



ORIGINAL ARTICLE

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## Symptoms of deficiency and growth of peach palm seedlings due to omission of micronutrients

*Sintomas de deficiência e desenvolvimento de mudas de pupunheira decorrentes da omissão de micronutrientes*

**ABSTRACT:** Peach palm (*Bactris gasipaes* H.B.K.) presents multiple economic uses especially regarding its heart-of-palm production; however, this species nutritional requirement should be better elucidated. In this study, we evaluated the visual symptoms of micronutrient omission, dry matter yield and nutrient contents of peach palm plants. The study was carried out in a greenhouse with randomized block experimental design with four replicates. The following treatments were adopted: complete (macro and micronutrients); complete with individual omission of B, Cu, Fe, Mn, Zn and Cl. Visual symptoms of deficiency occurred in all omission treatments. Decrease in plant size and leaf morphological alterations were observed. Dry matter yield of leaves, stem, roots and total decreased approximately 50%, with major limitation caused by Cu and B; root/shoot ratio was (Fe > B > Zn = Cl > Mn > Cu > complete) and relative growth presented the order (complete > Mn > Cl > Zn > Fe > B > Cu). Foliar nutrient contents in complete solution were (Cl > Fe > Mn > Zn > Cu). Chlorine appeared to be important for peach palm development. The most limiting micronutrients were Cu and B.

**RESUMO:** A pupunheira (*Bactris gasipaes* H.B.K.) apresenta múltiplos usos econômicos, destacando-se a produção de palmito; entretanto, a demanda nutricional da espécie ainda deve ser mais bem elucidada. Foram avaliados os efeitos das omissões de boro (B), cobre (Cu), ferro (Fe), manganês (Mn), zinco (Zn) e cloro (Cl) nos sintomas visuais, na produção de matéria seca e nos teores de nutrientes em plantas de pupunheira. O experimento foi realizado em casa de vegetação, utilizando-se mudas em vasos contendo soluções nutritivas. O delineamento experimental foi em blocos ao acaso, com quatro repetições. Os tratamentos foram: completo (macro e micronutrientes) e completo com omissão individual de B, Cu, Fe, Mn, Zn e Cl. Os sintomas visuais de deficiência se manifestaram para todos os tratamentos de omissão dos micronutrientes, permitindo-se constatar redução do porte das plantas e alterações morfológicas nas folhas. A produção da matéria seca de folhas, caule e raízes, e total reduziu-se cerca de 50% com a omissão dos micronutrientes, sendo a maior limitação ocasionada por Cu e B; a relação parte aérea/raiz foi Fe > B > Zn = Cl > Mn > Cu > completo; e o crescimento relativo apresentou a ordem completo > Mn > Cl > Zn > Fe > B > Cu. Os teores foliares em solução completa foram Fe > Mn > Zn > Cu > Cl. O Cl mostrou-se importante para o desenvolvimento da pupunheira. Os micronutrientes mais limitantes foram o Cu e o B.

## 1 Introduction

In Brazil, peach heart-of-palm (*Bactris gasipaes* H.B.K.) cultivation has increased because of the multiple uses of its fruit, which presents high nutritional value (YUYAMA et al., 2005), and its palm, which shows greater economic appeal due to its quality generating strong demand from domestic and international markets (SOARES et al., 2011). Furthermore, reduction in the raw material supply from acai palm and high market price (VERRUMA-BERNARDI et al., 2007) associated with earliness, tillering capacity and the ease of peach palm planting have encouraged its cultivation. The Brazilian production and consumption of palm are the largest in the world and 90% of this production is consumed domestically, the remainder is exported (SOARES et al., 2011). Despite the importance of palm crop to the Brazilian productive sector, research regarding its management, notably fertilization and nutrient requirement of plants, is scarce (DEENIK; ARES; YOST, 2000; FERNANDES; CARVALHO, 2001; NASCIMENTO et al., 2005).

