

## Foliar litter decomposition of four dominant tree species in the Hollongapar Gibbon Wildlife Sanctuary, Assam, North East India

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**The decomposition of leaf litter of four selected dominant tree species, *Vatica lanceaefolia*, *Artocarpus chaplasha*, *Lagerstroemia speciosa* and *Magnolia hookeri* was studied during July 2011–June 2012 in a semi-evergreen forest of Assam, North East India. The weight loss pattern and concentration of N, P and K were evaluated. The annual decomposition constant (*k*) ranged from 3.23 to 7.8 year<sup>-1</sup> and was positively correlated with rainfall, soil temperature, soil moisture content and total N. Litter quality and initial chemistry affected the rate of decomposition. *L. speciosa* having highest initial N, decomposed at a relatively faster rate. Rapid weight loss was observed during the monsoon period. The present findings indicate that rapid nutrient cycling is enhanced by fairly high decay rates of the dominant tree species maintaining proper nutrient cycling in this tropical semi-evergreen forest ecosystem.**

**Keywords:** Decomposition, dominant tree species, leaf litter, nutrient cycling, semi-evergreen forest.

LEAF litter decomposition is an important constituent of cycling of nutrients. The complex process of litter decomposition includes the breakdown of litter and transport of organic matter and other nutrients to the soil in available forms for plant uptake in a forest ecosystem. The supply of nutrients to the soil is controlled by the amount of decomposing litterfall. The rate of decomposition is influenced by a range of factors such as nature and abundance of microorganisms, physico-chemical properties of soil, litter quality, climate, etc. Site edaphic conditions and litter quality are often considered as the most important factors for controlling litter decomposition within a small area<sup>1,2</sup>.

Staaf and Berg<sup>3</sup> reported that nutrient release generally goes through three sequential stages – an initial phase of release wherein leaching prevails, a net immobilization phase in which nutrients are integrated in the residual mass of litter, and a net release phase where a complete reduction in the nutrient concentration takes place in the residual litter mass. Decomposition rate and nutrient

release pattern are species-specific and are correlated with quality, including chemical composition of the litter, season and environmental factors.

Hollongapar Gibbon Wildlife Sanctuary (HGWS) is a tropical, semi-evergreen forest of Assam, North East India, with high tree species density and diversity. Several workers have carried out studies on primate ecology and behaviour, but so far no record of leaf litter decomposition has been found. Thus, an attempt has been made to analyse the decomposition pattern and nutrient release of leaf litter of four selected dominant tree species of the sanctuary, viz. *Vatica lanceaefolia*, *Artocarpus chaplasha*, *Lagerstroemia speciosa* and *Magnolia hookeri*. The main aim of the study is to determine foliar decay rate of the selected tree species to understand their role and contribution towards nutrient cycling in this forest ecosystem.

The study was conducted in HGWS (26°40'–26°45' N lat. and 94°20'–94°25' E long.) in Mariani range of Jorhat district, upper Assam, NE India. Surrounded by tea gardens and villages and criss-crossed by many rainfed streams, this semi-evergreen forest is situated at an altitudinal range 100–120 m amsl, and covers an area of 20.98 km<sup>2</sup>. The forest type of HGWS is 'Eastern Alluvial Secondary Semi Evergreen Forest (1/2/2B/2S2)' under Moist Tropical Forests of India<sup>4</sup>. Species like *Dipterocarpus*, *Vatica*, *Artocarpus*, *Lagerstroemia*, *Castanopsis*, etc. are found in the top canopy layer.

The climate in the region may be classified as subtropical humid type (monsoonal climate) comprising four seasons – pre-monsoon (March to May), monsoon (June to September), post-monsoon (October to November) and winter (December to February). Monthly ambient temperature and relative humidity (RH) of the study site were recorded using air thermometer and hygrometer (Omsons wet and dry hygrometer) respectively. Rainfall data of the nearest Jorhat station were collected from the Regional Meteorological Centre, Guwahati, Assam. Rainfall, RH and air temperature recorded during the study period (June 2011–June 2012) were 10.3–462.3 mm (February–July), 35–96% (January–June) and 15–32.5°C (January–September) respectively (Figure 1). Soil moisture content was determined gravimetrically and soil thermometer was used to record soil temperature in the field. These ranged from 14.39% to 30.84% (December–August) and 16.8–29.1°C (January–September) respectively (Figure 1). The soil was sandy clay loam in texture (sand 67.47%, silt 10.04% and clay 22.49%) and acidic in nature with average pH of 4.93. Total N was estimated by CHN Analyzer (Perkin Elmer, 2400 Series II), which varied from 0.065% to 0.291% (December–September).

