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Nutrient accumulation in 'Fantasy' net melon cultivated on substrate

Acúmulo de nutrientes do meloeiro rendilhado 'Fantasy' cultivado em substrato

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Abstract

Knowledge of the most essential nutrients for plant growth facilitates the efficient handling of its nutrition, especially when they are grown on a substrate supported by fertigation. The objective of this study was to determine the accumulation of nutrients in net melon grown on a substrate and understand the relationship between mineral nutrition and plant growth. The Fantasy hybrid was cultivated in pots containing a substrate consisting of a mixture of sand and peanut shells (ratio, 1:1). Determination of nutrient accumulation was performed in 6 seasons. The substrate was chemically characterized before and after cultivation. Harvesting occurred 78 days after transplantation, resulting in an average yield of 70,120 kg·ha^{-1}. Substrate analysis showed a small increase in nutrient levels by the end of cultivation. The order of nutrient accumulation was as follows: N>Ca>K>P>Mg>S>B>Fe>Mn>Zn>Cu.
Key words: *Cucumis melo* var. *reticulatus*, greenhouse, nutrition

Resumo

O conhecimento dos nutrientes mais requeridos pelas plantas possibilita o manejo mais eficiente na nutrição destas, principalmente, quando são cultivadas em substrato com fertirrigação. Dessa forma, o objetivo deste trabalho foi determinar a marcha de acúmulo de nutrientes do meloeiro rendilhado cultivado em substrato. O híbrido Fantasy foi cultivado em vasos contendo substrato (mistura de areia e casca de amendoim em partes iguais). A determinação da marcha de acúmulo de nutrientes foi realizada em seis épocas. O substrato foi caracterizado quimicamente antes e após o cultivo. A colheita ocorreu aos 78 dias após o transplante, obtendo-se produtividade média de 70.120 kg ha^{-1}. A massa média e o teor de sólidos solúveis, obtido pelos frutos, foram de 1,75 kg e 10,2 °Brix, respectivamente. A análise do substrato demonstrou pouco incremento de nutrientes no fim do cultivo. A ordem de acúmulo de nutrientes foi: N>Ca>K>P>Mg>S>B>Fe>Mn>Zn>Cu.
Palavras-chave: *Cucumis melo* var. *reticulatus*, cultivo protegido, nutrição

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Introduction

Soil degradation due to intensive use in greenhouse conditions has encouraged vegetable producers to use alternative cultivation systems. Measures and adjustments in cultivation and irrigation management can be adopted to prevent soil degradation; however, growing vegetables without soil, especially on cultivation substrates, has also gained prominence, besides of faring several advantages to the producer.

The results of experiments conducted in Jaboticabal-SP have shown that a substrate consisting of a mixture of sand and peanut shells in equal proportions confers high productivity and quality to crops and serves as an ideal option for growing vegetables (MELO et al., 2012; FERNANDES et al., 2002; FERNANDES; CORÁ; BRAZ, 2006). However, plant nutrition in this system differs from that in traditional systems and may also vary depending on the materials used as substrate.

The mechanisms of absorption and accumulation of nutrients at different stages of crop development using a particular substrate requires of the identification of critical periods that require these nutrients as well as prevent the occurrence of nutrient deficiencies during plant development (CASTOLDI et al., 2009). Nutrient analysis throughout the crop cycle can provide valuable information that may also help in the design of substrate fertigation schemes. According to Gurgel, Gheyi, and Fabio (2010), the knowledge of nutrient uptake curves for a particular crop is essential in planning and split fertilization. Moreover, the use of fertigation allows the adjustment of the amounts and concentrations of specific nutrients required by crops at each developmental phase.

The aim of this study was to assess nutrient accumulation rates in net melon grown in a substrate consisting of sand and peanut shell sand to verify the relationship between mineral nutrition and plant growth

Material and Methods

The study was conducted at the Department of Vegetable Crops and Aromatic Medicinal Plants of the Faculty of Agriculture and Veterinary Sciences (UNESP-FCAV), Campus of Jaboticabal-SP. The site is located at an altitude of 614 m, latitude of 21° 14′05″S, and longitude of 48° 17′ 09″ W. The climate, according to the Köppen classification, is Aw with transition to Cwa(VOLPE[6]).

