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Wood and Leaf Litter Decomposition and Nutrient Release from *Tectona grandis* Linn. f. in a Tropical Dry Deciduous Forest of Rajasthan, Western India

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ABSTRACT : The present study was conducted to quantify wood and leaf litter decomposition and nutrient release of a dominant tree species, *Tectona grandis* Linn. F. in a tropical dry deciduous forest of Rajasthan, Western India. The mean relative decomposition rate was maximum in the wet summer and minimum during dry summer. Rainfall and its associated variables exhibited greater control over litter decomposition than temperature. The concentrations of N and P increased in decomposing litter with increasing retrieval days. Mass loss was negatively correlated with N and P concentrations. The monthly weight loss was significantly correlated ($P < 0.05$) with soil moisture and rainfall in both wood and leaf litter. *Tectona grandis* was found to be most suitable tree species for plantation programmes in dry tropical regions as it has high litter deposition and decomposition rates and thus it has advantages in degraded soil restoration and sustainable land management.

Keywords : Dry deciduous forest, Lignin, Litter bags, Litter decomposition, Nutrient release, *Tectona grandis* Linn. F.

INTRODUCTION

The decomposition of litter is an important part of the nutrient cycling in forests. Amount of nutrients delivered by annual litterfall to the soil through decomposition is a great importance factor for sustainable forest production and provides an index of forest productivity (Yang Wan-Qin *et al*., 2006). The quantification of these amounts is especially important in plantations of fast-growing trees grown as short rotation coppiced stands, e.g. *Eucalyptus globulus*. For better management of such systems it is therefore important to evaluate the influence of the litter characteristics on decomposition.

Nutrient return *via* litterfall represents a major biological pathway for element transfer from vegetation to the soil (Maguire, 1994; Nirmal Kumar *et al*., 2009) and plays an important role in maintaining soil carbon and nutrient pools as well as fertility in a forest ecosystem. Meanwhile, seasonal variations in nutrient concentration and return are related to climatic fluctuations and/or changes in plant phenology, which in turn can affect later processes, such as decomposition, mineralization, and immobilization (Zimmermann *et al*., 2002; Qingkui *et al*., 2008). Decomposition is a fundamental process of ecosystem functioning because it is a major determinant of nutrient cycling. The rate of plant decomposition and nutrient release varies with a number of factors, "including rain fall, temperature, soil moisture including the nature of the plant material" (Singh *et al*., 1999). In general, low-nutrient species produce litter that is more difficult to decompose than litter from high -nutrient species (Berendse, 1994; Aerts and De Caluwe, 1997).

Several environmental factors regulate the decomposition process i.e. humidity, temperature and edaphic factors (Pandey *et al*., 2006). Besides these, the leaf structure and their chemical constituents also play a significant role in

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this process. Litters having a high C/N ratio (Dix and Webster, 1995), lignin content and lignin/N ratio (Bloomfield *et al*., 1993), toughness/N ratio (Gallardo and Marino, 1993) and tannin content (Dix and Webster, 1995) shows a slow decomposition rate. Studies have shown that phosphorus content and the C/P ratio may also be a determining factor for decomposition (Raman and Madhoolika, 2001). The rate and course of litter decomposition influence biomass, nutrient content and biochemical properties of the soil. The decomposition studies in *Tectona grandis* plantations are not yet carried out. The objective of the study was the quantification of the decomposition process in such an ecosystem is of vital importance to understand the ecosystem functioning and how *Tectona grandis* is suitable for the plantation programmes.

MATERIALS AND METHODS

Study Area

The site was located between 23°3'–30°12'N longitude and 69°30'–78°17'E latitude in a tropical dry deciduous forest in the Aravally range of Rajasthan, India. The study was conducted from February 2008 to May 2009. There are three distinct seasons per year: winter (November to February), dry summer (April to mid-June), and a wet summer (mid-June to mid- September). The months of October and March are transitional periods and are known as autumn and spring, respectively. The mean minimum temperature ranged between 2.5°C and 26.8°C and mean maximum varied between 25.8°C and 45.7°C. The average annual rainfall of the area is 415 mm of which about 90% occurred in 4 months of the year from June to September (Fig. 1).

The soil is alluvial, yellowish brown to deep medium black and loamy with rocky beds. According to the classification of Champion and Seth (1968), the present forest area is categorized under group 5A/ (1b) as ‘tropical dry deciduous forest’. The experimental stand was planted in 1998–1999. A homogeneous area was selected for this experiment according to the criteria, i.e. soil type, soil bulk density, and productive vegetation area (Table 1).

