DECOMPOSITION OF *MESUA FERREA* LITTER IN HUMID TROPICS OF ARUNACHAL PRADESH, INDIA

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ARUNACHALAM, A. & SINGH, N. D. 2004. Decomposition of *Mesua ferrea* litter in humid tropics of Arunachal Pradesh, India. The decomposition dynamics of various types of *Mesua ferrea* litter were studied in a tropical rain forest zone of the Indian eastern Himalaya, Arunachal Pradesh. The senesced leaves, twigs (< 2 mm) and fruit coat decomposed in a three-phased pattern, while the green leaves showed a two-phased decay pattern. All phases were characterised by a composite linear regression model, $Y = a + bX_1 + cX_2 + dX_3 \ldots$, where Y is the percentage of initial mass remaining, a the Y intercept, b the rate of change in Y with respect to time, c the shift parameter for adjustment of the Y intercept in phase II and d the shift parameter for adjustment of the Y intercept in phase III. The values of c and d were taken as zero, if decay was slow, and/or equal to one, if decay was rapid. The annual decay constant was maximum (0.8) for senesced leaves and minimum (0.4) for twigs. Initial litter chemistry influenced the rate of decomposition of *M. ferrea* litter.

ARUNACHALAM, A. & SINGH, N. D. 2004. Penguraian sarap *Mesua ferrea* di hutan tropika yang lembap di Arunachal Pradesh, India. Dinamik penguraian beberapa jenis sarap *Mesua ferrea* dikaji di zon hutan hujan tropika di timur Himalaya, Arunachal Pradesh, India. Daun yang tua, ranting (< 2 mm) dan kulit biji mengurai dalam pola tiga fasa manakala daun hijau menunjukkan pola dua fasa. Kesemua fasa dicirikan oleh model regresi linear, $Y = a + bX_1 + cX_2 + dX_3 \ldots$, dengan Y sebagai peratusan jisim permulaan yang masih ada, a ialah pintasan pada paksi Y, b ialah kadar pertukaran Y berhubung dengan masa, c ialah parameter peranjakan untuk pelarasan pintasan Y dalam fasa II dan d ialah parameter peranjakan untuk pelarasan pintasan Y dalam fasa III. Nilai-nilai c dan d dianggap sifar jika penguraian lambat dan/atau sama dengan satu jika penguraian cepat. Pemalar penguraian tahunan adalah maksimum (0.8) untuk daun tua dan minimum (0.4) untuk ranting. Kandungan kimia permulaan bagi sarap mempengaruhi penguraian sarap *M. ferrea.*

Key words: Litter chemistry – decay pattern – humid tropics – north-east India

Introduction

Mesua ferrea is a medium-sized, shade-loving evergreen climax tree species of the tropical rain forests of the Indian eastern Himalaya, Western Ghats and the Andamans. The tree is cultivated in gardens and avenues for its flowers and foliage, which are attractive particularly in the young stages. It is commonly called the 'Excel Wood Tree'. Outside India, it occurs in Bangladesh, Myanmar and Sri

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Lanka. The species sheds its leaves all through the year with a peak during summer (March–April) when the wind velocity is high in the region. Although it is established that decomposition rate is influenced by climatic condition and plant chemistry, data on the decay pattern of tropical tree species are few (see Mohan Kumar & Deepu 1992). Therefore, a project was undertaken to investigate the ecology of this tree species and its environmental implications, as this species is important in both horticulture as well as forestry. The present study examines the decomposition pattern of various types of *M. ferrea* litter *in situ* as it is crucial in determining the nutrient budget of the tropical forest ecosystems (Vogt *et al.* 1986). The difference in decay rate between species is primarily due to initial chemical composition of the litter (Couteaux *et al.* 1995, Arunachalam *et al.* 1998).

