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Exportation and immobilization of nutrients by pear trees from the cultivars Cascatense and Tenra[1]

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ABSTRACT

The adequate fertilization management strongly depends on the knowledge of plant demands of mineral elements. In this context, an experiment was carried out in 2010 and 2011, in Guarapuava, Paraná State, Brazil, in order to estimate the nutritional needs of pear trees cultivars Cascatense and Tenra in an organically managed orchard. At the end of each vegetative cycle, in early autumn, plants were removed from the soil, separated in parts (roots, trunk, branches and leaves), and analyzed for mineral content. The fruits from 2010/2011 harvest were collected in January 2011 and were also analyzed. Both pear cultivars immobilized higher amounts of K in the roots and branches and lower quantities in the trunk. Ca was less accumulated in branches. The elements N, P, Mg and S did not show significant differences between the permanent parts. Macronutrients exported by pear fruits were in the following decreasing order K>N>P=S=Mg=Ca and N>K>P=S=Mg=Ca, for the cultivars Cascatense and Tenra, respectively. Considering the total nutrient immobilization in permanent parts (roots, trunk and branches) added to the exportation by the fruits, the minimum nutritional requirements of 'Cascatense' pear trees during its annual growth cycle, with a yield of 10.8 t ha^{-1}, were estimated as 24.0, 3.3, 20.7, 8.8, 3.0 and 2.7 kg ha^{-1} for N, P, K, Ca, Mg and S respectively. The minimum nutritional requirements for 'Tenra' pear trees, with a yearly yield of 13.5 t ha^{-1}, were 34.0, 2.8, 25.4, 10.3, 3.4 and 2.8 kg ha^{-1} for N, P, K, Ca, Mg and S respectively.

Index Terms: *Pyrus communis; Cydonia oblonga*; plant nutrition; agroecology; fertilizing

INTRODUCTION

Pear production in Brazil is around 21,990.00 tons $year^{-1}$. However, this volume does not meet consumer demand. More than 90 thousand tons were imported per year between 2007 and 2011, costing over US$747 million and making the pear the most imported fruit from Brazil (FAO, 2014).

The low level of pear production in Brazil is the same for last three decades as a result of several factors, including a lack of production technology, adapted rootstocks and cultivars, government incentive and post-harvest management (Nakasu and Leite, 1990; Pasa et al, 2012).One factor that can contribute to improve pear quality and yield is the adequate fertilization management, and for this purpose, the nutritional demands of each cultivar need to be evaluated (Stassen and North, 2005).

According to Sorrenti and Rombolà (2006), the nutritional exigencies of bearing pear trees vary sensibly according to the cultivar and rootstock. In this phase, the nutrient demands from the pear tree are delineated by the growth of permanent parts, that defines the yearly increase of the orchard biomass and from the deciduous parts exported (pruning wood, leaves and fruits) that constitute the most important fraction of the mineral elements consumption.

There are few studies about nutrition and fertilization of pear trees in Brazil. In the states of Santa Catarina and Rio Grande do Sul, simultaneous analysis of the following parameters are recommended for the fertilization management of a pear orchard: leaf analysis, soil analysis, plant age, vegetative growth, conduction system, number of previous fertilizations, production level, crop management, nutritional imbalances and nutritional deficiencies or toxicities (CQFS-RS/SC, 2004). However, there are no parameters of nutrient uptake.

The annual demand for the application of fertilizers depends on the plant nutritional requirements, the natural supply from the soil through mineralization and the decomposition of organic matter. Therefore, in order to estimate the full nutritional requirements of pear trees, it is necessary to quantify the levels of nutrient reserves contained in the trunk and roots, and; also the amounts exported by leaves, shoots and fruits (Neilsen and Neilsen, 2003).

Essential nutrients have important functions as constituents of plant tissue or as part of buffering systems, activating enzymes and regulating osmotic pressure and membrane permeability (Marschner, 2012). Insufficient supply, application at the wrong phonological stage and macronutrient mobility can all cause deficiencies, leading to the disorders associated with their low supply (Tromp, 2005). On the other hand, excess levels can stimulate growth, causing an imbalance in nutrients and inhibiting flower bud differentiation, affecting fruit production as a result (Marschner, 2012).

Weinbaumet al. (2001) suggested that sequential plant excavation along with biomass determination and nutrient analysis is the only method that can really reveal seasonal patterns of nutrient absorption. Various studies using this principle have been carried out to determine the seasonal uptake of nutrients and the distribution of macroelements in apple (Haynes and Goh, 1980), peach (Stassen et al., 1981), grapevines (Conradie, 1981), kiwi (Kotz and de Villiers, 1989), mango (Stassenet al., 1997) and pear trees (Quartieri et al., 2002; Stassen and north, 2005). Nevertheless, there is a lack of information about Brazilian pear cultivars.

