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Decomposition dynamics of three priority bamboo species of homegardens in Barak Valley, Northeast India

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Abstract: We investigated litter chemistry, and patterns of mass loss and nutrient release from leaf and sheath litter of three priority cultivated bamboo species, *Bambusa cacharensis*, *B. vulgaris* and *B. balcooa,* to understand litter decomposition. The study was conducted in a homegarden of Dargakona village in district Cachar, Assam, in northeast India. Leaf litter had higher concentrations of N, P and K than sheath litter, whereas sheath litter had higher carbon, ash free mass and cellulose. Percent weight loss decreased exponentially with time. Sheath litter had slower rates of mass loss than leaf litter. The pattern of N release was biphasic, P concentration exhibited an initial accumulation phase, and release of K occurred at all the stages of decomposition. We discuss the ecological significance of decomposition dynamics of bamboo litter – compared with litter of other cultivated tree species – for nutrient retention in homegardens.

Resumen: Investigamos la química del mantillo y los patrones de pérdida de masa y liberación de nutrientes del mantillo de hojas y vainas de tres especies cultivadas prioritarias de bambú, *Bambusa cacharensis, B. vulgaris* y *B. balcooa*, para entender la descomposición del mantillo. El estudio se llevó a cabo en un huerto familiar del poblado de Dargakona en el distrito Cachar, Assam, nordeste de la India. El mantillo foliar tuvo concentraciones más altas de N, P y K que el mantillo de vainas, mientras que el mantillo de vainas tuvo mayores contenidos de carbono, masa libre de ceniza y celulosa. La pérdida porcentual de peso decreció exponencialmente con el tiempo. Las tasas de pérdida de masa fueron más lentas para el mantillo de vainas que para el mantillo foliar. El patrón de liberación de N fue bifásico; la concentración de P mostró una fase inicial de acumulación y la liberación de K ocurrió en todas las etapas de la descomposición. Discutimos el significado ecológico de la dinámica de la descomposición del mantillo de bambú– en comparación con el mantillo de otras especies arbóreas cultivadas– para la retención de nutrientes en huertos familiares.

Resumo: Para compreender a decomposição da folhada investigou-se a química da folhada e os padrões de perda de massa e de libertação de nutrientes da folhada das folhas e das bainhas de três espécies cultivadas prioritárias de bambu, a *Bambusa cacharensis*, a *B. vulgaris* e a *B. balcooa*. O estudo foi empreendido num quintal de casa na vila de Dargakona no distrito de Cachar, Assam, no nordeste da Índia. A folhada das folhas apresentou uma maior concentração de N, P e K do que a da folhada das bainhas das folhas enquanto que esta apresentava teores mais elevados de carbono, massa livre de cinzas e celulose. A perda de peso percentual decresceu exponencialmente com o tempo. A folhada das bainhas apresentou menor taxa de perda de massa do que a folhada de folhas. O padrão de libertação de N foi bifásico: a concentração de P exibiu uma fase inicial de acumulação e a libertação de K ocorreu em todos os estados da decomposição. Discute-se o significado ecológico da dinâmica da decomposição da folhada de bambu - em comparação com a folhada de outras espécies cultivadas – para a retenção de nutrientes nos quintais de casa.

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Key words: Decay constant, litter chemistry, litter decomposition, nutrient retention.

Across large areas of semi-urban and rural South and South-east Asia, homegardens form an important component of land-use systems (Soemarwoto 1987). Homegardens, a land use system with an intimate mix of trees and crops, comprise a separate generic concept, similar to agroforestry (Kumar & Nair 2004) and are regarded as the 'epitomes of sustainability' for nutrients throughout the tropics (White *et al.* 1988). Decomposition of plant litter is a crucial stage in biogeochemical cycling within ecosystems (De Catanzaro & Kimmins 1985). A knowledge of litter decay rate is important in understanding the productivity and nutrient budgeting of homegardens (Isaac & Nair 2006) and quantitative data on biogeochemical processes in tropical homegardens are inadequate. Bamboos form an important component of homegardening systems in North-east India. In the tropical humid climate of Assam bamboo growers have prioritized three bamboo species viz. *Bambusa cacharensis* R. Majumder (*betua*), *B. vulgaris* Schrad. ex Wendl. (*jai borua*) and *B. balcooa* Roxb. (*sil borua*) based on their need and utility and these species are widely distributed and frequently cultivated in homegardens (Nath & Das 2008). Studies have been carried out worldwide on the litter decomposition of forest bamboos, but no such work has yet been reported on cultivated bamboos. Keeping this in view, the present study was framed to understand litter decomposition of three priority cultivated bamboo species, *B. cacharensis*, *B. vulgaris* and *B. balcooa,* with the following specific objectives: (i) to investigate the pattern of litter mass loss; (ii) to investigate the litter chemistry and decomposition dynamics of leaf and sheath litter; and (iii) to investigate the pattern of nutrient release from leaf and sheath litter.