Four dominant tree species of the forest, based on phytosociological study by Sarkar and Devi<sup>5</sup>, namely, *Vatica lanceaefolia* Bl., *Artocarpus chaplasha* Roxb., *Lagerstroemia speciosa* (L.) Pers. and *Magnolia hookeri* (Cubitt & Smith) Raju & Nayar were selected for the

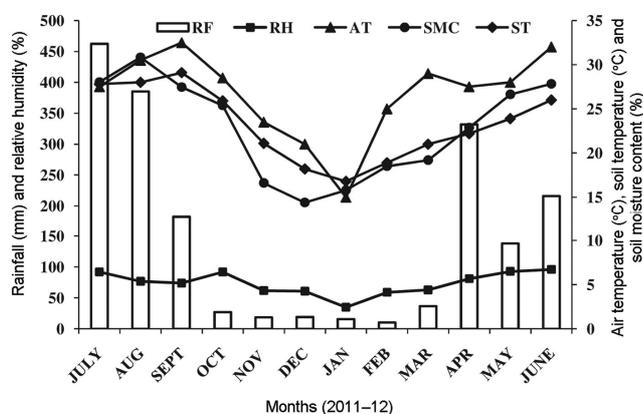
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study. *V. lanceaefolia* and *M. hookeri* are evergreen, while *A. chaplasha* and *L. speciosa* are deciduous tree species.

Freshly fallen leaves of these selected species were collected and 10 g of air-dried leaf litter samples were placed within nylon mesh bag of 15 cm × 15 cm having mesh size of 2 mm, good enough to avoid major losses of litter samples but allow aerobic microbial activity and free entry of small soil organisms<sup>6</sup>. The litter bags were placed on the soil surface (total 240; 4 species × 5 replicates × 12 months) just below the litter layer of the forest from June 2011. Five bags for each species were retrieved at monthly intervals, which were then gently brushed and cleaned at the laboratory, oven-dried at 70°C and weighed to determine weight loss. The litter bags were collected monthly for a period of 10 months, till the litter mass content in the bags was sufficient enough for analysis; after 10 months there was not enough litter mass in the bags for further analysis. The samples were ground in Wiley mill for chemical analysis. The litter decomposition rate, half life ( $t_{50}$ ) and time required for loss 95% ( $t_{95}$ ) were estimated from the equation given by Olson<sup>7</sup>.

The litter samples were analysed for total concentrations of C, N, P and K. C and N estimation was carried out by CHN Analyzer (Perkin Elmer, 2400 Series II), P was determined colorimetrically and K using a flame photometer<sup>8</sup>. Nutrient content of decomposing leaf litter was derived following Bockheim *et al.*<sup>9</sup>. C/N ratio for the decomposing litter samples was evaluated from the calculated N and C concentration values. All statistical analyses were carried out using SPSS 16.0 software.