The experimental protocol was a randomized block design comprising4 replicates. The experimental area consisted of 150 plants (96 evaluated and 54 border plants), distributed in 4 rows (blocks). Plants were grown in an arc-type greenhouse, 30× 6 × 3.5 m (L ×W× H), with lateral protection screen for 50% shade and a ceiling covered using low-density polyethylene film of150-μm thickness.

We used the hybrid Fantasy from the company TAKII SEED. Sowing was conducted on January 12, 2010 in 128-cell polystyrene trays containing Plantmax Hortaliças® HT substrate. Transplantation was performed 24 days after sowing, when the seedlings were at its first fully expanded leaf stage. The plants were grown in plastic pots of 31.3 and 22.1 cm top and bottom diameters, respectively, 27.5 cm height, and a total capacity of 13.0 dm^3, which were filled with substrate. The substrate used was a mixture of sand and peanut shell of equal volumes. The sand was acquired from specific construction establishments; the peanut shells were obtained from COPLANA, a cooperative of sugarcane planters in Guariba, which processes and sells peanuts, generating large amounts of the shell waste annually. The peanut shells were dried at room temperature, crushed, and then stored in a dry place. The distance between the vessels was set such that the distance between the centers corresponded to a 1.0-m space between rows and a0.5-m distance between plants.

[6] VOLPE, C. A. (Faculty of Agriculture and Veterinary Sciences, UNESP-Jaboticabal Campus) Personal communication, 2008.

Drip irrigation was performed using a nutrient solution recommended for hydroponic cultivation (CASTELLANE; ARAÚJO, 1994). The macronutrients and micronutrients ($g \cdot L^{-1}$) were as follows: 178 (N), 93 (P), 265 (K), 153 (Ca), 21.6 (Mg), 28.9 (S), 0.30 (B), 2.35 (Fe), 0.35 (Mn), 0.23 (Zn), 0.03 (Cu), and 0.04 (Mo). Fertigation was controlled using a timer; the programming and irrigation was based on the age of the crop and the vessel's minimal drainage.

During cultivation, the plants were monitored using plastic ribbons to a height of 2.2 m above the ground, when the removal of the apical bud was performed. We propagated 1 plant per pot, with regular pruning and thinning. The thinning was performed up to the 10th in tern ode by keeping the side stems of the 11th, 12th, and 13th internodes where fruiting occurred. After fruit setting to 3.0 cm in average diameter, one of the side stems was removed, leaving only 2 fruits per plant. In the lateral branches,2leavesremained after the fruits as well as in the stems above the side stems, to eliminate formation of the apical bud. The pruning of secondary stems continued in the internodes above and below the fruit.

The maximum and minimum temperature inside the greenhouse was measured using a thermo-hygrometer installed ina wooden shelter, 1.5 m above the ground. The mean maximum and minimum values observed, respectively, were 38.04 and 21.61°C(0–14 days after transplanting [DAT]); 40.48 and 20.48°C (14–28 DAT); 37.89 and 18.67°C (28–42 DAT); 36.45 and 20.57°C (42–56 DAT); 31.25 and 15.78°C (56–70 DAT);and 39.88 and 14.28°C (70–78 DAT).

To determine nutrient accumulation, samples were collected for 6 seasons, including4 samples of plants per block in each sampling period. The first sampling occurred 14 days DAT and afterward at 14-day intervals. The last evaluation was premature due to the harvest, occurring8 days after the penultimate assessment. During each sampling period, parts of the plants were properly prepared and submitted for chemical analysis according to the method proposed by Malavolta, Vitti and Oliveira (1997). The data were subjected to regression analysis by using the logistic function described by Hoffmann and Vieira (1977) with plant age expressed as DAT as the independent variable.

