Decomposition of woody branch litter on an altitudinal transect in the Himalaya*

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Abstract

Decomposition of branch litter of four angiosperm and one conifer species was studied over a two-year period. Litter species and the corresponding forest type are: (i) *Shorea robusta,* sal forest at 329 m; (ii) *Lyonia ovalifolia,* mixed-pine broadleaf forest at 1 350 m; (iii) *Pinus roxburghii,* pine forest at 1 750 m; (iv) *Quercus leucotrichophora,* mixed oak-pine forest at 1 850 m; and (v) *Quercus lanuginosa,* mixed oak forest at 2 150 m. The weight loss ranged from 44–89%. Litter moisture and air temperature had significant positive effect on decomposition. The decomposition rate decreased with an increase in altitude and was inversely related with lignin content. Linear combinations of lignin content with rainfall and with temperature indicated significant interactive influence on decomposition.

Introduction

Decomposition of leaf litter has been studied in many terrestrial ecosystems, but that of wood litter has received little attention (Kåårik, 1974). Wood litter is a conspicuous component of the forest floor. It increases habitat diversity, enhances seedling survival and functions as a significant reservoir for some nutrients (Abbott & Crossley, 1982). Wood litter generally has a slow turnover rate compared to leaf litter (Christensen, 1977; Whittaker *et al.*, 1979).

Our objectives were to examine the weight loss, and the effect of altitude and substrate quality on the decomposition of five branch wood litter species placed on the floor of forests occurring along an altitudinal transect in Central Himalaya. Branch litter fall in these forests is quantified in Mehra & Singh (1985).

* Authorities for plant names are given in Table 1.

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Materials and methods

The experimental sites are located along an altitudinal transect in the northwestern part of the central Himalaya between 29°7′ to 29°26′N and 79°15′ to 79°38′E. Litter species and corresponding sites are: (i) sal (*Shorea robusta*) in sal forest at 329 m altitude mean annual temperature (MAT) 24 °C; (ii) *Lyonia ovalifolia* in pine – mixed broadleaf forest at 1 350 m MAT 18 °C; (iii) Pine (*Pinus roxburghii*) in pine forest; (iv) *Quercus leucotrichophora* in mixed oak-pine forest at 1 850 m MAT 16 °C; and (v) *Quercus lanuginosa* in mixed oak forest at 2 150 m, MAT 13 °C. On these sites, the annual rainfall ranges from 1 313 mm (mixed oak-pine forest) to 2 488 mm (mixed oak forest). The soils at all stations are sandy and low in organic matter. On the sal forest site there were 8 mounds ha^{-1} of the termite *Odontotermes obesus* Rambur and 44 carton nests ha^{-1} of the the termite *Microcerotermes championii* Snyder (Singh & Singh, 1984).

Branches of the above species (4.4 to 5.4 cm

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diameter and 18–26 cm long) were cut from live healthy trees. Volume of the samples was estimated by measuring the length, and the diameter of the material at several points and using the formula for a cylinder. Subsamples were used for the determination of fresh and dry weights, nitrogen (micro-kjeldahl technique, Piper, 1944), Lignin (Edwards, 1973) and carbon (Mc Brayer & Cromack, 1980).

Pre-weighed branch samples were placed on the forest floor, with as little disturbance as possible, in permanent plots on respective sites on 7–8 August, 1981. There were 40 samples for each species. Three samples were recovered at 4-month intervals for each species from each diameter class. The recovered samples were weighed, oven dried at 80 °C and reweighed. The study was continued for a 2-year period. Half-life ($t_{0.5}$) was calculated as $0.693/k$ and time required for 95% weight loss as $3/k$ (Olson, 1963).

Results and discussion

Weight loss

Figure 1 illustrates the per cent weight loss in branch litter. The mean dry weight decreased by 89, 49, 44, 61, and 49% for *Shorea robusta, Lyonia ovalifolia, Pinus roxburghii, Quercus leucotrichophora* and *Quercus lanuginosa,* respectively, at the end of the two-year period. During the first four months, *S. robusta* lost 27% of its original weight. Compared to this, the weight loss was 2, 4, 5 and 2% for *L. ovalifolia, P. roxburghii, Q. leucotrichophora* and *Q. lanuginosa,* respectively.

First year weight loss was maximal for *S. robusta* at the sal forest site and lowest for *Q. lanuginosa* at the mixed oak forest site. *P. roxburghii* decomposed faster than *Q. lanuginosa* in the first annual cycle (24% compared to 16%). There existed a negative relationship between per cent weight remaining and time elapsed for all species (Table 1). The decomposition constants (k) ranged from −1.12 for *S. robusta* to −0.286 for *P. roxburghii* (Table 2). Heavy termite activity on the sal forest site is partly responsible for the high decomposition rate in *S. robusta.* Analysis of variance indicated significant differences in weight loss due to decomposition period (days) ($p<0.01$) and species ($p<0.01$). The period×species interaction was also significant ($p<0.01$).