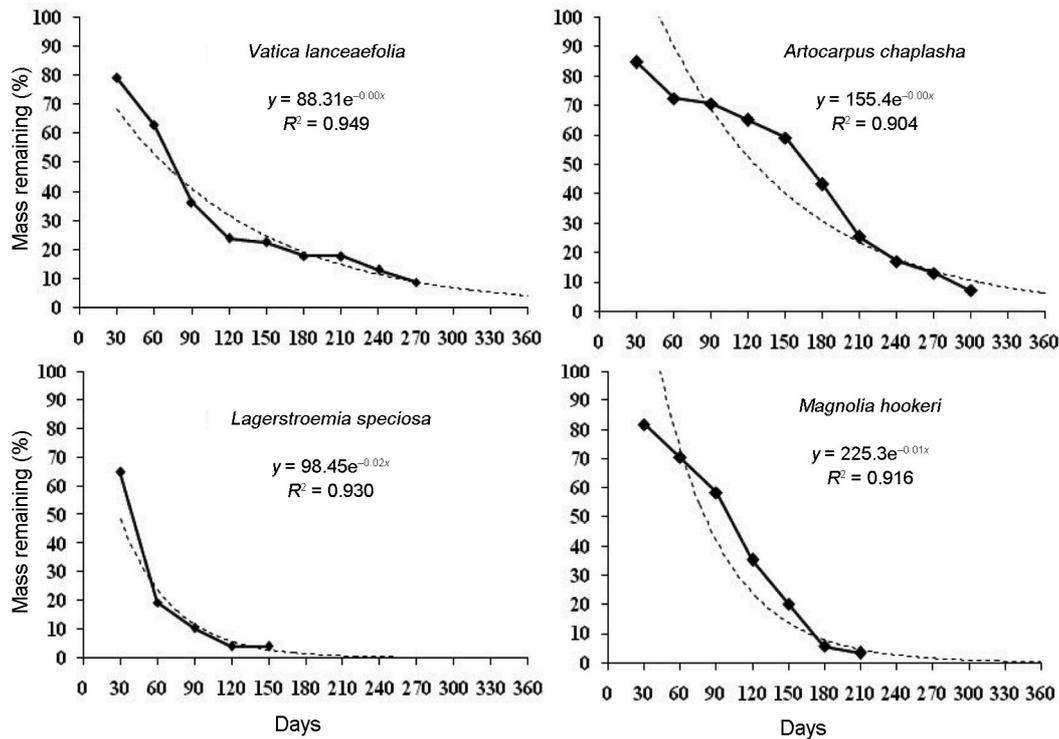
Decay rates of different foliar litter of selected species were noticeable from decomposition values expressed as mean percentage remaining dry weight for the different sampling times. In the present study, the time required for disappearance of the original biomass of different leaf litter ranged from 150 to 300 days. *L. speciosa* decomposed faster than other species (150 days), while *A. chaplasha*



**Figure 1.** Monthly variation of rainfall (RF), relative humidity (RH), air temperature (AT), soil temperature (ST) and soil moisture content (SMC) at the study site.

took the longest time to decompose (300 days). *V. lanceaefolia* and *M. hookeri* took 270 and 210 days for decomposition respectively. The varying rates of decomposition seemed to be influenced by their morphological characters<sup>10</sup> such as leaf area, toughness, texture, etc. Big leaf with hard and coarse texture of *A. chaplasha* may have attributed to its slower decomposition rate than other species. Figure 2 shows the residual mass (% of the original) of leaf litter of different species in retrieved litter bags at monthly intervals for the study site. About 91–96% of weight loss of the selected species took place at the end of the experiment and the residual litter mass declined exponentially with time for all the species. It was observed that the decomposition rate was high in the initial stage as all leaf litter species attained 50% mass within the first three months and the loss of mass gradually decreased as decomposition proceeded. The rapid decomposition in the initial months might be due to high initial content of water soluble materials and simple substrates, and the breakdown of litter by decomposers<sup>10</sup>. On the other hand, the accumulation of more recalcitrant constituents such as N-containing humus compounds, lignin-N compounds, etc. in the residual litter mass might have resulted in the relatively slower decay rates at the later stages<sup>11</sup>. The analysis of variance (ANOVA) between the residual leaf litter and sampling time indicated a significant difference ( $F = 7.63$ ,  $P < 0.001$ ). The rate of disappearance was high in August and September, which correspond to the wet and warm monsoon season, compared to the dry season. During monsoon season, high temperature and rainfall result in favourable soil moisture content and ambient temperature that intensify activities of soil microorganisms which lead to faster decomposition. The higher relative mass loss during the monsoon period (July–September) may be attributed to high soil moisture content, high RM, congenial atmospheric temperature and evapotranspiration, favourable for soil biological activity<sup>12,13</sup> and frequent rain showers for leaching<sup>14</sup>. The sandy clay loam texture of soil of the study site also facilitates gradual loss of residual mass through leaching. The decrease in the activity of decomposers during the dry period due to the associated lowering of soil moisture and temperature may have caused the decline in the rate of decomposition<sup>15,16</sup>. Similar trend of litter decomposition has been observed by several workers<sup>11,17,18</sup>.

