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Effect of Initial Litter Quality on Decomposition Rates of the Tree Leaf Litter in Himalayan Forest Ecosystems

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Abstract: Seasonal decomposition rates and the influence of initial chemical constituents on decomposition rates of leaf litter of 10 species were studied in different forest ecosystems of Central Himalaya. The species having higher lignin and lignin/nitrogen ratio decomposed slowly. Those species having higher water soluble compounds, base contents and acid soluble cell wall components decomposed faster. Lignin controlled effectively the rate of decay of leaf litter especially in the later phase of decomposition.

Résumé: Les taux de décomposition saisonniers et l' influence des constituents chimiques initiaux sur les taux de décomposition de feuilles de litière provenant de 10 espèces, ont été étudiés dans différents écosystèmes forestiers de l' Himalaya central. Les espèces ayant plus de lignine et un rapport lignine/azote plus fort, se décompose doucement. Les espèces qui ont plus de composés solubles dans l'eau, des bases et des composants de paroi cellulaire soluble dans l'acide se décomposent plus rapidement La lignine contrôle effectivement le taux de décomposition des feuilles de la litière, surtout dans les dernières phases de la décomposition.

Resumen: Se estudiaron las tasas de descomposición estacionales y la influencia de los constituyentes químicos iniciales en las tasas de descomposición de la hojarasca foliar de 10 especies en diferentes ecosistemas forestales del Himalaya Central. Las especies que tuvieron altas tasas de lignina y lignina/nitrógeno se descompusieron lentamente. Aquellas especies que tuvieron más compuestos solubles en agua, contenido de bases y componentes ácidos dolubles en la pared celular se descompusieron más rápido. La lignina controló efectivamente la tasa de desintegración de la hojarasca foliar especialmente en la última fase de la descomposición.

Resumo: As taxas de decomposição sasonal da folhada de 10 espécies e a influência dos seus constituintes químicos iniciais nas respectivas taxas de decomposição foram estudadas em diferentes ecossistemas dos Himalaias Centrais. As espécies com mais elevado teor em lenhina e na razão lenhina/azoto decompuseram-se mais lentamente. Aquelas espécies com teor mais elevado em compostos aquosos solúveis, em bases e componentes de parede celular solúveis em meio ácido decompuseram-se mais rapidamente. O teor em lenhina controla efectivamente a taxa de decomposição da folhada, especialmente na última fase de decomposição.

Key Words: Decomposition, Himalayan forests, Leaf litter, Lignin, Nitrogen Seasonality.

INTRODUCTION

The concentration of different nutrients in the senescing leaves plays major role in decomposition dynamics. Nutrient rich litters and nutrient limited litters entering in the decomposer subsystem may have different rates of decay. The availability of nutrients influences the activity of decomposer organisms. However, climate and soil properties also are equally important in the decay dynamics. Whereas some nutrients control the initial stages of decay, the others become important in the later part of the decay phase. Several authors have reported the influence of initial concentrations of nitrogen, phosphorus, lignin, cations, pH and some major nutrients on the decomposition rates (Daubenmire & Prusso 1963; Broadfoot & Pierre 1939; Swift 1978; Heal *et al.* 1978; Fogel & Cromack 1977; Singh & Gupta 1977; Upadhyay & Singh 1985). This study describes the influence of initial chemical composition decomposition rates of tree leaf litters in forest ecosystems of central Himalaya.

MATERIALS AND METHODS

Study site

The study sites are located in the Central Himalaya between 29°7' to 20°38' N lat. and 79°27' to 79°43'E long and altitude ranged from 350 to 2150 m. The geology, soil and climate for these sites are described elsewhere (Upadhyay 1987, 1988).