The chemical characterization of the substrate was performed according to the extraction method 1:1, 5 v/v proposed by Soneveld, Ende and Bes (1990) as follows: 0.16 and 0.28 $dS \cdot m^{-1}$ (electrical conductivity); 6.35 and 5.05 (pH); 1.74 and 2.13 $mg \cdot L^{-1}$ ($N\text{-}NH_4^+$), 5.45 and 25.31 $mg \cdot L^{-1}$ ($N\text{-}NO_3^-$), 0.61 and 3.83 $mg \cdot L^{-1}$ (P), 26.53 and 33.62 $mg \cdot L^{-1}$ (K), 3.4 and 42.71 $mg \cdot L^{-1}$ (Ca), 1.55 and 4.44 $mg \cdot L^{-1}$ (Mg), 1.23 and 9.85 $mg \cdot L^{-1}$ (S), 0.050 and 0.067 $mg \cdot L^{-1}$ (B), 0.010 and 0.006 $mg \cdot L^{-1}$ (Cu), 0.572 and 0.333 $mg \cdot L^{-1}$ (Fe), 0.019 and 0.190 $mg \cdot L^{-1}$ (Mn), and 0.008 and 0.040 $mg \cdot L^{-1}$ (Zn).

Harvesting occurred at 78 DAT or 102 days after sowing (DAS), when the fruits were ripe. The sampling point was based on the formation of an abscission layer near the stalk, change in color of the epicarp, and sampling of fruit harvested in the border plants. Upon harvest, 5 plants were sampled from each block, and the fruits were transported to the Vegetables Laboratory, Department of Plant Production, where the average fruit weight (kg), yield ($kg \cdot ha^{-1}$of fruit), and total soluble solids (°Bx) were estimated. By using these data, the meansand the standard errors of the means (SEMs)were calculated.

Results and Discussion

The estimated average yield was 70,120 $kg \cdot ha^{-1}$ (SEM = 4.20). The average mass and the content of soluble solids obtained from the fruits were 1.75 kg (SEM = 4.20) and 10.2 °Bx (SEM = 0.49), respectively. The results were similar to those reported by several authors for net melon cultivation in greenhouses (PADUAN; CAMPOS; CLEMENTE, 2007; QUEIROGA e al., 2008;

CHARLO et al., 2009). Although the results were similar to those shown in the literature, the soluble solids content was below the value prescribed by the supplier of the hybrid Fantasy (14° to 15°Bx). This variation in the content of soluble solids may be attributed to environmental factors, such as growth regulators, fertilizers, nutrients, temperature and light intensity, leaf area, and maturity (SILVA et al., 2002).

The accumulation of nitrogen (N) in the plant was continuous during the cycle and showed the highest accumulation (Figure 1A). This increased accumulation of N was observed at the time of harvest, corresponding to 5.87 g per plant, which is equal to the requirement of 117.4 kg·ha^{-1} N. The fruits accumulated the highest amount of this nutrient, followed by the leaves and stems. For the leaves, a more significant buildup occurred until approximately 28 DAT, at which the value corresponded to 1.53 g per plant. After this period, the rate of accumulation of nitrogen in the leaves decreased, leveling off at 43 DAT and reaching 1.78 g per plant at the end of the cycle, which was the maximum value observed in the organ. In stems, the nitrogen content was constant for most of the cycle. In this organ, a slight accumulation was observed only until 16 DAT, which remained at 0.37 g per plant until the end of the cycle. The fruits maintained a continuous accumulation until harvest. The maximum value observed in the fruits was 3.39 g per plant at 78 DAT.

For the dynamics of calcium (Ca), the second most accumulated nutrient in the plants, a high demand was observed between 28and 45 DAT (Figure 1B). After this period, the Ca content in the plants slowly increased until the end of the cycle, reaching the cumulative maximum of 5.76 g per plant (115.2 kg·ha^{-1}). The largest accumulation of calcium was significantly observed in the leaves, where the dynamics of this nutrient accumulation was similar to the plant itself, and a high accumulation rate of Ca was also verified. At the end of the cycle, the leaves accumulated 5.24 g per plant of Ca, which corresponds to slightly more than 90% of the total accumulated Ca in the plant. According to Prado (2008), translocation of Ca occurs along with water and is affected by the rate of transpiration. Further, Gondim et al. (2011) showed high rates of Ca accumulation in beet greens, highlighting the fact that Ca absorbed by the roots are translocated to the shoots and not redistributed within the plant; this may attribute to the low mobility of Ca. Thus, organs with high transpiration rates receive high amounts of Ca. Moreover, the high temperatures inside the greenhouse may have contributed to increase in leaf transpiration, resulting in increased accumulation of Ca in the leaves and in the plant in general.

