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RESEARCH ARTICLE

Effect of litter species and topography on litter quality and decomposition rates in central Himalayan region

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Abstract

Leaf litters from Oak (*Quercus leucotrichoflora*), Angyar (*Lyonia ovalifolia*), Melu (*Pyrus peshia*), Burans (*Rhododendron arboreum*) and Chir (*Pinus roxburghii*) were collected from north facing site and south facing site and at three slope positions (top, middle and bottom) on each aspect that had similar soil chemical characteristics (soil pH, Organic C and total N). The litters were analysed for initial carbon, total nitrogen, lignin, cellulose and polyphenol concentrations. Litter carbon, nitrogen, C: N ratio, lignin and lignin: N ratio varied significantly within and between species at different aspect and slope positions. Litter decomposition was studied in the field using litter bag technique. The litters were placed on two aspects and at three slope positions and were sampled every 90 days for a total of 410 days. The main effects of aspect, species and slope position on decomposition rates were all statistically significant. Oak leaf litter showed highest decomposition rates followed by *Lyonia*, *Pyrus*, *Rhododendron* and *Pinus*. The litters placed on north facing site decomposed faster than at those on the south-facing slope. The litters placed on top slope position decomposed slower than those at either middle or bottom slope position. Initial lignin concentrations explained most of the variation in decomposition rates between species and within species for the aspects and slope positions. The result shows that litter quality has the potential to define the rates of microbial decomposition however they are significantly affected by the biotic and abiotic environment in which the decomposition takes place.

INTRODUCTION

Decomposition of leaf litter is influenced by the environmental conditions under which decay takes place. In general the temperature and moisture governs decay rates at broad regional scales, where as initial litter quality variables carbon: nitrogen (C: N) ratio, lignin, N and lignin: N ratio are more important in controlling decay rates at small scales i.e. within sites (Berg et al., 1993; Heal et al., 1997). Slope aspect is an important topographic factor influencing site micro site as it determines the amount of solar radiation received by the site. South facing slopes receive maximum solar radiation so they are typically hot and dry and subject to rapid changes in seasonal and diurnal microclimate in contrast north facing slopes receive minimum amount of radiation and are therefore cool, moist and subject to slow changes in seasonal and daily microclimate (Sariyildz et al.,2005).

Slope position is another topographic feature that influences the microclimate. Ridge tops have convex slope surfaces and are exposed to intense solar radiation, experience high wind therefore they are drier than is the average for the region. The lower slopes are concave surface and tend to be sheltered from strong winds, subject to accumulation of organic matter and soil rather than erosion and are moister than average for the region. Mid-slopes are generally intermediate in their characteristics.

Although the effects of topographic land forms (slope aspect and position) on microclimate and soils as well as plant species composition have been studied extensively (Barnes et al., 1998; McNab, 1993) very few studies have investigated their effect on litter decomposition rates.
The five tree species for the present study namely (1) *Quercus leucotrichoflora* (Oak) (2) *Lyonia ovalifolia* (Angyar) (3) *Pinus roxburghii* (Chir) (4) *Rhododendron arboreum* (Burans) (5) *Pyrus peshia* (Melu) were chosen for decomposition study because a preliminary survey in the neighbouring villages showed that these were the most preferred species used for manuring after decomposing them.
The objectives of the present study was to evaluate the effect of species, and site aspect on leaf litter quality and rates of decomposition for five tree species.

MATERIALS AND METHODS :

Study site:
The study site was situated at three altitudinal gradient along the Song river valley across the Garhwal region of central Himalaya. The location of study site along with some basic characteristics is summarized in Table 1. The study sites were selected at three altitudes and differing north south slope aspect along the river Song. Site Deothala was a north facing site and Sites Sodasaruli and Sainji were south facing sites. Sites Deothala and Sodasaruli were at almost same altitude so that we can compare the north south effect. While Sodasaruli and Sainji were at different altitude so that we can compare the top bottom aspect along the same slope. All the sites experience typical monsoonal climate which is dominated by the southeast monsoon.
Both north and south sites are commonly forested by *Quercus, Rhododendron, Lyonia, Pyrus* and *Pinus* either pure or in species mixtures. The understory at the lower part of the slope was occupied by grasses, ferns and herbs. The farming system is characterized by settled rainfed agriculture on terraced slopes. Multipurpose tree species are common in private farms. Forests play a vital role in management of soil fertility in the farm land. Litter were collected from the top, middle and bottom slopes of the north and south facing sites (six replicate sites) so the effects of species, aspect and slope positions on litter quality could be evaluated. Initial organic carbon, total N, lignin, cellulose and polyphenol were used as indices of litter quality. The litter bag technique was used to quantify rates of decomposition.