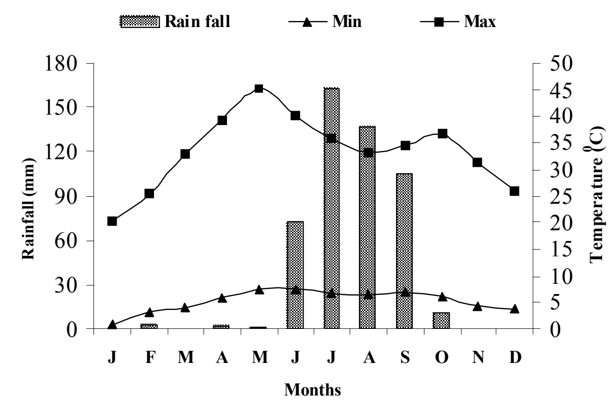

Fig. 1. Monthly rainfall (mm), Minimum and maximum of air temperature (°C).

Table 1. General characteristics of vegetation and soil in teak forest of Rajasthan, Western India

Parameters	Values
Vegetation	
Density (individuals ha^{-1})	654
Basal area (m^2 ha^{-1})	18.21
Leaf litter fall (t ha^{-1} $year^{-1}$)	22.59 ± 109
Soil properties	
Texture class	sandy clay loam
Bulk density (g cm^{-3})	1.22 ± 0.017
pH (1:5 w/v H2O)	6.5 ± 0.134
Organic C (g kg^{-1})	27.9 ± 0.036
Total N (g kg^{-1})	1.97 ± 0.067
Phosphorus (g kg^{-1})	0.28 ± 0.031
C:N	14.68 ± 0.045
N:P	6.78 ± 0.021
C:P	99.6 ± 0.043

Experimental design

For the determination of litter decomposition rate, the litter bag technique was used (Sharma and Ambasht, 1987). Different sizes and weights of wood slices have been collected (Genet *et al*., 2001 & Miller *et al*., 2002) and air-dried in the laboratory and made into equal weights of 10 g by cutting-off the excess weights. The litter bag technique was used to quantify the remaining weight of leaves by taking freshly fallen leaves of *Tectona grandis*.

100 Nylon net bags (10 cm × 10 cm, 1 mm mesh) containing 5 g air dried leaf litter and the wood slices were placed on the forest floor in five different plots having an area of 20 × 20 m each in February 2008 and monthly one each was collected from the plots until there was complete decomposition. The mesh size (1 mm) was large enough to permit aerobic microbial activity and allow free entry of small soil animals.

Five bags containing decomposing litter were randomly recovered at monthly intervals from each plantation site. After recovery, the bags were placed in individual polythene bags and transported to the laboratory. The bags were opened and the recovered litter materials were air dried initially, brushed to remove, adhering soil particles, and finally dried at 80ºC for 24 h and weighed. The recovered wood litter and litter bags were brushed and washed using tap water followed by distilled water with gentle agitation on a 1 mm mesh screen, and dried at 60ºC in an oven until constant weight to determine weight loss, and grounded into powdered form in a electric grinder for chemical analysis.

Chemical Analysis

All analyses were carried out in triplicate. Nitrogen (N) concentration was determined by the micro-Kjeldahl method (Jackson, 1958). Phosphorous (P) concentration was estimated by using the procedure outlined by Allen *et al*. (1974). For estimating lignin content, the freshly collected litter samples (0.5 g) were digested in hot sulphuric acid, and the insoluble residues obtained by filtration were oven dried and weighed (Effland, 1977).

Decomposition rates were calculated from ash-free dry mass remaining using a single negative exponential decay model $X/X_0 = e^{-kt}$, where X/X_0 is the fraction mass remaining at time t, t the time elapsed in years and k the annual decay constant (Olson, 1963). The decomposition constant (k) was calculated the equation given by Olson, 1963.

In another experiment, five air-dried wood slices and litter bags having equal weight (10 g of wood and 5 g of leaf litter) with the first set of experiments were kept at the same spot every month and picked up the next month in order to study the weight loss rates per month.

The change in lignin and N concentration during decomposition of wood and leaf litter was calculated following the formula given by Harmon *et al*., 1986:

Nutrient accumulation index (Nai) = $Wt\ Xt/Wo\ Xo$,

Where Wt is the dry weight of wood/leaf litter at time t, Xt the lignin/nitrogen/phosphorus concentration of wood/leaf at time t, Wo, the initial weight of wood/leaf, and Xo the initial concentration of lignin/nitrogen/phosphorus in wood/leaf.

Nai value of 1 indicates that decomposed litter contains the same amount of element as when the litter was placed in the field. Nai < 1 indicates net mineralization of element from the decaying litter, and Nai > 1 indicates net accumulation of element by the decaying litter.

Soil temperature of the study sites was determined using a soil thermometer, soil moisture by gravimetric method, soil pH by glass electrode (1: 5 soil: water ratio) and soil texture by international pipette method.