Fast rate of decomposition of litter of tropical tree species has been reported by many workers<sup>19,20</sup>. The  $k$  values for leaf litter decomposition are typically  $>1.0$  per year<sup>7</sup>. In the present study, the annual decomposition constant ( $k$ ) ranged from 3.23 (*A. chaplasha*) to 7.8 year<sup>-1</sup> (*L. speciosa*) and half-life ( $t_{50}$ ) of leaf litters ranged from 0.08 to 0.214 years. *V. lanceaefolia* exhibit similar values of annual decomposition constant ( $k$  year<sup>-1</sup>) and



**Figure 2.** Residual leaf litter (% of the original) in litter bags of four dominant tree species in the study site.

**Table 1.** Annual decomposition constant ( $k \text{ year}^{-1}$ ) and time required for the loss of one-half ( $t_{50}$ ) and 95% ( $t_{95}$ ) of the original leaf dry weight of selected tree species in the study site

Species	Dry mass		
	$k$	$t_{50}$	$t_{95}$
<i>Vatica lanceaeifolia</i>	$3.28 \pm 0.47$	$0.210 \pm 0.03$	$0.91 \pm 0.15$
<i>Artocarpus chaplasha</i>	$3.23 \pm 0.38$	$0.214 \pm 0.02$	$0.92 \pm 0.1$
<i>Lagerstroemia speciosa</i>	$7.82 \pm 1.23$	$0.08 \pm 0.01$	$0.38 \pm 0.05$
<i>Magnolia hookeri</i>	$5.9 \pm 0.35$	$0.11 \pm 0.01$	$0.5 \pm 0.04$

± Standard error,  $n = 5$ .

time required for the loss of one-half ( $t_{50}$ ) and 95% ( $t_{95}$ ) of the original leaf dry weight for four dominant tree species of the study site. It was observed from the  $k$  and  $t_{50}$  values that *L. speciosa* had high decomposition rate than the remaining selected dominant species. The rate of decomposition of foliar litter was high in the study site, which was revealed from the fairly high value of annual decomposition constant ( $k$ ). The recorded value ( $k \text{ year}^{-1}$ ) in the present study is comparable with those of Barbhuiya *et al.*<sup>6</sup> (1.04–5.37), Upadhyaya *et al.*<sup>21</sup> (3.90–8.16), Didham<sup>22</sup> (0.721–10.79), and Allison and Vitousek<sup>23</sup> (1.3–8.19). However, it is relatively higher than ranges reported by several others workers<sup>11,20,24,25</sup>.

Species-specific characteristics reveal different decay rates from one species to another, growing in different habitats. The annual decay rate constant ( $k$ ) for different species varied significantly ( $F = 32.8$ ,  $P < 0.001$ ). It was

found that *L. speciosa* recorded the highest rate of decomposition and *A. chaplasha* had the lowest decomposition rate. This difference in the decomposition rates of different species may be attributed to their chemical composition. The quality of substrate has been described in different ways – as the N concentration, lignin content and C : N ratio<sup>26</sup>. Estimation of initial nutrient concentration such as C, N, P and K in all leaf litter species followed a trend of  $C > N > K > P$  (Table 2). The initial N concentration was found maximum in *L. speciosa* (3.61%) followed by *V. lanceaeifolia* (2.13%), *A. chaplasha* (1.91%) and *M. hookeri* (1.77). Since the recorded mean N content of the litter was  $>1.5\%$  and C : N ratio was  $>25$ , all the four selected species can be considered as high-detritus N species<sup>27,28</sup>. The recorded values of primary litter quality characteristics, i.e. C, N and ratios of the two parameters (C/N) observed in the present study

**Table 2.** Initial chemical composition of leaf litter of the dominant tree species of the study site and Pearson correlation coefficients ( $r$ ) between initial chemical composition of leaf litter and decomposition constant ( $k$ )

Parameter	<i>V. lanceaefolia</i>	<i>A. chaplasha</i>	<i>L. speciosa</i>	<i>M. hookeri</i>	Correlation coefficient
C (%)	47.03	37.95	39.21	40.29	-0.395
N (%)	2.13	1.91	3.61	1.77	0.738
P (%)	0.193	0.146	0.058	0.105	-0.939
K (%)	0.502	0.547	0.237	0.247	-0.939
C : N	22.07	19.86	10.86	22.76	-0.719