Materials and methods

Study area

The study was carried out in a *M. ferrea* plantation (13 years old) in the Education Campus of the North Eastern Regional Institute of Science and Technology (NERIST) (latitude 27° 07' N; longitude 93° 22' E; altitude 126 m asl) in Arunachal Pradesh, India. The regional climate can be classified as cool (16 °C) and dry (RH = 54%) winter (November–February) and warm (36 °C) and wet (RH = 80–98%) summer (March–October) with a mean annual precipitation (1800 mm) distributed fairly evenly throughout the year. The soil of the study site is slightly organic (organic C = 1.2%) and acidic (pH = 5.6), formed from the PreCambrian quartzite rocks belonging to the Shela group. The humid tropical forest belt in and around the NERIST campus was dominated by tree species like *M. ferrea, Terminalia myriocarpa, Duabanga grandiflora* and *Anthocephalus cadamba.*

Litter chemistry

Mature green leaves and freshly fallen senesced leaves, twigs and fruit coats of *M. ferrea* were collected from several plants. The litter samples were air dried in the laboratory and kept at 80 °C for 48 hours for the determination of dry mass. The oven-dried samples were powdered in a Cyclotec and analysed for their chemical composition. The ash content was determined by igniting 1 g of ground litter sample at 550 °C for six hours in a muffle furnace. A total of 50% of the ash-free mass was calculated as the carbon content. Nitrogen was estimated following semi micro-Kjeldhal method in a Kjeltec Auto 1030 Analyser (TECATOR). The total phosphorus was analysed colorimetrically (molybdenum blue method), while lignin was measured gravimetrically (Anderson & Ingram 1993).

Litter decomposition

Decomposition of litter was studied using nylon bag (15 × 15 cm) technique (Gilbert & Bocock 1960). The mesh size was 2 mm, small enough to prevent major

losses of litter samples, yet large enough to permit aerobic microbial activity and free entry of small soil animals. However, it excludes larger arthropods and mature earthworms, which are important primary assessors of litter, and presumably, it becomes a litter system dominated by termites, bacteria, fungi and actinomycetes. Consequently, there could be an underestimation of litter decomposition rates. For the experiment, 10 g of air-dried material were kept in each bag that was then stitched with nylon threads. For each litter type, 60 bags were prepared and randomly dispersed on the top 0–5 cm soil layer under *M. ferrea* trees and existing litter was spread over the bags. Every 30 days, five litter bags of each litter type were brought to the laboratory carefully avoiding loss of material from the litter bags. The litter was washed in a bucket full of tap water by swirling briefly and carefully decanting through a 2-mm mesh sieve to remove any extraneous matter. According to Anderson and Ingram (1993), such brief washing permits little leaching. The litter was then dried at 80 °C for 48 hours and weighed.

Calculation of decomposition coefficient

Organic matter decay of the litter samples were computed using negative exponential decay model of Olson (1963).

$$\frac{X}{X_o} = \exp(-kt)$$

where

X = weight remaining at time t
X_o = initial weight
exp = base of natural logarithm
k = decay rate coefficient
t = time (year)

The time required for 50% (t_{50}) and 99% (t_{99}) decay were calculated as $t_{50} = 0.693/k$ and $t_{99} = 5/k$.

Statistical analysis

In order to distinguish between different phases of weight-loss pattern during decomposition, multiple regressions were developed using dummy factors (0 or 1) as the indicator variables (Zar 1974). The composite linear-regression model (Arunachalam *et al.* 1996) used for this purpose was $Y = a + bX_1 + cX_2 + dX_3 \ldots$, where Y is the percentage of initial mass remaining, a the Y intercept, b the rate of change in Y with respect to time, c the shift parameter for adjustment of the Y intercept in phase II and d the shift parameter for adjustment of Y intercept in phase III. The values of c and d were taken as zero, if decay was slow, and/or equal to one, if decay was rapid. The effects of climatic variables and initial litter chemistry on the rate of decomposition were assessed using simple linear

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regression function, $Y = a + bX$. Tukey's test at probability level $p < 0.05$ was used to compare the means across the litter types (Zar 1974).

