Environment & Ecology 29 (3A) : 1431—1435, 2011
 ISSN 0970-0420

Litter Quality, Decomposition Dynamics and Nutrient Release Pattern in *Tectona grandis* (Linn. f.) in Cachar District Assam, Northeast India

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Abstract

An attempt was undertaken to investigate the initial litter chemistry, decomposition dynamics and nutrients release pattern in decomposition of teak leaf litter in Cachar district of northeast India from May 2009 to April 2010. The analysis of initial chemistry of litter recognized that both C/N ratio (43.06) and lignin / N ratio (42.28) were high which indicate low rate of decomposability. Weight loss was expressed as percentage of original dry weight, decrease exponentially with time. The maximum weight loss was recorded during May 2005 to November 2005, may be due to the reason that this time of the year characterized by heavy rainfall, high relative humidity and temperature facilitate the growth of decomposers. The value of decomposition constant (*k*), half life ($t_{0.5}$) and time required for 99% decomposition ($t_{0.99}$) were recorded as 2.21, 114 days and 824 days, respectively much higher than other reported works. The pattern of both N and P release was biphasic while release of potassium occurred at all stages of decomposition. Lignin, cellulose and hemicellulose showed gradual degradation with the litter mass loss. As compared to other region the decomposition of teak litter was more rapid and this may attribute climatic conditions (high rainfall, relative humidity and temperature) of the Cachar district which in turn may facilitate the activity of decomposer organisms.
Key words : Litter quality, Decomposition, Nutrient release, *Tectona grandis.*

Major part of the net primary production in terrestrial ecosystems enters the detritus-based food web litter and therefore, litter decomposition is an important process regulating energy flow, nutrient cycles, and structures of ecosystems (1). Tropics are characterized by rapid turn over of nutrient and the decay rate coefficients are substantially higher for tropical species than that of temperate coniferous litter (2). In several studies it was established that decomposition is influenced by litter quality, climatic factors and soil biota (3). Decomposition and mineralization of litter are determined by qualitative and quantitative composition of soil organisms and the chemical nature of litter such as the content of tannin, lignin and C/N ratio (4). However, decomposition rates vary greatly even among tropical forests, depending on factors such as climate and litter quality. Here teak (*Tectona grandis* Linn.) leaf litters were subjected to investigate as it is planted in this region for commercial and aforrestation purpose. Teak belongs to the family Verbenaceae, indigenous in southeast Asia with a discontinuous or patchy distribution up to India. It is one of the most widely planted hardwood timber species in the world, covering 2.25 million ha (5). Although some works has been carried out in other parts of India (6—8), no attempt has been made so far on this aspect in Cachar district of Assam where rainfall and relative humidity prevail with moderate to high temperature, which is peculiar in nature compared to other part of the world.

Methods

Cachar district situated at the Valley of river Barak in northeastern region of India (24°41´N, 92°45´ E). This region is located in the confluences of indo-China, Indo-Malayan and Indo-Burma. The site selected for decomposition study was a teak garden (40 years old) situated at Dhalai Forest Division of Cachar district, 40 km away from the Assam Univer-

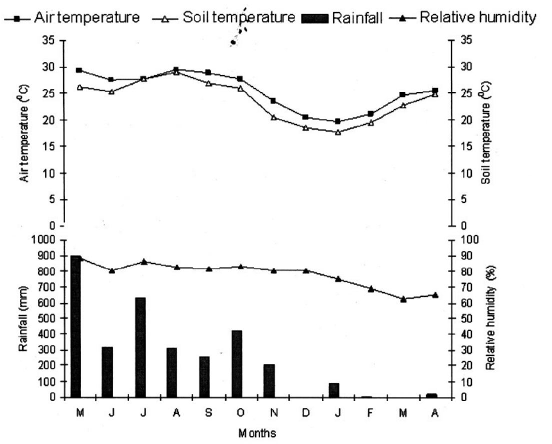

Figure 1. Meteorological parameters of the study period.

sity campus. The climate of the study site is subtropical warm and humid with mean annual rainfall 2,660 mm and most of which occur during the southwest monsoon season (May to September). The mean maximum temperature ranges from 25.1 ^{0}C (January) to 32.6 ^{0}C (August). The mean minimum temperature ranges from 11 (January) to 25 C (August). Average humidity of the area is 87% (Fig. 1).

Litter decomposition was studied using the nylon-bag technique (9). Freshly abscissed leaves were collected during the peak period of litter fall (February to March, 2009) and air dried ; 20 g air-dried litter was placed in 20 × 20 cm litter bags (2 mm^2 mesh size), and totally 90 bags were prepared. The litter bags enclosing leaf litters were placed under the closed canopy of the teak stand ; 5 litter bags were collected at regular intervals during May 2009 to April 2010. The residual materials were separated carefully from adhering soil particles and oven-dried at 60 C for 48 h

Table 1. Initial litter chemistry of teak leaf litter.

