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Soil and plant nutrition

Nutrients exportation in mandarin fruits managed in an organic production system in brazilian subtropics

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Abstract - The knowledge on the amount of nutrients exported by citrus fruit is an adequate tool to estimate nutrient demand reposition and this information about mandarin is very scarce. In this context, the objective of this study was to determine the nutrient content and exportation by mandarin fruits harvest, in an orchard managed under organic production system. An experiment was carried out in an organic orchard of adult mandarin trees (23 years), located in Rio Grande do Sul State (Brazil). The total content of macronutrients and micronutrients was determined in the mandarin fruits and the exportation was estimated by average yields in two seasons (2013/2014 and 2014/2015). The average exportation of macronutrient was 3.3, 2.3, 1.3, 0.4 and 0.3 kg t^{-1} for N, K, Ca, P and Mg, respectively; and of micronutrients was 6.3, 4.6, 1.5, 0.7 and 0.5 g t^{-1} for Fe, B, Zn, Mn and Cu, respectively. The N exportation in mandarin fruits does not comply with the current information used for citrus fertilizer recommendations, where the K is the nutrient most exported. Regarding micronutrients, besides the exported amounts vary among the literature, the magnitude order follows the same observed in our study. We propose these new standards for reposition of macronutrients and micronutrients in established mandarin orchards under organic management, contributing to a more accurate fertilizer recommendation.

Index terms – *Citrus deliciosa*, macronutrients, micronutrients, exportation, recommendation.

Exportação de nutrientes em tangerinas produzidas em sistema orgânico no subtrópico brasilero

Resumo - O conhecimento sobre a quantidade de nutrientes exportados por frutas cítricas é uma ferramenta adequada para estimar a reposição de nutrientes, e estas informações para tangerinas são escassas. Nesse contexto, o objetivo deste estudo foi determinar o teor e a exportação de nutrientes pela colheita de frutos de tangerineiras, em um pomar manejado sob sistema orgânico de produção. Um experimento foi realizado em um pomar orgânico de tangerineiras adultas (23 anos), localizado no Rio Grande do Sul, Brasil. O teor total de macronutrientes e de micronutrientes foi determinado nos frutos de tangerina, e a exportação foi estimada pela produtividade média de duas safras (2013/2014 e 2014/2015). A exportação média de macronutrientes foi de 3,3; 2,3; 1,3; 0,4 e 0,3 kg t^{-1} para N, K, Ca, P e Mg, respectivamente; e de micronutrientes foi de 6,3; 4,6; 1,5; 0,7 e 0,5 g t^{-1} para Fe, B, Zn, Mn e Cu, respectivamente. A exportação de N pelas tangerinas não condiz com as informações atuais utilizadas para recomendações de adubação em citros, sendo o K o elemento mais exportado. Em relação aos micronutrientes, além de as quantidades exportadas variarem entre a literatura, a ordem de magnitude segue a mesma observada em nosso estudo. Propomos esses novos padrões para reposição de macronutrientes e de micronutrientes em pomares estabelecidos de tangerina sob manejo orgânico, contribuindo para uma recomendação de adubação mais precisa.

Termos de indexação – *Citrus deliciosa*, macronutrientes, micronutrientes, exportação, recomendação.

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Soil and plant tissue analyses are the most used methods to determine the fertilization in citrus orchards. Soil analysis is performed after the orchard implantation to do soil fertility diagnosis, based on reference values calibrated for each region. The objective of soil analysis is increasing the nutrient availability above the standardized critical levels. When the orchard is established, the plant tissue analysis (common performed just in leaves) is the most used method to monitor the nutritional status of plants and to prescribe the fertilizer recommendations (CQFS RS/SC, 2016). In Brazil, the leaf analysis standards commonly used for citrus plants were established by GPACC (1994). However, these standards were obtained in experiments just with orange trees in São Paulo State, during the 1990s. The question that raises from this scenario is if these standards adequately represent the nutritional status of different citrus species in different production systems and regions.

