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Litter quality effects on decomposition rates of forestry plantations

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The decomposition of plant litter is one of the most crucial processes in the biogeochemical cycle of the forest ecosystems (DeCatanzaro & Kimmins 1985). It is governed by the interplay of abiotic and substrate quality variables (Upadhyay *et al.* 1989). Under the influence of the prevailing climatic environment, different litter species have their own specific rate of decomposition which govern the rate at which nutrients are released from litter. The dynamics of the nutrients during decomposition of litter is complex because the nutrients often occur in different forms and are subject to various transformations. Differential immobilization and release patterns may be exhibited by various nutrients (Upadhyay *et al.* 1989). Study on litter decomposition, therefore, provides opportunity to manipulate the timing of nutrients' release which is useful in species selection for sustainable agroforestry system. The present investigation was carried out to study the litter decomposition and nutrient release pattern as affected by litter quality in six-year-old plantations of *Eucalyptus tereticornis* Smith, *Dalbergia sissoo* Roxb, *Sesbania grandiflora* (L.) Poir and *Leucaena leucocephala* (Lam.) de Wit.

This study was conducted during 1996-97 in six-year-old plantations of *E. tereticornis, D. sissoo, S. grandiflora* and *L. leucocephala* planted as monoculture in 12m x 12m plots at the spacing of 2m x 2m in the Agricultural Farm of Rajendra Agricultural University, Pusa (25°59′ N, 85°48′E, 53 m elevation). Pusa has a monsoon subtropical climate with three distinct seasons, *viz.*, rainy (July – October), Winter (November – February) and Summer (March – June). During the study period, annual rainfall was 1141.7mm, of which about 84% occurred during the rainy seasons. The mean monthly maximum and minimum temperatures fluctuated between 23.8 – 36.8°C and 9.1 – 26.4°C, respectively. The soil at the plantation site is young alluvium calcareous sandy loam with a pH range of 8.1 to 8.4 and electrical conductivity of 0.70 to 0.75 dSm^{-1}. Organic carbon, available N, available P_2O_5, available K_2O and free $CaCO_3$ varied between 0.28 – 0.48%, 180 – 266 kg ha^{-1}, 14.0 – 28.2 kg ha^{-1}, 78 – 115 kg ha^{-1} and 33 – 36%, respectively.

Nearly senesced leaves were collected from the trees of different plantations in June 1996 and air dried. Litter bags of nylon hair net with a mesh size of 2mm diameter and an overall size of 20cm x 20cm were used for characterizing the litter dynamics. 10 g of air dried leaf litter of each species was confined separately in each of 60 nylon bags (12 months x 5 replications). The litter bags were randomly buried at 5cm depth on the floor of the corresponding plantations on 27th June, 1996. Five litter bags for each litter species were collected from the floor of the different plantations at monthly interval. The litter samples thus drawn were washed under a fine jet of water using a fine mesh screen to remove all the adhering soil particles, dried at 80 °C to constant weight, weighed and ground in a Wiley Mill to pass through a 1mm mesh screen. Samples were analyzed for N by micro Kjeldahl method (Piper 1944), P by colorimetrically (Jackson 1958) and K by flame photometry (Issac & Kerber 1971). Mean relative decomposition rates (R) for the different litter species during the various months of the study period were calculated using the following formulae :

$$R = \frac{1n\,W_1 - W_0}{t_1 - t_0}$$

where, R = mean relative decomposition rate (gg^{-1} day^{-1}), W_1 = weight (g) at time t_1, W_o = weight (g) at time t_o. 'R' values for the different months of a particular season were then averaged to determine the seasonality in decomposition.

The decomposition constant k was estimated using the equation of Thomas & Asakawa (1993) : $X_t = X_0e^{-kt}$, where, X_t is the dry weight of the litter remaining after a period of time 't' days and X_0 is the dry weight of the litter originally placed under the nylon bag, when t = 0 days.

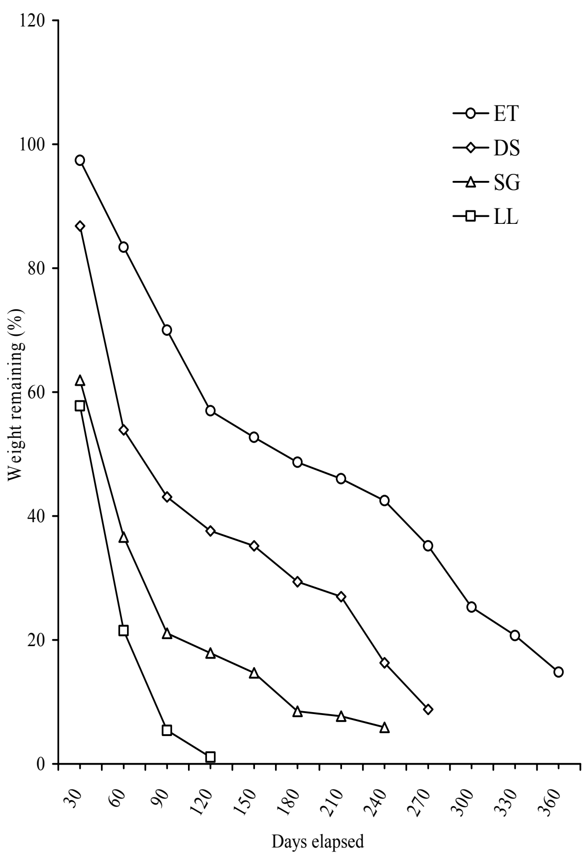

Fig. 1. Per cent leaf litter remaining in litter bags for different species. 'k' is the decomposition constant from the equation $X_t = X_0e^{-kt}$.
Abbreviations: ET - *E. tereticornis* (Mean k = 0.0040), DS - *D. sissoo* (Mean k = 0.0232), SG - *S. grandiflora* (Mean k = 0.0258), LL - *L. leucocephala* (Mean k = 0.0285).