Sample collection and preparation:
Foliar litter of *Quercus*, *Lyonia*, *Pyrus*, *Rhododendron* and needles of *Pinus* were sampled. At each area, freshly fallen foliar litter was collected and bulked to form a representative sample for each tree species. The samples were air dried in the laboratory and then oven dried at 40^0C for 48h.

Analysis of plant material:
Chemical analysis (cellulose, lignin and polyphenols): The stored leaf and needle litters were oven dried at 85^0C and then ground in a laboratory grinder and passed through a mesh size of 1mm. The ash free dry matter of each litter sample was determined by ashing the sample at 550^0C for 6 hours in a muffle furnace (Anderson and Ingram, 1998; Harmon et al., 1999). Plant organic C (%) for each litter was determined by the wet oxidation method (Walkley, 1947) and total N (%) was determined by Kjeldahl digestion (Allen, 1989). Plant litter collected initially before the start of the field experiment and those collected across the decomposition period was analysed for poly phenols (Anderson and Ingram, 1998), cellulose and lignin (Rowland and Roberts, 1994). The ethanol soluble substances were removed by extracting 500mg ground material with 50 ml ethanol (3x30 min). The residual solid material was dried over night at 105^0C and weighted. The residue was treated with 10 ml 72% H_2SO_4 at 30^0C for 1 h. This mixture was diluted with water to 250 ml and refluxed for 2 h. The residual solid material was filtered, washed with water, dried overnight at 105^0C and weighed. The cellulose content was estimated as loss in weight by acid treatment. The amount of lignin (Klason lignin, Effland, 1977) was determined as the weight loss on ignition of the acid insoluble residue. The Folin-Denis method was used for the extraction of total extractable polyphenols using tannic acid as a standard after extraction in hot (80^0C) 50% methanol.

D**etermination of residue decomposition:**
The decomposition and N release from the litter of the five species was determined using the litterbag technique (Wardle, 1993). The freshly collected litter was packed in known quantity (10g) evenly spread within each litter bag. The treatment litter bags were placed at 100 mm apart at each position to avoid interactions. Pegs were used to identify litter bag positions. Litter bags at all sites were given maximum contact with soil surface by pinning them down with paper clips in the centre and at all four corners. Constant monitoring of the litter bags were done throughout the experimental period to ensure that litter bags were in full contact with the mulches or the soil surface. The bags were 20cm x 20cm with a mesh size of 1.5mm to allow for inclusion of mesofauna but exclusion of macrofaunal decomposers.

In each treatment plot three treatment litter bags were harvested after 30, 120, 180, 270, 360, and 410 days from each site on six dates to follow the continuum of litter decay over time. After removing adhering soil or mulch materials the contents in each individual litter bag was dried at 105^0C for 48 h, then passed through a 0.1 mm sieve to remove soil or mulch material. Within each treatment plot weights of individual litter bags were recorded. The total number of litter bags used in the experiment was 540 litter bags (5 tree species) species x 2 aspects (north and south facing slopes) x 3 sites (Top, middle and bottom) x 6 removal dates x 3 replicates = 540 bags).

Calculations for litter decomposition:

The actual percentages of C and N remaining in the ash free dry matter in each pooled residue sample was calculated after corrections for soil C and N originating from contamination of plant litter samples by soil using the procedure of Harmon et al., 1999. Regression analysis by SPSS software package using the single exponential model, $Y = A_0e^{-kt}$ was used to determine the residue decomposition and the nitrogen release rate constants, K_c and K_n, respectively, according to Huang and Schoenau, (1997) and Lekasi et al., (1999). Rate constants K_c and K_n of individual replicates were calculated as:

$\ln (A_0/A_1) = kt$

Where A_0 is the original amount of ash free dry matter (assuming ash free dry matter was mainly C) or N in the litter, A_1 the amount of ash free dry matter or N remaining at time t and $k=k_c$ or k_n. The C and N half lives were calculated as:

Half life $(t_{1/2}) = \ln (0.5)/ -k$ or $t_{50} = 0.693/k$, $t_{95}=3/k$

All results were subjected to analysis of variance (ANOVA) using SPSS (SPSS Inc, 2002). A two way ANOVA was applied for analysing the effects of aspects and slope position on soil properties, litter qualities and mass remaining for each species using the spss programme, following the result of ANOVAs, Correlation coefficients of mass losses against the litter quality variables for *Quercus, Pyrus, Pinus, Lyonia* and *Rhododendron* litters from two aspects on three sites were determined using SPSS 11.5 (SPSS Inc., 2002).

RESULTS:

Variation in litter chemistry:

Mean concentration of C, N, lignin, polyphenol, C:N, lignin: N and lignin+polyphenol:N in *Quercus, Lyonia, Pyrus, Rhododendron* and *Pinus* litter from top, middle and bottom slope positions on two aspects is presented in table (2a, 2b and 2c).

