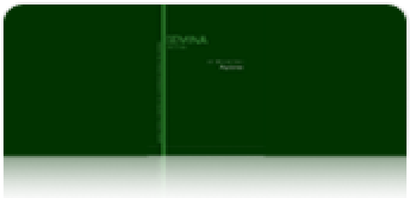

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Nutrient cycling in mango trees

Ciclagem de nutrientes em mangueira

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Abstract

Estimates of nutrient amounts both shedding and demanding replacement in the maintenance of productivity of fruit trees require studies on element dynamics within the many ecosystem components generally made up of nutrient cycling. Thus, it was the objective of this study to evaluate the nutrient biochemical cycling in a mango tree (*Mangifera indica* L.) orchard, Palmer variety. Macronutrients [nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), and sulfur (S)] had their contents evaluated in leaves at different stages: new, mature, senescent, and litter. First exploratory analysis was performed for main components which preserve the multivariate structure shown by the data. It was possible to observe the association of new leaves with N, P, K, Mg, and S; senescent leaves and the leaves from the litter were associated to Ca, while mature leaves, to K. As a complement, taking the independent variables into consideration, Tukey test ($p \leq 0.01$) showed that the averages of N, P, and Ca differ between the new and the mature leaves; average of Mg in new leaves differs from the others, and S does not differ along the stages. Also observed was the re-translocation of 41%, 63% and 57% of N, P, and K, respectively, when comparison was made among the contents of the elements in mature leaves as well as in litter, which indicates that the biochemical cycling is important for the mango tree cultivation.

Key words: *Mangifera indica* L., biochemical bycling, main components

Resumo

A estimativa das quantidades de nutrientes que saem e que devem ser adicionados para a manutenção da produtividade das frutíferas requer estudos sobre a dinâmica dos elementos nos vários compartimentos do ecossistema, o que compõe, em termos gerais, a ciclagem de nutrientes. Assim, objetivou-se com este estudo avaliar a ciclagem bioquímica de nutrientes em um pomar de mangueiras, variedade Palmer. Foram determinados os teores de macronutrientes (N, P, K, Ca, Mg e S) em folhas em diferentes estádios: folhas novas, folhas maduras, folhas senescentes e folhas do folhedo. Inicialmente, aplicou-se a análise exploratória de componentes principais que preserva a estrutura multivariada contida nos dados. Verificou-se a associação das folhas novas com N, P, K, Mg e S; folhas senescentes e do folhedo com Ca e folhas maduras com K. Em complemento, considerando as variáveis independentes, o teste de Tukey

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($p \leq 0,01$) mostrou que as médias de N, P e Ca diferem entre as folhas novas e maduras, a média de Mg das folhas novas difere das demais e que o S não difere entre os estádios. Foi observada a retranslocação de 41, 63 e 57% de N, P e K, respectivamente, quando se comparou os teores dos elementos em folhas maduras e em folhas do folhedo, indicando que a ciclagem bioquímica é importante para a cultura da manga.

Palavras-chave: *Mangifera indica* L., ciclagem bioquímica, componentes principais

The mango tree (*Mangifera indica* L.) is an important fruit tree for tropical and subtropical regions, and can be developed relatively well in a wide range of soil varieties (FERNANDES; NASCIMENTO, 2004). Brazil cultivates an approximate area of 68 thousand hectares of mango tree, producing one million tons per year, of which 10% are exported (AGRIANUAL, 2008).

The mango tree demands a great amount of nutrients as to supply its requirements for maintenance of the vegetative part of the plant, as well as for the exportation of such elements by the fruit. According to Souza (2007), the mango tree, Palmer variety, presents an average production of 200 fruit plant^{-1}, exporting 105; 14; 186; 19; 13, and 10 g plant^{-1} of N, P, K, Ca, Mg, and S respectively.

This way, estimates of element amounts exported from the orchard, and which must be restored for the maintenance of productivity, should be evaluated, making more studies necessary about the nutrient dynamics in the many ecosystem components, which corresponds, generally, to the nutrient cycling (REIS; BARROS, 1990). Understanding the element dynamics within the various agricultural system compartments may provide answers to questions about its potentiality as a source of nutrients and organic matter, this way informing the suitable fertilizer dosages. According to HAAG (1985), trees, in a forest system, are able to draw large amounts of nutrients from soil deep layers, but actually most part of their nutrient necessities is supplied by cycling.

