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Soil fertility and citrus nutrition in the central Amazon region. Fertilidade do solo e nutrição de citros na região central da Amazônia.

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Abstract

We aimed assess the soil fertility and nutritional status of pear orange plants in different orchards in the State of the Amazonas. The most soils showed: i) acidic pH and with high levels of Al; ii) low content of organic matter and base saturation; iii) low levels of P; K, Ca, Mn, Zn and B. The plants were deficient in Ca (86%), K (62%), S (52%), Mn (100%), Zn (86%), B (80%) and with excess of N (81%) and P (51%). We conclude that there is an urgent need to adjust the soil fertility in orange orchards aims to increase fruit yield and quality.
Keywords: Crop manage. Fertilization. Nutrient availability. Nutrient deficiency.

Resumo

Objetivamos com o presente estudo avaliar a fertilidade do solo e o estado nutricional de plantas de laranjeira pêra em diferentes pomares no estado do Amazonas. A maioria dos solos apresentou: i) pH ácido com níveis elevados de Al; ii) baixo teor de materia organica e saturação de base; iii) baixos níveis de P; K, Ca, Mn, Zn e B. As plantas estavam deficientes em Ca (86%), K (62%), S (52%), Mn (100%), Zn (86%), B (80%) e com excesso de N (81%) e P (51%). Concluimos que é urgente ajustar a fertilidade do solo nos pomares de laranjeira pêra visando aumentar o rendimento e a qualidade dos frutos.
Palavras-Chave: Manejo de culturas. Fertilização. Disponibilidade de nutrientes. Deficiência de nutrientes.

Introduction

The citrus production in Amazonas State, Brazil, is basically to supply the local demand of fruits consumed in nature. Considering the production of 71,830 of fruits in the citrus orchards of Amazonas State, the average yield in the state is 22.0 kg ha^{-1}, below the national average of 29.641 kg ha^{-1} (IBGE, 2017). Thus it is urgent to increase the yield of agricultural areas avoiding the deforestation in Amazonas. As well-known, the use of fertilizers and the best knowledge of soil fertility and plant nutrition play a key role on yield.

Previous surveys of nutritional status and soil fertility of citrus orchards were done in Israel (RAVEH, 2013), India (SRIVASTAVA; SHYAM, 2006), Florida (OBREZA; SCHUMANN, 2010), and Pakistan (RAZI et al., 2011). The foliar analysis evaluates the nutritional status of crops taken as a method of evaluating the nutritional condition of crops in certain leaves are analyzed (standard sheet) at defined periods of the plant cycle (PARENT, 2011).

Studies regarding soil fertility and citrus nutrition were carried out on São Paulo (CANTARELLA et al., 2003), Florida (MATTOS JUNIOR et al., 2003), Mediterranean (RASHID; RYAN, 2004) and China (WANG; GONG, 1998). Some surveys of citrus nutrition were carried out in São Paulo, the main state of citrus production in Brazil. In Pará, and Goias State, Brazil, P, K, Ca, Zn, Mn and B were the most limiting nutrients for Pêra orange yield (SANTANA et al., 2007), and it was mainly because the inadequate management of soil fertility and mineral nutrition of plants. Some studies pointed a nutritional imbalance in citrus in Amazon (Dias et al., 2013). A general survey (MOREIRA; FAGERIA, 2009) indicated limitations of soil fertility for crops production in Amazon state.

Thus a survey in Amazonas state is necessary to identify the nutricional status of citrus crop in Amazon to adjust and/or to develop a nutritional management in this region. Thus we evaluated the soil fertility and plant nutrition of citrus orchards on Amazon.

Material and methods

Study areas

On five municipalities of Amazon State - Manaus, Rio Preto da Eva, Iranduba, Manacapuru and Presidente Figueiredo - four citrus orchard were selected at well drained Haplic Acrisol and Rodic Ferralsol planted with seven years ‘Pêra’ orange [*Citrus sinensis* (L.) Osbeck] on ‘Rangour’ lime (*Citrus limonia* Osbeck), 7 x 4 m spaced, totalizing 357 plants ha^{-1}.

Considering the visual homogeneity of plants, each orchard was divided on four citrus grove block with 112 m^2, composed by four trees (4 grove blocks x 4 trees; n = 16), totalizing 80 grove blocks for soil and leaves sampling.

A questionnaire was filled by citrus growers with the following information: i) agronomic management; ii) yield; iii) varieties; iv) rootsctock; v) spacing; vi) plant age; viii) pests and diseases management and; and ix) nutrient management.

