© Académie des sciences / Elsevier, Paris
Surface geosciences / *Géosciences de surface*
(Pedology / Pédologie)

Change in lignin content during litter decomposition in tropical forest soils (Congo): comparison of exotic plantations and native stands

Évolution de la teneur en lignine et décomposition de la litière dans les sols des forêts tropicales (Congo): comparaison de plantations exotiques et de peuplements naturels

France BERNHARD-REVERSAT* and Dominique SCHWARTZ**

ORSTOM, Centre de Pointe Noire, Congo

ABSTRACT

Fast-growing tree plantations are being extended in tropical countries resulting in new forest ecosystems, the functioning of which is yet not well known. In particular, few data are available concerning lignin decay rate. Lignin, nitrogen and tannin contents of fresh and decaying litter were measured in natural rain forest and in planted stands of *Eucalyptus* hybrids, *Acacia mangium* and *A. auriculiformis* in Congo, together with litter-fall and forest-floor accumulation. Lignin evolution in aging litter exhibited different patterns. Lignin was accumulated under Eucalyptus plantation, but disappeared under natural forest, and was intermediate under *Acacia* plantations. The relationships with decomposition rates and lignin degradation factors, such as white rot fungi and termites, are also discussed.

Keywords: *Rain forest,* Eucalyptus, Acacia, *Congo, Lignin, Litter, Decomposition*

RÉSUMÉ

Les plantations d'essences forestières à croissance rapide se développent dans les pays tropicaux, conduisant à de nouveaux écosystèmes forestiers dont le fonctionnement reste encore mal connu. En particulier, les données sur l'évolution de la lignine dans les litières sont très rares. Au Congo, les teneurs en lignine, azote et tannin de litières fraîche et en voie de décomposition ont été mesurées dans des forêts ombrophiles et dans des parcelles d'Eucalyptus hybrides, *Acacia mangium* et *A. auriculiformis,* et comparées aux chutes de litière. L'évolution de la lignine avec l'âge diffère selon le type de forêts. Elle s'accumule sous *Eucalyptus,* mais disparaît dans la forêt naturelle, les plantations d'*Acacia* représentant un cas intermédiaire. Les relations entre taux de décomposition des litières et facteurs de dégradation de la lignine sont également discutées.

Mots clés : Forêt ombrophile, *Eucalyptus, Acacia,* Congo, Lignine, Litière, Décomposition

Note présentée par Georges Pédro
Note remise le 17 mars 1997, acceptée après révision le 26 mai 1997

…i-Varagnat, 93143 Bondy cedex, France.
…gonne, 67083 Strasbourg cedex, France.

VERSION ABRÉGÉE

La lignine est un composé organique abondant dans les végétaux et les litières végétales, qui participe pour une part importante à la matière organique du sol, et que seul un nombre restreint d'organismes sont susceptibles de dégrader (Andreux et Munier-Lamy, 1994 ; Berthelin et al., 1994 ; Ham-

des feuilles. On n'observe pas de relation entre la vitesse de décomposition et la teneur en lignine des litières fraîches. Cependant, une relation étroite entre la décomposition et le rapport lignine/N est mise en évidence si l'on exclut les litières d'Acacia, dont les teneurs élevées en azote résultent de la

The aim of this study is to compare data on lignin content change during litter decomposition in natural and planted forests, together with initial nitrogen and tannin content data from the same sites.

II. Sites and methods

The study was carried out in two semi-deciduous rain forest sites, including six plots, located at Dimonika (2 plots, i.e., 1A and 1B) and Les Saras (4 plots, i.e., 2A, 2B, 2C and 2D) in the Mayombe region (Schwartz, 1993), and in four plots in 7-year-old fast-growing tree plantations established in the coastal area savanna, 70–100 km apart. The tree plantations included two hybrids of Eucalyptus (PF1 and HS2), *Acacia mangium* and *A. auriculiformis,* described by Bernhard-Reversat (1993). The climate of the area was described by Clairac et al. (1989). The region is submitted to a 4 month dry season with temperatures lower than during the rainy season, and with cloudy weather and high atmospheric humidity. Amounts of rainfall during the rainy season range approximately between 1 200 mm in the Eucalyptus zone and at Les Saras, and 1 500 mm at Dimonika, at an altitude of 400 m. All sites were located on ferralitic soils although the clay content was higher in the Mayombe sites.

