, type of leaves, age), soil, fertilizer, climate, cultivation practices, and pests and diseases (Malavolta *et al.*, 1997). In general, the absorption of nutrients in the majority of crops follows the pattern of the growth curve (accumulation of dry matter).

Knowledge of the quantity of nutrients accumulated in the plant, at each stage of development, provides important information which can help in the fertilizing program of crops. It should be borne in mind, however that these curves reflect what the plant needs, and not what should be applied, since it is necessary to consider the efficiency of the provision of the nutrients, which is variable based on climatic conditions, type of soil, irrigation system, and cultivation management, among other factors. In a more effective manner, these curves help in the fertilizing program, mainly in determining the quantity of the nutrients which should be applied at distinct physiological stages of the crop (Grangeiro & Cecilio Filho, 2004).

Fontes *et al.* (2005b), evaluating the accumulation and nutrient content in sweet pepper (Elisa hybrid, cultivated in soil) in greenhouse, yield of 51.9 t ha^{-1}, found that N contents in shoot parts and fruits increased until the maximum of 11.562 and 4.679 mg $plant^{-1}$, respectively, at 224 days after transplantation. The accumulation of N was 193 kg ha^{-1}, where 40.5% were retained by fruits. For K, there was accumulation of 250 kg ha^{-1}, and 40% was accumulated in the fruit. The amounts of accumulation of Ca and S were 114 kg ha^{-1} and 23 kg ha^{-1}, respectively.

Therefore, the aim of the present work was to evaluate nutrient accumulation in sweet peppers cultivated in coconut fiber with fertirrigation in greenhouse.

MATERIAL AND METHODS

The study was conducted in a greenhouse with a metal structure, an arch-type roof and wall height of 3 m. The greenhouse was located in an area belonging to UNESP, located in Jaboticabal (SP).

The sweet pepper hybrid evaluated was Eppo (Syngenta Seeds), which had been studied by Charlo *et al.* (2009) in a protected environment utilizing coconut fiber and found to be one of the most productive (102.9 t ha^{-1}) and to have excellent fruit characteristics. Eppo is a compact plant with short internodes and produces greenish-yellow fruits which are smooth and have a thick pulp. The hybrid is resistant to *cucumber mosaic virus* (CMV) and tolerant to *tomato spotted wilt virus* (TSWV) (Syngenta, 2005).

Seedlings were grown using an indirect seeding system, which was carried out on May 1, 2006. The substrate Plantmax Hortaliças® HT was utilized, and seeding was in Styrofoam trays with a capacity of 128 pyramid cells with one seed per cell. After seeding, the trays were acclimated in a greenhouse, receiving irrigation 3 to 4 times a day.

At 33 days after seeding, the seedlings were transplanted to plastic cups of 300 mL, where they remained for 10 more days to guarantee a better development of the roots. When they had 5 to 8 definitive leaves and were approximately 12 cm in height, the seedlings were transplanted to plant pots in their final location.

Sweet pepper seedlings were grown further in plastic pots of 13 L, which were filled with substrate (coconut fiber). One seedling was transplanted to each pot, and the pots were placed in double rows with spacing of 0.5 x 0.8 m between simple rows and 1.10 m between double rows. Golden Mix® Misto 98 coconut fiber was utilized, whose physical characteristics are: total porosity of 94%, aeration capacity of 35%, and available water retention capacity of 41% (Amafibra, s.d.), and the chemical characteristics are: pH 5.1, electrical conductivity of 1.0 dS m^{-1}, 8.1 mg L^{-1} nitrate-N, 53.0 mg L^{-1} phosphorus, 44.6 mg L^{-1} chloride, 92.1 mg L^{-1} sulfur, 17.7 mg L^{-1} ammonia-N, 270.1 mg L^{-1}potassium, 12.6 mg L^{-1}sodium, 9.9 mg L^{-1} calcium, 6.6 mg L^{-1}magnesium, 0.5 mg L^{-1} boron, 0.1 mg L^{-1} copper, 0.4 mg L^{-1} iron, 0.1 mg L^{-1} manganese and 0.5 mg L^{-1} zinc.