In this context, the aim of this study was to evaluate the quantity of macronutrients that accumulated in different parts of the plant during the growth cycle and that were exported to the leaves and fruits of Cascatense and Tenra pear tree cultivars.

The trial was carried out in an experimental orchard located in Guarapuava, Paraná, Brazil (25º23’36”S, 51º27’19”W and 1,120 ma.s.l.). The region climate, according to Köppen, is classified as Temperate Oceanic (Cfb), with mild summers, frosts in winter and an annual rainfall ranging in 1,800 – 2,000 mm (Iapar, 2000). The soil is classified as Brown Latosol. The average accumulation of chilling hours this region is 308 h (≤7,2°C) (Botelho et al., 2006).

The Cascatense and Tenra pear tree cultivars, grafted on quince ‘CPP’ rootstock (*Cydonia oblonga*) with ‘FT’ pear tree (*Pyrus communis* L.) as interstem (filter), were obtained from a commercial nursery in Araucaria, Parana and, planted in September 2004 with a spacing of 4.0 x 1.0 m, corresponding to2,500 plants ha^{-1}. The orchard was set up in a central leader system with a slender canopy, and the crop management adopted was in organic system with drip irrigation. The experimental design was in randomized blocks, with two treatments (cultivars), five replications and a five-plants-plot. Each block was made up of one crop row.

Before planting the trees in 2004, the equivalent of 2,500 kg of agricultural gypsum, 1,250 kg of simple superphosphate, 420 kg of potassium chloride and 100 kg of mono ammonium phosphate were applied per hectare and 15 kg of manure were applied per meter of planting line, based in soil analysis (0-40 cm). The orchard was converted to organic system from the third growth cycle on, using the following nutrient
sources: wood ashes, manure, rock phosphate, green manure between rows (jack bean, fava bean, vetch, lupine, black oat, rye grass, among others), biofertilizers and calcitic limestone. Soil samples were taken for chemical analysis from 0-20 cm and 20-40 cm along the crop rows in May 2010, six years after the planting of the trees. The results of these analyses are shown in Table 1.

Table 1. Chemical characteristics of soil samples on depths at 0-20 and 20-40 cm from the experimental pear orchard with density planting of 2,500 plant ha^{-1} (Guarapuava-PR, Brazil. 2010).

Samples	pH $CaCl_2$	OM g dm^{-3}	P Mehlich mg dm^{-3}	K cmol dm^{-3}	Ca cmol dm^{-3}	Mg cmol dm^{-3}	Base Saturation (%)
0-20 cm	5.6	40.3	9.7	0.96	5.3	2.2	69.2
20-40 cm	5.0	38.9	2.6	0.68	3.5	1.2	48.6

Nutrient analyses were carried out during the sixth (2010) and seventh (2011) growth cycle. One whole plant from each experimental unit was removed at the end of the vegetative cycle in May 2011. The soil was carefully excavated around the trees in 100 cm diameter and depth. After removal, the pear trees were split in separately parts: roots, trunk, branches and leaves.

All of the separated parts were washed, weighed and kept in an air-circulating oven at 60°C until constant mass. The samples were then ground in a Wiley mill and stored to chemical analysis.

For fruit analysis, all pears were collected, counted and weighed at the end of December 2010. Six fruits per plant were then selected, weighted, cut lengthways and kept in an air-circulating oven at 60°C until constant mass. The fruits were ground and sent for chemical analysis at the laboratory.

Levels of P, S, K, Ca and Mg were determined according to methodologies described by Miyazawa (2009).

Estimates of the level of macronutrient retention in the permanent parts of the plant (roots, trunk and branches) were calculated using the total amount accumulated over the seven year period divided by the age of the plant, according to the methodology proposed by Stassen and North (2005).

The quantification of macronutrients exported by the leaves was performed by samples collected in two years, before their fall (May 2010 and May 2011).

The results were submitted to variance analysis and Student Newman-Keuls test with a significance level of 1%, using the SISVAR statistical program (Ferreira, 2011).

The decreasing order that macronutrients were immobilized in the roots was N>Ca=K>Mg=S=P for cv. Cascatense and Ca=N>K>Mg=S=P for cv. Tenra (Table 2).