The data recorded during the experiment were subjected to ANOVA (two-way, fixed effects model) to see the significant variations due to litter types. Pearson's correlation analysis was made to find out the relationship between wood and leaf litter loss rates with soil moisture and antecedent rainfall of each month.

RESULTS AND DISCUSSION

Fifty per cent of wood litter remained at the end of the fifth month (July), whereas for leaf litter it was at the end of the sixth month (August). About 4.2 and 7.7% of the wood and leaf litter respectively, remained at the end of the twelfth month (Fig. 2). Wood litter decomposed completely in 13 months, whereas leaf litter decomposed completely in 15 months.

ANOVA of the remaining litter indicated a significant difference between the sampling months ($P < 0.01$) in both wood and leaf litter.

Loss of wood and leaf litter between the months increased consistently and attained a maximum value during September and August in wood and leaf litter respectively. Thereafter, it decreased till the termination of the experiment. Loss of wood and leaf litter was maximum during the wet summer season followed by dry summer and winter seasons (Fig. 3).

Loss of wood and leaf litter during different months was significantly correlated with soil moisture and rainfall in both types of litter (Table 2). The initial lignin (IL) was found to be higher in wood litter, whereas initial N (IN) was found to be higher in leaf litter than wood litter (Table 3). However, the IL/IN and IL/IP ratios were higher in wood litter than leaf litter. The annual decomposition constant (*k*) was recorded to be higher in the wood litter compared to leaf litter.

Nitrogen and phosphorus concentration increased consistently during different months till the termination of the experiment in both wood and leaf litter (Fig. 4*a* & 4*b*). Lignin concentration decreased till the end of the experiment in wood litter decomposition, whereas in leaf litter decomposition the concentration of lignin declined in the initial stages and then increased slowly up to the final stage (Fig. 4*c*).

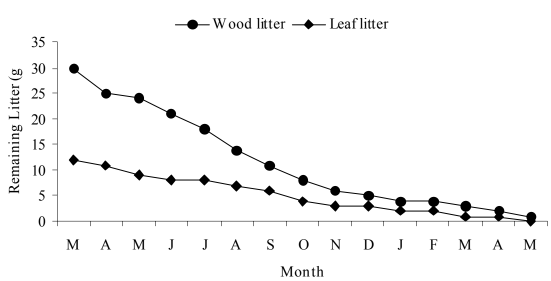

Fig. 2. Monthly variation (means of five replicates) of remaining litter (g) in leaf and wood.

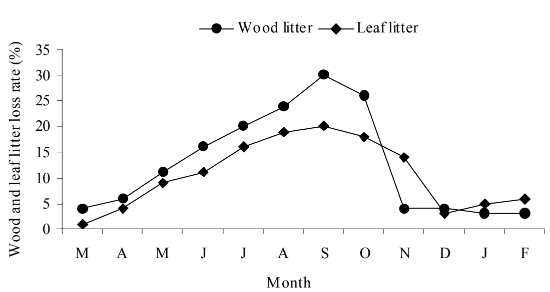

Fig. 3. Monthly variation (means of five replicates) of leaf and wood litter loss rate (%).

Table 2. Correlation between rate of weight loss of wood and leaf litter with abiotic variables (n = 12)

Parameter	*r*
Wood	
Soil moisture	0.76*
Rainfall	0.84*
Leaf	
Soil moisture	0.72*
Rainfall	0.86*

* Shows significance at P < 0.01 level.