Alternatively, the other method to determine the fertilizer recommendation in established orchards is consider the nutrient exportation through the yield and the nutrient content in fruits (Rozane et al., 2017; CQFS RS/SC, 2016). According to Koller et al. (2009), the knowledge on the amounts of nutrient exportation in the harvest of fruits is a valuable factor to determine the fertilizer requirement, if other factors are also considered: nutrient losses in the system (leaching and erosion); soil capacity in release or retain nutrients; the chemical forms found in the soil and immobilization of nutrients by the plants. Considering these factors, the input of nutrients through fertilization must be higher than that exported. In soils with high to very high fertility classification, the addition of 10 to 30% more nutrients than the amount exported in fruits is recommended (CQFS RS/SC, 2016).

However, information on the amounts of nutrients exportation in fruits are scarce – even more than the standardized values of leaf nutritional status. Bataglia et al. (1977) determined the references of the amounts of nutrients exported in fruits of citrus used currently, in studies performed in the São Paulo State with different orange cultivars. More recently, an update was performed in these references, but also the studies were performed only with orange and in the same region (Mattos Jr. et al., 2003; Boaretto et al., 2007). Although, the amount of nutrients exported varies among orchards, depending on soil, plant and climate factors (Koller et al., 2009). Thus, the lack of updated and specific reference values for other citrus species, such as mandarin, and other regions of the country, such as the Brazilian subtropics, make it difficult to recommend fertilizer rates based on nutrient exportation in fruits. In this context, the objective of this study was determine the nutrient contents and amounts exported in mandarin fruits in an orchard managed under organic production system, comparing them with the current data used for fertilizer recommendation.

The study was performed in the growing seasons of 2013/2014 and 2014/2015, in an orchard established in 1990 and managed under an organic production system since 1998, in municipality of Montenegro, physiographic region of Depressão Central, Rio Grande do Sul, Brazil (29°38’22”S and 51°28’38”W). The area is located at 60 m of altitude and the climate is classified as Cfa (Köppen classification), with well-distributed precipitation during the year (Bergamasch et al., 2013). The average yearly temperature and precipitation are 19.4 ºC and 1,468 mm, respectively. The soil was classified as an Ultisol, with sandstone as the parent material. The soil chemistry characteristics in 0-20 cm, according to the method of Tedesco et al. (1995) was: pH(H_2O) = 7.4; C content = 14,95 g kg^{-1}; Cation exchange capacity = 9,13 $cmol_c$ dm^{-3}; P = 80,3 mg dm^{-3}; K = 70 mg dm^{-3}; Ca = 7,4 $cmol_c$ dm^{-3}; Mg = 0,7 $cmol_c$ dm^{-3}; Cu = 2,0 mg dm^{-3}; Zn = 7,8 mg dm^{-3}; Mn = 1,5 mg dm^{-3}; B = 0,3 mg dm^{-3}. The cultivar of mandarin utilized was the ‘Montenegrina’ (*Citrus deliciosa* Tenore), grafted in *Poncirus trifoliata* (L.) Raf. The spacing used in the orchard was 3 x 6 m, between plants and rows, respectively.

The application of organic fertilizers was temporal and spatially different in the orchard. From 1998 to 2006, the entire area received 30 m^3 ha^{-1} of organic compost every two years and 30 m^3 ha^{-1} of liquid biofertilizer every year. From 2007 to 2011, an experiment was established and the area were split in four different managements of organic fertilization: 1) 100 m^3 ha^{-1} of organic compost every year; 2) 200 m^3 ha^{-1} of organic compost every two years; 3) 100 m^3 ha^{-1} of organic compost + 100 m^3 ha^{-1} of liquid biofertilizer every year; and 4) only cover crops: black oat (*Avena strigosa*) and vetch (*Vicia stiva* L.) in the winter and cowpea (*Vigna ungiculata*) in the summer. These managements were distributed in a randomized block design, with four replicates, in a total of 16 plots. Each plot was composed of 15 plants and the utile area corresponded to the three plants in the center of the plot. Finally, in 2011, the organic fertilization was suspended, because there was verified a nutritional imbalance and reduced yield in the area (Petry et al., 2012). These rates and managements used in each period were defined based on common rates and managements applied in the citrus orchards of the region, where there is a composting industry that produces those organic fertilizers that is commonly used by citrus producers. The chemical characterization of the organic fertilizers can be found in Balerini (2016) and in Table 1.