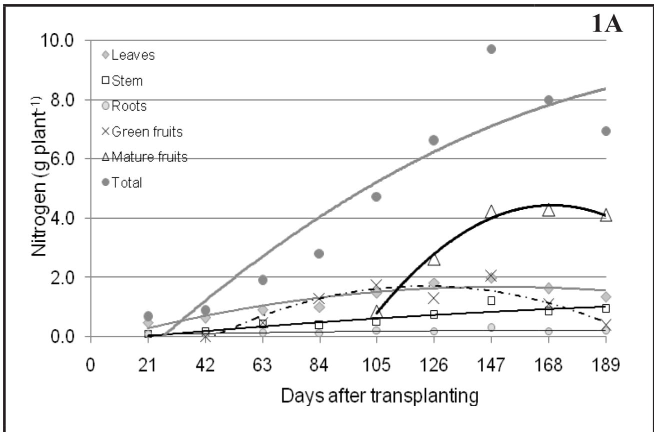
Sweet pepper cultivation was supplemented with the nutritive solution recommended by Goto & Rossi (1997) cited by Trani & Carrijo (2004). The following chemicals were used to prepare 1000 L of the solution: calcium nitrate (650 g), potassium nitrate (500 g), monopotassium phosphate (170 g), magnesium sulfate (250 g), magnesium nitrate (50 g), iron-EDTA (11 g of iron chloride + 15 g of disodium EDTA) and 150 mL of a stock solution of micronutrients. This stock solution of micronutrients was prepared with 16.70 g of boric acid, 15 g of manganese chloride, 0.82 g of copper chloride, 0.33 g of molybdenum oxide and 2.62 g of zinc sulfate, dissolved in 1 L of water.

To promote the flow of the drainage water and thereby reduce the humidity in the protected environment, the ground of the greenhouse was covered with pieces of rock and the pots were placed on supports made of wood.

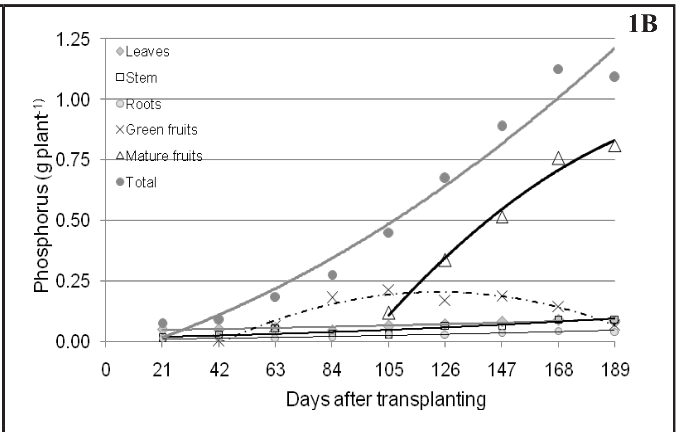
The plants were pruned to have four main stems and staked individually in the shape of a "V." For the rational control of both pests and diseases, the management adopted was where the plants were treated upon visual detection of the agent, insect or pathogen, and in accordance with the technical recommendations of the chemical product utilized.

The experiment consisted initially of 160 plants divided into four blocks, where the plants were evaluated every 21 days after transplanting. For each of the sampling periods, two plants were removed per block. The sampled plants were removed from the pots, and divided into roots, stem, leaves and fruits. Next, the organs were washed in deionized water, dried in a oven with forced-air circulation at 60°C until a constant weight was obtained and then ground. Later, the samples were submitted to chemical analysis according to the methods described by Malavolta *et al.* (1997). The levels of the following elements were determined in each part of the plant: N, P, K, Ca, Mg, S, B, Cu, Fe, Mn and Zn; the accumulation of each nutrient was calculated based on dry weight. Also estimated were the total and commercial productivity of the fruits.

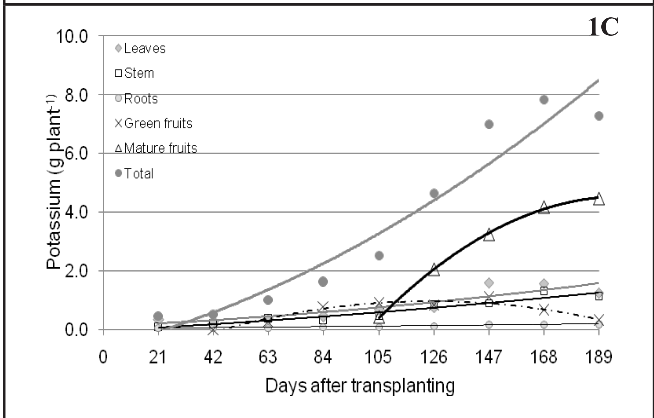
The examined characteristics were submitted to regression analysis, where the age of the plant was considered the independent variable expressed in days after transplanting. For the analysis of growth of the plants, a logistic function was utilized, which is widely employed to represent empirical data of growth of animals and plants (Hoffman & Vieira, 1977), or polynomial function which was used on occasion when more appropriate for each characteristic.



