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Original Article

Silviculture

Nutrient Cycling in *Corymbia citriodora* in the State of Rio de Janeiro, Brazil

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ABSTRACT

The quantification and transfer of nutrient stock among compartments in the forest environment is the key to understanding the nutrient cycling process. The aim of this study was to quantify the nutrient stock and dynamics by litter deposition in a *Corymbia citriodora* settlement in the Mountainous region of the State of Rio de Janeiro. Different plant parts, deciduous material and litter were chemically analyzed for nutrients. The biomass of trees was 127.23 Mg ha^{-1}, making up about 85.8% of the nutrient stock. On average, the nutrient flux represented 13.6% of nutrients stored in the biomass above the soil. The nutrient cycling process involving N, P, K Ca, and Mg in the long-rotation *Corymbia citriodora* crop represents an important strategy for maintaining productivity of the forest site.

Keywords: litter, eucalyptus, nutrient stock, forest sustainability.

1. INTRODUCTION

Corymbia citriodora (Hook.), K. D. Hill, & L. A. S. Johnson, widely known as eucalyptus citriodora, is a multi-use tree species. Recently, the use of this species has become very widespread and appreciated by loggers for industrial and furniture purposes due to the shortage of certified wood (Vilas Bôas et al., 2009). This is because eucalyptus citriodora wood has shown to be durable and little susceptible to cracking. In this respect, this species differs from other eucalyptus species that are usually grown in short cycles for cellulose, ceramics, coal, civil construction, etc. Moreover, extensive *C. citriodora* plantations are not common and rather have long cycle. This also partly explains why scientific studies for this species are scarce.

In the State of Rio de Janeiro, homogeneous forest plantations occupy 18,426 ha, and eucalyptus represents 97.9% of this total. It is the second largest mountain region of the state, regarding this species. It comprises 21.4% of the total cultivation area , with predominance in small- and medium-size rural properties (Amorim et al., 2012). In this sense, the state of Rio de Janeiro, in relation to other states of the federation, presents one of the smallest areas planted with eucalyptus in Brazil (IBGE, 2014), which makes it a major importer of this raw material. Therefore, evaluating the behavior of eucalyptus species, *C. citriodora* is an alternative for land use of great relevance as source of information for the state of Rio de Janeiro.

The first studies addressing some nutrient cycling aspects in *C. citriodora* in Brazil, were carried out by Rocha et al. (1978), and biomass production and nutrient export were studied by Pereira et al. (1984). Recently, several studies have evaluated nutrient cycling in eucalyptus for issues related to production sustainability in short cycles (Cunha et al., 2005; Laclau et al., 2010; Diniz et al., 2011; Viera et al., 2014b).

Nutrient cycling in eucalyptus stands allows the evaluation of possible changes in applied management techniques. Nutrient cycling also makes it possible to infer about the sustainability of plantations. In low-fertility soils, nutrient accumulation and distribution can serve as indicators of nutrient availability for plants (Reis & Barros, 1990; Gama-Rodrigues et al., 2008). Studies of this type could also provide support for the development of management techniques that are ecologically and economically feasible.

Sustained timber production such as eucalyptus depends on how the crop is harvested (Santana et al. 2008; Paes et al., 2013). In total harvest, where all tree parts are harvested from the area, higher nutrient content is exported from the system than when harvesting only the trunk or part of it (Santana et al., 2008). Natural ecosystems have served in many works as reference for various agricultural and forestry systems (Fonseca et al., 1993; Drumond et al., 1997). References regarding the size of the nutrient reservoir accumulated by litter of different forest allow inferring about the quality of the stored material and its decomposition rate. *C. citriodora* species, in relation to the natural forest, accumulates larger amount of litter, which would probably reflect the quality of the stored material. This results in lower decomposition rate, considering C/N ratio of 50 for eucalyptus litter and 25 for natural forest (Fonseca et al., 1993).

The aim of this study was to quantify the nutrient stock of a *Corymbia citriodora* stand and its nutrient dynamics by litter deposition throughout the year in the mountainous region of the state of Rio de Janeiro.