The amount of nutrients in the litter depends on the vegetable species, the proportion of leaves in relation to the other components, from nutrient translocation capability before senescence of leaves, as well as on the soil type.

Two large nutrient cycles are acknowledged, according to Haag (1985) and Reis and Barros (1990): the geochemical cycle, involving nutrient input and output processes; and the biological one, which encompasses transference within the ecosystem. The latter is divided into biogeochemical, consisting of nutrient transference processes within the soil-plant system; and the biochemical, which refers to the translocation of nutrients within the plant. The biochemical cycle is important for the nutrients with the greatest mobility within the vegetables, such as N, P, K, and Mg, and is less significant for Ca, S, and micronutrients in general since their translocation is restrict (REIS; BARRROS, 1990; MOREIRA; FAGERIA, 2009).

Vegetable residues are important not only as a nutrient source, but also for the improvement of the soil physical properties, like aggregation, water retention and absorption in the profile. That is because, according to Musvoto et al. (2000), the mango tree litter provides a slower decomposing rate than other materials making it an important component of soil improvement and conservation. By evaluation of decomposing and consequent releasing of nutrients through the mango tree litter, in a study developed in Zimbabwe, these researchers found that there was a quick release of phosphorus in the three first months of decomposing. The researches attributed that to the fact that P was soluble in the mango tree leaf components, indicating that that element is released to the plants. Still according to those researchers, the mango tree litter composition, based on percentage of dry material, is: 0.71% N; 0.04% P; 0.53% K; 2.72% Ca; 0.09% Mg, and 0.13% S. According to Soares et al. (2008), in the cashew plant (*Anacardium occidentale*) the highest amount of litter nutrients was released during the four first months of leaf decomposing, once decomposing rate during that period is faster.

Knowing input, output and translocation rates of each nutrient in cultures is important for the fertilizing management. On the other hand, virtually all works in literature involving nutrient cycling were performed by means of forest specimens, so that information on that subject in relation to fruit trees is scarce. That led to the choice of doing this study on nutrient cycling in a mango tree orchard, Palmer variety.

The experimental area is part of a commercial plot of mango trees belonging to *Indústria de Polpas e Conservas Val Ltda. (Val Pulp and Preserve Industry Ltd.)*, located in the largest fruit producer region in São Paulo State, in the city of Vista Alegre do Alto, geographic coordinates 21º 15’ South, 48º 18’ West, altitude 603 m. According to Koppen classification, the local climate is Cwa type, subtropical with short, moderate and dry winter, hot and rainy summer, in two distinct seasons. The experiment was conducted on an Udult, sandy/medium texture (USDA, 1975), of which chemical properties for soil fertility are presented in Table 1.

Table 1. Chemical attributes in an Udult, sandy/medium texture, in the 0–0.20 m layer

pH $CaCl_2$	MO	P Resin	K	Ca	Mg	H+Al	SB	T	V
	g dm^{-3}	mg dm^{-3}	-------------------------------			$mmol_c$ dm^{-3}	-----------------------------		%
4.8	11	37	3.2	13	7	28	23.2	51.2	45

Source: Elaboration of the authors.

The seven-year old mango tree (*Mangifera indica* L.), Palmer variety, under rootstock ‘coquinho’, orchard features 8 m × 5 m spacing among trees, receiving 40 kg ha^{-1} of fertilizer of N, P_2O_5 and K_2O in the form of ammonium nitrate (34% N), single superphosphate (18% P_2O_5) and potassium chloride (60% K_2O). The health of the plants is treated in a preventative manner at the time of leaves collection did not show symptoms of pests or diseases. The experiment design was totally randomized, comprehending four different kinds of leaves and four replications. Commercial plants were randomly chosen, of which composed samples were obtained. The composed samples were formed by simple samples from ten plants. Each simple sample was obtained from the collection of one leaf from each mango tree four cardinal points. According to Rozane et al. (2007), the sampling of ten trees from the mango tree homogenous plot is sufficient for determination of the macronutrients in the leaves, at error rates below 10%.

Treatments consisted of each of the four kinds of sampled leaves in 14 of august: *a)*new leaves from the first or second pair of leaves at the terminal edge of branches; *b)* mature leaves, collected from halfway through the branch vegetation flow having flowers at their edges; *c)* senescent leaves from the last and the penultimate leaf pair from the basal part of the branches (either reddish or yellowish, which spontaneously parted from the plant when touched); and *d)* leaves from the litter, sampled from under the treetop (dry and dark), demanding extreme care in collecting only intact leaves.