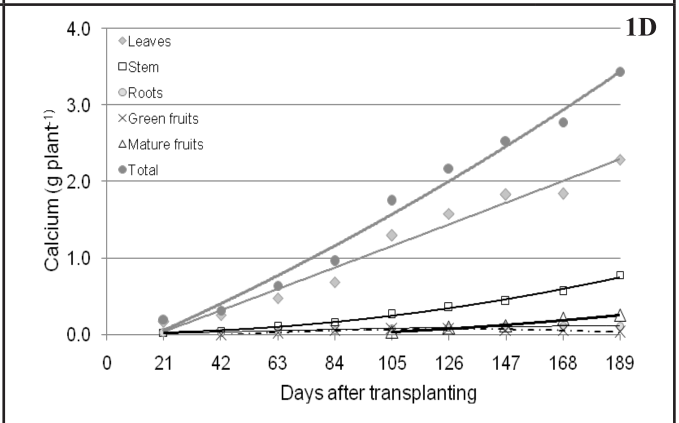
Leaves = $1.72436/(1+ e^{-0.03566 (X - 58.32857)})$	R^2=0.85*
Stem = $1.03015/(1+ e^{-0.03332 (X - 94.21633)})$	R^2=0.83*
Roots = $0.23067/(1+ e^{-0.02789 (X - 55.43944)})$	R^2=0.72*
Green fruits = $-0.00027954x^2 + 0.06869733x -2.52813798$	R^2=0.85*
Mature fruits = $4.2824/(1+ e^{-0.10073 (X - 120.40315)})$	R^2=0.99**
Total = $8.30586/(1+ e^{-0.04957 (X - 94.6088)})$	R^2=0.85**



Leaves = $0.20551/(1+ e^{-0.00604 (X - 232.13071)})$	R^2=0.83*
Stem = $0.28624/(1+ e^{-0.01102 (X - 252.19165)})$	R^2=0.82*
Roots = $0.05626/(1+ e^{-0.01682 (X - 119.92928)})$	R^2=0.93**
Green fruits = $- 0.00003154x^2 + 0.00778592x -0.27731583$	R^2=0.92**
Mature fruits = $0.87317/(1+ e^{-0.05311 (X - 137.29753)})$	R^2=0.99**
Total = $1.25875 /(1+ e^{-0.03368 (X - 120.50549)})$	R^2=0.97**



Leaves = $1.68848/(1+ e^{-0.02745 (X - 111.72194)})$	R^2=0.79*
Stem = $1.36457 /(1+ e^{-0.02935 (X - 1.36457)})$	R^2=0.92**
Roots = $0.21092/(1+ e^{-0.01932 (X - 108.24358)})$	R^2=0.91**
Green fruits = $-0.00015064x^2 + 0.03767358x - 1.39159615$	R^2=0.91**
Mature fruits = $4.47551/(1+ e^{-0.0703 (X - 131.0219)})$	R^2=0.99**
Total = $8.12412/(1+ e^{-0.04645 (X - 117.12381)})$	R^2=0.93**



Leaves = $2.25814/(1+ e^{-0.03353 (X - 102.4377)})$	R^2=0.97**
Stem = $1.55904 /(1+ e^{-0.02017 (X - 191.99323)})$	R^2=0.99**
Roots = $0.10655/(1+ e^{-0.03904 (X - 79.83099)})$	R^2=0.96**
Green fruits = $-0.00001037x^2 + 0.002630 - 0.09694484$	R^2=0.90**
Mature fruits = $0.35487/(1+ e^{-0.03628 (X - 163.03239)})$	R^2=0.98*
Total = $3.61429/(1+ e^{-0.0295 (X - 114.34594)})$	R^2=0.98**

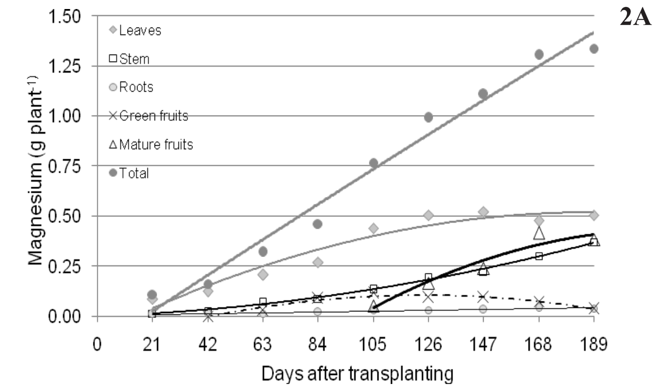
Figure 1. Accumulation of nitrogen (Figure 1A), phosphorus (Figure 1B), potassium (Figure 1C) and calcium (Figure 1D) in the sweet pepper Eppo, in different parts of the plant, depending on the age of the plant [acúmulo de nitrogênio (Figura 1A), fósforo (Figura 1B) potássio (Figura 1C) e cálcio (Figura 1D) em pimentão 'Eppo', nos diferentes órgãos, em função da idade da planta]. Jaboticabal, UNESP, 2007.

