Nutrient release from *Eucalyptus grandis* and *Pinus taeda* harvest residues

[A]Gabriela Sánchez[A],Amabelia del Pino[A,B] and Jorge Hernández[A]

[A]Department of Soil and Water, Facultad de Agronomía, Universidad de la República Oriental del Uruguay. Garzón 780 Montevideo, Uruguay.
[B]Corresponding author. Email amabelia@fagro.edu.uy

Abstract

Decomposition patterns of forest harvest residues produce the release of nutrients, which will be available for the next turn. Pine and eucalyptus harvest residues were aerobically incubated under controlled temperature (25ºC) for 300 days with the objectives: 1) to determine decomposition patterns of forest residues under controlled conditions, in relation to their physical and chemical characteristics, and 2) to evaluate nutrient release from the residues, comparing the results with those obtained in decomposition experiments in the field. The experiment consisted in six treatments and three replications. The treatments were: 1) control soil, 2) *P. taeda* needles, 3) *P. taeda* branches, 4) *E. grandis* leaves, 5) *E. grandis* bark, 6) *E. grandis* branches. The residues were cut into pieces and placed over the soil in the incubation pots. Soils were periodically leached to recover the released cations (Ca, Mg and K). Decomposition rates were estimated from evolved C-CO_2. The highest decomposition occurred in *E. grandis* leaves and *P. taeda* needles, which could be due to their higher soluble C and low C:N ratio compared to bark and branches. Among cations, K was easily leached while the opposite occurred with Ca.

Key Words

Forest harvest, nutrient leaching, soil respiration, potassium, calcium, magnesium.

Introduction

In commercial forests of Uruguay, the nutrient export with logs represents a minor proportion of the extracted nutrients (Hernández *et al.* 2009). Therefore, it is crucial to study decomposition patterns of forest harvest residues, after either clear cut or thinning, to evaluate the potential nutrient release from the residues. Residue decomposition depends on the characteristics of the materials (size and chemical composition), residue management and climatic conditions. The biochemical characteristics of residues influence decomposition patterns. Lignin is likely to retard decomposition because of its stability and detrimental effect on microbial growth (Berg and McClaugherty 1989). In contrast, a high content of soluble organic compounds is likely to promote the activity of microorganisms (Girisha *et al.* 2003). The decomposers population depends on C availability for energy, but they also need a certain amount of several other nutrients. Total N content and C:N ratios have been extensively considered as affecting decomposition rate of plant material (Burgess *et al.* 2002). When nutrients are scarce, decomposition rates are lower (Mary *et al.* 1996). Plant residues with low nutrient contents are likely to immobilize the required nutrients from the soil as decomposition proceeds. The immobilization of nutrients during decomposition often results in reduction of soil nutrient availability and also lower nutrient losses (Gómez Rey *et al.* 2008). The objectives of this study were: 1) to determine decomposition patterns of forest residues under controlled conditions, in relation to the physical and chemical characteristics of the residues, and 2) to evaluate nutrient release from the residues, comparing the results with those obtained in decomposition experiments in the field.

Methods

Soil and residue characteristics

For the incubation experiment, the soil from the 0-20 cm superficial layer of a thermic albic Argiudoll, Rivera (31º 22' 51.9''S and 55º 38' 31.4''W) was taken from a 12 year-old pine forest (Table 1). In this region the mean annual rainfall is 1,600 mm (evenly distributed) and the average temperatures of the coldest month (June) and the warmest month (January) are 11ºC and 24ºC, respectively. The harvest residues: *P. taeda* leaves and branches (diameter < 1 cm) and *E. grandis* leaves, bark and branches (diameter < 1 cm) were taken at harvest of commercial plantations (Table 2).

Table1. Chemical characteristics of the soil.