Table 2. Yearly macronutrients immobilization (g ha^{-1}) by permanent parts of pear trees cv. Cascatense and Tenra, in density planting of 2500 plants ha^{-1} (Guarapuava- PR, Brazil, 2011).

			cv. Cascatense				
Parts	N	P	K	Ca	Mg	S	DryWeight (Kg ha^{-1})
Roots	4,415.38 Aa	410.14 Ca	3,052.03 Ba	3,345.43 Ba	886.58 Ca	484.95 Ca	1,469.69
Trunk	5,150.27 Aa	298.73 Ca	1,459.96 Cb	3,250.72 Ba	930.57 Ca	534.16 Ca	2,365.19
Branches	4,585.67 Aa	485.38 Da	3,074.35 Ba	1,598.33 Cb	482.20 Da	371.42 Da	1,516.05
Média	4,717.11	398.08	2,528.78	2,731.49	766.45	463.51	1,783.64
CV (%)				37.96			
			cv. Tenra				
Parts	N	P	K	Ca	Mg	S	DryWeight (Kg ha^{-1})
Roots	4,184.69 Ab	405.13 Ca	3,050.80 Ba	4,673.28 Aa	1,026.16 Ca	430.51 Ca	1,238.63
Trunk	5,482.22 Aa	361.46 Da	1,674.45 Cb	2,965.60 Bb	704.78 Da	520.64 Da	2,292.71
Branches	4,096.48 Ab	461.81 Ca	2,472.01 Ba	1,914.20 Bc	530.22 Ca	316.25 Ca	1,160.83
Mean	4,587.80	409.46	2,399.09	3,184.36	753.72	422.47	1,564.06
CV (%)				30.34			

Means followed by the same letter, upper-case within a row and lower-case within a column, did not differ by the SNK test ($p \leq 0.01$). The values are means of seven vegetative cycles.

In a similar study with 'Forelle' pear, Stassen and North (2005) verified that plants grafted on quince 'A' immobilized nutrients in the roots at the following order: Ca>K>N>Mg>P. These results were different from those reported in pear trees grafted on 'BP1' hybrid that immobilized nutrients in the roots in the following decreasing order: N>Ca>K>P>Mg.

In the trunks, very similar decreasing order of importance was observed for both cultivars: N>Ca>K=Mg=S=P for cv. Cascatense and N>Ca>K>Mg=S=P for cv. Tenra. Analogous results were reported by Stassen and North (2005) in a trial in South Africa, except for Ca that was the most abundant element. In the branches, the order was N>K>Ca=P=Mg=S for cv. Cascatense and N>K=Ca>P=Mg=S for cv. Tenra.

Both pear cultivars immobilized higher amounts of K in the roots and branches and lower quantities in the trunk. Ca was less accumulated in branches. N, P, Mg and S did not show significant differences between the permanent parts (Table 2).

Nutrient immobilized in permanent parts are very important as a source of reserves for the new growth cycle. Neto et al. (2008) observed in 'Rocha' pear trees that the most of the N uptake during the previous year, accumulated in the trunk and in thicker roots, representing 28% and 32% of the total uptake, respectively. In 'Abate Fetel' pears, Quartieri et al. (2002) verified that the remobilization of N in the following spring accounted for 23–24% of the labeled N in the tree, regardless the timing of N uptake. Trees preferentially remobilized N taken up during the previous year than N absorbed earlier. In newly planted apple trees, the stored N for new growth can be redistributed from 35 to 55 days after planting (Nielsen et al., 2001).

A high proportion of the accumulation of Ca was observed in the roots, where 40.8% and

48.9% of the total Ca were found in cv. Cascatense and cv. Tenra, respectively (Table 2). Similarly, Stassen and North (2005) verified that between 38.8% and 54.9% of the Ca immobilized in pears cv. Forelle was found in the roots. In grapevines cv. Cheninblanc, Conradie (1981) verified at harvest that the bunches contained a relatively small part of the Ca (7.7%), whereas the leaves contained the major portion (46.4%) and the rest was distributed between the roots (19.8%), shoots (16.7%), and trunk (9.4%).

In both cycles, pear trees cv. Cascatense showed the highest extraction of nutrients by leaves. This is mainly due to its vegetative vigor, with a much higher dry matter of the leaves. For both cultivars, the decreasing order of extraction by the leaves was, as following: N>K=Ca>Mg=P=S (Table 3).

Table 3. Macronutrients extraction (g ha^{-1}) by leaves from pear tree cultivars Cascatense and Tenra, in 2010 and 2011, at planting density of 2500 plants ha^{-1} (Guarapuava- PR, Brazil).

cv. Cascatense								
Cycles	N	P	K	Ca	Mg	S	Dry Weight (Kg ha^{-1})	CV (%)
2010	17,955.94 A	915.41 C	8,514.08 B	6,787.43 B	2,431.82 C	816.56 C	280.26	46.99
2011	14,983.82 A	856.86 C	7,824.14 B	7,077.09 B	2,890.94 C	774.17 C	258.71	29.31
Mean	16,469.88	886.14	8,169.11	6,932.26	2,661.38	795.36	269.48	-
cv. Tenra								
Cycles	N	P	K	Ca	Mg	S	Dry Weight (Kg ha^{-1})	CV (%)
2010	5,512.69 A	310.50 C	3,201.73 B	3,683.79 B	866.59 C	285.12 C	124.84	39.34
2011	9,918.24 A	505.49 D	4,545.10 B	5,354.66 B	2,228.36 C	501.94 D	168.65	26.92
Mean	7,715.47	408.00	3,873.41	4,519.23	1,547.48	393.53	146.75	-

Means followed by the same letter, upper-case within a row and lower-case within a column, did not differ by the SNK test ($p \leq 0.01$).