Across all the three sites oak recorded the lowest C: N ratio and lignin: N ratio while Lyonia recorded the lowest lignin content. Pinus showed the highest C: N ratio and lignin: N ratio across all the three sites. C: N ratio of Oak was higher in the North facing slope in Comparison to its South facing slope at Sodasaruli. C: N ratios showed highly significant variations amongst the five species due to differences in total nitrogen. Pinus recorded the highest C: N ratio while Quercus recorded the lowest C: N ratio.

Lyonia had lowest lignin content across the three sites (tables 2a, 2b and 2c). Quercus and Pyrus had higher total nitrogen than the other three species while Pinus recorded the lowest total nitrogen (Tables 2a, 2b and 2c).Out of the five species Lyonia showed highest mass loss. It showed an half life of 69.3 days across all the three sites. Then the highest mass loss was recorded for Oak, Pyrus, Rhododendron, and Pinus in order (Tables 3a, 3b, 3c). For Oak the north south aspect and top bottom trend was very clear from Tables 3a, 3b and 3c). In the North facing bottom site of Deothala decomposition of Oak was fastest as it showed half life of 77.43 days, and at Sodasaruli south facing bottom site Oak recorded an half life of 84.40 and at Sainji, South facing top site decomposition was slowest as Oak recorded a half life of 88 days (Tables 3a, 3b and 3c). The single effects and interactions of species, site and sampling dates on litter quality variables are listed in table 4. The main effects of species, site and sampling dates on organic carbon, total nitrogen, C: N ratio, lignin and Lignin: nitrogen were all significant ($p<0.001$) (Table 4). Organic carbon concentrations were not significant due to site x date and species x site x date interactions. Mass losses from all five species showed the highest correlation with initial lignin: N for both north and south facing sites. (Table 5). Concentration of C: N and lignin were also significantly correlated with mass losses (Table 5). The decomposition trend across the sampling dates at three sites are presented in Figures 1a (Deothala, North bottom slope), 1b (Sodasaruli, south bottom slope) and 1c (Sainji, south top slope). There was rapid loss during the first six months followed by a slow loss phase.The percent mass remaining after 410 days of incubation was less than 20% for the four species and highest for Pinus species.

Table 1: Geographical coordinates and few general soil characteristics of the three experimental sites at the beginning of experiment. ±1SE, n= 45

Name of site	**Deothala**	**Sodasaruli**	**Sainji**
Geographical co- ordinates	$30^0$27'N & $77^0$52'E	$30^0$17'N & $78^0$07'E	$30^0$30'N & $78^0$01'E
Altitude	658m above mean sea level	645m above mean sea level	1145m above mean sea level
Aspect	North facing slope	South facing slope	South facing slope
Slope position	Middle	Bottom	Top
Soil parameters			
pH	6.6± 0.21	7.08 ± 0.13	6.4 ± 0.07
Soil moisture (%)	20.77± 0.24	23.25 ± 0.36	14.87 ± 0.58
Water holding capacity (%)	33.23 ± 0.24	36.86 ± 0.78	30.76 ± 1.46
Total N (%)	0.09 ± 0.01	0.12 ± 0.01	0.09 ± 0.01
Organic C (%)	0.84 ± 0.27	1.21 ± 0.24	1.01 ± 0.09
K (%)	0.59 ± 0.03	0.89 ± 0.06	0.28 ± 0.82

Table 2a: Chemical composition of litter and crop residues at Sainji (South facing top slope). N= 18.

Organic source	Concentration						
	C (%)	N (%)	C:N	Lignin (%)	Polyphenol (%)	Lignin: N	Polyphenol + Lignin : N
Quercus	62.46±3.83	1.68±0.66	19.13±5.86	18.8±5.20	1.47±0.72	11.60±0.83	12.52±0.88
Pyrus	38.28±3.16	1.55±0.72	25.50±7.15	23.76±5.0	1.90±0.03	15.78±0.91	17.0±0.91
Lyonia	36.35±3.47	0.85±0.47	42.44±4.54	15.22±3.49	1.09±0.56	17.77±0.64	19.0±0.67
Rhododendron	43.28±4.0	0.94±0.52	44.15±6.81	24.36±3.74	2.32±0.83	26.21±1.01	28.61±1.13
Pinus	47.28±3.81	0.80±0.49	58.89±6.20	28.61±5.10	3.52±0.72	35.57±1.20	39.97±1.27

Table 2b: Chemical composition of litter and crop residues at Soda saruli (South facing bottom slope). N= 18.