Total C	Total N	pH $_{(H2O)}$	pH $_{(KCl)}$	Ca^{2+}	Mg^{2+}	K^+	Na^+
(--------- mg/g	---------)			(----------cmol$_c$/kg			----------)
8.05	0.73	4.24	3.74	1.45	0.7	0.18	0.38

1 – 6 August 2010, Brisbane, Australia. Published on DVD.

Table 2. Chemical composition of harvest residues, and amounts of Ca, Mg, and K in the residues incorporated per pot.

Residue	Total C	Total N	Soluble C	Lignin	C/N	Ca	Mg	K	Ca	Mg	K
	(------------------- mg/g -------------------)					(------ mg/g -----)			(---------- mg/pot --------)		
Pinus needles	508.7	16.1	119.2	399.1	31	4.0	1.5	2.9	8.3	3.1	6.0
Pinus branches	493.6	4.7	78.9	370.7	105	3.0	1.4	1.7	10.4	4.9	6.0
Eucalyptus leaves	507.7	17.3	134.4	399.6	29	12.0	2.3	4.1	24.9	4.8	8.5
Eucalyptus branches	458.1	5.7	63.8	320.3	80	14.6	2.5	3.6	61.2	10.7	17.6
Eucalyptus bark	446.9	4.3	107.5	335.4	103	13.2	2.3	3.8	51.4	8.6	12.7

Incubation experiment

Mineralization patterns of forest residues were determined in an aerobic incubation experiment under controlled temperature (25ºC) for 300 days. The experiment consisted in 6 treatments and three replications. The treatments were: 1) control soil, 2) *Pinus taeda* needles, 3) *Pinus taeda* branches, 4) *Eucalyptus grandis* leaves, 5) *Eucalyptus grandis* bark, 6) *Eucalyptus grandis* branches. The soil for the incubation experiment, stored at field humidity, was crushed to pass a 5 mm mesh, and roots and litter were handpicked. The soil (25 g) was placed into a 50 mL plastic pot, with 5 small holes in the bottom and a filter paper to avoid soil losses. Plant residues were cut into 0.5 to 1 cm length pieces, and placed over the soil surface without mixing. The amounts (dry basis) were 2.08 g for pine needles and eucalyptus leaves, 3.52 g for pine and eucalyptus branches, and 4.64 g for eucalyptus bark. In order to measure the C-CO_2 evolved, the pots were placed into 1 L jars with a 5 mL vial with 0.5 M NaOH and hermetically sealed. Two extra jars were prepared to subtract the background C-CO_2. After the incubation period (1 week during the first 2 months and 2 weeks thereafter), the remaining NaOH was titrated with 0.1 M HCl, and the NaOH vials replaced. The incubation pots were leached every two weeks for the first 3 months, and once a month thereafter. For the leaching of the released nutrients, deionized water was poured over the residues in small drops for 15 minutes. The amount of water for the leaching was 80 mL at the beginning, when the incubation period was two weeks, and 160 mL for monthly samplings. The leachate was collected in 250 mL plastic flasks and stored at -4ºC.

Chemical analysis

Total and soluble C in residues were analyzed by oxidation with $K_2Cr_2O_7$ and concentrated H_2SO_4 at 150ºC for 1 hour, and colorimetric determination (Nelson y Sommers 1996). For total and soluble N determination, the Kjeldahl method was used. Total Ca, Mg, and K in residues were determined after ignition of the residues at 550ºC for 5 hours, and then ashes were diluted with HCl. Lignin was determined by acid hydrolysis. Soil exchangeable Ca, Mg, and K were extracted with 1 M NaH_4OAc at pH 7. The contents of Ca^{2+}, Mg^{2+} in the extracts and the leachate were analyzed by atomic absorption spectrometry, and K^+ by flame emission spectrometry.

Data analysis

The statistical analysis (ANOVA) was made at each sampling considering a completely randomized design with three replications. Differences among means (P < 0,05) were compared using Tukey analysis.
To characterize decomposition patterns an exponential model with two pools was adjusted:

$$w = w_r + w_d\, e^{(-kt)} \qquad (1)$$

where w is the remaining material at time t (percentage of initial weight), w_r is the estimated proportion of the pool resistant to decomposition, w_d is the proportion of decomposable material, k is the decay constant and t is the time in days.