2. MATERIAL AND METHODS

The eucalyptus crop under study (*Corymbia citriodora*), implanted in 1984, has current density of 1453 trees ha^{-1} with 3x2 m plant spacing. The initial purpose of the crop was to produce essential oil, but it has not yet been used for this purpose. The forest is located in the municipality of Santa Maria Madalena, a mountain region of the state of Rio de Janeiro, with geographical coordinates of 21° 52’ 4” S and 41° 58’ 33” W., according to data obtained from São Fidélis, Santa Maria Madalena, and Macabuzinho stations, the climate is dry sub-humid tropical, with heat being well distributed throughout the year. Rainfall during the study development is presented in Figure 1.

Three 25 x 20 m plots were marked, in which litter collectors were installed. This featured a ratio of five collectors (1m x 1m) per plot made of wood and nylon screens with 1 mm mesh opening.

In the three study plots, all trees of each plot were measured at eight of 1.30 m in order to obtain the diameter at breast height (DBH). With the aid of laser hypsometer, the height of trees was estimated. The measured trees were arranged into 4 diametric classes with the following frequency: DBH 9-12 cm 22.38%; DBH 12, 1-15 cm 56.72%; DBH 15, 1-18 cm 16.42%, and DBH 18-21 cm 4.48%. On average, the mortality rate was 19%.

The soil of the area was classified as Dystrophic Red-Yellow Latosol with attributes presented in Table 1.

Litter production was quantified every 30 days. For this, the material collected was air-dried and then separated into leaves, branches smaller than 2 cm in diameter, flowers and fruits, bark, and other materials that were difficult to categorize as a function of size. The material separated from each collector (leaf, branch, bark, reproductive structures, and fine residue) was dried at 70 °C in an air circulation oven until reaching constant weight. Samples were weighed until they no longer presented mass variation in the last weighing.

The chemical analyses of litter were carried out in all fractions separately. The five collectors of each plot composed simple samples that were mixed and became a composite sample.

The litter accumulated on soil was collected in the winter and summer periods using a wood template measuring 0.5 m x 0.5 m. Each plot was represented by 4 simple samples, which together formed a composite sample. The collected material was dried in oven at temperature of 70 °C until reaching constant weight.

In plots, the biomass of shoot components was quantified as follows: From measurements of DBH and height of all trees of each plot, the mean height and the mean DBH of the population of 84 trees were calculated. Thus, two trees with DBH and height equal to the mean value of the population were selected for biomass measurement, as similarly performed by Pereira et al. (1984), Teixeira et al. (1989), Santana et al.(2008), and Gatto et al. (2014). Trees were harvested and, then, measured to obtain volume by the Smalian method. With the aid of a chainsaw, stems were sectioned into pieces of 1 m in length. Discs were then removed to estimate dry matter content and to obtain samples for chemical analyses. At this point, the fresh biomass of leaves, thin branches, bark, and wood was also obtained. Samples were taken to the laboratory to obtain dry matter after drying to constant weight at 70 °C, in order to correct the fresh biomass and to estimate biomass per ha. Biomass estimation by area was obtained by multiplying the average biomass of felled trees by the number of trees in each plot.

All plant material was ground in a Wiley mill, from which a duplicate sub-sample was removed for nitro-perchloric digestion for P, K, Ca, and Mg determination. Another

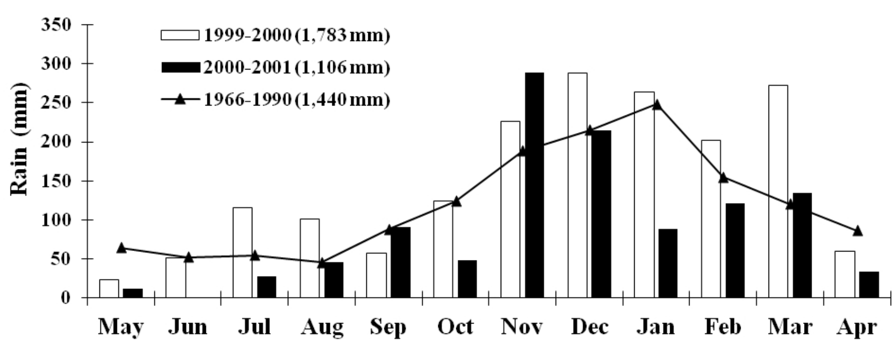

Figure 1. Monthly rainfall in Santa Maria Madalena, RJ, Brazil 21°37'S, 42°05'W (unpublished data provided by Instituto Nacional de Meteorologia – INMET).

Table 1. Chemical characteristics of soil on eucalyptus plantation (*Corymbia citriodora*) in the state of Rio de Janeiro, Brazil.