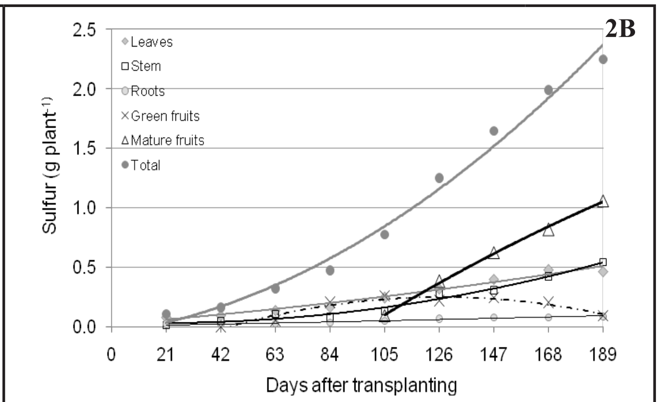
RESULTS AND DISCUSSION

The estimated total productivity was 98 t ha^{-1}, and the estimated commercial productivity was 97.3 t ha^{-1} for harvest at approximately three months (105 to 189 DAT). Charlo *et al.* (2009) evaluated five sweet pepper hybrids in coconut fiber in a greenhouse and found that the CLXP 1463 cultivar had higher commercial productivity (107.61 t ha^{-1}), although did not differ from Eppo hybrid (102.62 t ha^{-1}) and Matador hybrid (95.31 t ha^{-1}), being this productivity, similar to that one found in this work. On the other hand, the average yields obtained in this study exceeded the most values found in the literature conduced with another cultivars of sweet pepper (Furlan *et al.*, 2002; Fontes *et al.*, 2005).

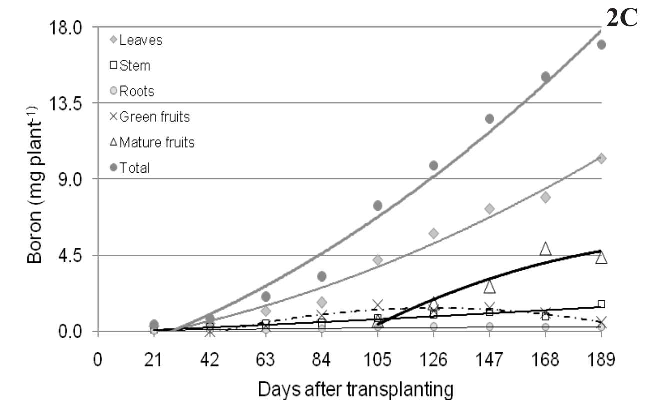
The total accumulation of N by the plants reached 8.22 g plant^{-1} (205.5 kg ha^{-1} N) at 189 DAT (Figure 1A). Mature fruits were the organs that most contributed to this accumulation (4.27 g plant^{-1}) followed by leaves (1.70 g plant^{-1}), stems (0.98 g plant^{-1}) and roots (0.22 g plant^{-1}). The green fruits reached a maximal nitrogen accumulation of 1.69 g plant^{-1} at 123 DAT, which decreased afterward up to 189 DAT, when the observed accumulation was 0.47 g plant^{-1} (Figure 1A). Negreiros (1995) reported that sweet pepper fruits, under field conditions, at 189 DAT, accumulated 2.70 g plant^{-1} of N. Besides, Ombodi & Saigusa (2000) showed, under greenhouse conditions, that the quantity of N absorbed was 160 kg ha^{-1}. With hydroponics, the absorption was 16 g plant^{-1} of N or 320 kg ha^{-1} of N (Bar-Tal *et al*., 2001a). Fontes *et al.* (2005) found an accumulation of 193 kg ha^{-1} of N, with a productivity of 52.8 t ha^{-1}, where the fruits accumulated 40.5% of this total. These differences among experiments could be due to the differences in the utilized cultivars, experimental conditions and mainly to the cultivation system.

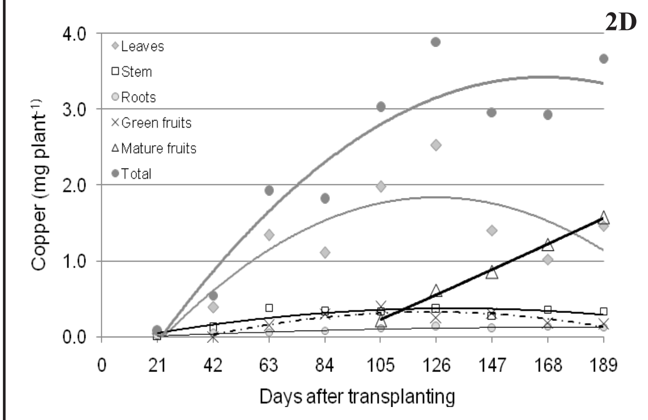
There was a greater efficiency in the conversion of N in production in the present study, which could have been due to the difference in hybrids used. The cultivation in substrate, with fertirrigation offers the plants nutrients in an easily absorbable form,