Decomposition rate of litter

Five forest ecosystems at different elevations were selected to compare seasonal decomposition rates of leaf litter of *Quercus leucotrichophora* and of different tree species. The other species selected are : Sal Forest (330 m): *Shorea robusta, Mallotus philippenesis; Pine–mixed* Broadleaf forest (1250 m); *Lyonia ovalifolia. Quercus glauca, Rhododendron arboreum;* Pine forest : *Pinus roxburghii;* Mixed oak-pine forest : *Myrica esculenta* and mixed oak forest : *Quercus lanuginosa* and *Quercus floribunda*. The litter bag technique was followed for studying the decomposition rates; the litter bags were of 10x10 cm with 1 mm mesh size and contained 5 g air-dried material of leaf litter. At the sal forest site, steel-wire netting bags with the same mesh size and painted with synthetic enamel to avoid rusting, were used because of the attack of termites on the bags. The average initial dry weight of the enclosed litter was determined by weighing five initial samples. Five litter bags were recovered in each month in individual polythylene bags and transported to the laboratory. In the laboratory the residual litter was separated from the bags and was carefully cleaned to remove the attached soil particles and weighed; mass loss and moisture content calculated on oven dry weight basis. Per cent mass remaining of the litter of each species at each site was calculated for rainy, winter and summer seasons.

Chemical analysis

The stock samples of litter materials were analysed for nitrogen by micro-kjeldahl method (Piper 1944). The ash content was determined by igniting the overn-dried material for 6 hrs. at 600°C in a muffle furnance. Carbon content was calculated following Mc Brayer & Cromack (1980) as 50% of ashfree dry weight. The acid soluble cell wall component (ASCC) was estimated according to Clancy & Wilson (1966), acid detergent fibre and lignin content following Edwards (1973). Phosphorus was determined colorimetrically (Jackson 1958); sodium, potassium and calcium by flame photometry (Black 1965) and water soluble compounds (WSC) following Anderson (1973).

RESULTS

Table 1 shows the per cent mass remaining of litter in different seasons, at different forest sites. To test for differences in mass loss among different species in different seasons, the mass loss data were subjected to student 't' test (Snedecor & Cocharan 1969). Most of the species pairs did not show significant differences in initial periods (rainy season) but did so in later stages of decay. Mass loss of *M. esculenta* was significantly different from all other species in all seasons. Mass loss of *M. philippensis* and *Q. leucotrichophora* placed at the Sal forest site and *L. ovalifolia* and *Q. glauca* placed at the Sal forest site and *L.ovalifolia* and *Q. glauca* placed at pine-mixed broadleaf site was significantly different-from all the species placed at the pine and mixed oak- pine forest sites and from *Q. lanuginosa* and *Q. floribunda* placed at the mixed oak forest sites. The above species of sal and pine-mixed broadleaf forest sites did not show significant difference in mass loss among each other.

TABLE 1. Percent mass remaining in the decomposing litter of different species in different seasons (± 1 SE).

Site/Species	Seasons		
	Rainy	Winter	Summer
Sal Forest			
Shorea robusta	54.6 ± 9.2	36.8 ± 1.7	3.7± 0.6
Mallotus philippensis	38.4 ± 7.1	10.5 ± 0.9	0
Quercus leucotrichophora	38.5 ± 2.2	16.4 ± 1.2	1.3 ± 0.3
Pine-mixed broad leaf forest			
Lyonia ovalifolia	38.3 ± 4.8	19.4 ± 0.8	3.7 ± 0.6
Quercus glauca	30.6 ± 6.2	20.1 ± 1.2	
Rhododendron arboreum	63.6 ± 2.6	55.2 ± 1.4	27.6 ± 1.1
Quercus leucotrichophora	60.2 ± 3.4	44.3 ± 3.6	13.0 ± 0.7
Pine forest			
Pinus roxburghii	79.0 ± 3.5	65.0 ± 0.4	48.7 ± 1.6
Quercus leucotrichophora	73.6 ± 5.4	51.5 ± 1.3	26.1 ± 2.7
Mixed oak-Pine forest			
Quercus leucotrichophora	64.1 ± 1.7	45.9 ± 6.2	23.6 ± 1.1
Myrica esculenta	87.7 ± 3.9	62.0 ± 11.0	26.8 ± 5.2
Mixed oak forest			
Quercus lanuginosa	67.3 ± 2.0	51.2 ± 0.7	32.1 ± 1.8
Quercus floribunda	70.9 ± 0.7	50.8 ± 6.7	35.9 ± 0.7
Quercus leucotrichophora	51.8 ± 4.8	41.4 ± 2.0	12.9 ± 0.6

Table-2 includes data on average initial chemical composition of different litter species. The leaf litter of all *Quercus species*, *S. robusta* and *M. philippensis* had higher initial concentrations of N, P, K, Na and Ca compared to leaf litter of *R. arboreum*, *P. roxburghii* and *M. esculenta*. Lignin content was higher in *P. roxburghii* (23.4%). *S. robusta*, *M. philippensis* and *Q. qlouca* had the lowest lignin content. Lignin content was in the range of 15.8-17.8% in remaining species. Fibre content in the initial litter of *Quercus* species was more (55-61%) compared to all other broad leaf species (38-45%) and *P. roxburghii* (54%).