**Table 3.** Correlation between litter decomposition rate and abiotic variables

Parameter	<i>V. lanceaefolia</i>	<i>A. chaplasha</i>	<i>L. speciosa</i>	<i>M. hookeri</i>
Rainfall (mm)	0.520	0.174	0.525	0.752*
Soil temperature (°C)	0.218	0.373	0.110	0.907**
Moisture content (%)	0.085	0.120	0.168	0.931**
Total N (%)	0.129	0.022	0.115	0.958**

\*\*Significant at 0.01 level; \*Significant at 0.05 level.

are within the reported range from various studies<sup>6,11,24</sup>. The initial N concentration was positively correlated ( $r = 0.738$ ) with the decay rate constants of all tree species (Table 2). During the study, *L. speciosa* having highest initial N concentration and lowest C : N ratio exhibited the highest decay rate among all the four selected species. Such positive relationship with N content has been observed in various studies<sup>18,24,25,27</sup>. In the initial stages, the microorganisms depend mainly on the original N stocks of the decomposing material<sup>29</sup>, resulting in faster decomposition rate. Hence, from the study, it has been established that among all the components of initial leaf litter chemistry taken into consideration, initial N concentration and C : N ratio of the leaf litter are the two crucial determining factors for their decomposition in the study site.

The decomposition rates of all species were correlated with abiotic variables like rainfall, soil characteristics – soil temperature, soil moisture content and soil total N (Table 3). Moisture and temperature are considered as vital variables that determine the decomposition rate<sup>30</sup>. Positive correlation with rainfall, air temperature, soil moisture and soil temperature reveals high rate of decomposition in hot, rainy season and low rate during cool, dry periods. Various reports also support such observations<sup>6,25,31</sup>. Likewise, Jamaludheen and Kumar<sup>27</sup> reported a positive yet non-significant relation of soil moisture with residual litter weight. Soil total N also showed a positive correlation with decay rate, which corroborates with reports by other workers<sup>6,32</sup>. According to Liu *et al.*<sup>32</sup>, N availability is essential for litter decomposition, as increased soil N can cause changes in the soil nutrient level and decomposers as well as the quality of decomposing litter. Therefore, it is observed that direct relationships exist between soil microclimate and decomposition of litter mass.

The concentration of N consistently increased from the original concentration in different sampling periods till the end of the experiment in all the selected species (Figure 3). The N concentration during decomposition was recorded to be maximum in leaf litter of *V. lanceaefolia* (4.08%), followed by *L. speciosa* (3.93%), *M. hookeri* (3.42%) and *A. chaplasha* (2.70%). Figure 4 shows the changes in remaining N concentration (% of the initial) in decaying leaf litter of four dominant tree species. Highest remaining N concentration (% of the initial) was recorded in *V. lanceaefolia* (9.80%). ANOVA indicated that the monthly concentration of N showed significant variation between species ( $F = 5.05$ ,  $P < 0.01$ ). For the release of N, significant variation was found within species and months ( $F = 4.28$ ,  $P < 0.05$ ) during decomposition. N was released rapidly during monsoon season (July–September) from decomposing litter than post-monsoon (October–November) and dry winter (December–February seasons). The rise in N concentration in the residual litter may be related to addition by various processes such as fixation, absorption of atmospheric ammonia, throughfall, dust, insect frass, green litter, fungal translocation and/or immobilization<sup>33</sup>. Such increasing trend of N concentration has also been reported by various workers<sup>33,34</sup>. Loss of N from residual litter due to leaching and microbial activity may have caused the gradual decrease of remaining N concentration<sup>35</sup>.

P concentration declined at the beginning of decomposition from July to August, and then increased in September. After this, a gradual decline was observed till the completion of decomposition (Figure 3). P concentration was highest in leaf litter of *L. speciosa* (0.11%) and lowest in *M. hookeri* (0.02%). The remaining P concentration in decaying leaf litter among four dominant tree species (Figure 4) was also highest in *L. speciosa* (7.97%) and was lowest in *M. hookeri* (0.63%). ANOVA indicated