Despite of the large quantity of nutrients exported by the leaves, a large proportion of them are recycled by translocation to the permanent parts of the plant or by organic mattered composition, and, therefore, they should not be considered for reposition by fertilization management. According to Haynes and Goh (1980), in a trial carried out with 'Golden Delicious' apple trees in New Zealand, total nutrient returns to the orchard floor through petal fall, fruit drop, leaf fall, foliar leaching (includes leaf washing) and pasture clippings in kg $ha^{-1}yr^{-1}$ were: N = 545; P = 33; S = 41; C = 1, 107; K = 442; Ca = 147; Mg = 35 and Na = 16.

Macronutrients extracted by pear fruits were in the following decreasing order K>N>P=S=Mg=Ca and N>K>P=S=Mg=Ca, for cv. Cascatense and cv. Tenra, respectively (Table 4). Overall, these results were very similar to those verified by Stassen and North (2005) for pears cv. Forelle, that verified fruit extraction of 751.3 g of N, 146.6 g of P, 1,202.0 g of K, 57.48 g of Ca and 73.00 g of Mg per ton produced, yielding 29 t ha^{-1}.

However, these quantities may vary according to the species. In Brazil, the extraction of 300 to 400 g of N, 100 to 150 g of P and 1,000 to 1,200 g of K per ton of fruit produced (CQFS-RS/SC, 2004) is assumed as reference for apple tree fertilization. Based on this scenario, it is possible to affirm that pear trees are different from apple trees in terms of nutritional demand, exporting higher amounts of nitrogen by the fruits (913.7 to 1,499.02 g t^{-1}). Botelho et al. (2010), in a study with five pear cultivars, verified that there were differences between cultivars in relation to nutrient levels in leaves and fruits, demonstrating different nutritional requirements among cultivars. The estimated amounts of macronutrients exported by the fruits per hectare are presented in table 4, considering the yield of 10.8 t ha^{-1} and 13.5 t ha^{-1}, for the cultivars Cascatense and Tenra, respectively.

The nutritional requirements of the pear tree can be calculated using information from productivity, nutrients retained in the permanent parts of the plant framework and the level of nutrients exported by the fruits. This information along with other parameters such as soil fertility, climate, nutritional condition, irrigation and plant management would allow recommendations of the fertilization for the adequate plant balance, while respecting the individual characteristics of each commercial variety.

Table 4. Macronutrients exportation by fruits from pear trees cultivars Cascatense and Tenra (Guarapuava- PR, 2011).

Nutrients	Amount per fruit production (g t^{-1})		Amount per area (g ha^{-1})	
	cv. Cascatense' [1]	cv. Tenra [2]	cv. Cascatense [3]	cv. Tenra [3]
N	913.70 b	1,499.02 a	9,867.99 b	20,236.78 a
P	198.12 c	113.33 c	2139.68 c	1529.93 c
K	1,211.72 a	1,344.76 b	13,086.58 a	18,154.25 b
Ca	52.29 c	52.37 c	564.68 c	707.02 c
Mg	65.06 c	87.29 c	702.60 c	1,178.35 c
S	123.23 c	112.53 c	1330.84 c	1,519.10 c
CV (%)	30.99	15.06	30.99	15.06

[1]fruit yield of 10.8 t ha^{-1}, [2]fruit yield of 13.5 t ha^{-1}, [3]Calculated considering 2.500 plants ha^{-1}. Means followed by the same letter within a column, did not differ by the SNK test ($p \leq 0.01$).

The two pear cultivars present different nutritional demands, which must be taken into account for the purpose of fertilization management. Considering the total nutrient immobilization in permanent parts (roots, trunk and branches) added to the exportation by the fruits, the minimum nutritional requirements of the cultivar Cascatense during its annual growth cycle, with a yield of 10.8 t ha^{-1}, were estimated in 24.0, 3.3, 20.7, 8.8, 3.0 and 2.7 kg ha^{-1} for N, P, K, Ca, Mg and S respectively. The minimum nutritional requirements for the Tenra cultivar, with a yearly yield of 13.5 t ha^{-1}, were 34.0, 2.8, 25.4, 10.3, 3.4 and 2.8 kg ha^{-1} for N, P, K, Ca, Mg and S respectively. Future long-term researches should focus different soil and climate conditions, different cultivars and rootstocks to improve the knowledge about pear nutrition and consequent better adjustments of fertilizing programs.

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