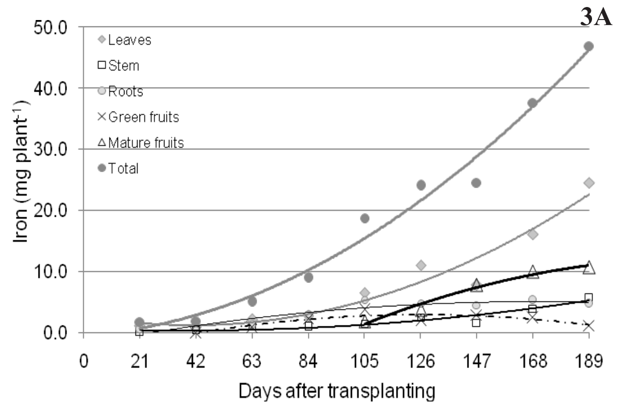
Leaves = $0.52421/(1+ e^{-0.04068\ (X-73.07471)})$	$R^2=0.94^{**}$	Leaves = $0.58348/(1+ e^{-0.02302\ (X-117.07742)})$	$R^2=0.97^{**}$
Stem = $0.56759/(1+ e^{-0.02173\ (X-161.65872)})$	$R^2=0.99^{**}$	Stem = $0.97886/(1+ e^{-0.02233\ (X-180.19316)})$	$R^2=0.98^{**}$
Roots = $0.04727/(1+ e^{-0.02123\ (X-100.63385)})$	$R^2=0.95^{**}$	Roots = $0.10276/(1+ e^{-0.0222\ (X-107.50452)})$	$R^2=0.96^{**}$
Green fruits = $-0.00001658x^2 + 0.00410434x - 0.1483347$	$R^2=0.92^{**}$	Green fruits = $-0.00003764x^2 + 0.00956175x - 0.3574844$	$R^2=0.91^{**}$
Mature fruits = $0.42479/(1+ e^{-0.05982\ (X-136.6916)})$	$R^2=0.94^{*}$	Mature fruits = $1.16932/(1+ e^{-0.04675\ (X-145.45143)})$	$R^2=0.99^{*}$
Total = $1.42315/(1+ e^{-0.03286\ (X-102.606)})$	$R^2=0.98^{**}$	Total = $2.60372/(1+ e^{-0.03144\ (X-130.1622)})$	$R^2=0.99^{**}$



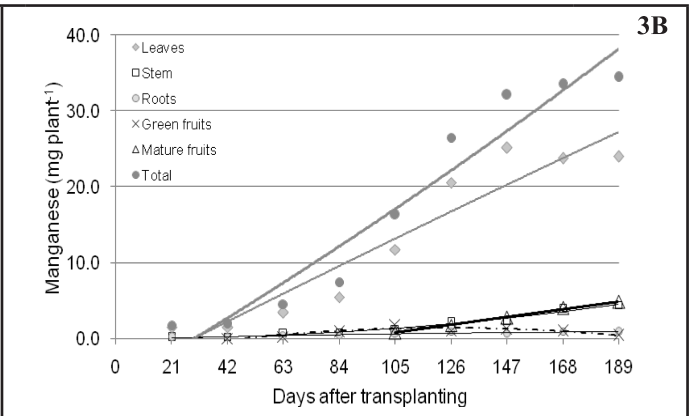


Leaves = $10.81021/(1+ e^{-0.0333\ (X-124.61652)})$	$R^2=0.98^{**}$	Leaves = $-0.0001748x^2 + 0.0439723x - 0.92373161$	$R^2=0.71^{*}$
Stem = $1.6075/(1+ e^{-0.02453\ (X-116.76691)})$	$R^2=0.90^{**}$	Stem = $-0.00002665x^2 + 0.00704683x - 0.08850375$	$R^2=0.75^{*}$
Roots = $0.25419/(1+ e^{-0.0359\ (X-69.97693)})$	$R^2=0.91^{**}$	Roots = $0.13065/(1+ e^{-0.04054\ (X-66.63614)})$	$R^2=0.94^{**}$
Green fruits = $-0.00021039x^2 + 0.053207x - 1.99194829$	$R^2=0.90^{**}$	Green fruits = $-0.00004701x^2 + 0.01160615x - 0.38508011$	$R^2=0.81^{**}$
Mature fruits = $4.93778/(1+ e^{-0.06335\ (X-139.101)})$	$R^2=0.91^{*}$	Mature fruits = $1.99562/(1+ e^{-0.034646\ (X-154.05972)})$	$R^2=0.99^{*}$
Total = $18.1194/(1+ e^{-0.03581\ (X-0.9829)})$	$R^2=0.98^{**}$	Total = $3.37242/(1+ e^{-0.0534\ (X-68.2654)})$	$R^2=0.89^{**}$