Among different species studied, the highest rate of decomposition in terms of percent weight remaining was observed in the leaf litter of *L. leucocephala* followed by *S. grandiflora, D. sissoo* and *E. tereticornis* (Fig. 1). Complete disappearance of litter of *L. leucocephala, S. grandiflora* and *D. sissoo* was observed in 5th, 9th and 10th month of placement in soil, respectively. Only 85.2% weight loss occurred in *E. tereticornis* by the end of 12th month. At the end of 1st month, the percentage weight loss was maximum for *L. leucocephala* (42.2%) which was followed by *S. grandiflora* (38.1%), *D. sissoo* (13.2%) and *E. tereticornis* (2.6%). In *L. leucocephala* and *S. grandiflora*, more than half litter decomposed within 2 months indicating the suitability of these species as ideal decomposing green manures. The decomposition constant k for the litter ranged from 0.0040 to 0.0285 g g^{-1} day^{-1} (Fig. 1). A significant negative correlation between time elapsed (days) and natural log of per cent weight remaining was obtained for all species. These regression equations explain 78-97% variability in per cent weight remaining on account of time elapsed. Intercept values for the species varied from 3.892 – 4.758. The mean relative decomposition rates in different seasons for all the litter species indicated higher values during rainy season except for *E. tereticornis* where the mean decomposition rate was higher in the summer.

The initial leaf litter concentration (%) of N, P and K was maximum in *L. leucocephala* and minimum in *E. tereticornis* (Table 1). The species having highest nitrogen percentage showed the fastest decomposition rate, and that with lowest nitrogen content decomposed slowly. Meentemeyer & Berg (1986) reported that the initial N to be moderately well correlated with weight loss. In the present study initial P and K concentration also showed positive and significant correlation with the cumulative weight loss. Work by Meentemeyer & Berg (1986) in Scandinava has shown good rela-

Table 1. Chemical composition of fresh leaf litter of different tree species (% $\pm$ 1 SE).

Species	N	P	K
E. tereticornis	1.42 $\pm$ 0.02	0.09 $\pm$ 0.001	0.76 $\pm$ 0.01
D. sissoo	1.96 $\pm$ 0.04	0.14 $\pm$ 0.003	0.87 $\pm$ 0.01
S. grandiflora	2.42 $\pm$ 0.03	0.15 $\pm$ 0.003	1.10 $\pm$ 0.02
L. leucocephala	2.97 $\pm$ 0.04	0.18 $\pm$ 0.002	1.85 $\pm$ 0.02

tionships between weight loss and initial phosphorus concentration.

Nitrogen and phosphorus concentration decreased during decomposition in the residual leaf litter of *L. leucocephala* indicating a net mineralization of N and P, while concentrations of these nutrients gradually increased in *D. sissoo* showing immobilization of N and P. In case of *E. tereticornis* and *S. grandiflora*, these nutrients initially increased and then decreased. There was decrease in K concentration of the residual litter of all the species throughout the decomposition period. Among the different species *L. leucocephala* showed fastest release of all the nutrients followed by *S. grandiflora*, *D. sissoo* and *E. tereticornis*. Based on the percent release of different nutrients, the relative mobility of the elements may be arranged as K > N > P. Coefficient of determination (r^2) values for the relationship between percentage of weight loss and nutrient concentrations indicated that N, P and K explained 61 – 77% (except *L. leucocephala*), 48 – 60% (except *S. grandiflora* and *L. leucocephala*) and 58 – 94% variability in weight loss, respectively (Table 2).

During litter decomposition nutrients may undergo three sequential stages (i) initial release stage in which leaching predominates (ii) the net immobilization stage in which nutrients are imported in the residual litter mass, and (iii) the net release (net mineralization) stage in which an absolute decrease in the nutrient concentrations occurs in the residual litter mass (Staaf & Berg 1982). In the present study, N and P passed through the net immobilization phase in *E. tereticornis, D. sissoo* and *S. grandiflora* and the net release phase in *L. leucocephala* whereas K exhibited a continuous net release phase from the beginning in all species. Bargali *et al.* (1993) have reported that K being highly mobile is lost mainly by leaching. Absolute increases of nitrogen and phosphorus might be attributed partly to microbial immobilization. Net mineralization of N in the decomposing leaf litter of *L. leucocephala* in the present study may be due to the high initial N concentration in leaf litter (2.97%). This is in confirmity with the result of Berg & Staaf (1981) who argued that the immobilization phase could be missing, particularly in litter having high N-content. Decomposing leaf litter of *E. tereticornis* in the present study was found to have increasing level of N concentration upto 240 days and then it decreased, indicating that immobilization of N occurred before mineralization started.

From the foregoing results it may be concluded that incorporation of nutrient-rich *L. leucocephala* leaves which results in more rapid loss of dry matter has important implications for synchronizing nutrient release with crop uptake in low input cropping systems in the tropics where turn over rates are reportedly high (Jordan 1985). In addition, climatic factor such as frequency of rainfall should receive much more consideration when these materials are incorporated into the soil in humid tropic conditions.

Table 2. Regression parameter (r^2) relating percent weight loss per month (as dependent variable) to nutrients (N, P and K).

Variables	Coefficient of determination (r^2)			
	E. tereticornis	*D. sissoo*	*S. grandiflora*	*L. leucocephala*
N	0.767**	0.662**	0.608*	NS
P	0.482*	0.601*	NS	NS
K	0.608**	0.580*	0.684*	0.941*

* Significant at P <0.05
** Significant at P <0.01

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