Potassium (K) was the third most accumulated nutrient in the plant; accumulation continued until the end of the cycle, reaching the maximum value of 2.89 g per plant or 57.8 kg·ha^{-1} (Figure 1C). In the leaves, the highest accumulation occurred within 30 DAT, whereupon the levels remained constant until the end of the cycle. The largest amount of K found in these organs was 0.61 g per plant. In the stems, the dynamics of K was similar to that in the leaves; however, these organs showed low rates of accumulation, reaching only the maximum value of 0.32 g per plant during most of the plant cycle. In fruits, K was continuously accumulated at high levels unlike that in other organs, showing the accumulation in an exponential curve indicating a very high demand for this nutrient. At the end of the cycle, the amount of K that was accumulated at the maximum in the fruits was 2.54 g per plant.

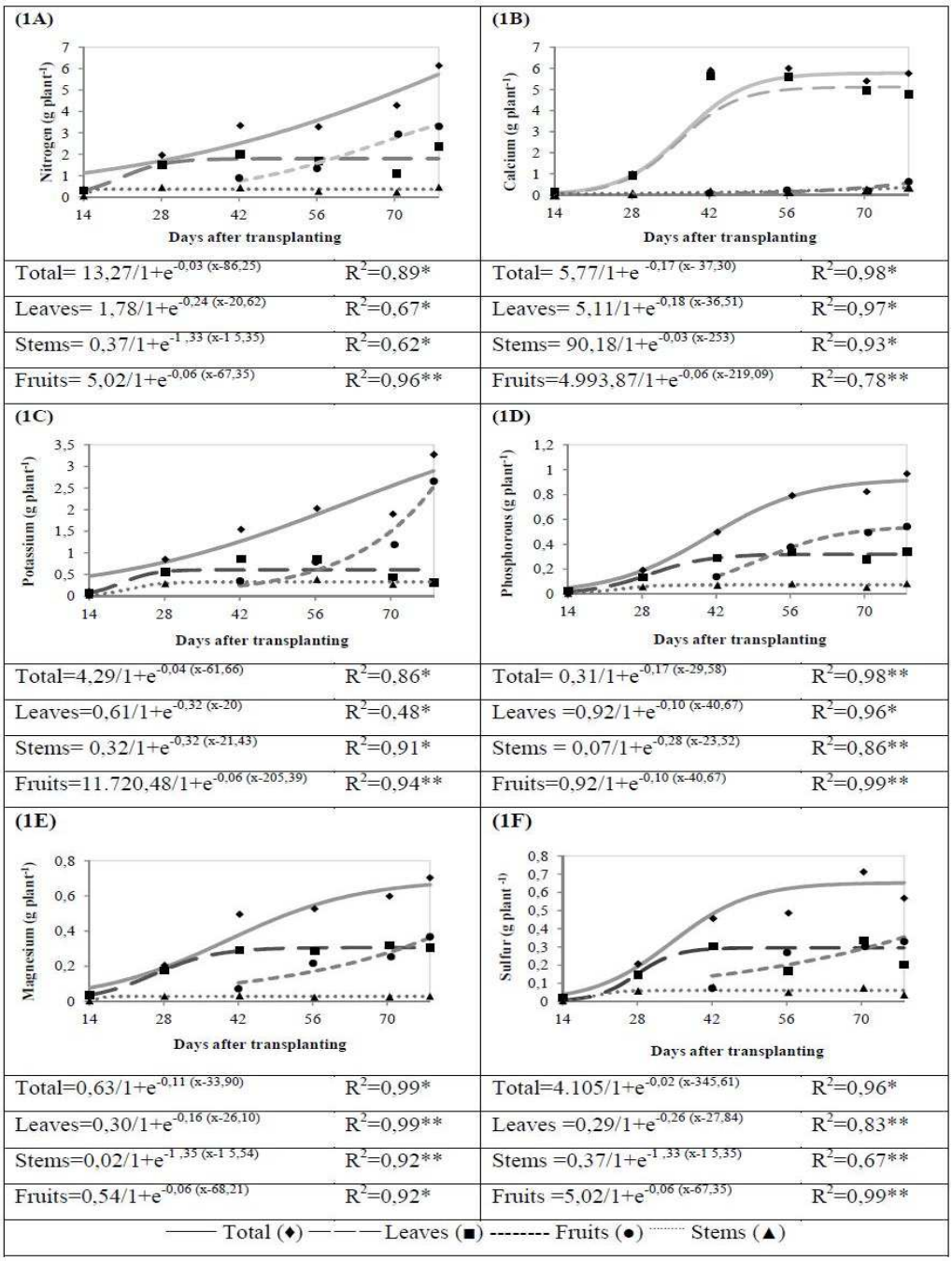
Phosphorous (P) was the fourth most accumulated nutrient by the plants (Figure 1D). The highest accumulation of P was observed at the time of harvest, at 0.91 g per plant or 18.24 kg·ha^{-1}. The fruits accumulated the highest amount of P at 0.53 g per plant.