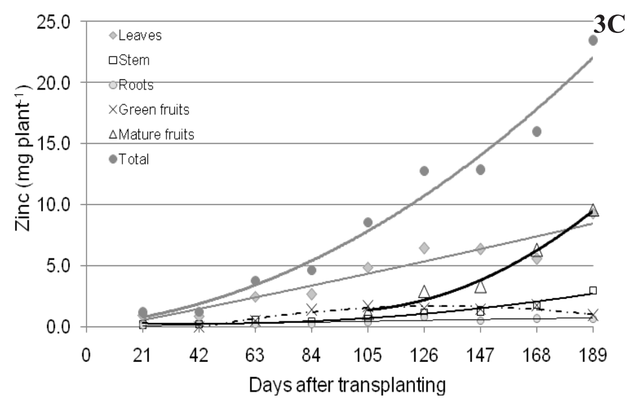
Figure 2. Accumulation of magnesium (Figure 2A), sulfur (Figure 2B), boron (Figure 2C) and copper (Figure 2D) in the sweet pepper Eppo, in different parts of the plant, depending on the age of the plant [acúmulo de magnésio (Figura 2A), enxofre (Figura 2B) boro (Figura 2C) e cobre (Figura 2D) em pimentão 'Eppo', nos diferentes órgãos, em função da idade da planta]. Jaboticabal, UNESP, 2007.



Leaves = $82.1044/(1+ e^{-231.82499 (X - 0.02139)})$	R^2=0.93**
Stem = $21.80815/(1+ e^{-0.0203 (X - 243.42164)})$	R^2=0.91**
Roots = $4.96296/(1+ e^{-0.09358 (X - 76.23439)})$	R^2=0.87**
Green fruits = $-0.00043261x^2 + 0.1091570x - 3.9420133$	R^2=0.78*
Mature fruits = $11.11381/(1+ e^{-0.06245 (X - 134.88275)})$	R^2=0.97**
Total = $71.3045/(1+ e^{-163.234 (X - 0.02315)})$	R^2=0.98**



Leaves = $25.02968/(1+ e^{-0.06143 (X - 103.96734)})$	R^2=0.90**
Stem = $6.57498/(1+ e^{-0.02547 (X - 159.71653)})$	R^2=0.98**
Roots = $0.89654/(1+ e^{-0.03622 (X - 81.53768)})$	R^2=0.89**
Green fruits = $-0.00022534x^2 + 0.005584726x - 2.10512845$	R^2=0.76*
Mature fruits = $5.64144/(1+ e^{-0.04186 (X - 147.21661)})$	R^2=0.99**
Total = $35.2493/(1+ e^{-0.05222 (X - 106.522)})$	R^2=0.94**



Leaves = $8.7819/(1+ e^{-0.02692 (X - 105.08804)})$	R^2=0.90**
Stem = $11.42258/(1+ e^{-0.01996 (X - 245.49368)})$	R^2=0.95**
Roots = $0.6794/(1+ e^{-0.03253 (X - 87.42453)})$	R^2=0.77*
Green fruits = $-0.00021006x^2 + 0.05560167x - 2.0035914$	R^2=0.91**
Mature fruits = $59.00274/(1+ e^{-0.02489 (X - 25479332)})$	R^2=0.98*
Total = $43.011/(1+ e^{-0.0194 (X - 185.263)})$	R^2=0.97**

Figure 3. Accumulation of iron (Figure 3A), manganese (Figure 3B) and zinc (Figure 3C) in the sweet pepper Eppo in different parts of the plant, depending on the age of the plant [acúmulo de ferro (Figura 3A), manganês (Figura 3B) e zinco (Figura 3C) em pimentão 'Eppo', nos diferentes órgãos, em função da idade da planta]. Jaboticabal, UNESP, 2007.

during the whole growing cycle, which consequently results in a greater accumulation of nitrogen.

The accumulation of P by the plant was 1.14 g plant^{-1} at 189 DAT (Figure 1B), where 50% of this total accumulation was observed at 120 days after transplanting. The mature fruits were the organs that accumulated the most phosphorus (0.82 g plant^{-1}) at 137 days (50% of the total). It is noted that the greatest requirement of P in sweet peppers occurred during fruiting. The stem was the second organ that accumulated the most P (0.09 g plant^{-1}), followed by leaves, green fruits and roots, which accumulated respectively 0.08 g plant^{-1}, 0.07 g plant^{-1} and 0.04 g plant^{-1} at 189 DAT.

Fontes *et al.* (2005) reported that the absorption of P by the plant was 23.3 kg ha^{-1}, where the fruits accounted for 60%. Considering a total of 25,000 plants in the present study, the accumulation of P would be 28.5 kg ha^{-1}, where these values would thus be similar. However, it should be pointed out that in the present study the commercial production of fruits was superior to that observed by Fontes *et al.* (2005). This fact could be related to the coconut fiber that provides more efficient utilization of nutrients, once the quantities absorbed are similar in both studies.

The greater total accumulation of K was 7.84 g plant^{-1} at 189 DAT. This value represents an extraction of 196.0 kg ha^{-1} K (25,000 plants/ha), where 117 days were needed for the culture to accumulate 50% of this total. At this same time, mature fruits contributed the most to this accumulation (4.40 g plant^{-1}), followed by leaves (1.50 g plant^{-1}), stem (1.21 g plant^{-1}) and roots (0.17 g plant^{-1}). Green fruits showed a maximal accumulation of K (0.96 g plant^{-1}) at 125 DAT, decreasing by 189 DAT (Figure 1C). It is evident that the accumulation curves for K are similar to N, as showed by Fontes *et al*. (2005).