Soil sampling and analysis

In February and March 2010, on each citrus grove block four soil cores were sampled from the trunk at 0 to 20 and 20 to 40 cm depth, to make a composite sample for each depth. Two sub samples were taken from the right side of blocks at first and third plants, and two sub samples were taken from the left side at second and fourth plants (SANTANA et al., 2007).

Air-dried soil samples were ground to 2 mm particle size before the following chemical analysis according to Embrapa (2009). Soil organic matter (S.O.M) was determined by the oxidation of C with $K_2Cr_2O_7$; Soil active acidity (pH_{H2O}) was determined in water at 1:2.5 soil: solution ratio. Soil total acidity (H+Al) was determined using a pH 7.0 SMP buffer solution. Potassium, P, Cu, Fe, Mn and Zn were extracted with Mehlich^{-1} solution (1:10). Potassium was determined by flame-emission photometry (FEP) and P by the colorimetric method (λ = 660 nm) (Micronal B642) with acid solution of $(NH_4)_6$ Mo_7O_{24}. Copper, Fe, Mn and Zn were determined by atomic absorption spectrophotometry (AAS) (Perkn-Elmer, model 1100B). Calcium, Mg and Al were extracted with a 1 mol L^{-1} KCl solution and also determined by AAS. Sulphate was extracted with $Ca(H_2PO_4)_2$, solution and determined turbidimetry with $BaCl_2$ in spectrophotometer (λ = 420 nm). Available B was extracted with $BaCl_2$ solution heated in hot plate and determined by colorimetric method using curcumin (λ = 660 nm). The following variables were calculated: cation exchange capacity at pH 7.0 (CEC), basis saturation (BS%), and aluminum saturation (m%). Soil granulometric fractions were determined using the Bouyoucos (1927) method modified by Carvalho et al. (1988) with NaOH 0.1 mol L^{-1} solution.

For the samples at 20 to 40 cm depth, only Ca, exchangeable Al^{3+} and m% were determined.

Leaf sampling and analysis

The canopy of plants used as soil-sampling reference were divided into four quadrants (N, S, E, W) and in the middle third of canopy five leaves were collected on each quadrant (20 leaves per plant and 80 leaves per citrus block grove). Twigs with 2 to 4 cm diameter fruits were chosen and the third leaf far from the fruit was sampled (EMBRAPA, 2009). Leaves were rinsed in deionized water and then in a low-concentration detergent solution (0.1%), rinsed in deionized water and dried in a forced-air oven at 70 ºC until constant weight. The leaves were ground in a Willye mill and an aliquot of 0.5 g was digested in 6 mL of HNO_3 + HCl (2:1) on block digester (Tecnal model TE 040/25), at 210 ºC and P, K, B, Cu, Fe, Mn and Zn were determined in Inductively Coupled Plasm (ICP) (MALAVOLTA et al., 1997). Calcium, Mg were determined by AAS, and S by turbidimetry and for N determination samples of 0.1 g were digested in 2 ml of H_2SO_4 + 0.5 ml of H_2O_2 on plate heater at 200 ºC, and the digested solution distilled on using semi-micro-Kjeldahl distiller (Marconi, MA036, Brazil) and titrated using H_2SO_4 (0.02 mol L^{-1}) (MALAVOLTA et al., 1997). The P was determined by the reduction of the phosphomolybdate vitamin C, and K by flame photometry.

Statistical analysis

The Shapiro-Wilk test ($P \geq 0.05$) was used to evaluate the normality of the data. Descriptive statistic was used to evaluate (n = 16) the central tendency (mean, minimum and maximum) and data variability (standard deviation - SD and coefficient of variation - CV). The soil variables SOM, T, pH, K, Ca, Mg, S, Mn, Zn, Cu, B, m% and BS% were interpreted according to the Paulist Group of Liming and Fertilization for Citrus (1994) and Quaggio et al. (1997). Phosphorus and gronulometry were interpreted according to CFSEMG (1999). Quaggio et al. (2014) was used to interpret the nutrients concentration on leaves. Nutrients at higher frequency of “low” and “high” levels were considered the most limiting.

Results

At 1% and 5% level all variables of soil and plant analysed have normal distribution (Table 1 and 2).