Leaf sampling (the four types) was performed at the same time, at a determined physiological stage of the plant (blooming). That choice was aimed at including the diagnosis-leaf for comparisons with literature (RAIJ et al., 1997). Those authors recommend the leaf collection halfway through the last vegetation flow, with flowers at the edges of the branches, during blooming stage.

At the laboratory, leaves were first washed with distilled water, followed by neutral detergent at 0.1%, then with HCl (chloride acid) solution at 3% in volume, and, again, in distilled water. Immediately after washing, the leaves were stored in paper bags and taken to a forced-air circulation chamber at a controlled temperature (65-70°C), up to constant weight.

Grinding of samples was performed in a type Willey mill (20-30 mesh screen), making manipulation easy and securing its homogeneity. Macronutrient contents (N, P, K, Ca, Mg, and S) for the different kinds of leaf samples were determined according to method described by Bataglia et al. (1983). Results of chemical nutrient findings were analyzed for variance and averages were compared by Tukey test at 5% of probability.

The biochemical cycling process intensity was assessed by the percentage variations in the nutrient concentrations between mature leaves (ML) and litter leaves (LL), in which negative figures indicate that there was nutrient translocation, according to Gama-Rodrigues, Gama-Rodrigues and Barros (2008), Zaia and Gama-Rodrigues (2004) and Caldeira et al. (1999). Therefore cycling was estimated from the following expression:

$$\text{Biochemical cycling (litter VS mature)} = \{([LL]-[ML])/[ML]\} \times 100 \tag{1}$$

The multivariate structure of the results was evaluated by main component analysis in an attempt to condensate relevant amount of information contained in the original set of data into a smaller set. Those dimensions (main components) are linear combinations of the original variables generated from the highest auto-values of the covariance matrix.

The average values from the four replications were standardized (null mean and unit variance) for the processing of multivariate analysis of main components which allowed for the assessment, in an exploratory sense, of leaf distribution in a two-dimensional plane formed by two new latent variables: main component 1 (MC_1) and main component 2 (MC_2) which are self-vectors generated from the two largest self-values at the initial set formed by the linear combinations of the six variables: N, P, K, Ca, Mg, and S.

This way, the distribution of the different types of leaves starts being made by the two latent variants MC_1 and MC_2. They were able to condensate 93.74% (78.30% in MC_1 and 15.44% in MC_2) of the variability contained in the original set. For a better interpretation of distribution of the different kinds of leaves, a *two-way plot* was constructed where one can clearly observe a contrast in MC_1 between the new leaves and the senescent and litter ones.

The discriminatory power of individual variable in each main component is measured by the correlation between each original variable and a main component so described in decreasing importance order: in MC_1, Ca (0.991), P (-0.988), K (-0.833), S (-0.820), and Mg (-0.702), being the negative correlation variable and the leaf discrimination shown on the left side of the graph, while positive ones can be found on its right side; for MC_2, Mg (-0.687) and K (0.541) the positive correlation which indicates variable and leaf discrimination is on top of the graph, while the negative one is on the bottom. This way, senescent and litter leaves are directly associated to the low Ca contents and to the high S, Mg, P, N and K contents, while mature leaves own the highest K content and the lowest Mg content.