Miller *et al.* (1979) reported that

sweet peppers absorbed 135.6 kg ha^{-1} of K, and Ombodi & Saigusa (2000) found absorption of 242 kg ha^{-1} of K, under greenhouse and soil. Besides, Bar-Tal *et al.* (2001b) found a higher value (520 kg ha^{-1} of K). Considering 5.97 kg of K were needed for the production of 1000 kg of fruits, while in the present study 2.01 kg of K were needed, which reinforces the idea that the efficiency of utilization of nutrients with cultivation in coconut fiber is greater.

Quantities of nitrogen and potassium accumulated by the plant in this work were similar. These results differ from those obtained by Fontes *et al.* (2005) who showed that the quantity of K accumulated was greater than that of N. These latter authors found an accumulation of 20.09 g $plant^{-1}$ for K, this being approximately 2.5 times higher than the amount accumulated in the present study. This finding is probably due to the difference in cultivars utilized and also the cultivation system in which the plants were grown.

The accumulation of Ca occurred continuously, reaching a maximum of 3.25 g $plant^{-1}$ at 189 DAT. The leaves were the organs that accumulated the highest quantity of calcium (2.14 g $plant^{-1}$), followed by the stem (0.75 g $plant^{-1}$), mature fruits (0.25 g $plant^{-1}$) and roots (0.10 g $plant^{-1}$). The maximal accumulation of Ca in green fruits (0.07 g $plant^{-1}$) was observed between 125 and 129 DAT. It was similar to other nutrients, because there was a decrease in the accumulation of Ca in theses organs (Figure 1D). The leaves contributed the most to the total Ca absorbed, due to the fact that calcium is a nutrient absorbed by mass flow and is considered immobile in the plant, that is, it is not redistributed from the site of accumulation (leaves mainly) to other parts of the plant. 114.34 days were necessary to reach 50% of the total Ca accumulated. This fact showed that Ca uptake is greater in the fruiting phase, even though this nutrient is accumulated in larger amounts in other organs.

Fontes *et al.* (2005) found an accumulation of 8.47 g of calcium/plant at 224 DAT, where of this total 1.64 g were accumulated by the fruits. The quantities accumulated in this latter study were greater than that observed in the present work. This could be due to a difference in the duration of the experiments, because in the present study the plants were monitored for 189 days after transplanting, that is, 35 days less than the above-mentioned study. Another difference was in the cultivation system, where in the research of Fontes *et al.* (2005) the plants were grown in soil, which is generally rich in calcium due to liming often required to correct for acidity. Still, it should be noted that different cultivars were utilized, which could have different requirements.

The quantity of magnesium accumulated increased during the whole growing cycle, resulting in 1.34 g $plant^{-1}$ at 189 DAT. Of this total, the leaves and mature fruits accumulated the most Mg, 0.52 and 0.40 g $plant^{-1}$, respectively. The stem, roots and green fruits showed an accumulation of Mg at 189 DAT of 0.36, 0.04 and 0.03 g $plant^{-1}$, respectively (Figure 2A). Negreiros (1995) evaluated the growth and accumulation of nutrients in a culture of sweet pepper and found an accumulation of magnesium of 0.16, 0.06 and 0.16 g $plant^{-1}$ for leaves, stem and fruits, respectively. Values obtained in the present work were higher than those observed by the latter author. This fact is probably due to the difference in cultivation system, since the research of Negreiros (1995) was carried out in soil. This demonstrates that the nutritional requirements of sweet pepper grown in coconut fiber are higher than in other cultivation systems, and that fertilizing is required.

The accumulation of sulfur by the plant was continuous (Figure 2B). At 189 DAT, there was an accumulation of 2.25 g $plant^{-1}$, where 130.16 days after transplanting were needed for an accumulation of 50% of this amount. This means that a greater demand for this nutrient occurs during the fruiting phase, because the physiological activity of the plant is greater, as can be seen by the accumulation of dry mass in the research of Charlo *et al.* (2011). The mature fruits, stem and leaves were the organs that accumulated the most sulfur, with respective amounts of 1.03, 0.54 and 0.49 g $plant^{-1}$. The roots showed the least accumulation of S, with 0.09 g $plant^{-1}$. Fontes *et al.* (2005) found an accumulation of S of 1.88 g $plant^{-1}$, where 0.49 g $plant^{-1}$ was accumulated by the fruits.