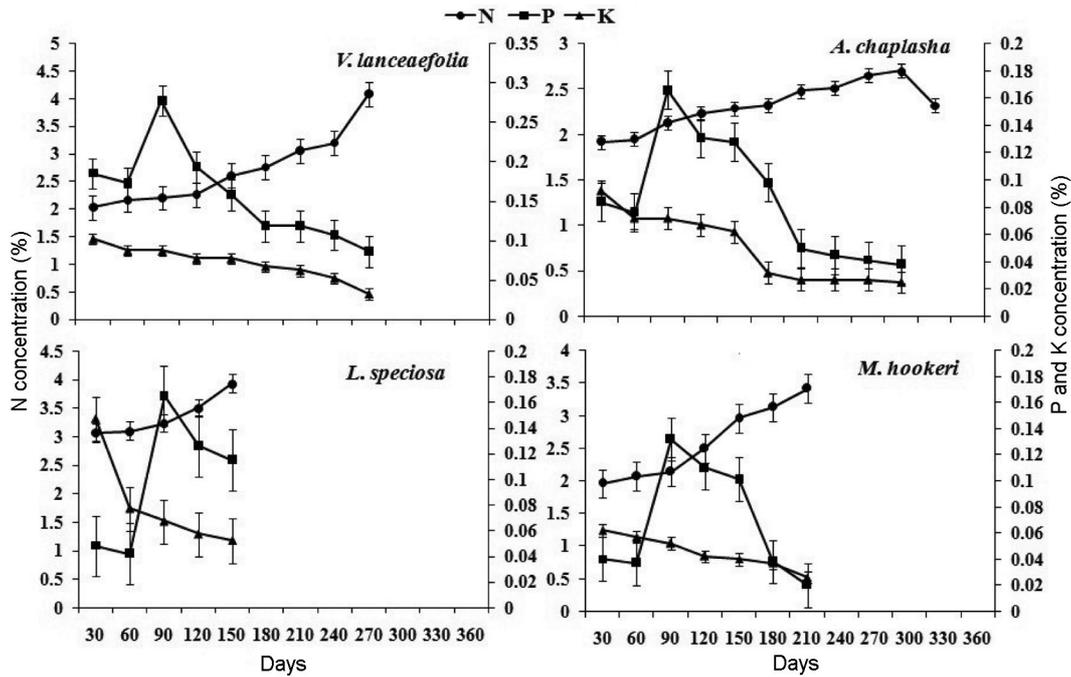


Figure 3. Changes in nitrogen, phosphorus and potassium concentration (%) in decaying leaf litter of four dominant tree species.