Agronomical management of orchards

The questionnaire answered by citrus growers showed that: i) the average land area is 30 ha; ii) only 50% of growers analyse the soil fertility each two years, and 10% used leaf tissue analysis on the nutrient management; iii) 100% of citrus growers planted Pêra orange on Rangour lime at 7 x 4 m spacing and; iv) the average yield is ~800 fruits plant^{-1} yr^{-1}, with 90% of production for fresh consume and 10% for juice. Growers do not register yield based on fruit mass (t ha^{-1}), only number of fruits.

Liming is appled at rate of ~ 3 t ha^{-1} of dolomitic lime limestone (14% of MgO, 32% of CaO and relative neutralizing power = 90%), each two or three years.

Twice a year 2 kg plant^{-1} of N-P-K, 20-00-20, + 1 g of single superphosphate. Besides, three times a year 2 g L^{-1} of a commercial fertilizer is sprayed on leaves (13% of Zn; 6% of Mn; 4% of B; 0.1% of Mo; 0.7% of Mg and 7% of S) + 5 g of B as H_3BO_3 applied on the soil.

For the control of the main disease – Verrugose – (*Elsinoë* spp.) - they use commercial products based on $ClCu_2H_3O_3$ and Cu $(OH)_2$.

The lack technical support for lime and fertilizer use is pointed by growers as the main reason for the low yield in Amazon.

Chemical properties of soil at 0 – 20 cm depth

In general, considering all soil variables at 0 - 20 cm depth, SOM, pH, P, K, Ca, Mn, Zn and B were considered at low ranges. On the other hand, S, Cu and Fe had adequate or high levels (Table 1). Exchangeable Al^{3+} in soil was mostly at medium or high ranges.

Tabela 1. Minimum (Min), maximum (Max), average, standard desviation (SD), adequated (A), coefficient of variation (CV), Shapiro-Wilk (W) test and distribution of frequency for soil variables at 0 – 20 cm depth of citrus orchards (n = 16) cutivated with 'Pêra' orange in Amazon.

Variables	Sufficiency Levels and Occurence										
	Min	Max	Aver.±SD	CV	W	Low	%	A	%	High	%
pH	4.0	4.8	4.5±0.5	62.2	0.90*	< 4.5	100	5.5 – 6.0	0.0	>6.0	0
g kg^{-1}											
S.O.M	13.2	48.7	26.6±10.6	40.0	0.90*	<30	100	30 –45	0	>45	0
$cmol_c$ dm^{-3}											
H + Al	1.0	4.0	2.2±0.9	39.1	0.89*	<2.5	67	2.5 – 5.0	33	>5.0	0
C.E.C.	1.5	4.7	2.6±0.6	12.8	0.95**	<9.0	100	9.0 –13	0	>13	0
Al^{3+}	0.1	2.0	0.8±0.5	5.5	0.91*	< 0.5	37	0.51 – 1.0/3	35	> 1.0/3	28
%											
BS	28.1	81.0	54.9±13.6	24.8	0.97**	<60	57	60 – 70	27	>70	16
M	3.1	57.4	24.1±14.3	59.0	0.94**	< 30	56	31 – 50	40	> 50	4
Clay	37.5	75.0	64.8±10.5	19.3	0.91*	<15	0	15-36	0	> 36	100
mg dm^{-3}											
P	2.1	5.0	4.4±1.2	27.7	0.95**	< 5.5	92	5.5 – 5.8	4	> 5.8	4
K	20.0	54.0	33.5±7.0	21.1	0.96**	< 8.0	100	8.0 –12	0	> 12	0
Ca	0.9	2.8	1.6±0.5	29.0	0.94**	< 50	97	50 – 80	3	> 80	0
Mg	0.5	1.8	0.9±0.2	25.7	0.91*	< 1.5	57	1.5 – 7.0	43	> 7.0	0
S	15.2	38.1	25.0±5.1	20.6	0.97**	< 0.5	1	0.5 – 2.0	99	> 2.0	0
Mn	0.21	0.9	0.5±0.2	30.2	0.76*	< 4.1	100	4.1-9.9	0	> 9.9	0
Zn	0.02	0.9	0.2±0.2	77.3	0.76*	<1.0	100	1.0 – 1.6	0	>1.6	0
Cu	0.04	0.7	0.2±0.12	70.6	0.80*	<0.4	1	0.4 – 0.8	24	>0.8	75
Fe	24.4	139.0	47.3±17.7	37.4	0.79*	<30	9	30 – 45	36	>45	55
B	0.02	0.1	0.05±0.01	20.0	0.87**	<0.2	75	0.2 – 0.5	5	>0.5	20

H+Al = Potential acidity; S.O.M = Soil organic matter; C.E.C = Cation exchange capacity at pH 7.0;BS = Basis saturation; m = Aluminum saturation; Al^{3+} = Exchangeable aluminum; P = Available phosphorus (M-1); K = Exchangeable potassium (KCl); Ca = Exchangeable calcium (KCl); Mg = Exchangeable magnesium (KCl); S = sulfur as sulfate; Mn = Manganese (M-1); Zn = Zinc (M-1); Cu = Copper (M-1); Fe = Iron; B = Boron. For H+Al, m, Al^{3+}; the "adequated" level is changed by "medium".*, ** = significant difference at $P \geq 0.05$ and 0.001, respectively.

