Introduction

Brazilian citriculture is world renowned, especially that of São Paulo State, the country's largest citrus producer. Seedling production is considered the basis for the current citriculture; however, fertilization is one of the main obstacles in this process since it is based on the same principles used for plants grown in the field (Boaventura, 2003).

Copper deficiency is frequent in plants that grow in soils with high organic matter content, in which this element is complexed in insoluble organic forms not available to the plants. The major association of copper with organic matter is in humic and fulvic acids, which form stable complexes with copper. In citrus seedlings, copper deficiency is common and considered a severe problem to nurserymen.

Material and methods

The experiment was settled in July/2006 and carried out in a commercial citrus seedling production nursery in Botucatu, São Paulo State, Brazil. The substrate used was *Pine bark* (composed of 31mg L-1 N, 10mg L^{-1} P, 232 mg L^{-1} K, 49 mg L^{-1} Ca, 25mg L^{-1} Mg, 99mg L^{-1} S, 0.80 mg L^{-1} B, 0.15mg L^{-1} Cu, 0.25mg L^{-1} Fe, 0.01mg L^{-1} Mn, 0.11mg L^{-1} Zn, pH 7.06 and electrical conductivity (mS) of 1.17).

The rootstock used was Rangpur lime (*Citrus limonia* Osbeck), and 120 days after transplant (March/2007), inverted "T" budding was made with 'Valência' orange (*Citrus sinensis* L. Osbeck), followed by seedling conduction.

Copper-based treatments were first applied in January/2007. Control plants did not receive any copper fertilization. In the second treatment, 1.8 g L^{-1} copper oxychloride was applied fortnightly onto leaves using a backpack sprayer. In the third treatment, 3 mL L^{-1} cuprous oxide were also applied fortnightly onto leaves. The fourth treatment, 0.04 mL L^{-1} copper chelate EDTA, was supplied by fertigation twice a week. In the fifth treatment, plants received copper sulfate through irrigation, 2.5g L^{-1}, once a week.

For monthly evaluations, two plants per replicate of each treatment were randomly harvested from February/2007 (1^{st} evaluation), which corresponded to 90 days after transplant, to June/2007 (5^{th} evaluation), i.e. 90 days after budding.

Evaluations consisted of measuring plant height by using a graduated ruler (cm) and rootstock stem diameter at the budded site with a caliper (mm). Leaves were stored into paper bags and dried in a forced aeration oven at temperatures ranging from 60º to 65º C for 48 hours. A precision balance was employed to weigh shoot and root dry matter mass. Copper content in the leaves was assessed according to the methodology described by Malavolta et al. (1997).

The statistical design was randomized plots comprised of five treatments and six replicates. There were twenty plants per plot.

Data were subjected to analysis of variance and, when there was significance, means were compared by using the mean test LSD at 5% probability, according to Ferreira (2000).

Results and Discussion

Considering all analyzed variables, the first two evaluations refer to Rangpur lime rootstock, and the other three, to 'Valência' orange.

There were no significant differences for the variables plant mean height (Figure 01a), rootstock mean diameter (Figure 01b), and root (Figure 02a) and shoot dry matter mass (Figure 02b).