The present study was conducted during 2004 - 2005 in a homegarden of Dargakona village, in Cachar district of Barak Valley. The area is situated at longitude 92º 45' E and latitude 24º 41' N. The climate of the study site is sub-tropical warm and humid. Mean annual rainfall during the study period was 2515 mm, most of which was received during the southwest monsoon season (between June and September). Average maximum and minimum temperatures were 30.4 ºC and 20.2 ºC respectively. The average relative humidity varied between 45 percent (January) to 96 percent (June). The soil bulk density of the soil is 1.15 - 1.30 g cm^{-3} with soil pH [measured in 1:2.5 soil water (w/v) suspensions], water holding capacity and organic carbon content of 5.10 - 5.15, 35.87 - 42.72 % and 0.92 - 1.35 %, respectively. Moisture content of the soil ranges from 16.7 - 21.5 %. Total soil nitrogen (N), available soil phospohorus (P), and exchangeable soil potassium (K) were 0.18 - 0.23 %, 25 - 48 mg kg^{-1} and 54 - 64 mg kg^{-1}, respectively.

Freshly abscissed leaves and sheaths were collected during the peak litterfall period (February - March) from the floor under the canopy of the three species under investigation. Samples of air dried litter weighing 5 g were placed in 15 x 15 cm nylon litter bags (1 mm^2 mesh size) and 60 such bags were prepared for leaf and sheath for each species (60 × 3 × 2). Litter bags enclosing leaf and sheath of each species were placed under the closed canopy of the respective species on 1 June 2004. Subsequently, 5 litter bags were removed at monthly intervals from the month of June until 95 % decomposition was observed. The residual material from the sampled litter bags was separated carefully from the adhering soil particles using a small brush. The litter samples from each bag were oven dried at 70 ºC till they reached a constant weight to determine the dry weight.

Samples of litter, to determine initial litter chemistry and to determine chemistry of litter retrieved at each sampling period, were ground in a Wiley mill for chemical analysis. Total N and P were determined by the semi-micro Kjeldahl and molybdenum blue methods respectively (Anderson & Ingram 1993). Potassium was determined by flame photometrically (Systronics 121). The total stock of N, P and K was calculated by multiplying the concentration (%) of these elements in litter with the dry mass of litter.

Monthly mass loss (g $month^{-1}$) from decomposing litter was determined from the difference between the mass of litter remaining in the litterbags in a particular month, and the mass of litter in the litterbags in the previous month. Mass loss over time was computed using the negative exponential decay model (Olson 1963). The time required for 50 % (t_{50}) and 99 % (t_{99}) decay was calculated as $t_{50} = 0.693 / k$ and $t_{99} = 5/k$. Data analysis was