Acidity, aluminum, soil organic matter

The average of H+Al of studied blocks was in the low range with values between 1 and 4 $cmol_c$ dm^{-3} and S.O.M ranged between 13 and 49 g kg^{-1}, average 26±10 g kg^{-1} (low). About 63% of citrus blocks had medium or high Al^{3+} concentration, besides 67 and 100% of samples were at low range for H+Al and SOM, respectively (Table 1). Soil pH ranged between 4.0 and 4.8 (Table 1) with 100% of blocks with pH values lower than 4.8 (Table 1). Most of areas (57%) had low BS levels.

Macronutrients in soil

In general Ca (97%) and Mg (57%) were low in the blocks (Table 1). Calcium ranged between 0.9 and 2.8 $cmol_c$ dm^{-3} with average of 1.6±0.5 $cmol_c$ dm^{-3}. Magnesium levels ranged between 0.5 and 1.8 $cmol_c$ dm^{-3} at average of 0.9±0.2 $cmol_c$ dm^{-3}. All studied areas had low exchangeable K concentration, at average of 33.5±7.0 mg dm^{-3} (Table 1). Most of the blocks (92%) had low level of available P. On the other hand, average S concentration was 25.0±5.1 mg dm^{-3} with 99% of blocks at adequate range (Table 1).

Micronutrients in soil

Bore, Mn and Zn were mostly at deficiency range in soil. On the other hand, 75% and 55% had high ranges of Cu and Fe, respectively (Table 1).

Chemical properties of soil at 20 – 40 cm depth

Considering exchangeable Ca at 20 – 40 cm depth the average concentration, 87% of samples, were at low level. Regarding Al^{3+}, 100% of samples, and for m%, 92% of had medium or high level (data not shown).

Macronutrientes in leaves

The macronutrients concentrations in leaves were (in g kg^{-1}): N (29.2±3.6), P (1.6±0.2), K (9.5±2.1), Ca (27.3±6.0), Mg (3.8±1.0) and S (2.0±0.5) (Table 2). Considering N (81%), P (51%) and Mg (46%) of citrus leaves were at high range, besides most plants were at low range for K (62%), Ca (86%) and S (52%) (Table 2).

Tabela 2. Minimum (Min), maximum (Max), average, standard desviation (SD), adequated (A), coefficient of variation (CV), Shapiro-Wilk (W) test and distribution of frequency of nutrients of Pêra orange leaves (n = 16) cultivated in Amazon

Nutrients	Sufficiency Levels and Occurence										
	Min	Max	Aver.±SD	CV	W	Low	%	A	%	High	%
g kg^{-1}											
N	10.0	36.0	29.2±3.6	12.3	0.83*	<25.0	2	25-30	17	>30	81
K	5.5	15.2	9.5±2.1	22.0	0.99**	<12.0	62	12-16	36	>20	2
Ca	15.6	42.8	27.3±6.0	22.1	0.97**	<35.0	86	35-50	14	>60	0
Mg	1.5	6.5	3.8±1.0	26.3	0.98**	<3.5	10	3.5-5.0	44	>6.0	46
P	1.0	2.2	1.6±0.2	15.7	0.98**	<1.2	5	1.2-1.6	44	>2.0	51
S	0.8	3.3	2.0±0.5	24.6	0.98**	<2.0	52	2.0-3.0	46	>5.0	2
mg kg^{-1}											
Fe	42.3	113.1	76.7±15.8	20.6	0.99**	<49.0	5	50-120	95	>200	0
Mn	3.8	29.0	13.7±4.6	33.9	0.96**	<35.0	100	35-75	0	>100	0
Zn	10.2	43.7	17.9±6.7	37.2	0.85*	<50.0	86	50-75	14	>100	0
B	16.5	115.8	49.5±19.0	38.4	0.92**	<50.0	80	75-125	20	>200	1
Cu	2.0	77.2	17.5±18.8	107.8	0.63*	<4.0	2	8.0-12	53	>20	45

Quaggio et al. (2014) - IAC: Novo Boletim 100, (not published data). *, ** = significant difference at $P \geq 0.05$ and 0.001, respectively.