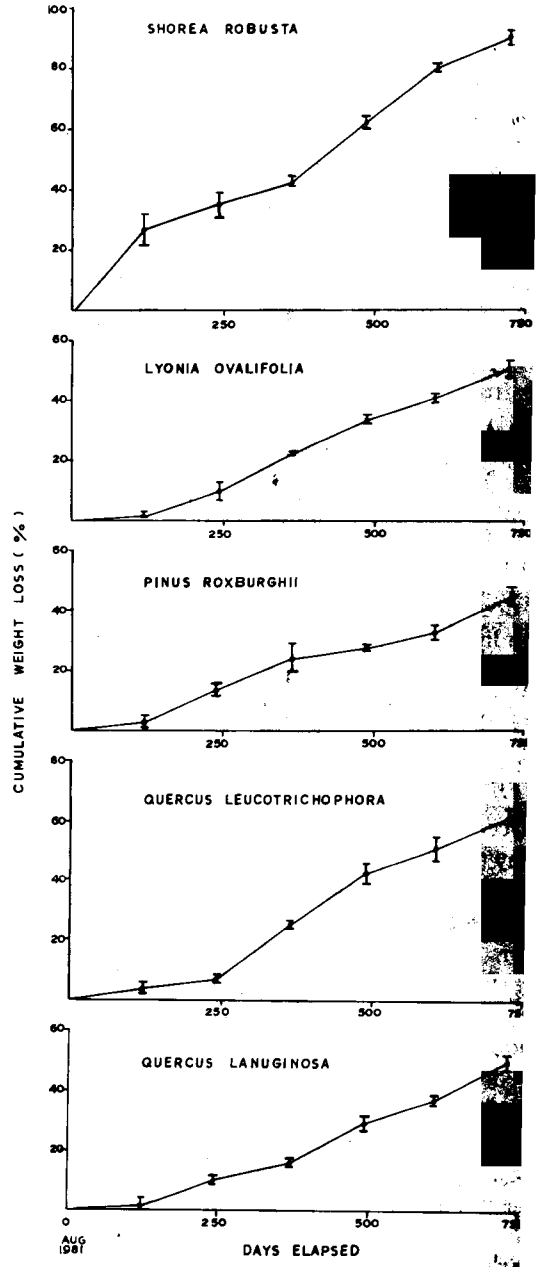

Fig. 1. Percent weight loss of branch litter based on 80 °C dry weight, during decomposition on forest floor.

The lower surface of the bark of a *S. robi* branch, which was in contact with the soil, damaged extensively in the first annual cycle. In second year, both surfaces were damaged by feeding activity of termites. In other spe

Table 1. Relationship between percent weight remaining (Y) with time elapsed (days X), according to Ln $Y = a + b\,X$.

Litter species	Intercept	Slope	r
Shorea robusta Gartn.f.	2.67	−0.0029	−0.957
Lyonia ovalifolia (Wall.) Drude.	3.97	−0.00097	−0.990
Pinus roxburghii Sarg.	4.08	−0.00076	−0.983
Quercus leucotrichophora A. Camus.	3.72	−0.0014	−0.973
Quercus lanuginosa Don.	4.03	−0.00088	−0.968

All equations significant at $p < 0.01$.

marked morphological changes did not occur and the original shape of the cylindrical wood was maintained (Table 2). Fogel & Cromack (1977) found the bark to be highly refractory. Abbott & Crossley (1982) examined the bark: wood ratio of decomposing *Quercus prinus* litter and found that the easily decomposable material was the wood tissue and not the bark. In contrast to the present finding on *S. robusta* branch litter, T. Abe (unpubl.) pointed out that the bark, in a Malaysian forest, was more resistant to attacks by termites than wood.

Stark (1973) estimated a 6.82% weight loss after one year for *Pinus jeffreyi* branches of 1.5 to 2 cm diameter. Decay coefficient for mass loss of *Quercus prinus* branches of 3–5 cm diameter ranged between 0.0377 to 0.1644 (Abbott & Crossley, 1982). The half-life of branch litter in two *Eucalyptus* forests in New South Wales ranged from 3.17–6.47 yr (Pressland, 1982). The higher weight loss reported in the present study for *Quercus* and *Pinus* wood litter as compared to other temperate forest species may partly be due to the use of fresh live material in which microbial utilization of easily decomposable non-structural carbohydrates had not been inhibited by drying (Hulme & Shields, 1970; Abbott *et al.*, 1980). Further, these forests are situated, latitudinally, in a sub tropical belt where temperatures are never too low to inhibit faunal and microbial activity.