Results

Initial chemistry of litter

C and N concentrations were greater in green leaves as compared with the senesced leaves (Table 1). Nutrient concentration in fruit coat was relatively greater compared with senesced leaves and twigs. Lignin and P concentrations did not vary significantly between fractions. C/N ratio varied from 57.7 in green leaves to 75.4 in twigs while lignin/N ratio from 34.0 to 57.1 respectively. Concentrations of nutrients in the plant detritus correlated with one another (Table 2).

Table 1 Initial litter chemistry of *Mesua ferrea*

Litter	C (%)	N (%)	P (%)	Lignin (%)	C/N	C/P	Lignin/N	N/P
Green leaf	47.9 a	0.83 a	0.05 a	28.2 a	57.71 a	958.0 a	33.98 a	16.60 a
Senesced leaf	43.7 b	0.61 b	0.04 a	28.7 a	71.64 b	1092.5 b	47.05 b	15.25 b
Twig (< 2mm)	39.2 c	0.52 c	0.04 a	29.7 a	75.38 c	980.0 c	57.11 c	13.00 c
Fruit coat	45.6 abd	0.78 d	0.06 a	29.2 a	58.46 bd	760.0 d	37.44 bd	13.00 c

Means in each column with the same letter are not significantly different at the 0.05 probability level.

Table 2 Regression coefficients for the relationship between the initial litter chemical composition

Parameter	C	N	P	Lignin
C	1.000	0.987**	0.976**	0.891**
N		1.000	0.869**	0.770**
P			1.000	0.546*
Lignin				1.000

* = significant at the 0.05 probability level, ** = significant at the 0.01 probability level

Weight-loss pattern

Senesced leaves, fruit coat and twigs of *M. ferrea* decomposed in a three-phased manner (Figure 1). The first phase lasted for 60 days and was characterised by a slow rate of decay (0 and 0.056% weight loss day^{-1}) in the case of twigs and fruit coat. This was followed by a period of rapid weight loss (0.19% day^{-1}) up to 180 days in the case of twigs and at the rate of 0.20% day^{-1} for up to 240 days in the case of fruit coat. During the third phase, i.e. from 181–360 days for twigs and from 241–360 days for fruit coat, weight loss was more or less at a constant rate.