Under field conditions, peach palm has responded satisfactorily to nitrogen (N), phosphorus (P) and potassium (K) fertilization, with best species response to N (NASCIMENTO et al., 2005; YUYAMA et al., 2005). Deficiency symptom of main micronutrients in peach palm has seldom been reported in the literature. In this sense, the work by Silva and Falcão (2002) should be highlighted; they observed deficiency symptoms such as interveinal chlorosis on plant leaves with Fe and Zn omission, as well as leaf blade corrugation due to omission of B. The same authors found no deficiency symptoms for Cu, Mn and Mo omission. In acai palm (*Euterpe oleracea*) crop, which belongs to the peach palm family, besides B omission (VIÉGAS et al., 2008), lack of Mn was also reported as limiting to plant development (VIÉGAS et al., 2004). Although little assessed in plant nutrition studies, chlorine plays an essential role in photosynthesis and osmoregulation (MARSCHNER, 2012), which is more noticeable in plants from the family Areaceae (FERNANDES et al., 2002). Species of this family are tolerant to high salinity levels caused by Cl (FERNANDES et al., 2003), also their productive potential is increased when this micronutrient is supplied through fertilization (SOBRAL; LEAL, 1999). Common visual symptoms of Cl deficiency occur in more mature tissues due to chlorine mobility from tissues of residence to developing tissues and are related to growth reduction, wilting and premature senescence of leaves, generalized chlorosis and necrosis, as well as to root system atrophy (FAÇANHA; CANELLAS; DOBBS, 2008). In this study, we aimed to evaluate the visual symptoms, dry matter yield and mineral nutrition of peach palm seedlings cultivated in nutrient solution submitted to omission of micronutrients (B, Cu, Fe, Mn, Zn and Cl).