Parameters	
Carbon (%)	40.73 ± 0.40
Nitrogen (%)	00.96 ± 0.04
Phosphorus (%)	00.17 ± 0.01
Potassium (%)	00.33 ± 0.01
Lignin (%)	39.67 ± 0.48
Cellulose (%)	39.81 ± 0.50
Hemicellulose (%)	08.50 ± 0.26
C/N	43.06
C/P	275.6
Lignin/N	42.28
Lignin/P	270.6
Lig/Cel	1.04

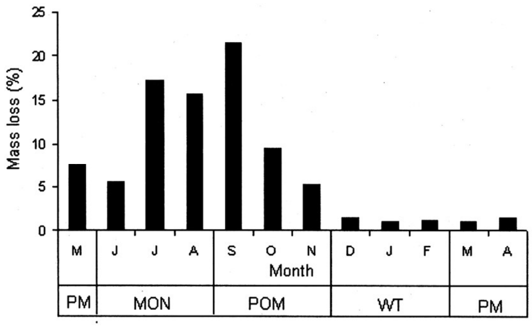

Figure 2. Litter mass loss during the investigation period. PM = Pre monsoon, MON = Monsoon, POM = Post Monsoon and WT = Winter.

and weighted.

Samples of initial litter chemistry and those retrieved during the sampling periods were powdered and analyzed for their chemical composition. The ash content was determined by igniting 1 g of powdered litter sample at 550 C for 6 h in a muffle furnace. A total of 50% of the ash free mass was calculated the carbon (C) content. Total nitrogen (N), phosphorus and potassium were determined by a semi micro-Kjeldahl method, molybdenum blue method and flame photometer method, respectively (10). Major cell wall components viz. lignin, cellulose and hemicellulose were analyzed (11).

Mass loss over time was computed using the negative exponential decay model (12)

$$X / X_0 = \exp(-kt)$$

The time required for 50% (t_{50}) and 99% (t_{99}) decay was calculated as $t_{50} = 0.693 / k$ and $t_{99} = 5/k$. Monthly mass loss (g/month) from decomposing litter was determined from the difference between the mass remaining in the litter bags in each month.

Absolute amount of nutrient in the litter bag was investigated as,

$$(C/C_0) \times (L / L_0) \times 100$$

Table 2. Annual decay constant for teak leaf litter.

Decomposition rate constant (k/year)	Time required for 50% decomposition (days)	Time required for 99% decomposition (days)
2.21	114	824

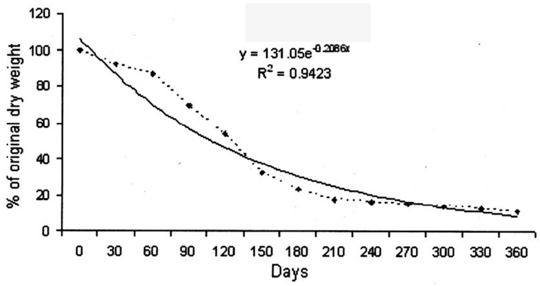

Figure 3. Leaf litter decomposition in teak. Solid line denotes cumulative weight loss while broken line denotes predicted weight loss based on exponential model.

Where, C is the nutrient concentration in the litter samples at the time of sampling, C_0 is the nutrient concentration of the initial litter, L is the mass of dry matter at the time of sampling and L_0 is the initial dry mass of the litter sample.

Results and Discussion

Litter decomposition is governed by a host of variables including initial litter chemistry (Table 1), climatic factors and decomposers organisms. Here initial teak leaf litter chemistry revealed that the amount of carbon, lignin, cellulose and hemicellulose contents were 40.73% ± 0.40, 39.67% ± 0.48, 39.81% ± 0.50 and 08.50% ± 0.26, respectively (Table 2). Litter nitrogen concentration was found to be higher (0.96% ± 0.04), followed by potassium (0.33% ± 0.01) and phosphorus (0.17% ± 0.01). Here the C/N ratio was found to be 43.06 which were lower than the investigated report of the Attignon et al. (13) in Lama Forest reserve in Benin. Myers et al. (14) reported that the substrate with C/N < 25 are of high quality and release mineral nitrogen at a faster rate compared to low quality residues (C/N > 25). Osono and Takeda (15) reported litter types with initial L/N ratios higher than 23—25 or with an initial L/P ratio higher than 500—620, contained initially excess lignin compared to N and P and had the potential to immobilize N and P until L/N and L/P ratio reached critical values. Loss of litter mass from the decomposing teak litter is shown in Figure 2. The mean monthly leaf litter loss was 7.40% with the highest amount during September, 2009 (21.41%). Weight loss expressed as a percentage of the original dry weight, decreased exponentially with time (Fig. 3). The exponential equation