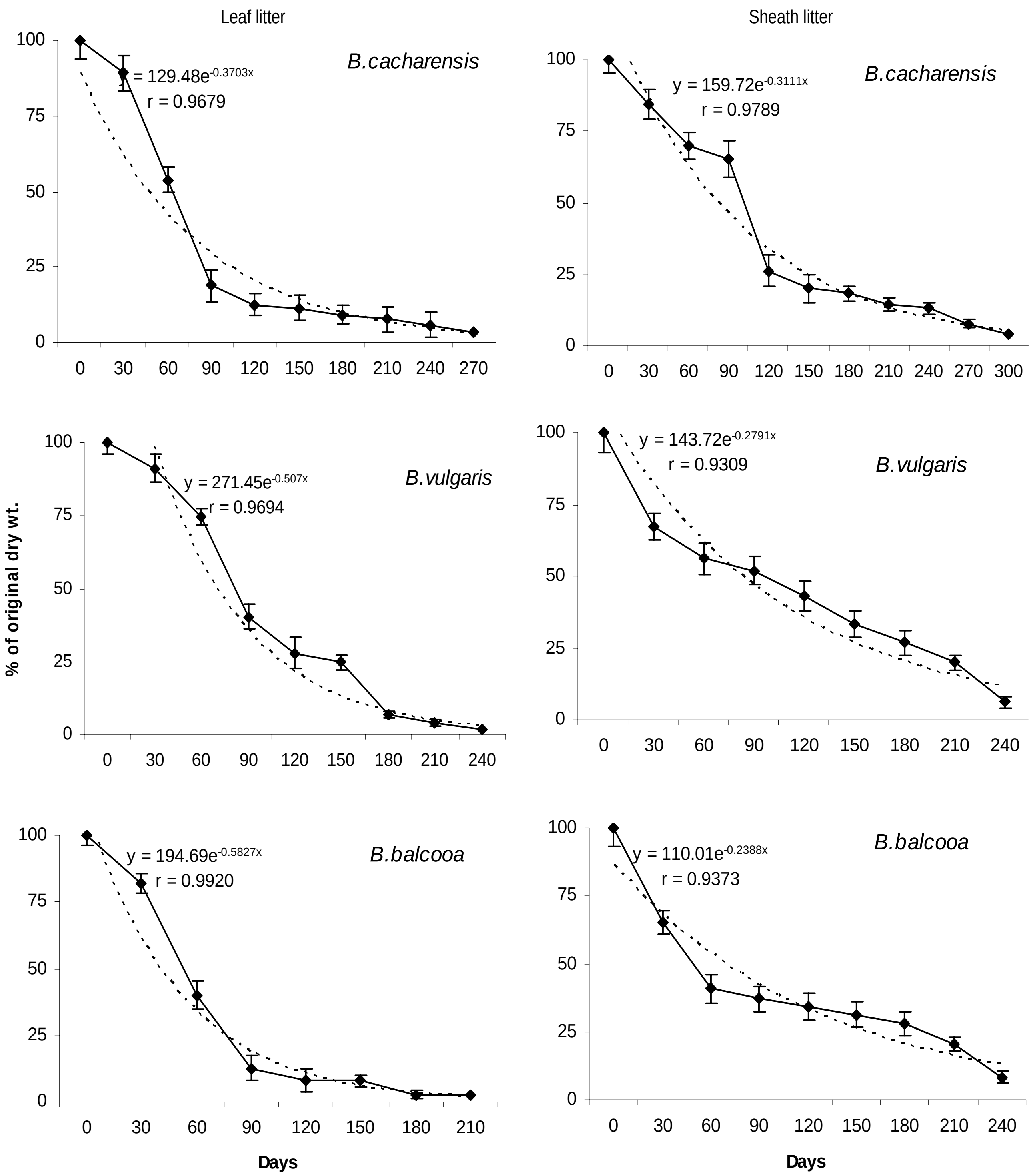

Fig. 1. Leaf and sheath litter decomposition in *B. cacharensis*, *B. vulgaris* and *B. balcooa*. Solid lines denote cumulative weight loss while broken lines denote predicted weight loss based on an exponential model.

performed using the statistical soft-ware M.S. Excel 2003.

Litter mass, expressed as a percentage of the original dry mass, decreased exponentially over time. Total mass loss of leaf and sheath litter increased over time but the monthly mass loss was not uniform (Fig. 1). Comparatively higher mass loss occurred during the period of June to Novem-

Table 1. Initial leaf and sheath litter chemistry of *B. cacharensis*, *B. vulgaris* and *B. balcooa.*

Species	N (%)	P (%)	K (%)	Carbon (%)	C/N
B. cacharensis					
Leaf	0.82	0.065	0.38	37.5	45.6
Sheath	0.63	0.053	0.23	42.0	66.6
B. vulgaris					
Leaf	0.92	0.072	0.43	35.5	38.6
Sheath	0.71	0.049	0.31	46.1	64.9
B. balcooa					
Leaf	0.98	0.078	0.45	34.6	35.3
Sheath	0.66	0.045	0.37	45.5	68.9

Table 2. Decay constants for leaf and sheath litter of *B. cacharensis, B. vulgaris* and *B. balcooa.*

Species	Litter type	Decomposition rate constant k (Year $^{-1}$)	Time required for 50% decomposition (Days)	Time required for 99% decomposition (Days)
B. cacharensis	Leaf	1.44	130	934
	Sheath	1.31	147	1060
B. vulgaris	Leaf	1.71	97	702
	Sheath	1.21	137	987
B. balcooa	Leaf	1.64	88	637
	Sheath	1.07	154	1113

ber in leaf litters. All three species lost 60 - 75 % of total leaf mass during this period. The mean monthly leaf mass loss over the study period was highest for *B. balcooa* (13.96 %), followed by *B. vulgaris* (12.26 %) and then *B. cacharensis* (10.71 %). Greatest sheath mass loss occurred during the period June to October with highest loss occuring during September in *B. cacharensis* (39 %) and during June for both *B. vulgaris* and *B. balcooa* (33 % and 35 %, respectively). The mean monthly sheath mass loss over the study period mirrored the monthly leaf mass loss, with the highest monthly loss observed for *B. balcooa* (11.45 %) followed by *B. vulgaris* (10.84 %) and then *B. cacharensis* (9.44 %). Our data show, that litter decomposition under warm and humid conditions is more rapid than at other times.