Magnesium (Mg) was the fifth most accumulated nutrient in the plants, with the highest Mg accumulation within 55 DAT. From this date, the amount of Mg remained the same until the end of

the cycle, yielding in total the maximum of 0.63 g per plant (12.68 kg·ha^{-1}) at the time of harvest (Figure 1E).

The macronutrient sulfur (S) accumulated in small quantities in the plants. The highest accumulation occurred within 61 DAT, with the maximum range of0.59–0.61 g per plant (at the time of harvest) (Figure 1F), thus, representing a nutritional requirement of 12.30 kg·ha^{-1}.

Figure 1.Accumulation of nitrogen (A), calcium (B), potassium (C), phosphorus (D), magnesium (E), and sulfur (F) in 'Fantasy' net melon grown on substrate (UNESP-FCAV, Jaboticabal-SP, 2011).



Source: Elaboration of the authors.

Briefly, at the time of harvest, except for calcium, the fruits accumulated the highest amounts of macronutrients, followed by the leaves and stems. The amounts accumulated by the plants reflects their nutritional requirement, which varies depending on several factors, such as the level of production, species or cultivar, soil fertility and/or fertilization, climate, and cultural practices (MALAVOLTA, 2006).

As shown in this study, the high demand for nutrients in plants is as follows: N>Ca> K> P> Mg> S. The default order, in decreasing extraction of crops in general is as follows: N> K>Ca> Mg> P ↔ S (MALAVOLTA, 2006; PRADO, 2008). From the data shown in the literature, N, K, and Ca are the most accumulated macronutrients in melon. However, most study results differ in the order of nutrient accumulation.

Duarte (2002) investigated mineral nutrition in melon by varying the salinity of the irrigation water and showed that K was absorbed in high quantities, followed by N, and then Ca. Kano et al. (2010) observed increased accumulation of K in the shoots of melon cultivated using the conventional system, followed by N, and then Ca. Furthermore, when adding $CO_2$to the irrigation water, N was observed as the most absorbed nutrient, where as the K content decreased. Silva Júnior et al. (2006) examined the accumulation of dry matter and nutrient uptake in the frog-skin melon grown by using soil and found the following sequence of macronutrient uptake: K>Ca> N> P. Grangeiro and Cecílio Filho (2004) evaluated the accumulation and nutrient export by the Tide hybrid watermelon grown by using soil and obtained the following order of nutrient accumulation: K> N>Ca> Mg> P> S.