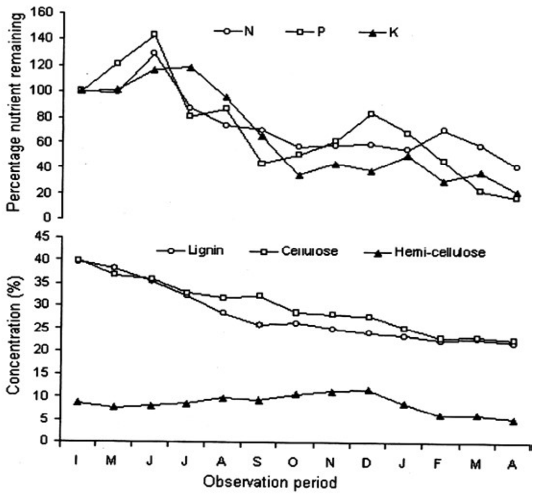

Figure 4. (a) Nutrient remaining in the decomposing of teak (*Tectona grandis*) leaf litter and (b) organic compounds in the decomposing leaf litter of teak.

for leaf litter in first annual cycle may be expressed as $Y=131.05\ e^{-0.2068x}$, r=0.9707 ; where, Y = percent leaf litter loss in weight, x=decomposition time and e=base of the natural logarithm. Litter mass loss showed a rapid phase of initial mass loss in which 75% weight loss was occurred during the first 150 days (i.e. wet months of the year). Lavelle et al. (16) had opined that litter decomposition in the warm and humid condition is more rapid as the prevailing environmental conditions are conducive for rapid decay. The rainy months recorded maximum weight loss, may be related to the favorable conditions for decay-high litter and soil moisture contents, high relative humidity and congenial atmospheric temperature, all indirectly favoring the soil biological activity. The annual decay constant (k), half life ($t_{0.50}$) and time for 99 percent loss of dry weight ($t_{0.99}$) of teak litter were calculated as 2.21, 114 days and 824 days, respectively. Kumar and Deepu (7) reported very low value for k (0.32) from south India but Attignon et al. (13) reported k value 1.3 – 1.7 in Lama Forest plantation in Benin. The half-life recorded here (3.8 month) little bit similar (4.2 months) to the findings of Sankaran (8) but not corroborated with the findings of Attignon et al. (13) (5 – 6.3 months). Half-life is an indication of the persistence of the litter on the soil surface and hence its use as a mulch material.

A complex dynamics of nutrient release was observed and furnished in Figure 4. The pattern of nitrogen and phosphorus release was biphasic. For nitrogen, an initial accumulation phase was observed in June, 2009 and a similar rise in the concentration was recognized during February, 2010. Phosphorus concentration exhibited an increasing trend from May, 2009 to June, 2009, and a sharp increase of concentration was also recognized during December, 2009. End of the study period nitrogen, phosphorus and potassium concentration from the original amount was recorded up to 31.11%, 17.64% and 22.05%, respectively. Berg et al. (17) reported that nitrogen and phosphorus concentration tends to accumulate and potassium declined during litter decomposition. Potassium content showed initial immobilization stage and thereafter it was found as readily released element. Potassium was the most mobile, declining rapidly over the measurement period, reflecting that it was readily leached (18).

Lignin is considered as the primary variable in determining the decay rates of litter, which is resistant to decay as well as slow down the decay of other cell constituents (19). The concentrations of lignin, cellulose and hemicellulose declined during the decomposition process (Fig. 4). The lignin , cellulose and hemicellulose concentrations of the leaf litter were 21.00%, 22.56% and 5.43%, respectively, at the end of the study. Meentemeyer (20) reported that lignin concentration in plant materials inversely related to its decomposition rate. Cellulose and other structural polysaccharides are easily attacks by the microbes after the soluble fractions have been depleted (21). Although hemicellulose is a glucose compound, it takes time to decompose, as it is highly cross-linked with lignin, creating a complex web of bonds which allows slower degradation of cell-wall compounds.

The litter break down in subtropical humid climate of Cachar district was, generally fast, indicating high biological activity and nutrient turnover. The high rainfall, relative humidity and temperature in the initial months (May 2009 to October 2009) may be attributed for the faster rate of decomposition which is incomparable with works of other part of the globe. These environmental variables support healthy growth of soil microflora and decomposer fauna. Moreover, age of the plantation (40 years old) may contribute to establish a stable community of decomposer (both microflora and fauna), as they have the significant role in decomposition.