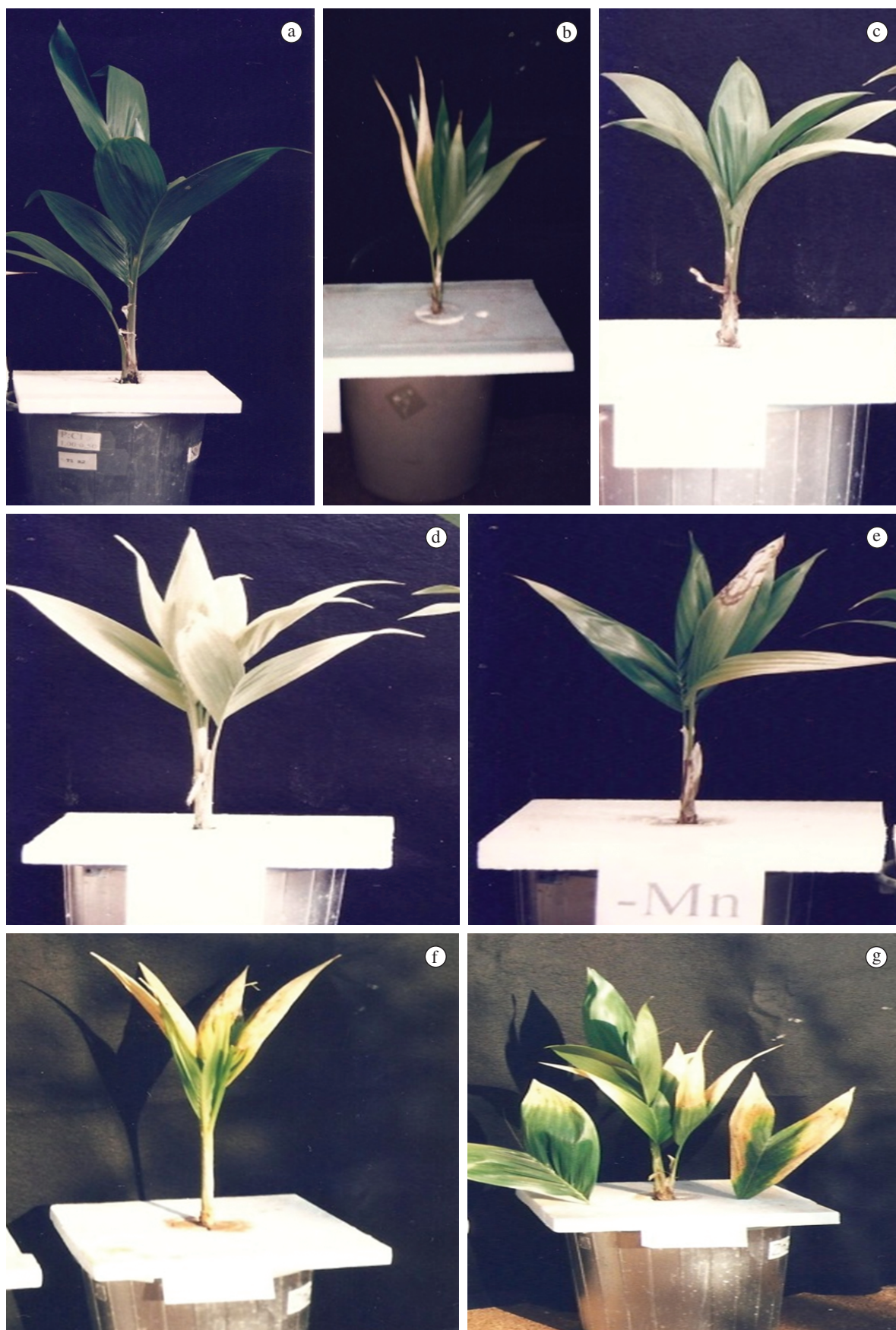
## 2 Materials and Methods

The experiment was carried out under greenhouse conditions in the Department of Soil Science at the Federal University of Lavras using peach palm (*Bactris gasipaes* H. B. K.) seedlings cultivated in nutrient solution. Seeds were germinated in plastic trays with vermiculite. Thirty days after

germination, the seedlings were placed on collection trays with capacity for 36 liters of Dufour, Quencez and Schmitti (1978) solution at ¼ ionic strength for 30 days and ½ ionic strength for 15 days; they were subsequently transferred to 9 L capacity pots where the treatments were applied for five months. The experimental design was in randomized blocks with seven treatments and four replicates adopting the missing element technique. The following treatments were applied: complete (N, P, K Ca, Mg, S, B, Cu, Mn, Zn, Fe and Cl); complete with individual omission of B, Cu, Mn, Zn, Fe and Cl. Experimental units consisted of pots containing one plant. The nutrient solutions used in this study were kept under constant aeration and were renewed every 20 days for the first two months, and every 15 days thereafter. During the experimental period, solution pH was controlled and kept above 5.5. The basic nutrient solution (DUFOUR; QUENCEZ; SCHMITTI, 1978) with macronutrient concentrations in mmol L<sup>-1</sup> was N-NO<sub>3</sub> = 8; N-NH<sub>4</sub> = 2; P = 1; K = 2; Ca = 2; Mg = 1.5; S = 1; Na = 1.0 e Cl = 0.5. The following concentrations in mg L<sup>-1</sup> were used for the micronutrients: B = 0.20 Cu = 0.05 Fe = 3.00 Mn = 0.35 Mo = 0.02 Zn = 0.05. The following salts were used: Ca(NO<sub>3</sub>)<sub>2</sub>; KNO<sub>3</sub>; NH<sub>4</sub>NO<sub>3</sub>; NaNO<sub>3</sub>; Mg(NO<sub>3</sub>)<sub>2</sub>; (NH<sub>4</sub>)<sub>2</sub>SO<sub>4</sub>; NaH<sub>2</sub>PO<sub>4</sub>; KH<sub>2</sub>PO<sub>4</sub>; KCl; MgSO<sub>4</sub>; MgCl<sub>2</sub>; Ca(SO<sub>4</sub>)<sub>2</sub>; H<sub>3</sub>BO<sub>3</sub>; CuSO<sub>4</sub>·5H<sub>2</sub>O; FeEDTA; MnSO<sub>4</sub>·H<sub>2</sub>O; (NH<sub>4</sub>)<sub>6</sub>Mo<sub>7</sub>O<sub>4</sub>·4H<sub>2</sub>O and ZnSO<sub>4</sub>·7H<sub>2</sub>O. Nutrient concentrations in the different treatment solutions were identical to the complete solution concentration, except for the nutrient omitted. After collection, plant material was separated into leaves, stems and roots and washed with distilled water; it was then oven dried with forced airflow at 65-70 °C until constant weight was reached. Plant material was weighed to obtain the dry matter of each component for later determination of root/shoot (R/S) ratio and relative growth (RG). R/S ratio was calculated dividing shoot (leaves and stems) dry matter by root dry matter. RG was determined by the following formula: RG = (dry matter with individual omission of nutrient/control dry matter) × 100. Dry matter was ground in a Wiley type mill and subjected to wet nitric-perchloric digestion for determination of Cu, Fe, Mn, Zn and Cl (MALAVOLTA; VITTI; OLIVEIRA, 1997). Results were submitted to analysis of variance (F test) and, when significant for the treatments, Tuckey's test (p ≤ 0.05) was performed for comparison of means.