Micronutrients in leaves

The distribution of frequency showed that 100, 86 and 80% of citrus blocks were classified at low level for Mn, Zn and B, respectively. Iron (95%) and Cu (52%) were mostly at the adequate levels in plants (Table 2).

Considering the sufficiency levels, the limiting order of nutrients in plants were in the following order: Ca > K > S > Mn > Zn > B, and the limiting nutrients in the soil were: P > K > Ca > Mn > Zn > B.

Discussion

Agronomic management of citrus orchards

It is necessary to increase the monitoring of soil fertility and plant nutrition because only 50% of citrus growers are using soil fertility evaluation and 10% are doing plant analysis. As well-known, the nutrient availability in soil is closed related with their concentration in plants and consequently plant yield. Moreover, the nutritional status of plants is related with productivity gains and detects and corrects nutritional imbalances or helps to optimize the management of fertilization (MALAVOLTA et al., 1997; RASHID, 2005).

In São Paulo state the average of fruits harvest by tree were ~460 fruits per tree, considering the 15.8×10^7 fruiting trees and 10.6×10^9 kg of orange produced in 2016 (IEA, 2016) and the weight of 0.146 kg per each orange fruit (POZZAN; TRIBONI, 2005). The number of fruit per tree is much lower than observed in this survey, ~800 fruits plant^{-1} yr^{-1}, despite the lower fertility of soil. - However, in this study were not considered fruit quality parameters -. This higher number of fruits per tree comparing with São Paulo state is may related with higher pluviosity, of 2,370 mm yr^{-1} and average temperature of 27.7 ºC observed in Manaus, Amazonas compared with São Paulo state, 1,150 mm yr^{-1} and 23.6 ºC, at Caranduva municipality (INMET, 2016). In Amazonas growers revealed that fruits are present in the trees almost every year long, despites there are two peak of harvest on February – May and October - December.

Soil acidity

The high soil acidity and Al^{3+} concentration are related with inefficient management of liming and lack of technical assistance as confirmed by the citrus growers. Considering 3,340 soil samples evaluated in Amazon state, the average pH was under natural conditions, suggesting the natural acidity of these soils due to the intense weathering, basis leaching and rapid decomposition of SOM (MOREIRA; FAGERIA, 2009). Considering the absence of technical bulletin of lime and fertilizers recommendation in the Amazon state, we highlight the need of liming rates adjusts because 100% of citrus blocks had pH lower than 4.8. Considering 13 different soil types in Amazon was estimated the average rate of lime necessary for citrus crop is 6.1 t ha^{-1} instead of 3.0 t ha^{-1} actually used by citrus growers (BATISTA, 2014). It is well known the response of citrus to the basis saturation (BS%) of 70% because its high demand of Ca (CAMACHO et al., 2012).

This scenario emphasizes the urgency need of technical support of agricultural extension as well studies to determine the specific critical levels, sufficiency ranges, calibrated to this region by long-term studies on field.

Low Ca and high Al^{3+} and m% at 20 – 40 cm layer suggest that citrus growers of Amazon do not use of gypsum that has ~ 18% of Ca and ~ 15% of S which increase levels of Ca and neutralizes Al^{3+} [$Al_2(SO_4)_3$] at layer > 20 cm depth.

Soil Macronutrients

Potassium was the most limiting nutrient in soil followed by Ca and Mg (Table 1). This result suggests to split K application more than twice a year, and to calibrate K levels in Amazon, as well as Ca could be increased alternating calcitic limestone with dolomitic limestone to increase Ca:Mg at 4:1. In Amazon, the estimated average of lime rate to raise pH was 6 t ha^{-1} (BATISTA, 2014), instead of 3.1 t ha^{-1} reported by citrus growers. A study with more than 3 thous and soil samples from Amazon State found deficiency of K, Ca and Mg in soils because of the inadequate soil fertility management (MOREIRA; FAGERIA, 2009).

The general low concentration of extractable P (Table 1) corroborates with the low P rates used by citrus growers. Besides, the P deficiency is common in soils of Amazon rainforest (PEREIRA et al., 2014) and between 80 to 100% of these soils had P concentration lower than 5 mg dm^{-3} (MOREIRA; FAGERIA, 2009). It is well known the lower P concentration on acid soils highly weathered with high concentration of Al of tropical soils.