TABLE 2. Initial nutrient concentrations in the fresh leaf litter of trees in Himalayan forests (% ± 1SE).

Species	N	P	Na	K	Ca	Lignin	Fibre	Ash	WSC	C/N
Sal forest										
S. robusta	0.99 ± 0.02	0.28 ± 0.03	0.04 ± 0.003	0.47 ± 0.01	1.63 ± 0.04	9.3 ± 0.5	45.0 ± 1.1	4.33 ± 0.18	38.0 ± 1.7	48
M. philippensis	0.52 ± 0.04	0.13 ± 0.01	0.13 ± 0.01	0.25 ± 0.01	2.13 ± 0.04	5.8 ± 0.3	35.0 ± 1.1	6.13 ± 0.03	44.0 ± 1.8	90
Pine-mixed broadleaf forest										
L. Ovalifolia	0.80 ± 0.02	0.08 ± 0.003	0.08 ± 0.001	0.83 ± 0.01	1.27 ± 0.01	15.8 ± 0.1	37.1 ± 1.6	8.67 ± 0.09	37.9 ± 1.6	57
Q. glauca	0.94 ± 0.04	0.07 ± 0.009	0.08 ± 0.02	0.80 ± 0.01	1.13 ± 0.01	10.7 ± 0.2	36.8 ± 0.9	4.90 ± 0.06	38.6 ± 0.2	50
R. arboreum	0.70 ± 0.01	0.06 ± 0.012	0.04 ± 0.003	0.61 ± 0.01	0.95 ± 0.02	17.8 ± 0.3	45.9 ± 0.3	8.30 ± 1.15	45.4 1.1	65
Pine forest										
P. roxburghii	0.67 ± 0.01	0.05 ± 0.003	0.011 ± 0.001	0.13 ± 0.01	0.51 ± 0.01	23.4 ± 0.7	54.0 ± 0.3	8.30 ± 0.15	28.4 ± 0.8	70
Mixed oak-pine forest										
Q. leucotrichophora	1.15 ± 0.03	0.22 ± 0.003	0.07 ± 0.03	0.69 ± 0.05	1.10 ± 0.1	16.7 ± 0.1	55.1 ± 0.05	6.33 0.03	37.2 1.12	40
M. esculenta	0.58 ± 0.01	0.057 ± 0.003	0.029 ± 0.001	0.38 ± 0.01	0.88 ± 0.01	17.1 ± 0.4	57.9 ± 0.3	5.20 ± 0.31	32.0 ± 1.2	81
Oak forest mixed										
Q. lanuginosa	1.32 ± 0.02	0.12 ± 0.003	.06 ± 0.003	0.74 ± 0.01	1.24 ± 0.01	16.9 ± 0.1	59.2 ± 1.5	6.86 ± 0.18	35.6 ± 0.8	35
Q. floribunda	0.97 ± 0.01	0.12 ± 0.003	0.08 ± 0.006	0.72 ± 0.02	1.32 ± 0.03	17.3 ± 0.3	61.2 ± 0.8	6.00 ± 0.12	32.6 ± 0.7	52

Table 3 shows the coefficient of corelation between initial chemical composition and percent mass remaining for different species in different seasons. The initial ash content, K, N and P concentrations did not show significant difference with per cent mass remaining in rainy, winter and summer seasons. Initial concentration of Ca and WSC also did not show significant relation with per cent mass remaining in rainy and winter seasons, respectively. These two constituents did not show strong significant relation in other seasons also ($P<0.05$). The relationship between ASCC, Fibre and Sodium and per cent mass remaining in summer season was significant at $P < 0.05$. All other nutrients showed significant relationships ($P < 0.01$) with per cent mass remaining in all seasons showing amount of variability between 37 and 59%.