In the present study, the high production of fresh fruits and low soluble solids observed in these organs probably occurred under the influence of high N content and low levels of K in the plants. Several researchers have shown that K is responsible for the transport of photoassimilates in the phloem, thus, providing high levels of soluble solids in the fruit. According to Brady (1993), K plays an important role in the quality of the melon fruit because this element plays an important role in the translocation of carbohydrates. Filgueira (2008) considers K as the nutrient responsible for improving the flavor of the fruit. Silva Júnior et al. (2010) evaluated the fertigation management in the net melon based on the control of ions in the soil solution; the study showed that the soluble solids in fruits gradually decreased with increasing N concentrations, and the reverse occurred when K concentrations were increased in the soil solution.

The limited accumulation of K by plants can be explained by a low level of absorption caused by the antagonism between K and Ca. According to Malavolta (2006), high levels of Ca in the soil solution (or substrate) can reduce K absorption in a plant. This statement is reinforced by the observation that high Ca levels in the substrate at the end of cultivation, which probably inhibited the absorption of K. Hubbard, Hubera and Pharr (1989) showed that most of the sugar is accumulated during the late stages of fruit development, approximately 2 weeks prior to harvesting. Thus, the optimal amount of K in the plant during this period is essential to obtain high levels of soluble solids in the fruit.

The low uptake of K by the plants can also be related to the efficiency of nutrient absorption, type of cultivar used, fertilizer type and form of application, and formation of insoluble compounds in the nutrient solution.

Among the micronutrients, boron (B) was accumulated in greater quantities by the net melon. During plant development, increasing accumulation was observed until the end of the cycle (Figure 2A), yielding a maximum of 19.44 mg per plant at the time of harvest, corresponding to a nutritional requirement of 3.88 $kg \cdot ha^{-1}$.

Iron (Fe) was the second most accumulated micronutrient in plants, and an increased accumulation of Fe, with a maximum value of 18.01

mg per plant at the time of harvest, corresponding to a nutritional requirement of 3.60 kg·ha^{-1} (Figure 2B) was observed. Although the fruits are the preferred drains, the leaves accumulated relatively high amounts of Fe. According to Taiz and Zeiger (2004), Fe is a constituent of the cytochrome and non-heme iron-proteins involved in photosynthesis,N_2 fixation, and respiration, and is thus, responsible for the synthesis of some of the chlorophyll-protein complexes in the chloroplast, which explains its high demand in the leaves. Furthermore, this micronutrient is precipitated in older leaves in the form of oxides or insoluble phosphates or by forming complexes with phytoferritin (storage protein). Approximately 80% of the Fe contained in the plant is located in the chloroplasts as phytoferritin (MALAVOLTA, 2006; PRADO, 2008). Further, the study results confirmed the function of Fe in the plant, which is necessary for the synthesis of chlorophyll, in addition to its participation in ion transport in the reduction process through cytochromes and ferredoxin.

Manganese (Mn) is the third most accumulated micronutrient in the plant. The greatest demand for this nutrient occurred between 25 and 48 DAT (Figure 2C). The maximum Mn accumulated in the plant was 14.90 mg per plant (2.98 kg·ha^{-1}). In general, similar to Fe, a high accumulation of Mn was observed in the leaves. By observing the buildup curve of this nutrient, it is found that the dynamics were similar to that for Ca. The highest Mn requirement in the leaves occurred during the period similar to that for the entire plant, and afterward the quantity that accumulated in the leaves stabilized by the end of the cycle, corresponding to 11.17 mg per plant.