The initial leaf litter concentration (%) of N, P and K was maximum for *B. balcooa* and minimum for *B. cacharensis*. For sheath litter *B. vulgaris* had the highest N concentration among the three species as well as lower C/N ratio compared to the other two species (Table 1). Comparatively, leaf litters had lower C/N ratio than sheath litters. The leaf and sheath litter having higher N and lower C/N ratio showed the fastest decomposition rate compared with litters with lower N and higher C/N ratio (see Table 2 for decay constants). Initial N (Meentemeyer & Berg 1986) and lower C/N ratio (Swift *et al.* 1979) have been well correlated with the weight loss. Among the litter types, leaf litters decomposed faster than sheath litters for the three species and this is attributed to the differences in the surface toughness. Sheath litter has a tougher surface than leaf litter, and it has been reported that physical toughness can affect the rate of decomposition (Rogers 2002).

Complex dynamics of N and P release were observed. The pattern of N release was biphasic. There was both an initial accumulation and a later accumulation of N in leaf litter of *B. cacharensis* and *B. balcooa*. For sheath litter N content declined initially and then increased in all the three species. Phosphorous concentration in leaf litter of *B. cacharensis* and *B. vulgaris* exhibited an accumulation in the first 60 days and thereafter declined. However, no marked P accumulation was observed in leaf litter of *B. balcooa*. Concentration of P in the decomposing sheath litter declined after an initial accumulation phase in *B. cacharensis* and *B. vulgaris*. Loss of K occurred at all the stages of decomposition in both leaf and sheath

Table 3. Regression parameters (R^2) relating percent weight loss per month to N, P and K.

Nutrient variable	Coefficient of determination (R^2)					
	B. cacharensis		*B. vulgaris*		*B. balcooa*	
	Leaf	Sheath	Leaf	Sheath	Leaf	Sheath
N	0.2903 NS	0.3136 NS	0.0756 NS	0.0823 NS	0.4264 NS	0.1883 NS
P	0.5041*	0.6271**	0.5184*	0.4251 NS	0.6634*	0.3469 NS
K	0.7569**	0.4761*	0.8325**	0.4830*	0.5490*	0.7551**

*significant at 5% level, ** significant at 1% level, NS not significant.

litter, across all three species. Among the different species *B. vulgaris* showed the fastest release of all nutrients compared with *B. balcooa* and *B. cacharensis*, for both leaf and sheath litter.

In the present study, N and P exhibited net immobilization for leaf and sheath litter while K exhibited continuous net release. Intense accumulation of N and P is due to immobilization by microbes and nutrient input from throughfall (Upadhyay *et al.* 1989). On the basis of the pattern of nutrient release relative mobility of these elements may be arranged as K > P > N. Similar patterns of mobility of elements from leaf litter of *D. hamiltonii*, was reported from early successional vegetation of Northeast India (Toky & Ramakrishnan 1984).

Regression parameter (R^2) relating percent weight loss per month (as the dependent variable) to nutrients (N, P and K) indicated that for leaf litter P and K explained 50 to 66 % and 54 to 83 % of the variation in weight loss, respectively (Table 3). For sheath litter K explained 44 to 75 % of the variation in weight loss. N concentration was found to be insignificantly related with the weight loss in leaf and sheath litter for all three species. Due to the complex dynamics in the release of N and P from leaf and sheath litter, linear relationships between weight loss and N and P release, respectively, were insignificant for the three species, unlike the relationship between weight loss and K release.

In comparison to 10 multipurpose tree species of homegardens (Das & Das 2010) bamboo leaf and sheath litter exhibited a pattern of relatively greater nutrient retention in litter mass. Further, slower decomposition rate of bamboo litters compared with litter of other tree species (Das & Das 2010) could decrease the rate of organic matter turnover in the former, which, in turn, makes the soil rich in humus (Toky & Ramakrishnan 1984) and this is effectively utilized *in situ* in homegardening systems. Therefore, bamboo litter is a potential source of nutrient input in the homegarden system and its decay and subsequent nutrient release replenish the soil nutrient pool and influence the soil microenvironment of this traditional land use system.

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