The total accumulation of boron by the plant was 16.65 mg $plant^{-1}$ at 189 DAT, where 50% of this amount was accumulated at 121.15 days after transplanting. As in the case of Ca, boron was most accumulated by the leaves (9.67 mg $plant^{-1}$) due to its mobility in the plant phloem, that is, immobile elements in the plant tend to accumulate mainly in the leaves, because they are not redistributed to other organs. At 189 DAT, mature fruits accumulated 4.73 mg $plant^{-1}$, the stem 1.37 mg $plant^{-1}$, green fruits 0.54 mg $plant^{-1}$ and the roots 0.25 mg $plant^{-1}$ (Figure 2C). These values are close to those observed by Fontes *et al.* (2005) who found a total accumulation of 18.86 mg $plant^{-1}$ and an accumulation of 6.68 mg $plant^{-1}$ by the fruits.

The total accumulation of Cu by the plant was 3.36 mg $plant^{-1}$ at 189 DAT (Figure 2D). The accumulation of Cu in the leaves was maximal at 126 DAT with 2.52 mg $plant^{-1}$, decreasing thereafter to 1.14 at 189 DAT. A similar behavior was found for the stem, where the maximum was 131 at 133 DAT with 0.037 mg $plant^{-1}$, declining to 0.29 mg $plant^{-1}$ at 189 DAT. The roots and mature fruits showed continuous accumulation of Cu, and reached 0.13 and 1.53 mg $plant^{-1}$ at the end of the cycle. The results for green fruits were similar to those for leaves and stem, showing a maximal accumulation of Cu at 123 and 124 DAT (0.33 mg $plant^{-1}$) and a gradual decrease in levels until 189 DAT (0.13 mg $plant^{-1}$). The accumulation of Cu in leaves, stem and green fruits showed great variation during the growing cycle at times of fertilizing. This is likely related to the pulverizations of Cu-based products, which was also reported by Fontes *et al.* (2005).

The total iron accumulated by the plant was 45.98 mg $plant^{-1}$ and leaves showed superior values (23.46 mg $plant^{-1}$). Green fruits showed, as with other nutrients, a maximal accumulation at 124 to 129 DAT (2.94 mg $plant^{-1}$), where it decreased up to the end of the growing cycle with a final accumulation of 1.23 mg $plant^{-1}$. The stem, roots and mature fruits showed continuous accumulation of Fe, resulting in levels of respectively 5.52, 4.96 and 10.74 mg plant^{-1} at 189 DAT (Figure 3-A). Fontes *et al.* (2005) found an accumulation of 87.72 mg plant^{-1} for Fe, which was higher than that observed in the present work. These authors carried out their study in soil which functions as large reservoir and source of Fe, resulting in high absorption and accumulation of this element. Another factor could be the difference in the utilized cultivars.

The accumulation of Mn was found to be continuous in leaves, stem, roots and mature fruits, which at 189 DAT reached respective levels of 24.89, 4.459, 0.87 and 4.80 mg plant^{-1}. Green fruits had a maximal accumulation of 1.36 mg plant^{-1} at 124 DAT, followed by a decrease until 189 DAT when the accumulation of Mn was 0.40 mg plant^{-1}. The total accumulation of Mn was continuous reaching 34.78 mg plant^{-1} at 189 DAT, where 106.52 days after transplanting were needed for the plants to accumulate 50% of this total (Figure 3B).

The total Zn accumulated by the plant was 22.28 mg plant^{-1} at 189 DAT (Figure 3C), being the highest values found in the mature fruits (9.60 mg plant^{-1}). The green fruits showed maximal accumulation at 131 to 134 DAT (1.67 mg plant^{-1}), and 1.00 mg plant^{-1} in these organs at the end of the cycle. The stem, roots and leaves displayed continuous accumulation of Zn, which was observed up to 189 DAT, with final respective values of 2.79, 0.65 and 7.95 mg plant^{-1}.

Analyzing the accumulation dynamics of nutrients, we observed that nitrogen and potassium are the most absorbed macronutrients, especially after the beginning of fruiting. The absorbed N:K proportion was 1:1, indicating that the nutrient solutions must respect this relationship to avoid a nutritional imbalance. The other nutrients mostly accumulated after the beginning of fruiting, which means that the fertirrigation should be more rigorously monitored after the appearance of fruits.

According to the results obtained in this study, we suggest the adoption of two types of nutrient solution in the sweet pepper cultivation, especially for levels of nutrient fertirrigation: the use of lower concentrated solution during the vegetative phase of the plants (0 - 42 DAT) and a more concentrated solution from 42 DAT on. It is also suggested to perform new studies in order to determine the optimal concentration of nutrients in these two phases.

This study demonstrated an accumulation of 8.22 g plant^{-1} of N, 1.14 g plant^{-1} of P, 7.84 g plant^{-1} of K, 3.25 g plant^{-1} of Ca, 1.34 g plant^{-1} of Mg, 2.24 g plant^{-1} of S, 16.65 mg plant^{-1} of B, 3.36 mg plant^{-1} of Cu, 45.98 mg plant^{-1} of Fe, 34.78 mg plant^{-1} of Mn and 22.28 mg plant^{-1} of Zn at 189 days after transplanting.

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