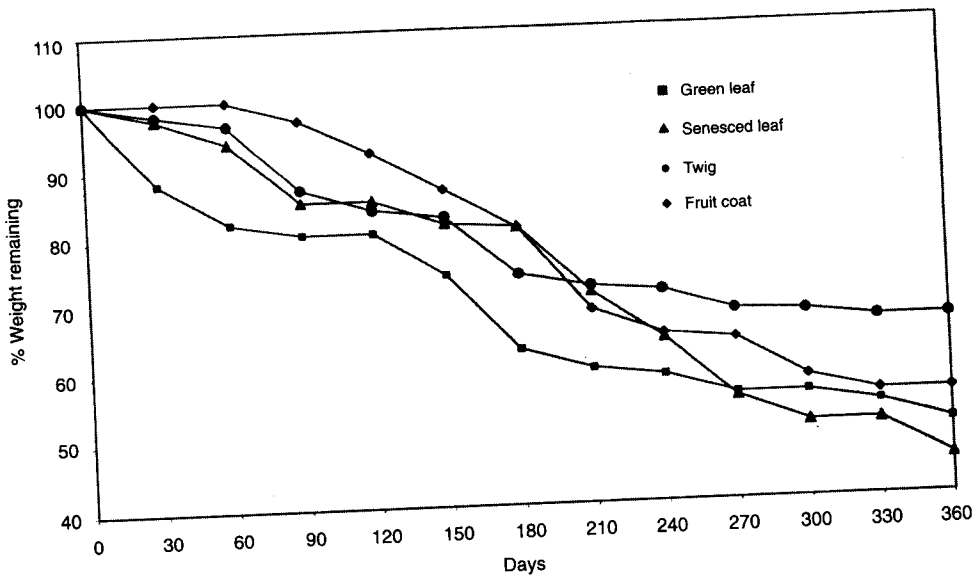

Figure 1 Decay pattern for green leaves, senesced leaves, twigs and fruit coat

The senesced leaves had the first phase lasting for 90 days, which was characterised by a moderate weight loss, followed by a slow rate of decay until 180 days and a faster decomposition period up to 360 days (third phase). The green leaves initially started decomposing at a faster rate up to 180 days and then the rate of weight loss decreased and continued more or less at a constant pace up to 360 days, i.e. two-phased decay pattern. A composite linear regression equation, $Y = a + bX_1 + cX_2 + dX_3$ showed a good fit for weight loss pattern in senesced leaves, fruit coat and twigs, while a multiple regression equation, $Y = a + bX_1 + cX_2$ fitted well for the decay of green leaves.

Decay constants and relationship between initial litter chemistry and weight loss

The variations in the decay coefficients (k) were statistically significant between different fractions (Table 3). The dry masses (Figure 1) remaining (% of initial) at the end of the experiment were senesced leaves (45.6), green leaves (50.7), twigs (66.1) and fruit coat (55.3). The annual decay constant (k) was minimum (0.4) for twigs and maximum (0.8) for senesced leaves (Table 3). Simple linear regression analysis between mean daily weight loss and initial chemistry of plant residues yielded significant positive correlations (Table 4).

Discussion

Residue quality

The range of lignin concentrations for various plant materials of *M. ferrea* (28.2–29.7%) was well within that reported for various tropical tree species (Das & Ramakrishnan 1985, Laishram & Yadava 1988, Okeke & Omaliko 1992, Bloomfield *et al.* 1993, Sankaran 1993, Arunachalam *et al.* 1998). Interestingly, in spite of the

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Table 3 Annual decay constants (k) for litter decomposition

Litter	k	t_{50}	t_{99}
Senesced leaf	0.803	0.863	6.22
Green leaf	0.657	1.050	7.61
Twig	0.402	1.723	12.44
Fruit coat	0.584	1.186	8.56

Table 4 Percentage weight loss as influenced by initial leaf chemistry

	Linear regression			
Initial chemistry	a	b	r	p
C (%)	39.41	50.88	0.907	0.001
N (%)	0.51	1.95	0.885	0.001
P (%)	0.04	0.09	0.708	0.001
Lignin (%)	28.16	5.82	0.937	0.001
C/N	57.52	80.37	0.618	0.005
C/P	798.04	1685.45	0.754	0.001
Lignin/N	12.93	16.61	0.615	0.005
N/P	34.66	83.97	0.650	0.002

a = constant, b = regression coefficient, r = correlation coefficient, p = significance level

variability in the type of plant samples, the lignin concentration did not vary significantly (Table 1), whereas N concentration varied significantly. Myers *et al.* (1994) reported that substrates with C/N < 25 were of high quality and released mineral N at a faster rate as compared with low quality residues (C/N > 25). According to them, the litter quality of *M. ferrea* was of low quality and was therefore expected to release mineral N at a slow speed. Nevertheless, the ratio was well within the reported range for humid subtropical forest ecosystems (45.9–77.3; Arunachalam *et al.* 1998).

The importance of translocation of nutrients prior to litter fall in tropical forests has been stressed by Attiwill *et al.* (1978). This process has been termed biochemical nutrient cycling by Switzer and Nelson (1972). In this study, at least one-third of the N had been withdrawn prior to senescence and abscission. This could be the reason for the greater nutrient concentration in the fresh green leaves.