Depth	pH	C	P	K	Ca	Mg	Al	H+Al
cm		g kg^{-1}	Mg kg^{-1}		cmol$_c$ kg^{-1}			
0-5	4.50	20.9	5.7	174	1.82	1.59	0.27	6.61
5-10	4.31	17.5 b	5.1	122	1.10	1.33	0.46	5.80

duplicate sub-sample was removed for sulfuric digestion for N determination by the Kjeldahl method, (Tedesco et al., 1985). After digestion, K was determined by flame photometry, P was colorimetrically determined after reduction of the phosphomolybdic complex, and ascorbic acid, Ca, and Mg were determined by atomic absorption. C was determined by wet digestion using a 0.200 g plant material sample (Anderson & Ingram, 1996).

Soil fertility characterization was followed by the sampling of 15 single samples/composite samples at depths of 0-5 and 5-10 cm. The plot was represented by four composite samples.

K (flame photometry) and P (colorimetrically) concentrations were determined after extraction with Mehlich-1. Ca and Mg (atomic absorption spectrophotometry) were determined after extraction with KCl 1M L^{-1}, N and pH in water, Al and H + Al and organic carbon, according to EMBRAPA (1997).

To calculate the nutrient concentration variation in leaves, the following terms were designated: canopy leaves (cl) (those collected after the harvest of trees), leaf fall litter (ll) (obtained by the collector), and forest floor leaf litter (lf) (obtained by collecting litter accumulated on the soil).

The nutrient content per area was determined by multiplying the concentration of nutrients in the various components of trees by biomass per area.

To estimate the decomposition rate (K_L), the annual leaf litter production and the average leaf litter layer value were estimated: K_L = annual leaf litter production / forest floor leaf litter (Olson, 1963). In the estimation of the mineralization rate (K_E), the annual average nutrient intake of the leaf fall litter produced and the average annual nutrient stock of the forest floor leaf litter mass were considered: K_E = nutrient supply / nutrient stock intake.

Data were evaluated by descriptive statistics, obtaining means, standard error, confidence interval, and standard deviations of means.

3. RESULTS AND DISCUSSION

The estimated *C. citriodora* biomass was 127.23 Mg ha^{-1} (±10.39), distributed into wood (87.42 Mg ha^{-1}), bark (24.53 Mg ha^{-1}), branches (12.28 Mg ha^{-1}), and leaves (3.00 Mg ha^{-1}). This represented 72% of the *C. citriodora* biomass estimated by Pereira et al. (1984) in in the same spacing, presenting 177.34 Mg ha^{-1} nine years after planting. The mean diameter (DBH) of trees was 13.61 cm (±0.58), and the basal area was 20.80 m^2 ha^{-1}. In a *C. citriodora* settlement in the state of São Paulo, Vilas-Bôas et al. (2009) found DBH and basal area of 12.5 cm and 20.7 m^2 ha^{-1}, respectively, after 8 years of development in 3 x 2 m spacing, while Pereira et al. (1984) obtained DBH of 14 cm at 9 years of age with the same planting density. Likely, climatic limitations such as water deficiency that are common in the lower slopes of the Serra do Mar, a northern part of the State of Rio de Janeiro where there are dry times (Sant'Anna, 2005), in addition to genetic material from seeds that may cause lower yields in eucalyptus (Ferreira, 1992). Probably, climatic limitations such as water deficiency, common in the western slopes of Serra do Mar, as in the northern part of the State of Rio de Janeiro, where dry islands or rain shadows are observed (Sant'Anna, 2005) and/or genetic material from seeds may cause less eucalyptus productivity. Santana et al. (2008) estimated lower productivity in eucalyptus forest sites located in regions with water deficits, compared to regions with higher water availability.

Wood biomass accumulated most of nutrients and carbon, except for Ca (Table 2), which is found in the tree part above the ground, referred as to shoots. On average, wood contains 42% of N, 45% of P, 33% of K, 34% of Ca, 47% of Mg, and 68% of carbon stored in plants. Considering that among eucalyptus species, *C. citriodora* has one of the highest commercial values for sawmills, the extraction of wood (wood + bark) would represent 60% removal of N, 72% of P, 62% of K, 81% of Ca, 78% of Mg, and 87% of carbon. Surely, exclusive extraction of wood would reduce the nutrient withdrawal from the forest site.