Previous studies dealt with the amount of litter-fall and some decomposition processes in native rain forest and in artificial forests of exotic species in Congo (Bernhard-Reversat, 1993; Schwartz, 1993). Litter-fall was measured weekly in ten traps in each plot over 1 or 2 years. Traps were 1 × 1 m in forest plots and 0.5 × 0.5 m in plantations. Litter accumulation on soil (forest floor) was measured over 1 year in ten 0.5 × 0.5 m quadrats in each plot, twice a year in native forest where litter-fall was seasonal, and each month in plantations where litter-fall distribution was more even over the year. The results showed that litter-fall ranged between 4 and 6 t/ha/year under Eucalyptus and Dimonika forest, and between 8 and 10 t/ha/year under *Acacia* and Les Saras forest. It was irregular over the

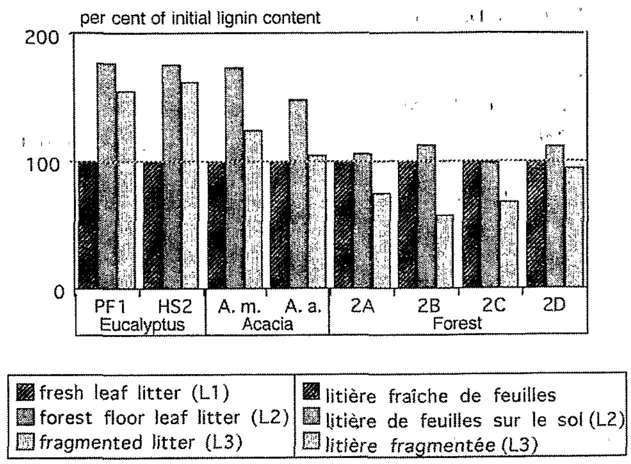


Figure 1. Lignin change with aging of leaf litter: lignin content of litter fractions, expressed as percentage of initial lignin content of freshly faller leaf litter.

Évolution des teneurs en lignine avec l'âge des litières, exprimées en pourcentage de la teneur initiale dans les litières fraîchement tombées.

floor litter (W2) were added for lignin determination. The decomposition coefficient was estimated according to Olson (1963) as $K = L1/(L2 + L3)$. An approximation of the mean age of the various fractions (table I), was calculated as $a = 1/K$ with $K = L1/L2$ for the age of the L2 fraction and $K = L1/(L2 + L3)$ for the age of the F2 + F3 fraction.

Lignin content was determined for each compartment on composite samples from all sampling traps and from 1-month collections. The results showed a relatively low variability among several sampling dates.

Lignin was determined by the Van Soest (1963) acid detergent method and tannin with the Folin-Ciocalteu reagent (Marigo, 1973) at the CIRAD-EMVT laboratory (Maison-Alfort, France). Nitrogen was determined by the Kjeldahl method at the ORSTOM analytical laboratory (Pointe Noire, Congo).

Table II. Lignin content of litter, percentage of dry weight (and standard error).

Teneur en lignine de la litière, pourcentage de poids sec (erreur standard).

Fraction	L1 Fesh leaf litter	L2 Floor leaf litter	L3 Fragmented litter	W1 Fresh wood litter	W2 Floor wood litter
Eucalypt PF1	**21.6 (1.2)**	**38.7 (0.7)**	**33.6**	—	**30.0**
Eucalypt HS2	**24.6**	**43.1 (3.2)**	**39.8 (2.5)**	**23.4**	**30.9**
A. mangium	**31.3**	**54.4**	**38.9**	**25.8**	**35.6**
A. auriculiformis	**34.2 (2.5)**	**50.8**	**36.1**	**34.8**	**37.3**
Forest 1 A	45.3	—	—		—
Forest 1 B	45.2		—	—	—
Mean forest 1	**45.2 (0.1)**	—	-	-	—
Forest 2 A	40.4	42.8	30.1	40.4	—
Forest 2 B	33.7	38.2	19.4	-	—
Forest 2 C	36.3	35.8	24.7	—	—
Forest 2 D	37.5	42.1	35.2	49.7	21.4
Mean forest 2	**37.0**	**39.7 (1.7)**	**27.4 (3.4)**	**45.0 (4.7)**	**21.4**

Table III. Tannin content of litter, percentage of dry weight.

Teneur en tannin de la litière, pourcentage du poids sec.