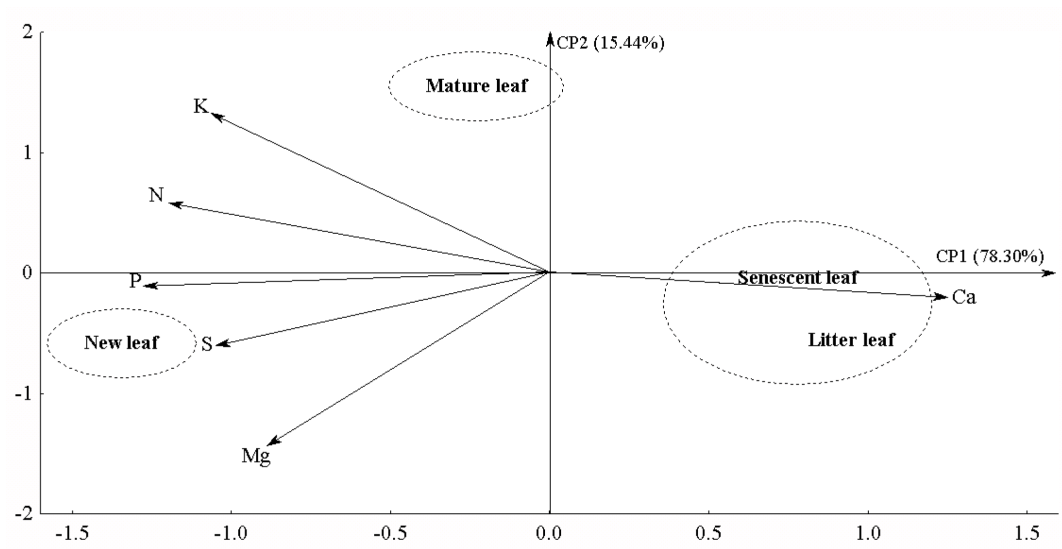
In addition, data with repetition underwent univariate analysis of variant analysis for checking of possible differences among leaves, as well as Tukey test ($p \leq 0.01$), for checking of differences among those repetition averages. It can be observed that N, P, and Mg contents were higher in new leaves, in comparison to contents in mature leaves (Table 2). That may be attributed to the effect and concentration, once the new leaves had not entirely expanded yet. As they reach its physiological fullness (mature leaves), contents are stabilized at a lower level, according to what is observed for N, P and Mg. Nevertheless, in more advanced vegetative stages (senescence and litter), leaves will reflect a lower content of those elements (N, P, K, and Mg), which can be attributed to the retranslocation caused by the mobility in phloem, confirmed by the two-dimensional plane created by MC_1 and MC_2 (Figure 1).

Table 2. Nutrient contents in mango leaves, cv. Palmer, at different development stages.

Leaf	N		P		K		Ca		Mg		S	
	g kg^{-1}											
New	13.9	a	1.4	a	8.9	a	3.0	c	2.3	a	1.2	a
Mature	11.9	b	0.8	b	9.3	a	16.5	b	1.7	b	1.1	a
Senescent	5.7	c	0.2	c	5.8	b	32.5	a	1.7	b	1.2	a
Litter	7.0	c	0.3	c	4.0	c	36.8	a	1.9	b	1.1	a
F Test	97.7**		272.1**		66.7**		191.7**		16.8**		0.4^{ns}	
DMS	1.66		0.14		1.30		4.70		0.30		0.27	
CV (%)	8.2		9.7		8.8		10.1		7.7		11.2	

Same small letters in column do not differ among themselves according to Tukey test at 1% probability.
Source: Elaboration of the authors.

Figure 1. Byplot graph showing variable distribution: N (nitrogen), P (phosphorus), K (potassium), Ca (calcium), Mg (magnesium) and S (sulfur) and mango tree leaves at different vegetative growth stages: senescent, litter, mature and new leaves.



Source: Elaboration of the authors.

According to Camargo and Silva (1990), there is a tendency for young leaves to remain green, while the older ones yellow and die, which is a display of N mobility in plants. According to those authors, when the roots are not able to absorb enough N amounts as to supply the growing needs of the plant, the nitrogen compounds of the older parts suffer autolysis. Thus, N content in proteins is converted into soluble forms and is translocated to the active meristematic regions, where it is reused in a new protoplasm synthesis. However, content of N (11.9 g kg^{-1}) in the diagnosis leaf (mature leaf), which had been collected in full blooming stage, according to instructions by Raij et al. (1997), is virtually within the range considered adequate for the mango tree culture (12 to 14 g kg^{-1}), due to fertilizing.

The same phenomenon happens with P and Mg, that is, those nutrients are translocated from the older tissues to the active meristematic regions (CAMARGO; SILVA, 1990). P is translocated through the phloem to other parts of the plant (MALAVOLTA, 2006), when its demand is bigger than the amount available in soil, which means, in poorer soils internal cycling must be relatively more intense. This translocation occurs both in the organic way [ATP – adenosine triphosphate), for instance] and in the inorganic one (Pi). At the passage between organelles and cytoplasm, Pi is transformed into P-esters. Content of P found in the mature leaf, at 0.8 g kg^{-1}, is adequate for the culture, according to suggestions by Raij et al. (1997). However, Mg content (1.1 g kg^{-1}), is taken as deficient being under the range considered adequate by the same authors, which would be of 2.5 to 5.0 g kg^{-1}. Soil analysis (Table 1) shows the quite low saturation value by basis for the mango culture (the ideal is of 80%), due to the low concentrations of Ca and Mg in the soil, which resulted in lower contents in the leaves.