The nutrient content stored in the tree part above the ground varies greatly, depending on the forest site, genetic material, and age of plants. Notably, the effect of climate, mainly water restriction, impairs the absorption of nutrients, generally leading lower biomass and nutrient contents (Santana et al., 2008).

In Curvelo-MG, where the climate is characterized as tropical humid savanna (AW, according to Köppen) with expressive dry season, Pereira et al. (1984) found immobilized 325.14 kg ha^{-1} of N, 68.61 of P, 335.27 of K, 298.72 of Ca, and 142.69 of Mg in the total aerial biomass in a *C. citriodora* plantation. Trunk (wood + bark) represented about 50% of N, 63% of P, 50% of K, 72% of Ca, and 64% of Mg contained in aerial biomass.

The annual litter production (Table 3) varied during the two years of study; however, the leaf fraction that represented about 50% of the litter biomass did not change, indicating seasonality due to the bark litter contribution, especially in the first year as a resut of suber detachment, typical of some genera of the Mirtaceae family. Other studies have reported leaf yield of 3.48 Mg ha^{-1} and total annual litter production of 5.63 Mg ha^{-1} for *E. grandis* in northern state of Rio de Janeiro (Cunha et al., 2005) and 11.84 Mg ha^{-1} for *E. grandis* in the state of Rio de Janeiro (Balieiro et al., 2004). While observing litter production from the age of 5.5 years in *E. urophylla* × *E. globulus* plantation up to 9 years, Viera et al. (2014b) found variation in litter production over time. At 9 years, production was 8.50 Mg ha^{-1}.

In February of the first year, the highest litter production occurred, and it was observed that the bark deposition was high during this period, but the same pattern was not observed during the second year. In the second year, the material presented greater variation over time. This litter deposition behavior is possibly associated to climate variations verified by the reduction of rainfall in the second year and probably to temperature variations (Figure 2). For *E. grandis* at 8 years of age and cultivated in the northern state of Rio de Janeiro, the contribution of leaves was greater in the month of December (Cunha et al., 2005). Therefore, it is, evident that in the southeastern region, the production of litter in eucalyptus is concentrated in the hotter and rainier months (Balieiro et al., 2004; Cunha et al., 2005). In the present study, 76.84% of litter biomass contribution occurred between September and March. Nevertheless, Corrêa et al. (2014) found higher eucalyptus litter deposition in autumn and lower deposition in summer in the state of Rio de Janeiro.

There was a decrease in nutrient concentration in canopy leaves (cl), leaf fall litter (ll), and forest floor leaf litter (lf), except for Ca (Table 4). Rocha et al. (1978) and Pereira et al. (1984) also identified similar variation in studies with *Corymbia citriodora*. Thus, there is a pattern in the reduction of the nutrient concentration among photosynthetically active leaves and litter leaves accumulating on the ground.

Most N and P contained in newly fallen leaves (leaf fall litter) are not found in decomposing leaves; however, it does not reflect in higher mineralization rate (Table 5). Differences in nutrient concentrations in leaves before senescence and levels observed in forest floor leaf litter may indicate the intensity of the nutrient retranslocation process (biochemical cycling). On the other hand, differences in nutrient concentrations

Table 2. Nutrient contents and relative distribution in different parts of *C. citriodora* trees grown in the mountainous region of the state of Rio de Janeiro, Brazil (Standard errors in parentheses).

Fraction	N	P	K	Ca	Mg	C
	kg ha^{-1}					
Leaf	64 (37.6)	2.7 (1.6)	35.0 (20.6)	26 (15.0)	7 (3.9)	1,336 (786)
Branch	64 (33.0)	2,5 (1.3)	65 (33.2)	103 (53.1)	17 (8.8)	5,883 (3,005)
Bark	56 (12.1)	5.1 (1.6)	78 (18.7)	317 (43.6)	33 (7.7)	10,990 (1,154)
Wood	134 (8.1)	8.6 (1.1)	88 (4.9)	231 (5.6)	51 (9.7)	39,513 (3,371)

Table 3. Litter production in *C. citriodora* in the mountainous region of the state of Rio de Janeiro, Brazil.

Year	Fraction					
	Leaf	Branch	Bark	Flower and fruits	Residue	Total
	Mg ha^{-1}					
2000	3.22	1.17	2.09	0.43	0.13	7.04
2001	3.31	1.42	0.72	0.57	0.10	6.12

between produced leaf fall litter and stored forest floor leaf litter indicate the intensity of the biogeochemical cycling process (Reis & Barros, 1990).