Effect of litter moisture, altitude and temperature

The litter moisture averaged across the study period, ranged from 76.9 to 157.5% in different species, on oven dry weight basis. Analysis of variance indicated significant variation due to species and time ($p < 0.01$). The time × species interaction was also significant ($p < 0.01$). The moisture content of wood litter often increases with decay (Kåårik, 1974). In the present study, the moisture

Table 2. Decay parameters, diameter changes and substrate quality for branch wood litter.

	Shorea robusta	*Lyonia ovalifolia*	*Pinus roxburghii*	*Quercus leucotricho-phora*	*Quercus lanuginosa*
			Decay parameters		
k	-1.12	-0.339	-0.286	-0.475	-0.334
$t_{0.5}$ (yr)	0.619	2.04	2.42	1.46	2.08
$t_{0.95}$ (yr)	2.05	6.75	8.01	4.83	6.88
% litter remaining after 2 years	10.64	50.76	56.43	38.66	51.32
			Changes in diameter		
Mean diameter (cm)	4.28	4.83	4.80	4.48	5.32
d_1/d_0	0.62	0.97	0.96	0.99	0.99
d_6/d_0	0.68	0.98	0.98	1.00	0.99
			Initial substrate quality (% dry weight)		
Carbon	46.80	48.32	52.93	46.23	47.24
Nitrogen	0.29	0.20	0.19	0.39	0.36
C:N	161	245	279	120	132
Lignin	28.43	37.20	48.93	37.40	35.89

d_0 = initial diameter, d_1 = diameter after four months of decomposition, d_6 = diameter after 2 years of decomposition.

content showed a significant positive relation with weight loss only in *L. ovalifolia* and *P. roxburghii,* according to:

L. ovalifolia: $Y=0.144\ X-4.66$; ($r^2=0.893$, $p<0.01$);

P. roxburghii: $Y=0.055\ X-0.302$; ($r^2=0.801$, $p<0.01$);

where, Y=percent weight loss between time t_2 and t_1, and X=percent moisture content at time t_2.

As expected, the weight loss declined with the increase in altitude. A positive significant relationship was found between altitude and percent weight remaining according to:

$$Y=8.90+0.022\ X;\ (r^2=0.696,\ p<0.01);$$

where, X=altitude (m) and Y=percent weight remaining at the end of 2 year.

The percent weight remaining at the end of a 2-year period was inversely related with mean annual temperature according to:

$$Y=128.96-5.02\ X;\ (r^2=0.798,\ p<0.05);$$

where, X=mean annual temperature (°C) and Y=percent weight remaining after two years of decomposition.

A linear combination of mean annual rainfall and mean annual temperature explained about 77% variability in percent weight remaining according to the following regression:

$$Y=109.35+0.0042\ X_1-4.433\ X_2;\ (r^2=0.774,\ p<0.05);$$

where, Y=% weight remaining after 2 years; X_1=mean annual rainfall (mm) and X_2=mean annual temperature (°C).

Although the above three relationships are not independent of species, they do signify the effects of such factors as altitude, temperature and rainfall, on decay rates. Madge (1965) and Abbott *et al.* (1980) have reported that the dessication of wood inhibits the activity of decomposers. The combined effect of temperature and moisture on decomposition is often more prominent than the effect of temperature alone (Singh & Gupta, 1977).

Effect of substrate quality

Initial carbon, nitrogen and lignin content of the wood litter are given in Table 2. *P. roxburghii* having higher lignin content decomposed slowest. The C:N ratio for *P. roxburghii* was much higher (279 than for other species. Initial lignin content was positively related with percent weight remaining according to:

$$Y=2.12\ X-38.02;\ (r^2=0.714,\ p<0.01);$$

where, Y=percent weight remaining at the end of years and X=initial lignin content (%).

Fogel & Cromack (1977) found that the rate of annual weight loss is more influenced by lignin than by C:N ratio. Lignin retards overall decomposition because of its own even more resistant decomposition products and in physical interference with cellulase activity owing to lignin encrustation of cellulose fibres (Bailey, 1973).

Linear combinations of lignin content (L, % with mean annual rainfall (R, mm), and with mean annual temperature (T, °C) explained 72–87 variability in percent weight remaining (Y, %) after 2 years of decomposition according to the following equations:

$Y=38.85+2.11L+0.00059R$; ($r^2=0.715$, $p<0.01$); and $Y=31.85+1.39L-2.49T$; ($r^2=0.871$, $p<0.01$).

Such relationships indicate a significant interactive influence of abiotic environmental variables and chemical composition of the litter. A linear combination of lignin content with altitude (L, also had a significant effect on percent weight remaining ($Y=2.12+0.835L+0.0083A$, $p<0.0$ but the r^2 for this relationship was only 0.544 and therefore there was no improvement over single variable regressions discussed earlier.

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