K contents in new and mature leaves do not statistically differ between each other. Nevertheless, lower contents of that nutrient could be observed in senescent leaves and even lower ones in the litter. Therefore, there was translocation of potassium from the senescent leaves to other parts of the plant. According to Camargo and Silva (1990), K is absorbed in its ionic form and is translocated within the apoplast, being quite mobile in the plant. It can be seen that K content in mature leaf is in the range taken as adequate for the mango culture, which, according to Raij et al. (1997), is between 5 and 10 g kg^{-1}.

Ca presented the highest contents in the senescent and litter leaves which were not statically different between each other ($p \leq 0.01$), supporting the results found by Murbach et al. (2003). Because it is a nutrient known as virtually motionless in the plant phloem, Ca is not redistributed from the most advanced physiological stage of the leaves for supplying the deficiencies of the leaves still in the development stage, or even for other parts of the plant (CAMARGO; SILVA, 1990; MALAVOLTA, 2006). Hence the senescent and the litter leaves will present higher contents of that nutrient. According to Raij et al. (1997), the adequate Ca contents in the diagnosis-leaf, during mango tree full blossom, are between 20 and 35 g kg^{-1}. It can be observed, so, that there is deficiency of that element, showing mean contents of 16.5 g kg^{-1}. According to what was previously mentioned, the low saturations by soil basis (Table 1) were reflected in the low Ca leaf contents. Although S contents have not statistically differed among the four kinds of leaves studied (Table 2), it cannot be ignored from the main component analysis point (Figure 1). According to Malavolta (2006), S is classified as having little mobility in relation to the redistribution activity within the plants.

There was retranslocation of approximately 41% of N, 63% of P and 57% of K among the litter and the mature leaves. According to Gama-Rodrigues, Gama-Rodrigues and Barros (2008), biochemical cycling varies according to the nutrient, the vegetable species and the planting system. Cavalcante et al. (2005), using ^{32}P, observed in banana trees an interrupted retranslocation of P between matrix and new plants. Caldeira et al.

(1999) and Gama-Rodrigues, Gama-Rodrigues and Barros (2008) observed that P and K were the elements with the greatest retranslocation in *Acacia mearnsii*, and in forest species, respectively. Cunha et al. (2005) found in a commercial planting of *Eucalyptus grandis* that the nutrient with the most intense retranslocation (biochemical cycling) was K.

In this study retranslocation order was: P>K>N, showing that biochemical cycling in a mango tree is important for those elements. Murbach et al. (2003) also found that P and K were the nutrients with the highest rates of retranslocation in a study performed at a rubber plantation in production stage. The bigger the biochemical cycling for a determined element, the smaller its importance for the biogeochemical cycle (nutrient transference process between soil and plants), that is, the exogenous cycling. That is a very important fact since the nutrient dynamics in the soil involves fixation, immobilization, volatilization and leaching processes. Thus, only one part of the elements absorbed by the plants during their cycle will return to them by means of litter decomposing. Musvoto et al. (2000), while studying decomposing and releasing of nutrients through the mango tree litter during 18 months, found that there is N immobilization by that material.

Nevertheless, in this study there was no Ca, Mg and S retranslocation, that is, low biochemical cycling, as was also observed by Zaia and Gama-Rodrigues (2004) and Moreira and Fageria (2009). Gama-Rodrigues, Gama-Rodrigues and Barros (2008) also observed that there was no Mg retranslocation in woodcreeper (*Sclerolobium chrysophyllum*), one of the forest species studied. It can be stated that there really occurred distinctions among the mango tree leaves at different stages, in relation to the macronutrient contents, showing that biochemical cycling is important for the culture.

New leaves are characterized by the lowest calcium contents and the highest contents of nitrogen, phosphorus, potassium and magnesium. Senescent leaves as well as the litter ones are directly associated to high calcium contents and to low nitrogen, phosphorus, potassium and magnesium contents. Mature leaves own the highest potassium content, and lowest magnesium content. Retranslocation was found of 41%, 63% and 57% of N, P and K, respectively, when comparison was made between contents in mature leaves and the litter ones, showing that the biochemical cycling is important for the mango tree culture.

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