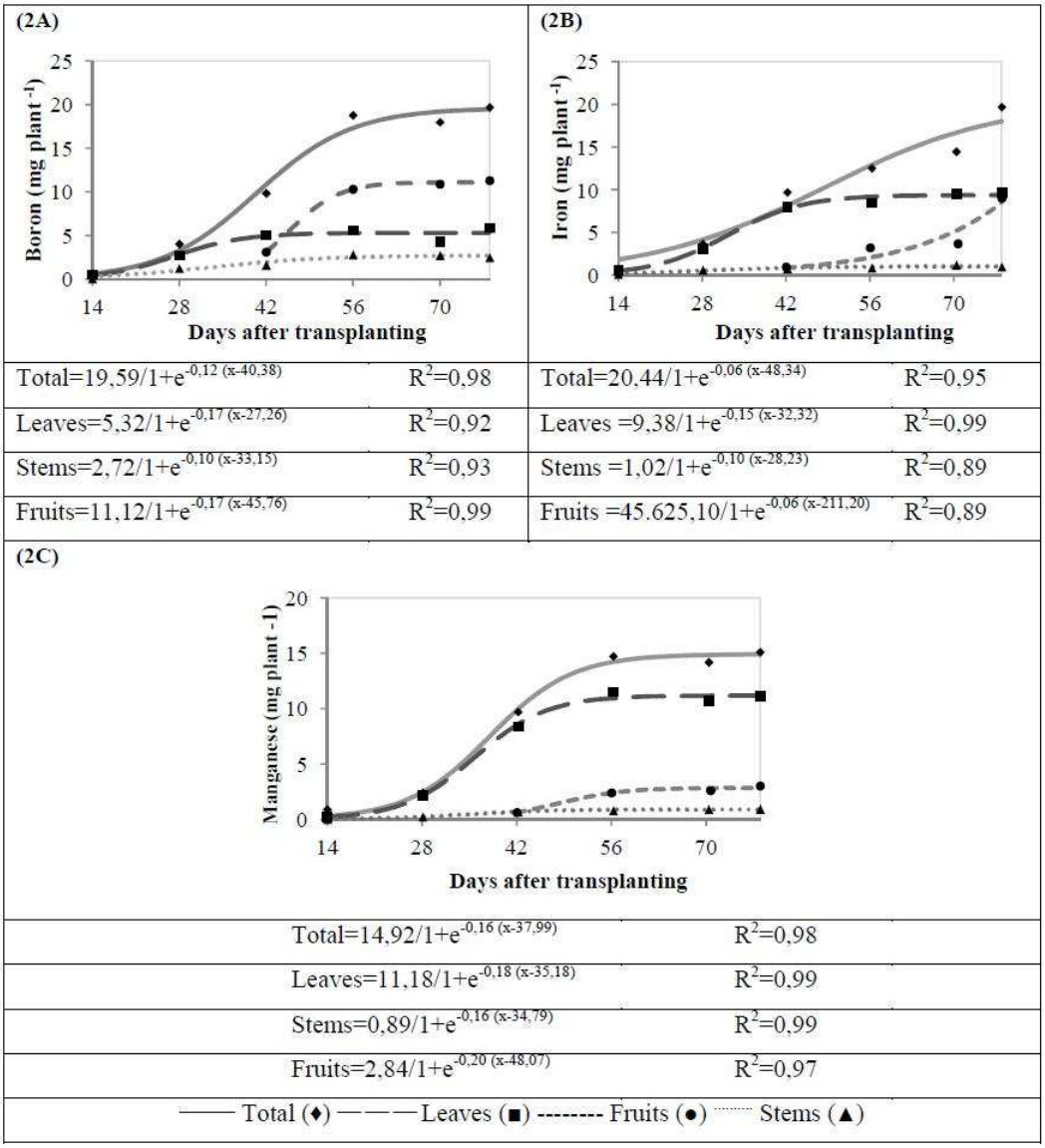
The increased demand of Mn by leaves occurs primarily in the xylem, which is responsible for the movement of nutrients through the respiratory chain, in the acropetal direction, i.e., from the root to the shoot. The opposite is rarely observed because of its very low concentration in the phloem (MALAVOLTA, 2006; PRADO, 2008). Furthermore, Mn is connected to the thylakoid membranes and participates directly in the chemical composition of 2 enzymes (S enzyme and peroxide dismutase) that perform several functions in the plant, especially in terms of photosynthesis, including the photolysis of water. When studying the content and accumulation of nutrients in other vegetables, high amounts of Mn were observed in the leaves (RODRIGUES et al., 2002; CHARLO, 2008).