Table 1. Average chemical characterization of organic compost and biofertilizer used as organic fertilizers for mandarin fruits (dry matter base)

Attributes	Organic compost	Biofertilizer
pH	8.2	7.3
C:N Ratio	12.2	19
C-org. (g kg^{-1})	180	400
N (g kg^{-1})	14.8	21
P (g kg^{-1})	2.6	9.2
K (g kg^{-1})	6.6	8.7
Ca (g kg^{-1})	77.3	44.0
Mg (g kg^{-1})	5.4	4.1
Cu (mg kg^{-1})	51	150
Zn (mg kg^{-1})	62	317
Fe (g kg^{-1})	9,8	15.8
Mn (mg kg^{-1})	651	264
B (mg kg^{-1})	17	17
$CaCO_3$ equivalence (%)	25	3

The average yield of the fruits harvests of 2013/2014 and 2014/2015 growing seasons were used to estimate the nutrients exportation, being 12.9 t ha^{-1}. All fruits of the trees from utile area were sampled and its weight was determined in an analytical balance. After, ten fruits were randomly sampled for the laboratory analyses. A total of 320 (160 fruits per year) fruits were analyzed for our study.

The fruits were splitted into three parts: pulp (seedless endocarp), bark (exocarp and mesocarp) and seeds (Bataglia et al., 1977) – the data can be found in Balerini (2016). After, macronutrients (N, P, K, Ca and Mg) and micronutrients (Cu, Zn, Mn, Fe and B) contents were determined according to the method described by Tedesco et al. (1995). The amount of nutrients exported in the harvest of fruits was estimated, considering the nutrient contents and fruit yield. The averages of treatments and years were used to have general values of nutrient exports by fruits, independently of the experimental treatments and parts of fruits, for the purpose of general recommendations for nutrient exports. The nutrient contents at the three fruit parts was averaged weighted to obtain the total fruit contents, that were statistically analyzed by boxplot, a graphical tool to represent the variation of observed through the determination of minimum, mean, maximum and quartiles.

The average contents of macronutrients in 'Montenegrina' mandarin fruits were 1.23, 0.95, 0.38, 0.17 and 0.12% for N, K, Ca, P and Mg, respectively (Figure 1a and 1b). The K contents demonstrated the highest variation among the nutrients, with a difference between the maximum and the minimum values of 0.75% (Figure 1a), while this difference was from 0.41 to 0.04% for the other macronutrients (Figure 1a and 1b). In many studies, K is reported as the macronutrient with the highest concentration in the fruit, followed by N, Ca, P and Mg (Paramavisan et al., 2000; Mattos Jr. et al., 2003; Boaretto et al., 2007; Liu et al., 2012). The third macronutrient in greater content quantity was Ca, due to the significant amounts of Ca that citrus species needs for its fruit composition (peel, pulp and seeds). For this reason, deficiencies of this nutrient can cause important damages on fruits, as cracks on the peel (Meena et al., 2017). The P contents in fruits were the lowest when compared to the other macronutrients that were applied in the yearly fertilizations of the production system, being closer to the average content determined for Mg (Figure 1b).