DISCUSSION

In the present study, initially several constituents were important in determining the rate of decomposition, but with the progress in decay only few remained important. Water soluble compounds (WSC) explained 28% variability in per cent mass remaining across species and site in rainy seasons followed by 25% in winter season. In summer season the variability in percent mass remaining was 33%. The WSC provide a readily available energy source for the decomposers and are, therefore, most influential in the initial stages of decomposition. Melin (1930) suggested that the water soluble materials incluenced the decomposition rates only during the first few weeks. Singh & Gupta (1977) concluded that the rate of decomposition is markedly affected by the amount of WSC.

TABLE 3. Coefficient of correlation (*r*) between initial nutrient concentrations and per cent mass remaining in litter bags.

Nutrients	Correlation coefficients		
	Rainy	Winter	Summer
Ash	-0.130^{NS}	-0.091^{NS}	-0.016^{NS}
Water soluble compound (WSC)	-0.533^{*}	-0.503^{NS}	-0.574^{*}
Potassium	-0.334^{NS}	-0.243^{NS}	-0.281^{NS}
Sodium	-0.626^{*}	-0.664^{**}	-0.579^{*}
Nitrogen	-0.20^{NS}	-0.20^{NS}	-0.055^{NS}
Phosphorus	-0.113^{NS}	-0.153^{NS}	-0.351^{NS}
Calcium	-0.518^{NS}	-0.657^{NS}	-0.607^{NS}
Acid soluble cell component	-0.733^{**}	-0.693^{**}	-0.660^{**}
Fibre	0.733^{**}	0.693^{**}	0.660^{**}
Lignin	0.641^{*}	0.712^{**}	0.767^{**}
Lignin/nitrogen	0.586^{*}	0.763^{**}	0.667^{**}

* Significant at $p<0.05$, d.f. = 12; ** Significant at $P<0.01$, d.f. = 12.
NS = Not significant.

Initial ash, nitrogen, phosphorus and potassium contents of litter did not show a significant relation with mass loss. Singh & Gupta (1977) argued that the nitrogen-rich broadleaf litter decomposes at a faster rate than nitrogen-poor needle litter. In contrast, Daubenmire & Prusso (1963); Aber & Melillo (1980) and Upadhyay & Singh (1985) did not find a significant correlation between initial nitrogen content and the rate of decomposition for several conifer and broadleaf species. Initial C/N ratio also did not show any significant relationship with the percent mass remaining.

During the initial periods of decomposition i.e. in rainy and winter seasons, sodium and calcium seemed to have influenced the decomposition rate, but with progress of decay, the amount of variability in the decomposition rate explained by these two bases was reduced. The variability in percent mass remaining explained by sodium was 39, 44 and 34% and for calcium 27, 43 and 37% for rainy, winter and summer seasons, respectively. In the present study, *P. roxburghii*, which had lowest initial concentrations of K, Na and Ca (respectively, 0.13, 0.1 and 0.51%), exhibited minimum mass loss. Pandey & Singh (1982) also reported positive relation between initial calcium content and weight loss for seven species in a mixed-oak-conifer forest.

Initially acid detergent fibre and acid soluble cell wall components (ASCC) were important determinants of the decomposition rate. The amount of variability in percent mass remaining explained was 54, 48 and 44% respectively, in rainy, winter and summer seasons, by fibre and ASCC each. Gupta & Singh (1981) and Pandey & Singh (1982) found similar relationship in a tropical grassland and a mixed-oak conifer forest study, respectively.

It was found that initial lignin/nitrogen ratio was most effective in the initial periods of decomposition but as decomposition progressed, only lignin remained important. The variability in decomposition rates due to L/N ratio was 34, 58 and 45% respectively, for rainy, winter and summer seasons. Berg & Staaf (1980) have also observed that in litters with high initial lignin concentration, the nitrogen controlled decomposition phase tends to be shortened. The amount of variability in percent mass remaining explained by initial lignin was 41, 51 and 59%, respectively, in rainy, winter and summer seasons. Tripathi & Singh (1992) have also found increasing role of lignin with passage of time during decomposition of different parts of tropical bamboo.

Thus, it is apparent that initially several constituents showed a significant relation with percent mass remaining e.g. water soluble compounds, sodium, lignin, lignin/nitrogen ratio, fibre and ASCC. But at the last phase of annual cycle i.e. in the summer season the amount of variability in percent mass remaining explained by all other nutrients was low and that by lignin high.

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