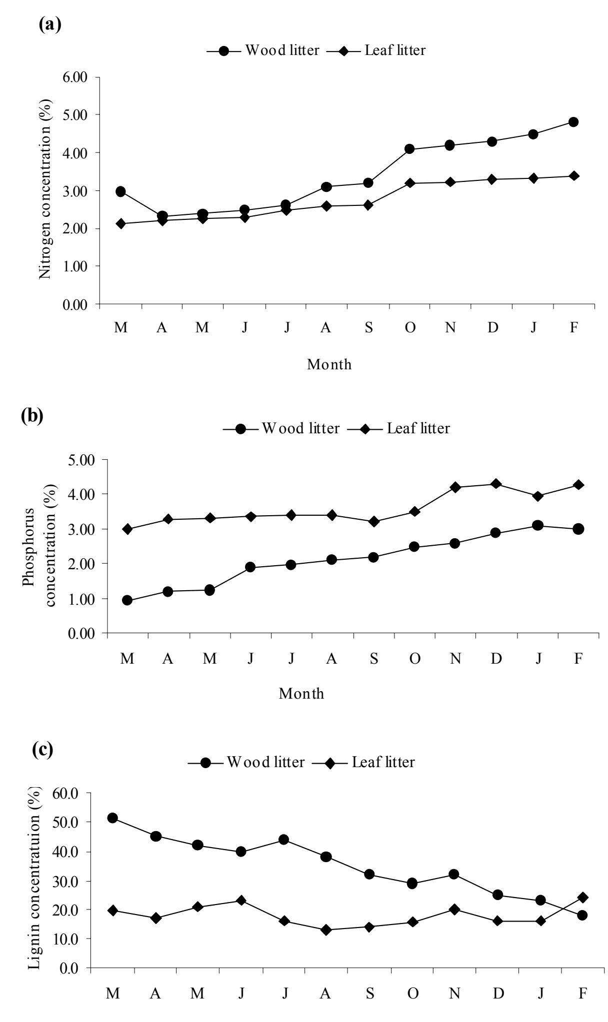

Fig. 4. Monthly variation (means of five replicates) of (a) nitrogen (b) phosphorus (c) lignin concentration in leaf and wood litter decomposition.

The values of Nai for wood and leaf litter were less than 1, showing that there is mineralization of lignin, N and P during the study. The Nai of both lignin, N and P in wood litter was less than that in leaf litter (Table 3), showing higher rate of mineralization in wood litter. The higher weight loss in wood and leaf litter in the initial stages and a gradual decreasing trend as observed in the present study could be due to high initial content of water-soluble materials and simple substrates; breakdown of litter by decomposers, especially microorganisms, and removal of leaf litter particles by soil animals (Yamashita and Takeda, 1998). Wood litter decomposed faster in comparison with leaf litter, which may be due to white ants and other termite activity in the decomposition of wood. It was observed during the study that termites rarely attacked the leaves, but attacked the woody litter vigorously. Therefore, feeding activities of termites may accelerate decomposition. The preference of termite to wood over leaf litter needs to be investigated further. Termites are an important faunal component for litter decomposition in tropical forests, accelerating the decomposition rates (Sandhu *et al*., 1990).

Relationship of mass loss with abiotic variables

Greater weight loss during the rainy season may be due to high percentage soil moisture and soil temperature, and also due to leaching of water-soluble substances from the litter mass. Smaller weight loss during winter might be due to cool and dry conditions. This is obvious from the positive correlation between the rate of weight loss with soil moisture and rainfall (Moretto *et al*., 2001; Austin and Vitousek, 2000). A high value of *k* indicates that the rate of weight loss of wood as well as leaf litter was high. Since the value of *k* was higher in wood litter, it decomposed faster.

Although wood litter has high initial lignin content, the rate of weight loss was faster compared to leaf litter. This might be due to the difference in soil fauna attacking wood and leaf litter. Many studies have reported a decline in the rate of weight loss of litter due to high initial lignin content (Ribeiro *et al*., 2002). However, the present study is contrary to these. The reason for faster rate of decomposition of wood litter may be due to rapid mineralization as well as termite feeding activities. In the present study though wood litter exhibits higher IL/IN ratio compared to leaf litter (Table 3), it decomposed faster. Therefore, the IL/IN ratio cannot be a good predictor for the pattern of decomposition as reported by several workers (Koukoura *et al*., 2003; Laishram and Yadava, 1992).

Musvoto *et al*. (2000) emphasized that the increase in N during leaf litter decomposition in different forest ecosystems, which could be due to addition as a result of one or more of the following mechanisms: fixation, absorption of atmospheric ammonia, green litter. Similarly in the current investigation nitrogen concentration in both types of litter increased throughout the study.

The decrease in lignin concentration in wood litter could be attributed to the weight loss due to rapid breakdown of lignin by termite-feeding activities. In the leaf litter lignin concentration followed an initial decrease, which slowly increased until the end of the experiment. This could be due to a decrease in mineralization in the later stages (Ribeiro *et al*., 2002).

In the present study it was found that though wood litter had high initial lignin than leaf litter, weight loss

Table 3. Initial N (IN), initial P (IP), initial lignin (IL), IL/IP, IL/IN, remaining weight (%) after 12 months, turnover rate, decomposition constant (k) and nutrient accumulation index (Nai) of wood and leaf litter decomposition

									Nai		
	IN	IP	IL	IN/IL	IP/IL	Remaining weight (%)	Turn over rate (days) 50%	*k*	Lignin	N	P
Wood	2.12	0.96	51.3	24.2	53.4	3.41	147	1.19	0.02	0.09	0.10
Leaf	2.98	1.21	19.5	6.96	16.1	8.52	164	1.10	0.09	0.15	0.19

was rapid due to feeding of termites as well as increase in the mineralization of nutrients. Therefore, it can be stated that the termites play an important role in decomposition of wood and the decomposition rate is also influenced by soil moisture and rainfall.

The study revealed that *Tectona grandis* is a suitable tree species for plantation programmes in dry tropical regions as it has high litter deposition and decomposition rates and thus it has advantages in degraded soil restoration and sustainable land management.

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