The biochemical P cycling was more intense, and 52.2% of P contained in mature leaves were reused before senescence. In contrast to the biochemical cycling efficiency with respect to N and P, eucalyptus produces relatively poor litter for nutrients that control substrate quality to some extent. In contrast to the biochemical cycling efficiency, in reference to N and P, nutrients that control, to a certain extent, substrate quality, eucalyptus produces relatively poor litter. Given the results above and others observed by (Drumond et al., 1997), it could be hypothesized that if the plant or stand has high biochemical cycling efficiency, it would be less dependent on the decomposition process (losses by

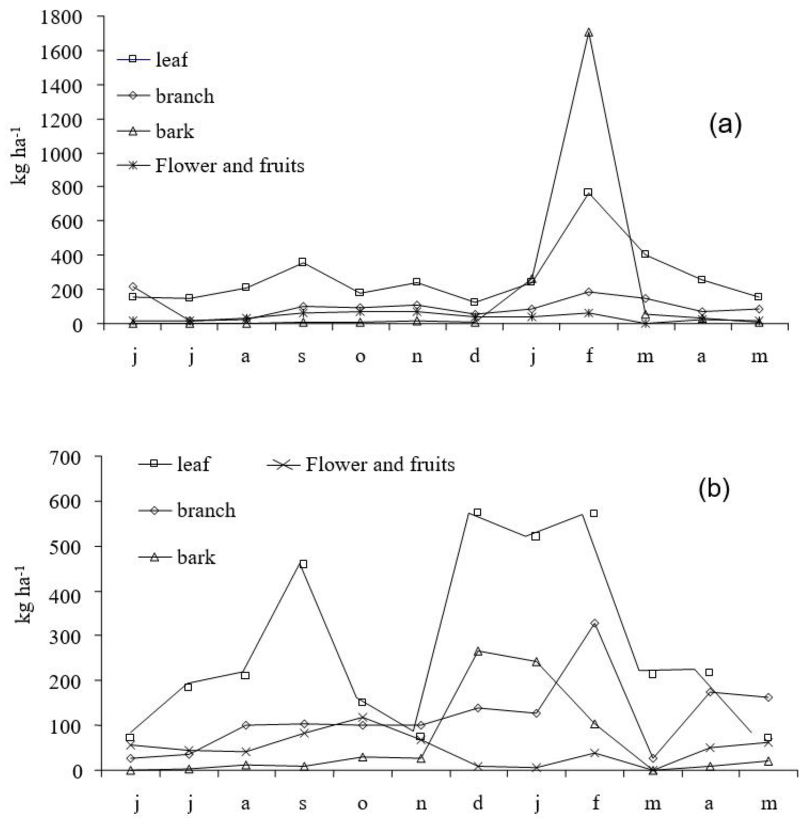

Figure 2. Monthly seasonality between June (j) and May (m) of litter components in *C. citriodora* in the mountainous region of the state of Rio de Janeiro, Brazil. (a) 2000 and (b) 2001.

Table 4. Nutrient concentration in canopy leaves, leaf fall litter, and forest floor leaf litter. Percentage variation of nutrient content between leaf fall litter (ll) and canopy leaves (cl) and percentage variation between forest floor leaf litter (lf) and leaf fall litter (ll) in *C. citriodora* in the mountainous region of the state of Rio de Janeiro, Brazil. (Standard errors in parentheses).

Leaf	N	P	K	Ca	Mg
	g kg^{-1}				
canopy	21.30 (±1.06)	0.90 (±0.07)	11.66 (±0.98)	8.67 (±0.69)	2.33 (±0.25)
leaf fall litter	12.04 (±2.62)	0.43 (±0.08)	7.28 (±0.67)	8.10 (±0.82)	1.84 (±0.28)
forest floor	9.80 (± 1.96)	0.32 (±0.06)	2.51 (±0.43)	10.34 (±1.09)	1.60 (±0.20)
ll x cl[1]	-43.5	-52.2	-37.5	-6.6	-8.5
lf x ll[2]	-18.6	-25.5	-65.5	+27.6	-13.0

[1]{([ll] - [cl]) / [cl]}x 100; [2]{([lf] - [ll]) / [ll]}x 100.