Results

Carbon mineralization

Soluble C in the leachate was almost negligible compared to evolved C-CO_2 (data not shown). Figure 1 shows the cumulative evolved C-CO_2 from harvest residues, which were closely adjusted to the exponential decay model (Table 3). Decomposition rates of residues in this experiment were lower than those observed in field experiments (Hernández *et al.* 2009). One possible reason for this result is the effect of macrofauna in field experiments. Sunlight exposure and temperature fluctuations are also likely to contribute to higher decomposition in the field. The leaching regime, which removed the released nutrients, could also have negatively affected decomposers, because unlikely in the field situation, where rain is usually distributed along the year, the soils received a large amount of water in a short period. In this case it is possible that the microbial population was deprieved nutrients from soil and residues.

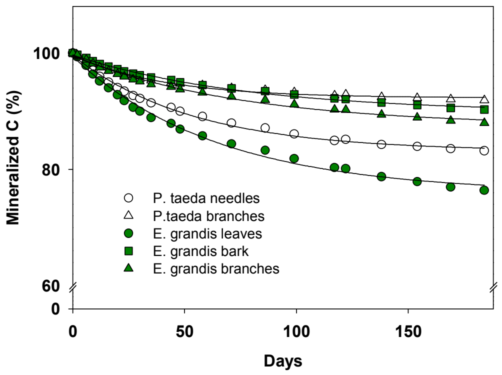

Figure 1. Mineralized C from harvest residues of *P. Taeda* and *E.grandis*.

Table 3. Parameters of the adjusted model: $w = w_r + w_d\, e^{(-kt)}$.

Residue	w_r	W_d	k	R^2
P. needles	83.12	16.46	0.019	0.99
P. branches	92.28	7.40	0.024	0.98
E. leaves	75.91	23.48	0.015	0.99
E. branches	87.45	12.06	0.013	0.99
E. bark	89.76	9.91	0.013	0.99

The fractions that experienced the highest decomposition were *E. grandis* leaves and *P. taeda* needles. This fact could be due to the higher soluble C and low C:N ratio of needles and leaves compared to bark and branches. Moreover, the fine sized residues (needles and leaves) could be easier to reach by decomposers than the coarse ones. *Pinus taeda* needles had significantly lower mineralization rates than *E. grandis* leaves throughout the study. A similar situation was observed for branches; *P. taeda* branches were the least decomposed residue at the end of the incubation, while bark was in the middle.

Release of Ca, Mg and K

The amounts of cations in the leachate showed an increasing trend in the first 60 days of incubation, slowing thereafter (Figure 2). This trend is coincident with the C-CO_2 evolution, and suggests that the cations were released as the material decomposed.

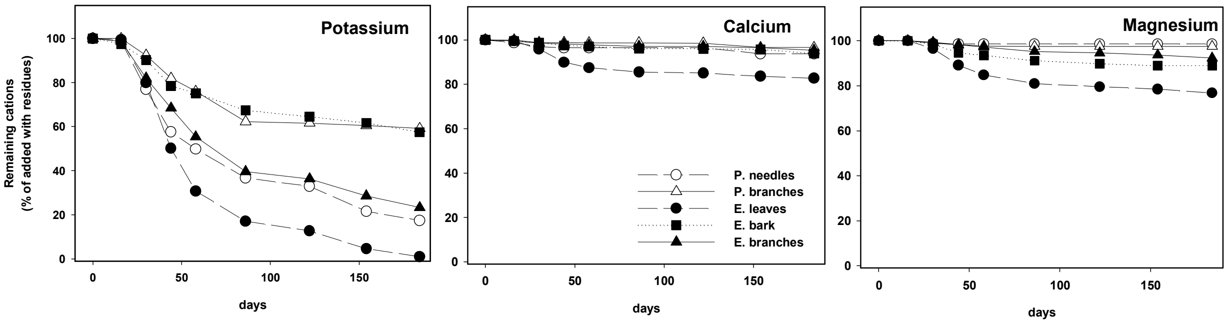

Figure 2. Remaining cations (K, Ca and Mg) from *P. Taeda* and *E.grandis* harvest residues in soils periodically leached (% of the initial amounts).