## 3 Results and Discussion

B-deficient plants (Figure 1b) presented smaller growth than those submitted to the complete treatment (Figure 1a), with coarser and more brittle leaves. Leaf apices of younger leaves necrotized, and yellowing of older leaves from tips to limbo center was observed. The role played by Boron in plants is linked to development of meristematic zones, cell wall structuring and synthesis, carbohydrate and indole acetic acid (IAA) metabolism, cytokine synthesis and lignification (MARSCHNER, 2012). Thus, B deficiency in plants initially causes meristem decrease due to inhibition of growth plant hormones, while necrosis of leaves may be associated with accumulation of phenols in their tissues (FAÇANHA; CANELLAS; BOBBS, 2008). The symptoms observed are similar to those described for other species of the family



**Figure 1.** Peach palm plant corresponding to the complete treatment (a) and with omission of B (b), Cu (c), Fe (d), Mn (e), Zn (f) and Cl (g).



Areaceae such as coco palm (*Cocos nucifera*), oil palm (*Elaeis guineensis*) and acai palm. In coco palm plants, omission of B caused reduced development, less expanded leaves and necrosis (BROSCHAT, 2007). In oil palm and acai palm plants, coarsening or coriaceous appearance and reduced leaf growth were observed (VIÉGAS et al., 2008).

Omission of Cu caused reduced growth of plants regarding the complete treatment, the younger leaves became deformed and with chlorosis, which expanded to the whole leaf limbo over time (Figure 1c). Leaf deformation is related to impaired lignification of cell walls, mainly the sclerenchyma cells, as two cupric enzymes - polyphenol oxidase and diamine oxidase, which are linked to lignin biosynthesis, experience reduced activity (MARSCHNER, 2012). In guava plants, 20 days after the onset of Cu omission, the younger leaves presented sparse chlorotic spots. Over time, deficiency caused leaf blade to present corrugated or deformed surface with protrusion or protuberance of secondary veins (SALVADOR; MOREIRA; MURAOKA, 1999).

On the other hand, omission of Cu in peach palm seedlings caused no visual symptoms (SILVA; FALCÃO, 2002). Nevertheless, according to these authors, lack of response to Cu omission may be associated with this nutrient supply in a period prior to treatment induction and with solution contamination by Cu from low purity reagents. Researches carried out with sangra d'agua (*Croton urucurana* Baill) (SORREANO et al., 2008) and Australian cedar (*Toona ciliata* M. Roem var. *australis*) (MORETTI et al., 2011) plants also showed reduced growth besides twisting and deformation of younger leaves under Cu omission treatments. Leaf deformation and wilting are characteristic symptoms of Cu deficiency; leaves become brittle and may fall prematurely (TAIZ; ZEIGER, 2010).