Macronutrients in leaves

Although the low SOM concentration in soil (< 3%), were found high N concentration in citrus leaves, probably due to the high N fertilization rates used by citrus growers. On the other hand, despite P concentration in leaves mostly adequate or at high level (Table 2), it was low in soil (< 8 mg dm^{-3}) (Table 1). This may be associated with plant efficiency to absorb it more efficiently due to the high mobility of P on plant, also for cycling/recycling of P in plants through homeostatic processes adjusting the internal recycling of inorganic P reallocating P from tissues to younger (SHEN et al., 2011).

The generalized K and Ca deficiency probably by the K and Ca imbalance in soil (Table 1 and 2) reflecting their lower content in leaves. As these nutrients are absorbed by the same way, probably Mg absorption was preferred to other cations (MEDEIROS et al., 2008). Moreover, these results suggest the need of attention on K fertilization. Fruit size increased with K rates which was associated with K concentration in leaves (QUAGGIO et al., 2011), most influent nutrient on fruit quality variables. Thus, suggesting that despite the higher number of fruits per tree reported by grower, their quality and mass are low. Therefore, following the low yield 7 t ha^{-1} in Amazonas, comparing with the brazilian average of 20 t ha^{-1} (IBGE, 2017).

Low Ca concentration in citrus leaves is due to natural low concentration of Ca in highly weathered soils besides the insufficient liming rates used by citrus growers. It is common to find lower Ca concentration in younger leaves as consequence of low mobility of Ca in the phloem, competition between fruits and leaves by assimilates (FERREIRA et al., 2012).

Although most of citrus blocks had low S concentration on soil, ~ 50% of samples were S under-nourished (Table 1 and 2). The the low S mobility in the phloem and its redistribution may explain this fact (CRAM, 1990). The increasing N levels in plants also tend to reduce S concentration in plants (EMBLETON et al., 1978). Moreover, the out-of-season fruits - very intense in Amazon – may contribute as S drain.

Soil Micronutrients

Low Mn and Zn on soil are explained by the wrong rates, source, application way chosed by grower. Besides, the minerals of these soils (eg.: kaolinite, goethite, gibssite and hematite) have low interactivity with Mn and Zn facilitating their leaching.

The low B soil concentration is also related with its low concentration in soils and insufficient fertilization rates used by growers (Table 1). Low SOM was previously associated B concentration in soil was previously reported (MALHI et al., 2003) as we found (Table 1). Zinc and B deficiency are usually reported on soils from Brazil (FRANCO et al., 2011).

The low levels of Zn and B besides P, K, Ca, emphasizes the poor monitoring and/or the fertilizer management of citrus crop in Amazon. Thu we highlight the need of higher levels of P, K, Ca, Mn, Zn and B and to intensify the frequency soil fertility evaluation and recommendation of lime and fertilizes.

Leaves micronutrients

Manganese, Zn and B low concentration in leaves (Table 2) were positively correlated with their concentration in soil (Table 1) and the visual deficiency symptoms observed on field, specially for Mn and Zn. Positive correlation was also found Cu and Fe on soil (Table 1) and leaves (Table 2). The high Cu leaves concentration is related with copper hydroxide or copper oxychloride spraying against diseases. The micronutrients excess or deficiency is common in brazilian orchards, specially for Pêra orange (SANTANA et al., 2007).

In general plants were Ca, K, S, Mn, Zn e B deficient. The DRIS method also detected Ca, K, S, B, P, Cu and Fe bellow the critical levels (DIAS et al., 2013). We did not find P, Cu and Fe foliar deficiency.

Therefore, the low yield of Amazon orchards is consequence of unourished plants. There is a narrow relationship between the nutrient concentration in leaves and/or yield and the nutrient concentration in soil supplied by lime or fertilizers (SALVADOR et al., 2011).

New studies with nutrient levels calibration for soil and plant are necessary to the best management of lime and fertilizers to increase citrus yield avoiding deforestation in Amazon. Therefore, it is urgent an integrated action between research, extension service and growers.

The soil fertility of most citrus orchards in Amazon are unbalanced with low soil pH, low organic matter levels, deficiency of P, K, Ca, Mn, Zn and B. Besides, plants are undernourished for Ca, K, S, Mn, Zn and B. This scenario seems to be consequence of: i) poor monitoring of soil fertility and plant nutrition; ii) lack technical support assistance for growers; and iii) poor management of lime and fertilizers.

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