Potassium release from residues was rapid, and the amounts in the leachate were higher than the control at most sampling times. This result is coincident with decomposition studies in the field, which showed a rapid disappearance of K from harvest residues, attributed to leaching rather than to residue decomposition (Ganjegunte *et al.* 2003; Hernández *et al.* 2009). Moreover, K is less likely to be retained in exchangeable form by soil colloids when divalent cations (Ca and Mg) are released at the same time. Also, eucalyptus residues presented significantly higher K release than the same corresponding fraction (leaves or branches) for pine residues, which is coincident with their higher K content.

Magnesium concentration in leachate from eucalyptus residues was greater than control soil at most samplings, but this was not observed in pine residues. In field experiments with eucalyptus residues Hernández *et al.* (2009) reported Mg losses from residues which were closely linked to decomposition rates. On the other hand, the amounts of Ca in the leachate were similar in control soils and the soils amended with residues, except for eucalyptus leaves, which showed higher Ca release. Calcium is a structural component of vegetal tissues; consequently the Ca concentration in residues tends to increase as decomposition proceeds and it is only released at advanced stages of decomposition (Ouro *et al.* 2001). Considering the lower Ca and Mg content of pine residues compared to eucalyptus, it is possible that an important proportion of the divalent released cations from pine was retained in exchangeable forms in the soil, and hence, was not leached.

Conclusions

Decomposition of harvest residues followed an exponential decay trend with the highest losses corresponding to *P. taeda* needles and *E. grandis* leaves. Cation release followed a similar trend, with the lowest supply from coarse residues. While released K was easily leached, Ca and Mg tended to remain either within the residues or as exchangeable forms in the soil.

References

Berg B, McClaugherty C (1989) Nitrogen and phosphorus release from decomposing litter in relation to the disappearance of lignin. *Can. J. Bot.* **67**, 1148-1155.

Burgess MS, Mehuys GR, Madramootoo CA (2002) Nitrogen dynamics of decomposing corn residue components under three tillage systems. *Soil Sci. Soc. Am. J.* **66**, 1350-1358.

Gangegunte GK, Condron LM, Clinton PW, Davis MR, Mahieu N (2003) Decomposition and nutrient release from radiata pine (*Pinus Radiata*) coarse woody debris. *For. Ecol. Manage.* **187**, 197-211.

Gómez Rey MX, Vasconcelos E, Madeira M. (2008). Effects of eucalypt residue management on nutrient leaching and soil properties. *Eur. J. Forest Res.* **127**, 379-386

Hernández J, del Pino A, Salvo S, Arrarte G (2009) Nutrient export and harvest residue decomposition patterns of a *Eucalyptus dunnii* Maiden plantation in temperate climate of Uruguay. *For. Ecol. Manage.* **258**, 92-99.

Mary B, Recous S, Darwis D, Robin D (1996) Interactions between decomposition of plant residues and nitrogen cycling in soil. *Plant Soil* **181**, 71-82.

Nelson DW, Sommers LE (1996) Total carbon, organic carbon, and organic matter. In ´Methods of Soil Analysis. Part 3. Chemical Methods´. (Eds. DL Sparks *et al.*) pp. 961-1010. ASA and SSSA, Madison WI.

Ouro G, Pérez Batallón P, Merino A (2001) Effect of sylvicultural practices on nutrient status in a *Pinus radiata* plantation: Nutrient export by tree removal and nutrient dynamics in decomposing logging residues. *Ann. For. Sci.* **58**, 411-422.