Plants with Fe deficiency presented reduced growth compared to the complete treatment (Figure 1d). Younger leaves showed whitish color throughout the leaf blade while mature leaves presented chlorosis on the margins, which evolved towards the midrib. Fe is little redistributed from its place of residence in the plant; therefore, deficiency symptoms appear initially on younger leaves, which in extreme situations present whitish color (MARSCHNER, 2012). Reduced Fe redistribution through the phloem is a result of its precipitation in the older leaves as insoluble phosphate oxide and of its phytoferritin storage (TAIZ; ZEIGER, 2010). Fe deficiency in plants compromises the formation of chlorophyll complexes and ferredoxin, a non-heme iron protein that participates in electron transport in photosynthesis. Therefore, under Fe deficiency plants have only xanthophyll and carotene - yellowish pigments, which explains chlorosis and white colored leaves (MALAVOLTA; VITTI; OLIVEIRA, 1997). Moreover, Fe-deficient plants present reduced respiratory activity, which is compromised by electron transport in the terminal oxidation processes in mitochondria (MALAVOLTA, 2006), reducing growth. Similar symptoms were observed by Silva and Falcão (2002) in peach palm plants and by Lange et al. (2005) in mammon plants (*Ricinus communis* L.), both Fe-deficient. Symptoms of Mn deficiency were characterized by reduced plant growth compared to the complete treatment, younger leaves presented chlorosis

throughout the leaf blade and older leaves showed coalesced necrotic lesions from the margins until the mid-part of the limbo (Figure 1e). Mn is present in the antioxidant system enzymes, as in the superoxide dismutase, which regulates oxygen reactive species in plant; insufficient supply of this nutrient may cause elevated levels of the superoxide radical ( $O_2^{\cdot-}$ ) with harmful effect on tissues (MARSCHNER, 2012), explaining leaf necrosis. Reduced growth may be associated with decreased cell division and reduced photosynthesis due to inhibition of water photolysis or Hill reaction, which provides electrons to photosynthetic reaction, while tissue chlorosis is associated with structural alterations in chloroplast due to reduced lipid synthesis (TAIZ; ZEIGER, 2010). Omission of Mn in acai palm plants caused reduction in plant size (VIÉGAS et al., 2004) and, in sangra d'agua plants (*Croton urucurana* Baill) (SORREANO et al., 2008), Mn deficiency caused necrotic spots throughout the limbo. In guava plants, interveinal chlorosis in leaves from the middle third shoot, paleness of younger leaves and early reticular formation of ribs were observed (SALVADOR; MOREIRA; MURAOKA, 1999; SALVADOR et al., 2003).

Zn deficiency reduced plant growth and promoted chlorosis, narrow and elongation of younger leaves (Figure 1f). Over time, necrosis occurred from leaf margins towards the rachis and leaves acquired rosette shape. Symptoms of Zn deficiency occurred initially on younger leaves because it is an element of little mobility in plants (MALAVOLTA, 2006). Reduced growth and leaf expansion are consequences of less intensive enzymatic activity and indoleacetic acid synthesis caused by Zn deficiency, while tissue chlorosis is associated with increased activity of toxic oxygen radicals (TAIZ; ZEIGER, 2010). Moreover, Zn deficiency affects the synthesis of auxins and amino acids and, because it is a structural constituent of various enzymes such as oxidases and dehydrogenases and it is involved in nitrate reduction and formation of chloroplasts (MARSCHNER, 2012), reduces photosynthesis and growth. Similar Zn deficiency symptoms were observed by Silva and Falcão (2002) in peach palm plant and by Neves, Sá and Carvalho (2004) in umbu plant (*Spondias tuberosa* Arr. Cam.). In guava plant, leaves became smaller, narrower and pointed with protruding ribs and strong interveinal chlorosis with marked green ribs (SALVADOR; MOREIRA; MURAOKA, 1999).

Cl-deficient plants became smaller than those in the complete treatment and presented leaves, mainly the older ones, with necrosis in the tips and margins and chlorosis from the margins towards the midrib (Figure 1g). Such observations are important because of the small amount of research related to Cl deficiency in plants. These foliar symptoms differ from those observed for Cl-deficient soybean plants, which presented interveinal chlorosis of older leaves (SFREDO; BORKERT, 2004).