energy transfer, volatilization, and leaching). When the decomposition process is imperative for the ecosystem, it is more dependent on biotic and abiotic factors involved in the process. Thus, nutrient reuse depends on the interaction among controlling factors of the decomposition process, and there may be situations of prolonged water deficit that would delay nutrient cycling because it limits the microbiological activity (Turchetto & Fortes, 2014). From the point of view of internal cycling in eucalyptus, Reis & Barros (1990) reported that during the decomposition process, there may be immobilization of N, as well as losses due to leaching and reduction of nutrient availability (for example, conversion from labile to non-labile P) from soil to plant. Thus, through biochemical cycling, nutrients are directly used for the growth of new tissues, being a constant source of nutrients for plants. In *E. grandis*, the magnitude of biochemical cycling was of the order of -46.3% for N and -48% for P (Cunha et al., 2005), which values are very close to those found in the present study. In contrast, the difference in nutrient concentration between leaf fall litter and forest floor leaf litter as an estimate of biogeochemical cycling intensity showed that K was the nutrient with the highest difference between concentrations at -65.5%, followed by P and N. Since K is not a structural plant element, its transfer by leaching is more intense than other elements (Diniz et al., 2011). By comparison, Ca concentration is relatively higher in residues stored on the soil, as reported by Cunha et al. (2005) and Viera et al. (2014b).

The input of N, P, K, Ca, and Mg averaged 180.55 kg ha^{-1} yr^{-1} (Table 6). The order for average transfer magnitude was N> Ca> K> Mg> P. Nutrient intake and the N> Ca or Ca> N sequence may vary due to the nutritional status and also to the fact that the material returned to the soil. In turn, the nutritional status may vary according to the genetic material (Wadt et al., 1999). Thus, in *E. urophylla* × *E. globules* plantations, the mean order of nutrient supply was Ca> N> K> Mg> P with totals of 54.2; 43.6; 18.6; 14.0; 4.1; 2.3 kg ha^{-1} yr^{-1}, respectively (Viera et al., 2014b), while Cunha et al. (2005) found the sequence to be N> Ca> K> Mg> P for *E. grandis* in northern state of Rio de Janeiro.

The contribution of leaves to the transfer of nutrients to the soil was, on average, 57, 45, 74, 42, and 50%, respectively for N, P, K, Ca, and Mg. This demonstrates the relevance of this fraction for nutrient cycling, as pointed out by Cunha et al. (2005) and Viera et al. (2014b). The average litter biomass stored on the soil was 11.10 Mg ha^{-1} (Table 5), which is composed of 51% of leaves. The Ca stock in the litter was higher than that of N, P, K, and Mg.

Table 5. Accumulated litter (leaves and total) and nutrient content stored in the forest floor litter of *C. citriodora* in the mountainous region of the state of Rio de Janeiro, Brazil.

Year	Leaf	Total	Nutrients				
			N	P	K	Ca	Mg
	t ha^{-1}		kg ha^{-1}				
2000	5.88	12.01	103.0	3.49	21.4	111.0	18.0
2001	5.43	10.20	87.0	2.96	18.1	94.2	15.3

Table 6. Annual production of nutrients in leaf fall litter in *C. citriodora* in the mountainous region of of the state of Rio de Janeiro, Brazil.

Fraction	N		P		K		Ca		Mg	
	------------------------------ kg ha^{-1} ano^{-1} ------------------------									
	2000	2001	2000	2001	2000	2001	2000	2001	2000	2001
Leaf	38.8	41.8	1.4	1.4	23.5	24.1	26.1	26.8	5.9	6.1
Branch	14.5	17.5	0.2	0.2	3.7	4.5	11.8	14.3	1.4	1.7
Bark	8.4	2.9	0.8	0.3	3.7	1.1	27.7	9.0	4.2	2.0
Flower and Fruits	6.7	8.6	0.4	1.3	1.0	1.2	3.2	4.3	1.0	1.4
Residues	1.7	1.2	0.1	0.1	0.6	0.4	1.0	0.9	0.1	0.1

Litter stock reduction probably occurred in the second year in part due to the lower amount of leaf fall litter (Table 3). Litter stock in *E. grandis* in northern state of Rio de Janeiro was estimated at 9.56 Mg ha^{-1} (Cunha et al., 2005), while Viera et al. (2014b) found average of 14.0 Mg ha^{-1} in *E. urophylla* × *E. globulus* plantations in the state of Rio Grande do Sul, with mean values of 117.4 kg ha^{-1} of N, 5.1 kg ha^{-1} of P, 16.9 kg ha^{-1} of K, 146.8 kg ha^{-1} of Ca, and 26.4 kg ha^{-1} of Mg.