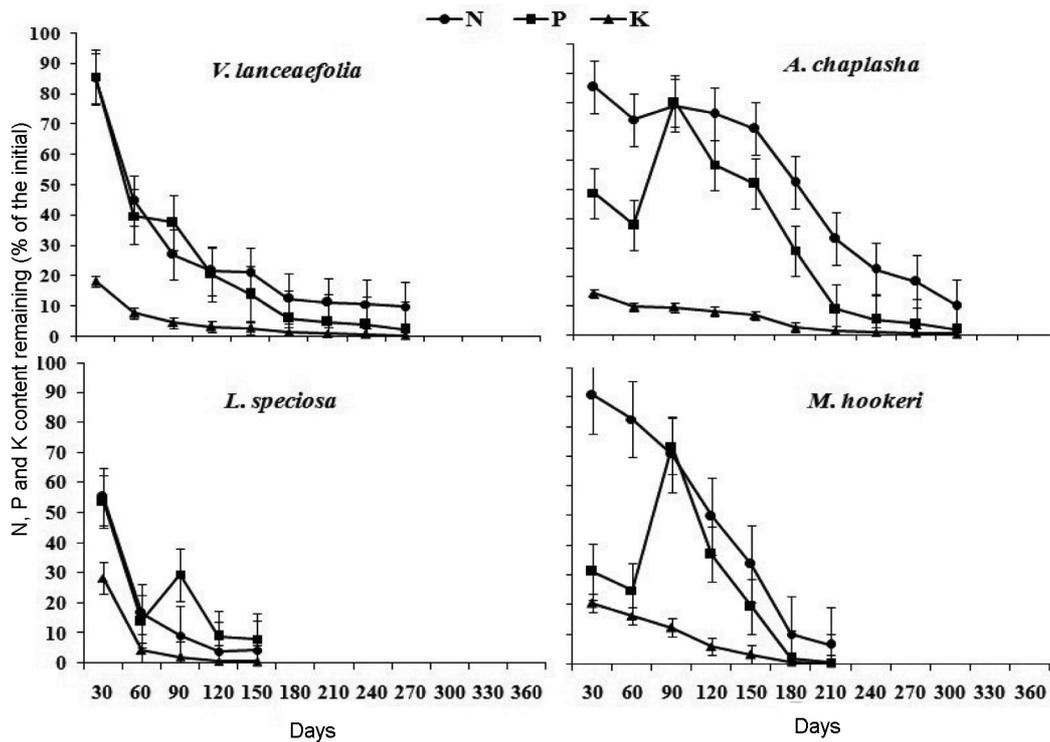


Figure 4. Changes in remaining nitrogen, phosphorus and potassium concentration (% of the initial) in decaying leaf litter of four dominant tree species.

that the monthly P concentration showed significant differences between species ( $F = 5.00, P < 0.01$ ). No significant difference was found for the remaining P or its release between species. The initial drop in P concentra-

tion or the rapid P release from leaf litter in July and August could be attributed to high leaching due to heavy rainfall. The P content increase may be linked to through-fall, insect frass and addition from the soil due to

impoundment by raindrops in the monsoon season. The low P release in September may be due to microbial immobilization during this period. Slow but gradual increase in P release was observed till the completion of decomposition through post-monsoon and dry winter periods. The high decomposition and release of P in leaf litter correspond to the warm, wet season and active microbial activities. Similar observations of P concentration and its release pattern have also been made by other researchers<sup>18,25,34</sup>.

During leaf litter decomposition, K concentration of all the four species decreased gradually till the end of the experiment (Figure 3). K content was recorded highest in leaves of *L. speciosa* (0.052%) and it was lowest in leaf litter of *A. chaplasha* (0.02%). The remaining K concentration was highest in decaying leaf litter of *L. speciosa* (0.62%) and lowest in *A. chaplasha* (0.32%) (Figure 4). ANOVA showed that the monthly concentration of K significantly differed between months and species ( $F = 3.15$ ,  $P < 0.05$ ). For the release of K from decomposing samples, significant differences were found within months ( $F = 3.51$ ,  $P < 0.05$ ). The consistent decline of K from the decomposing leaf litter can be associated with leaching. Similar pattern of K release has been reported in other studies<sup>18,35</sup>. Since leaching is the major process in the release of K, rapid release rate of K was observed during monsoon season than the rest of the study period.

On the basis of the pattern of nutrient release relative mobility, N, P and K may be arranged as follows:  $K > P > N$ . Toky and Ramakrishnan<sup>36</sup> also reported similar patterns of mobility of elements from leaf litter from forests of NE India. As K is more mobile than N and P, for all the four selected dominant species in the studied site, the release of K from the decomposing foliar litter was faster in comparison to that of N and P.

Plant nutrients become available for recycling within the ecosystem during nutrient release from the litter layer by leaching, mineralization and by direct transfer of litter fragments to the mineral soil<sup>37</sup>. Hence, litter decomposition enhances the soil fertility through replenishment of plant nutrients and maintains soil organic matter.

The outcome of the present study contributes towards better understanding of foliar litter decomposition pattern of four dominant tree species of the tropical semi-evergreen forest of Assam. The high value of annual decomposition constant ( $k$ ) indicates that rate of decomposition and nutrient release are high in the study area due to high temperature and rainfall. *L. speciosa* was the fastest decomposing species among those selected. Litter quality such as high initial N content and low C:N ratio determines faster decay rate. Prevailing environmental conditions and soil characteristics also influence the litter decomposition and nutrient release. Overall, it can be concluded that rates of decomposition of dominant tree species of this forest are relatively high; the nutrients in decomposing litter are recycled rapidly within the soil to

replenish its fertility and maintain proper nutrient cycling in this tropical semi-evergreen forest ecosystem.

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## Erratum

### Status of regulation on traditional medicine formulations and natural products: Whither is India?

Nandini K. Kumar and Pradeep Kumar Dua  
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Under the subtopic 'Present Regulatory Scenario' on page 300, the word 'Draft' was inadvertently missed in line no. 18 after mention of GSR 364. The sentence should read as '... and audio-visual recording of the informed consent process (vide GSR 364 (E) Draft Rule dated 7 June 2013)<sup>25</sup>.

We regret the error.

–Authors