Presence of bronze color leaves is one the marked symptoms of Cl deficiency (TAIZ; ZEIGER, 2010); this was not observed in the work though. Necrosis of older leaves occurs because of the high redistribution or mobility capacity of this element to more photosynthetically active tissues (MALAVOLTA, 2006). Cl participates in water photolysis together with Mn; therefore, its absence directly compromises photosynthesis reducing

plant growth, in addition, because of its role in osmotic regulation, its deficiency also compromises cell turgescence (FAÇANHA; CANNELAS; DOBBS, 2008). In species of the family Areaceae, which present higher Cl requirement, the lack this element is also related to wilting and premature senescence of leaves, as well as to rupture of younger leaves and stem (MARSCHNER, 2012) at very advanced levels of deficiency. Individual omission of micronutrients limited ( $p \leq 0.05$ ) the dry matter yield of leaves, stems and roots of peach palm plants compared to the complete treatment with no difference between the elements (Table 1). Nutrient omission effects on dry matter of peach palm plants had not yet been reported in the literature; therefore, such results are important as they noted that the omission of each micronutrient reduced by 50% the dry matter of plant parts. Zn was not limiting to leaf and root dry matter yield of acai plants (VIÉGAS et al., 2004).

Total dry matter yield was less limited by Mn omission while the opposite was observed for Cu omission; therefore, the greatest limitations to peach palm plant development resulted from Cu omission. In guava plants, omission of Mn was also the least limiting factor to dry matter yield (SALVADOR; MOREIRA; MURAOKA, 1999). Cu omission was also the most limiting factor to Australian cedar crop (*Toona ciliata* M. Roem var. *australis*) (MORETTI et al., 2011). B omission caused the second greatest reduction in dry matter yield after Cu. B omission was also influential in acai (VIÉGAS et al., 2008) and sunflower (*Helianthus annuus*), which presents high B requirement (SOUZA, OLIVEIRA; CASTIGLIONI, 2004), as well as in eucalyptus (*Eucalyptus* sp.), which is associated with the serious problem of dry pointer (RAMOS et al., 2009).

Root/shoot (R/S) ratio followed the treatment order: Fe > B > Zn = Cl > Mn > Cu > complete. This pattern demonstrated that all micronutrients were more limiting to roots than to shoot and that omission of Fe and B were the most expressive. Fe deficiency in roots is associated with inhibition of elongation and diameter size of apical zones (MARSCHNER, 2012). Fe influences the activity of peroxidases, enzymes responsible for cellular expansion and growth, differentiation and development, metabolism of auxins, nucleic acids and lignification (CUNHA et al., 2009). On the other hand, high levels of Fe affected the growth of guarana plant seedlings and caused leaf blight (PEREIRA et al., 2012). Omission of B leads to coarsening and death of root apices (MALAVOLTA;

VITTI; OLIVEIRA, 1997). B deficiency in the root system reflects on the enzymes that metabolize carbohydrates, lignin, auxins and nucleic acids, and also increases phenol contents reducing root growth (FAÇANHA; CANNELAS; DOBBS, 2008). The different treatments caused reduction in RG in the following order: complete > Mn > Cl > Zn = Fe > B > Cu. Thus, the omission of each micronutrient compared to the complete solution reduced plant dry matter by 50% for Mn, 52% for Cl, 56% for Zn and Fe, 58% for B and 60% for Cu, demonstrating that, for peach palm plant, Mn is the least limiting micronutrient while Cu is the most limiting one. This pattern was different from that found for acai palm plants, in which RG followed the order complete > Fe > B > Zn > Cu > Mn, showing Mn greater limitation to plant growth (VIÉGAS et al., 2004). It is important to note that Cl reduced seedling dry matter by over 50% demonstrating the relevance of this element in peach palm nutrition, reported by Fernandes et al. (2002) as important for the growth of family Areaceae species. On the other hand, according to Fernandes et al. (2003), peach palm maximum growth occurs in nutrient solution at 0.5 mmol L<sup>-1</sup> dose of Cl and plant growth is reduced beyond this level due to nutritional imbalance. Micronutrient foliar contents in the complete treatment followed the order Cl > Fe > Mn > Zn > Cu (Table 2). This pattern, excepting Cl, is similar to that found by Deenik et al. (2000) for peach palm leaves cultivated in Costa Rica considering that these authors discriminate adequate variation (mg kg<sup>-1</sup>) ranging from 100-200 for Fe, 50-200 for Mn, 15-25 for Zn and 8-15 for Cu. Silva and Falcão (2002) observed Fe and Zn contents for the shoot of 175 and 33 mg kg<sup>-1</sup>, respectively. The contents observed were higher than the ones found for oil palm crop (MALAVOLTA, 2006). Therefore, it is possible to observe that the micronutrient contents found for peach palm plant at adequate nutritional level in the present research were greater than those reported in the literature. However, it is worth noting that different from the findings of other works, in the present study, we used the Dufour, Quencez and Schmitti (1978) nutrient solution, originally created for palm tree cultivation. It is possible to imply then that the adequate values for peach palm foliar nutrition are those correspondent to the complete treatment (Table 2).