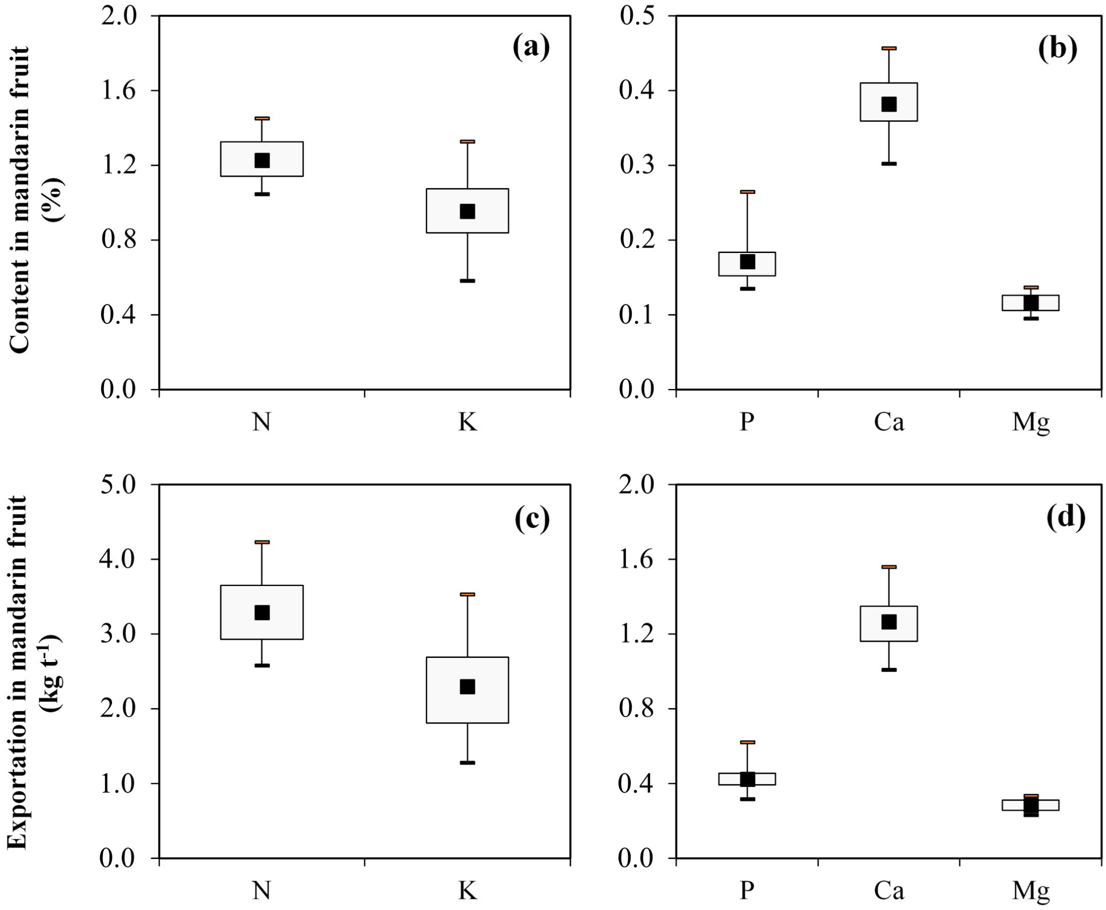

Figure 1. Nitrogen (N), potassium (K), phosphorus (P), calcium (Ca) and magnesium (Mg) contents (a, b) and amounts exported (c, d) in 'Montenegrina' mandarin fruits in an orchard managed under organic production system in Brazilian subtropics.

Concerning macronutrients exportation, the average amounts observed were of 3.3, 2.3, 1.3, 0.4 and 0.3 kg t^{-1} for N, K, Ca, P an Mg, respectively (Figure 1c and 1d). All these values are greater than those actually used for mandarin fertilizer recommendation through the replacement of nutrient exportation, obtained by Bataglia et al. (1977) in orange cultivation, which are 2.2, 1.7, 0.6, 0.2 and 0.1 kg t^{-1} for N, K, Ca, P and Mg, respectively. Nitrogen showed the highest amount of exportation when compared to the other nutrients (Figure 1c) and commonly this is the nutrient that has the higher variation in its exportation in fruits (Mattos Jr. et al., 2003; Alva et al., 2001; Boaretto et al., 2007). However, the sequence order of the nutrient exportation may be influenced by several factors, such as fertilization, soil, climate, rootstock and crown (Bataglia et al., 1977). In some studies, K was the most exported macronutrient for fruits (Mattos Jr. et al., 2003). The nutrient contents in fruits are affected by nutrient availability, which varies according to the soil type and fertilization (Koller et al., 2009). Probably, the high amount of N exportation in our study is a result of the high soil nutrient availability in the area (Alva et al., 2001; Balerini, 2016), mainly due to the high N input with the organic fertilizer (Table 1). Oelofse et al. (2010) compared nutrient exports in organic and conventional orange production systems in Brazil, founding no differences in N and K exportation between the systems. However, the organic system exported a higher amount of P than the non-organic system, due to the greater amounts of P applied and availability in the soil under organic fertilization.