Based on leaf stock accumulated on the soil, the average leaf decomposition coefficient (K_L) was estimated at 0.58 (Table 7). Studies by Viera et al. (2014b) indicated variation in the litter decomposition coefficient between 0.47 and 0.61. On the other hand, Cunha et al. (2005) reported litter decomposition coefficients between 0.35 and 0.93. The authors suggested that this depends on the plot age and the re-growth time, highlighting litter decomposition restriction in *E. grandis* in in northern state of Rio de Janeiro. Thus, in this settlement, the average residence time of *C. citriodora* litter was 1.68 years, whereas Balieiro et al. (2004) and Schumacher et al. (2013) reported average litter residence time of 1.43 years and 1.33 years in eucalyptus, respectively.

The nutrient mineralization rate was higher for K (Table 7), notably due to its high solubility in intercellular space (Chapin et al., 2002; Viera et al., 2014a), which favors leaching. Despite the higher Ca content in litter, the mineralization rate was the lowest found among analyzed nutrients, probably because Ca played a structural role in the cell wall (Hawkesford et al., 2012), providing greater recalcitrance of the element to mineralization.

The nutrient distribution for production system components can be observed in Table 8. The annual litter production varied from 9 to 22% of N, P, K, Ca, and Mg for the nutrient capital immobilized in *C. citriodora* biomass. This indicates that the production of deciduous material considerably contributed to the maintenance of the nutrient stock in the accumulated litter, which acts in a gradual way through the decomposition process in the transfer of nutrients and carbon to the soil.

Due to the soil sampling depth, most nutrients of the soil-plant system are stored at these depths, however, vegetation is the most vulnerable portion because nutrients and carbon that are immobilized in the biomass can be removed from the system through harvest, which results in nutrient extraction and risk of fire. Gatto et al. (2010) evaluated the carbon stock in both soil and biomass of eucalyptus plantations and found that more than half of the system carbon accumulated in the soil, while in wood, stocks are about 29% of the total carbon. In eucalyptus citriodora, tree biomass comprises 36% of the total carbon (Table 8).

Table 7. Litter decomposition rate (K_L = annual production of leaf fall litter/annual average of forest floor leaf litter) and mineralization rate (K_E = nutrient supply in leaf fall litter / nutrient content in forest floor leaf litter) of *C. citriodora* in the mountainous region leaf fall litter, Brazil.

Year	K_L	K_E				
		N	P	K	Ca	Mg
2000	0.55	0.67	0.85	1.59	0.43	0.63
2001	0.61	0.79	0.81	1.77	0.48	0.70

Table 8. Nutrient and carbon distribution in tree, forest floor litter, leaf fall litter, and soil in *C. citriodora* in the mountainous region of the state of Rio de Janeiro, Brazil.

	N	P	K	Ca	Mg	C
	kg ha^{-1}					
Tree	318 (77%)[1]	19 (86%)	266 (93%)	677 (87%)	108 (86%)	57,772 (92%)
Stored in litter forest floor	95 (23%)	3 (14%)	20 (7%)	102 (13%)	17 (14%)	5,111 (8%)
Leaf fall litter	71 (22%)[2]	3 (16%)	32 (12%)	63 (9%)	12 (9%)	-
Soil (80 cm)	6,998(94%)[3]	30 (55%)	491(61%)	1,087 (56%)	283 (67%)	95,020

[1]Percentage in relation to the stock in vegetation plus litter; [2]Percentage of annual production in relation to stock in vegetation; [3]Percentage in relation to the total nutrient stock in the system.

4. CONCLUSION

Of the total nutrients in the biomass, 71, 3, 32, 58, and 12 kg ha^{-1} for N, P, K, Ca, and Mg, respectively, were returned by the litter. This demonstrates the importance of the nutrient cycling process for maintaining the productive capacity of the environment.

As the most labile fraction in the decomposition process, leaves transferred more than 50% of nutrients to the soil, as compared to the other litter constituents.

The retranslocation of nutrients from leaves before senescence contributes to reduce the N and P concentration in litter accumulated on the soil.

The *Corymbia citriodora* long-rotation nutrient cycling process represents an important strategy for maintaining productivity of the forest site.

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