Decay pattern

Twigs and fruit coat showed a slightly different decay pattern than that of leaf litter by showing an initial time lag, probably due to the delay in colonisation and establishment of the microbial population on the litter. The slow colonisation process could be due to their sclerophyllous and/or fibrous nature. The rapid rate of decay after an initial lag phase was the net effect of a large number of processes such as utilisation of readily available energy sources by microbes, loss

of water-soluble components and non-structural carbohydrates from the litter (Bloomfield *et al.* 1993), and removal of litter particles by soil microfauna (Swift *et al.* 1979) also operating in the top soil system. A decline in the decomposition rate may be attributed to higher percentage of recalcitrant fractions like cellulose, lignin and tannin during the advanced stage of litter decay. These substances are known to control decay rate by showing resistance to enzymatic attack and by physically interfering with the degradation of other chemical fractions of the cell wall (Bloomfield *et al.* 1993). The excessive initial weight loss in green leaves could be due to loss of more water-soluble compounds.

The greater is the initial N and/or lower the lignin concentration in the litter, the faster would be the decomposition and vice-versa. Thus, several workers have established a positive correlation between initial N and decay rate, and a negative correlation between initial lignin and decay rate (Singh & Gupta 1977, Vogt *et al.* 1986, Arunachalam *et al.* 1998). Nevertheless, in this study, both lignin and N concentrations and lignin/N ratio showed a significant positive correlation with the decay rate (Table 4). This observation is in contradiction with the above studies. On the other hand, several authors failed to find strong dependence of either lignin or lignin/N ratio on decay rate coefficients (e.g. Melillo *et al.* 1982).

However, before confirming this position with respect to tropical species, more such species with a wider range of initial lignin and nitrogen contents need to be analysed. Such a differential trend could be explained based on the microbial immobilisation process. For example, in spite of greater N concentration in the green leaves, decay was slow as compared with the senesced leaves. This could be due to greater colonisation of micro-organisms on fresh green leaves as the resources are in readily available form and hence better chances of microbial immobilisation of nutrients that may cause delay in the decomposition process. However, twigs and fruit coat decomposed slowly which is due mainly to their sclerophyllous and fibrous nature. The initial faster decay rate of green leaves appears to be related to high initial N concentration. Berg (1984), in this regard, suggested that as decomposition proceeds the influence of N decreases while that of lignin increases. Hence, with time the decomposition rate reduces.

Leaves had greater k values (0.7, 0.8) in the present study than those of twigs and fruit coat (Table 3). However, these values were less compared with some of the regional tree species like *Pinus kesiya* (1.3), *Quercus dealbata* (0.9–1.2), *Quercus griffithii* (1.4), *Schima khasiana* (1.0) and *Rhododendron arboreum* (0.8) (Arunachalam *et al.* 1998). As such, the number of published reports concerning litter decomposition dynamics of tropical tree species is lower from the high rainfall areas like in north-east India (Arunachalam *et al.* 1998, Laishram & Yadava 1988). In one study on the tropical tree species in southern India, Mohan Kumar & Deepu (1992) calculated the k values to be varying from 3.5–5.3 which were profoundly greater, indicating that tropical moist deciduous forest species exhibit markedly higher decay rates as compared with subtropical/temperate species. In another study, Bhardwaj *et al.* (1992) reported k value 0.9–1.8 for four tropical tree species in the western Himalayan belt. Nevertheless, the tropical tree species under study showed very low decay constant compared with other decomposition studies in India. The large differences observed could be attributed to low quality litter and decomposer population dynamics, especially macro-arthropods and also

to the forest microclimate and soil (Arunachalam *et al.* 1996). Furthermore, in the tropical rain forests, usually there is very little or no accumulation of litter, implying a fast turnover of organic matter in the soil (Swift *et al.* 1979). Changes in temperature and moisture availability, their interactions and the higher activity of the decomposer organisms need to be analysed. This can, to a greater extent, explain the large variation in litter decomposition rates existing between these three regions—Western Ghats as well as western and eastern Himalaya in India.

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