The absence of each micronutrient (Cu, Fe, Mn, Zn and Cl) reduced its respective content compared to the complete treatment; this was more significant for Fe. Peach palm plants

**Table 1.** Dry matter of leaves, stem, roots, shoot (S), total, root/shoot ratio (R/S) and relative growth (RG) of peach palm plants according to micronutrient omission treatments.

Treatment	Leaf	Stem	Roots	S	Total	R/S	RG
	g/plant						
Complete	30.5 a	30.3 a	29.9 a	60.2 a	99.7 a	2.0	100
-B	15.5 b	14.3 b	12.4 b	29.8 bc	42.1 bc	2.4	42.2
-Cu	15.1 b	11.7 b	12.9 b	26.8 c	39.7 c	2.1	39.8
-Fe	16.6 b	14.6 b	12.4	31.2 bc	43.6 bc	2.5	43.7
-Mn	18.9 b	15.0 b	15.0 b	33.9 b	49.5 b	2.2	49.6
-Zn	16.6 b	13.8 b	13.1 b	30.4 bc	43.6 bc	2.3	43.7
-Cl	17.6 b	15.6 b	14.4 b	33.2 b	47.6 bc	2.3	47.7
CV%	12.4	11.9	11.9 b	11.2	13.0		

Means followed by the same letter in the column do not significantly differ by the Tuckey test ( $p \leq 0.05$ ).

**Table 2.** Micronutrient foliar contents in peach palm plant seedlings according to micronutrient omission treatments.

Treatments	Cu	Fe	Mn	Zn	Cl
	mg kg <sup>-1</sup>				g kg <sup>-1</sup>
Complete	20.2 a	373.4 b	88.4 b	59.3 a	7.6 b
-B	5.2 b	282.8 b	90.2 b	40.6 ab	6.8 b
-Cu	3.9 b	415.9 a	124.4 a	31.6 b	9.1 ab
-Fe	3.9 b	125.8 d	84.3 b	31.6 b	11.2 a
-Mn	2.6 b	215.0 c	52.2 c	29.8 b	10.7 a
-Zn	2.6 b	279.8 c	82.2 b	27.8 b	9.8 ab
-Cl	3.5 b	232.2 c	78.8 b	27.7 b	1.3 c
CV (%)	11.6	22.0	14.8	13.4	8.7

Means followed by the same letter in the column do not differ by the Tuckey test ( $p \leq 0.05$ ).

submitted to Fe omission presented content of 191 mg kg<sup>-1</sup> in a work carried out by Silva and Falcão (2002), higher than the one in the present study. The lower value found in this work may be related to the form and time of seedling preparation until treatment application. In the work developed by Silva and Falcão (2002) the seedlings were placed in washed sand after germination and received Fe solution for two months and then the experimental period was carried out in the same substrate – a methodology different from the one adopted herein.

## 4 Conclusions

Visual symptoms of micronutrient deficiency were easily identified and were similar to those presented by other crops. The micronutrients that influenced plant growth the most were Cu and B. Micronutrient foliar content in complete solution followed the order Cl > Fe > Mn > Zn > Cu. The micronutrient contents adequate to peach palm cultivation in mg kg<sup>-1</sup> were the following: 20.4 to 29.2 of Cu; 124.0 to 373.4 of Fe; 78.8 to 124.4 of Mn; 40.6 to 59.3 of Zn; and 2.5 to 9.5 g kg<sup>-1</sup> of Cl.

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