The average content of micronutrients observed in mandarin fruits were 23.6, 14.4, 5.9, 2.2 and 1.9 mg kg^{-1} for Fe, B, Zn, Mn and Cu, respectively (Figure 2a and 2b). The lowest contents of Cu in our study, compared to other micronutrients, indicated that the usage of the Bordeaux mixture in the phytosanitary management – commonly used in organic production system and with Cu as the main element – did not affect the nutrient concentration in the fruits. In addition, Cu may have been complexed by high rates of organic fertilizers (Balerini et al., 2018). The Cu contents were similar to the contents of Mn (Figure 2a). Zinc showed intermediary values, with superior contents as compared to Cu and Mn (Figure 2a), but inferior to Fe and B (Figure 2b). This result corroborates with Mattos Jr. et al. (2003), who studied a six-year old Hamlin sweet orange trees on Swingle citrumelo rootstock. The Fe and B contents in fruits were similar, with high variation for Fe contents emphasizing the importance of these micronutrients due to their higher concentrations in relation to Cu, Zn and Mn (Boaretto et al., 2007).

The micronutrients exportation in mandarin fruits were, on average, 6.3, 4.6, 1.5, 0.7 and 0.5 g t^{-1} for Fe, B, Zn, Mn and Cu, respectively (Figure 2c and 2d). As approached for macronutrients, the standard values currently used, which were obtained by Bataglia et al. (1977) analyzing oranges, are very different than those obtained in our study, especially for B, Cu, Zn and Mn, being: 6.6, 2.2, 0.9, 2.8 and 1.2 g t^{-1} for Fe, B, Zn, Mn and Cu, respectively. It is important to highlight that the B exportation obtained in our study was 109% higher than that observed by Bataglia et al. (1977). This can be explained both by the need for B to the fruit development (Boaretto et al., 2011) and by the amount of B in the organic compounds (Table 1). Boaretto et al. (2007), analyzing five-year old 'Pera' orange trees on Rangpur lime rootstock, obtained lower values of exportation for Fe, B and Cu, and higher values for Zn and Mn, as compared to our study. However, the exportation order for micronutrients was Fe > B > Zn > Mn > Cu, corroborating our study.