Regarding zinc (Zn), continuous accumulation was observed until the end of the cycle (Figure 3A). Zn was the fourth most accumulated micronutrient in the plant, with the maximum quantity recorded at harvest at 10.37 mg per plant (2.07 kg·ha^{-1}). Copper (Cu) accumulation was low in the plants. In Figure 3B, an increase in accumulation of this nutrient is shown during the cycle, at 1.28 mg per plant, which is the maximum value observed at harvest, corresponding to a nutritional requirement of 0.25 kg·ha^{-1}

The accumulation of Zn and Cu in the fruit occurred intensely and followed an exponential trend, thus, showing the high demand for these micronutrients. The level of Cu considerably decreased in the substrate, showing that plants consumed most of what was supplied.

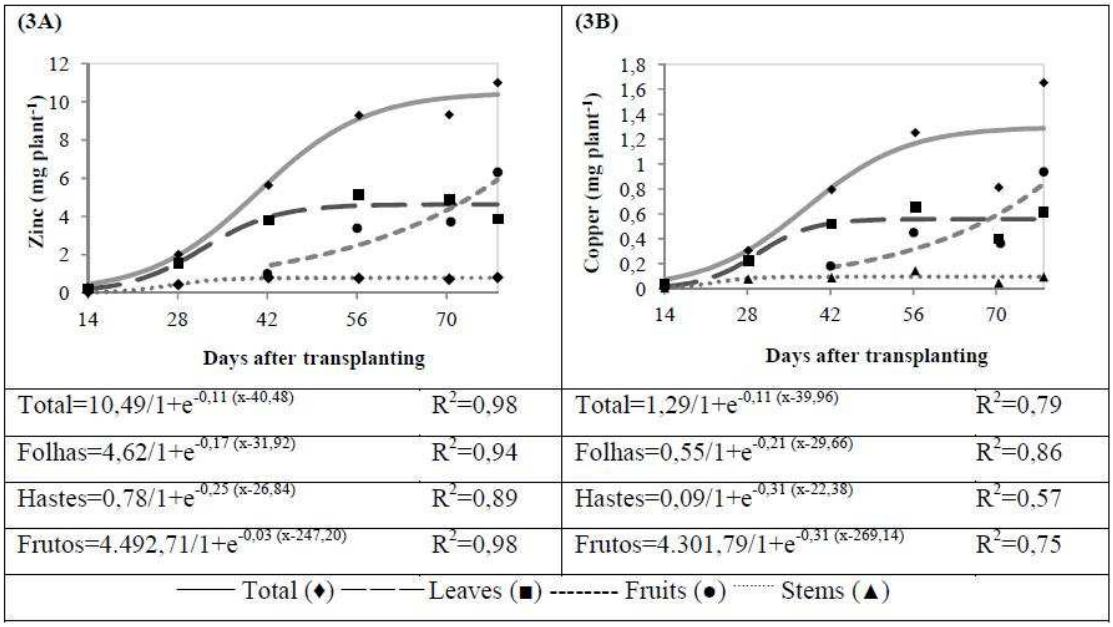
Thus, the decreasing order of micronutrient accumulation is as follows: B> Fe> Mn> Zn> Cu. Similar to the dynamics of macronutrients, except those of Fe and Mn, micronutrients accumulated in high quantities in the fruits, followed by the leaves and stems.

Figura 2. Accumulation of boron (A), iron (B) and manganese (C), in 'Fantasy' net melon grown on substrate (UNESP-FCAV, Jaboticabal-SP, 2011).



Source: Elaboration of the authors.

Figure 3. Accumulation of zinc (A) and copper (B), in 'Fantasy' net melon grown on substrate (UNESP-FCAV, Jaboticabal-SP, 2011).



Source: Elaboration of the authors.

Conclusions

This study showed that net melon grown ona substrate consisting of peanut shells and sand in equal quantities follow the following order of nutrient accumulation: N>Ca> K> P> Mg> S> B> Fe> Mn> Zn> Cu. The amount of nutrients provided by the nutrient solution was sufficient to obtain 70,120 kg·ha^{-1} fruit, without requiring excessive accumulation of fertilizer in the substrate. The relation between N, Ca, and K should be further investigated in plants to determine its influence on the content of soluble solids in the fruit.

Acknowledgments

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