Fraction	L1 Fresh leaf litter	L2 Forest floor leaves	L3 Fragmented litter
Eucalypt PF1	4.62	1.65	0.21
Eucalypt HS2	3.89	1.84	1.00
A. auriculiformis	0.75	—	
Forest 1 B	2.08	0.00	- -
Forest 2 A	1.20	0.48	0

Table II shows lignin content at various decomposition stages (fresh leaf litter, forest floor leaf litter, fragmented litter). The high lignin content of fresh leaf litter (L1) from native forest did not change between L1 and L2 and decreased sharply in L3. Unlike what was observed in natural forest, L2 and L3 litters from *Eucalyptus* stands had higher lignin content than L1, and in *Acacia*, only L2 had a higher lignin content than LI. The ratio of these values to the initial L1 value is given in figure 1 to make the comparison between stands easier. Lignin accumulates in *Eucalyptus* litter where it was not, or at least very slowly, metabolized. In *Acacia* stands, lignin accumulated in leaf litter and then disappeared faster than dry matter. In native forest lignin first disappears at the same rate as dry matter, and then faster than dry matter. If the age of litter fractions (estimated in table I) was to be considered, at the stage of decomposition, the difference in lignin evolution between *Eucalyptus* and forest should be increased.

The same trend was observed for the woody litter, the lignin content of which decreased from W1 to W2 during decay in natural forest, but it increased in *Eucalyptus* stands (table II).

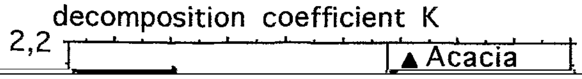
It was obvious from table IV that the decomposition coefficient was not related to lignin content of fresh litter in the overall stands ($\rho = 0.312$), although in natural forest a higher lignin content was found with a lower K coefficient ($\rho = 0.797$, $p = 0.056$). Lignin content did not relate to stand production, expressed as annual litter-fall, when the overall stands were taken into account, but a significant inverse relationship between lignin content of L1 litter and total litter production was observed when *Eucalyptus* stands were excluded (figure 3). If the nitrogen-rich *Acacia* litters were excluded from the data given in table IV, a close relationship ($\rho = 0.938$, $p = 0.002$) was shown between lignin/N ratio of L1 and decomposition coefficient (figure 2).

Table IV. N percentage of dry weight and lignin/N ratio of the fresh leaf litter (L1), and decomposition coefficient of total litter in tree stands.

Pourcentage de poids sec N et rapport lignine/N de la litière fraiche (L1) et cœfficient de décomposition de la litière totale.

Plot	N	Lignin	Lignin/N	Coef. K
Eucalypt PF1	0.65	22	34	
Eucalypt HS2	0.67	25	37	0.24
A. mangium	1.62	31	19	0.76
A. auriculiformis	1.51	34	22	0.69
Forest 1 A	1.35	45	33	1.26
Forest 1 B	1.36	45	33	0.90
Forest 2 A	1.57	40	25	1.85
Forest 2 B	1.40	34	24	1.96
Forest 2 C	1.42	36	25	1.76
Forest 2 D	1.40	37	26	0.73

While sampling litter in the field, visual observations were made on white rot fungi. Spots of white rot fungi were not found under *Eucalyptus*, and they were scarce under *Acacia*. They were common in the Mayombe forest, although to a lesser extent than in some temperate forests (Toutain, pers. comm.).



the main factor contributing in the decrease in the turnover rate in *Eucalyptus*. Palm and Sanchez (1990) suggest tations (Rouland, pers. comm.). The reason for which termites do not consume plantation leaf litter is not known, and if tannin content may be put forward for *Eucalyptus* litter, *Acacia* litter exhibited a low tannin content.

According to Swift et al. (1979), white rot fungi are inhibited by polyphenols, as shown by several studies. The high tannin content of *Eucalyptus* litter as compared to forest litter (table III) could prevent the growth of white rot fungi. Without either termite consumption or white rot fungi activity, lignin is expected to accumulate.

V. Conclusion

Lignin changes in the litter of recently man-made forests were shown to be very different from that of native forest. In a previous study, Bernhard-Reversat (1993) suggested a poor adaptation of local soil biota to *Eucalyptus*. The long delay for lignin disappearance in *Eucalyptus* litter shown by the present data suggest that adapted lignin decayers could be among the lacking organisms, whereas lignin decayers should adapt to the exotic *Acacia* litter in the later stage of decomposition.

Acknowledgements: Professor C. Rouland (Laboratoire d'Écologie des Invertébrés, Université de Paris XII) is acknowledged for