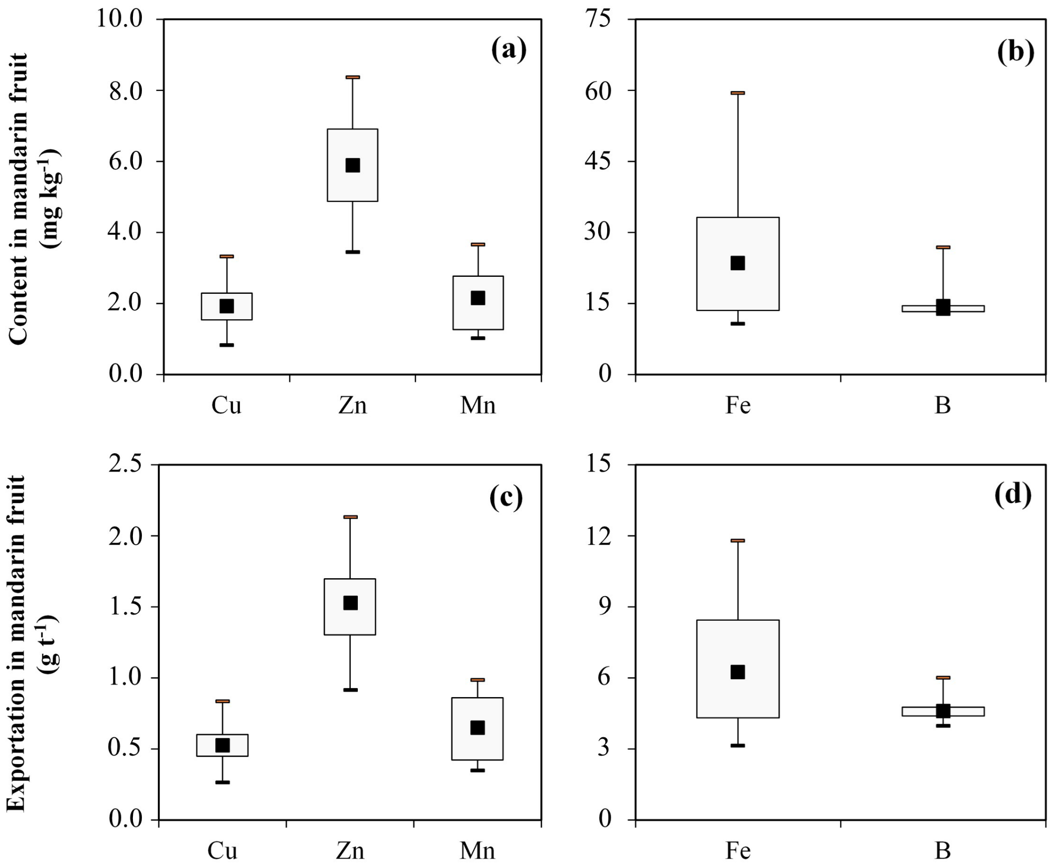

Figure 2. Copper (Cu), zinc (Zn), manganese (Mn), iron (Fe) and boron (B) contents (a, b) and amounts (c, d) exported in 'Montenegrina' mandarin fruits in an orchard managed under organic production system in Brazilian subtropics.

Paramasivan et al. (2000) studied nutrient contents in four oranges varieties (Hamlin, Parson Brown, Valencia and Sunburst) and found different values among them. Mattos Jr. et al (2003) also found different values as compared to Boaretto et al. (2007), studying different varieties of oranges and climate conditions. All these studies and most of other studies were done with oranges. However, Liu et al. (2012) found differences in nutrient contents among different citrus species, corroborating with our study and with the importance of considering differences of citrus species in a fertilizer recommendation. Therefore, the divergence between the nutrients exportation observed in our study and the observed in other studies with orange – the citrus species most researched –, in addition to the absence of nutrients exportation standards for mandarin, indicate the importance of more studies being performed for the determination of reliable exportation standards of nutrients, considering others citrus species, climate conditions, production systems and fertilization (Bataglia et al., 1977).

In conclusion, the macronutrients present in higher contents and more exported by 'Montenegrina' mandarin fruits are N and K followed by Ca, P and Mg. The macronutrients exportation was, on average, 3.3, 2.3, 1.3, 0.4 and 0.3 kg t^{-1} for N, K, Ca, P an Mg, respectively. The N content and exported in fruits does not comply with the current information used for fertilizer recommendations, originated from orange fruits, where the K is the element most exported, followed by N, Ca, Mg and P. The micronutrients contents of 'Montenegrina' mandarin fruits are, in descending order, B, Fe, Zn, Mn and Cu, following the current information used for fertilizer recommendations. The micronutrient exportation was, on average, 6.3, 4.6, 1.5, 0.7 and 0.5 g t^{-1} for Fe, B, Zn, Mn and Cu, respectively.

Based on the information presented in our study, we propose new standards for reposition of macronutrients and micronutrients in established mandarin orchards, under organic management (Table 2). Such data can contribute to a better establishment of more scientifically improved fertilizer recommendations, with the aim of maintain nutrient availability in the soil and improve plant nutrition and harvest profit.

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Table 2. Suggestion of new standards for reposition of macronutrients and micronutrients in established mandarin orchards, based on fruit exportation

Macronutrients	N	P_2O_5	K_2O	Ca	Mg
	----------	----------	kg t^{-1}	----------	----------
	3.5	1.0	3.0	1.5	0.5
Micronutrients	Fe	Cu	Zn	B	Mn
	----------	----------	g t^{-1}	----------	----------
	7.0	0.5	1.5	5.0	1.0

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