References

1. Wachendrof C., U. Irmler and H. P. Blume . 1997. Relationship between litter fauna and chemical changes of litter during decomposition under different moisture conditions. Pp. 135—144. *In* G. Gadisch and K. E. Giller, editors. *Driven by nature*. CAB Int. Publ., Walingford.
2. Cromack K. Jr., J. A. Entry, and T. Savage. 1991. The effects of disturbance by *Phellinus weini* on decomposition and nutrient mineralization in a *Tsuga mertensiana* forest. *Biol. Soil. Fert.* 11 : 245—249.
3. Gonzalez G. and T. R. Seastedt. 2001. Soil fauna and plant litter decomposition in tropical and subalpine forests. *Ecology* 82 : 955—964.
4. Reddy M. V. 1995. Litter arthropods. Pp. 113—140. *In* M. V. Reddy, editor. *Soil organisms and litter decomposition in the tropics*. Westview Press, Boulder, Co, USA.
5. Ball J. B., D. Pandey and S. Hirai. 1999. Global overview of teak plantations. Reg. Sem. on site, technology and productivity of teak plantations. Chiang Mai, Thailand. 26—29 Jan. 1999.
6. Ananthakrishnan T. M. 1996. *Forest litter insect community. Biology and chemical ecology*. Sci. Publ., Lebanon, NH, USA.
7. Kumar B. M. and J. K. Deepu. 1992. Litter production and decomposition dynamics in moist deciduous forests of the Western Ghat in Peninsular India. *For. Ecol. Manag.* 50 : 181—201.
8. Sankaran K. V. 1993. Decomposition of leaf litter of albizia (*Paraserianthes falcataria*), eucalypt (*Eucalyptus tereticornis*) and teak (*Tectona grandis*) in Kerala India. *For. Ecol. Manag.* 56 : 225—242.
9. Crossley D. A. and M. P. Hogland. 1962. A litter-bag method for the study of microarthropods inhabiting leaf litter. *Ecology* 43 : 571—573.
10. Allen S. E., H. W. Grimshaw, J. A. Parkinson and C. Quarnby. 1974. *Chemical analysis 101 of ecological materials*. 1st editions. Blackwell Sci. Publ., Oxford, UK.
11. Peach K. and M. V. Tracey. 1956. *Modern methods of plant analysis*. Volume 1. Springer, Berlin.
12. Olson J. A. 1963. Energy storage and the balance of producers and decomposers in ecological system. *Ecology* 44 : 322—331.
13. Attignon S. E., D. Weibel, T. Lachat, B. Sinsin, P. Nagel and R. Peveling. 2004. Leaf litter breakdown in natural and plantation forests of the Lama Forest reserve in Benin. *Appl. Sol.* 27 : 109—124.
14. Myers R. J. K., C. A. Palm, E. Cuevas, I. U. N. Gunatilleke and M. Brossard. 1994. The synchronization of nutrient mineralization and plant demand. Pp. 81—116. *In* P. L. Woomer and M. J. Swift, (eds). *The biological management of tropical soil fertility*. John Wiley and Sons, UK.
15. Osono T. and H. Takeda. 2004. Accumulation and release of nitrogen and phosphorus in relation to lignin decomposition in leaf litter of 14 tree species

in a cool temperate forest. *Ecol. Res.* 19 : 593—602.
16. Lavelle P., E. Blanchart, A. Martin and S. Martin. 1993. A hierarchical model for decomposition in terrestrial ecosystems : application to soil of the humid tropics. *Biotropica* 26 : 130—150.
17. Berg B., C. McClaugherty and M. B. Johansson. 1992. *Litter mass loss rates in late stages of decomposition at some chemically and nutritionally different pine sites, a study on the effects of climatic change*. Dep. Forest Ecol. and Forest Soils, Swedish University of Agric. Sci. Rep. No. R 67.
18. O' Connell A. M. and K. V. Sankaran. 1997. Organic matter accretion, decomposition and mineralization. Pp. 443—480. *In* E. K. S. Nambiar and A. G. Brown (eds). *Management of soil, nutrients and water in tropical plantation forests*. ACIAR, Canberra, Australia.
19. Chesson A. 1997. Plant degradation by ruminants : parallels with litter decomposition in soils. Pp. 47—66. *In* G. Cadisch and G. E. Giller (eds). *Driven by nature : Plant litter quality and decomposition.* CAB Int. Wallingford, UK.
20. Meentemeyer V. 1978. Macroclimate and lignin control of litter decomposition rates. *Ecology* 59 : 465—472.
21. Swift M. J., O. W. Heal and J. M. Anderson. 1979. *Decomposition in terrestrial ecosystems*. Blackwell Science, Oxford, UK.