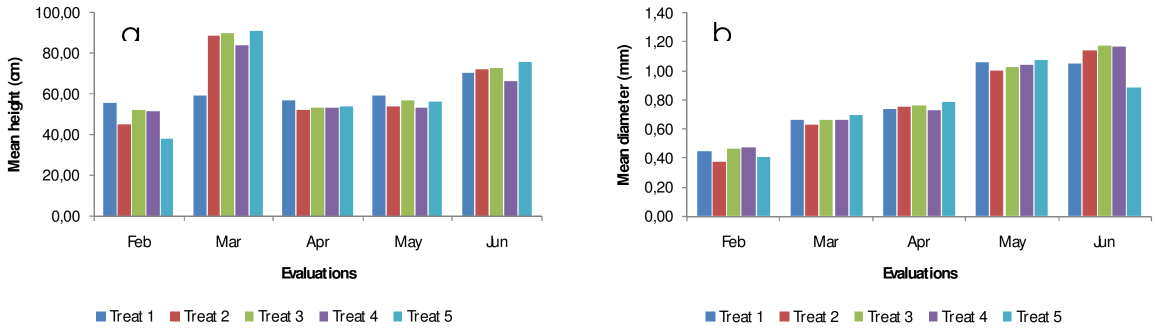

Figure 01: Plant mean height (a) and rootstock mean diameter (b) in five evaluations. Botucatu, São Paulo State, Brazil, 2008.

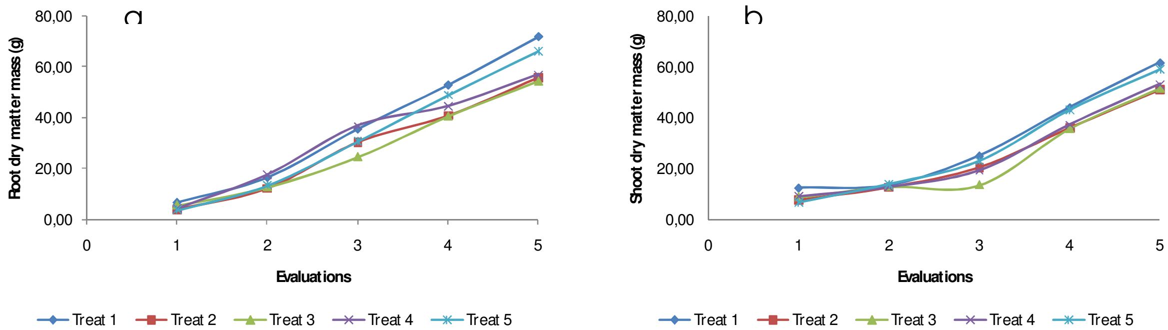

Figure 02: Root dry matter mass (a) and shoot dry matter mass (b) in five evaluations. Botucatu, São Paulo State, Brazil, 2008.

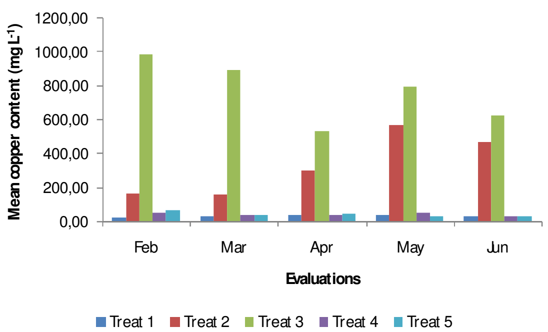

Figure 03: Mean copper content (mg L^{-1}) in five evaluations. Botucatu, São Paulo State, Brazil, 2008.

Copper content found in leaves (Figure 03) was significant for treatments two and three, both applied onto leaves. The obtained values were above the excessive levels; in cases of toxicity (levels over 300 ppm available in the soil), alterations are manifested in the roots which tend to lose vigor, become dark, present thickness and stop growing. Excessive levels can also cause iron deficiency since copper acts in reactions that affect the iron oxidation state, limiting its absorption and translocation in the plant (Denchen and Natchigal, 2006).

A probable explanation for the higher copper content in treatments applied onto leaves is the greater accumulation of the products (copper oxychloride and cuprous oxide) in the leaf cuticle which remained impregnated in the leaf surface, even after leaves were washed. According to Chamel and Gambonnet (1982), washing leaves with water removes only 40% of the copper retained in the cuticle and the remaining copper will be detected in leaf analysis; thus, the amount determined in leaf analysis does not reflect the actual nutritional condition of plants.

Nevertheless, the treatments did not interfere with plant development even at toxic levels since plants continued growing normally, which can be observed in Figures 01a, 01b, 02a and 02b.

References

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