Organic source	Concentration						
	C (%)	N (%)	C:N	Lignin (%)	Polyphenol (%)	Lignin: N	Polyphenol + Lignin : N
Quercus	30.69±3.38	1.29±0.58	24.12±4.73	17.83±3.28	1.28±2.59	13.98±0.64	15.01±0.70
Pyrus	38.49±4.27	1.50±0.99	26.48±5.89	23.83±3.97	1.82±0.81	16.25±0.82	16.46±0.90
Lyonia	36.08±2.94	0.88±0.47	40.91±3.92	15.46±3.61	1.03±0.51	17.57±0.52	18.76±0.54
Rhododendron	43.62±3.52	0.91±0.44	48.53±12.09	26.85±3.62	2.38±0.78	29.90±1.27	32.58±1.33
Pinus	49.52±3.23	0.93±0.51	53.16±6.84	23.7±3.71	3.51±2.96	25.52±0.85	29.15±0.92

Table 2 c: Chemical composition of litter and crop residues at Deothala North facing bottom slope). N= 18.

Organic source	Concentration						
	C (%)	N (%)	C:N	Lignin (%)	Polyphenol (%)	Lignin: N	Polyphenol + Lignin : N
Quercus	30.30±3.77	1.15±0.63	26.86±5.29	18.23±3.70	1.18±0.61	16.22±0.67	17.27±0.71
Pyrus	39.16±3.43	1.46±0.77	28.51±9.03	24.05±5.40	1.75±0.74	17.34±1.25	18.64±1.32
Lyonia	36.39±3.21	0.88±0.47	41.59±4.59	14.82±3.71	1.03±0.52	16.94±0.45	18.2±0.46
Rhododendron	42.48±4.10	0.95±0.53	45.18±4.86	21.44±7.41	2.37±0.73	22.70±1.39	25.22± 1.41
Pinus	48.28±3.56	0.99±0.70	49.28±5.47	25.61±4.43	3.44±0.75	25.97±25.97	29.51±0.91

Table 3a: Instantaneous decay rate constant (k) and estimated time required for 50% (t_{50}) and 95% (t_{95}) mass loss, loss of carbon and nitrogen content of plant litter and crop residues placed in field at Sainji (South facing top slope). Calculated at 270 days

Organic source	k (day^{-1})	T_{50} (days)	T_{95} (days)	Kc (day^{-1})	Kn (day^{-1})
Oak	0.0078	88	384.61	$3.4x10^{-4}$	$8.5x10^{-4}$
Lyonia	0.0102	69.3	294.11	$1.71x10^{-4}$	$2.5x10^{-4}$
Pyrus	0.00784	88.39	382.65	$8.5x10^{-4}$	$1.8x10^{-3}$
Rhododendron	0.00639	108.54	469.48	$8.5x10^{-4}$	$9.4x10^{-4}$
Pinus	0.00316	219.30	949.36	$2.5x10^{-5}$	$5.9x10^{-4}$

Table 3b: Instantaneous decay rate constant (k) and estimated time required for 50% (t_{50}) and 95% (t_{95}) mass loss and loss of carbon and nitrogen content of plant litter and crop residues placed in field at Soda saruli (South facing bottom slope). Calculated at 270 days

Organic source	k (day^{-1})	T_{50} (days)	T_{95} (days)	Kc (day^{-1})	Kn (day^{-1})
Oak	0.00821	84.40	365.40	$8.5x10^{-3}$	$7.7x10^{-4}$
Lyonia	0.010	69.3	300	$1.7x10^{-4}$	$3.4x10^{-4}$
Pyrus	0.00788	87.94	380.71	$2.6x10^{-4}$	$1.02x10^{-3}$
Rhododendron	0.00660	105	454.54	$1.7x10^{-4}$	$5.9x10^{-4}$
Pinus	0.00331	209.36	906.34	$8.5x10^{-5}$	$7.6x10^{-4}$

Table 3c: Instantaneous decay rate constant (k) and estimated time required for 50% (t_{50}) and 95% (t_{95}) mass loss, loss of carbon and nitrogen content of plant litter and crop residues placed in field at Deothala (North facing bottom slope). Calculated at 270 days

Organic source	k (day^{-1})	T_{50} (days)	T_{95} (days)	Kc (day^{-1})	Kn (day^{-1})
Oak	0.00895	77.43	335.19	$4.3x10^{-4}$	$1.5x10^{-3}$
Lyonia	0.010	69.3	300	$8.5x10^{-4}$	$9.3x10^{-4}$
Pyrus	0.00834	83.09	359.71	$8.5x10^{-4}$	$2.0x10^{-3}$
Rhododendron	0.00727	95.32	412.65	$1.7x10^{-4}$	$8.1x10^{-4}$
Pinus	0.00341	203.22	879.76	$8.5x10^{-5}$	$5.8x10^{-4}$

Table 4: Univariate analysis of variance of litter quality. Asterisks refer to the level of significance: * $p<0.05$; ** $P<0.01$; ***, $p<0.001$, NS = not significant.

Variable	Sources	SS	df	MS	F
Carbon	Species	9689.167	4	242202	1053.65***
	Site	9.32	2	4.66	2.02**
	Date	43.63	5	8.73	3.79**
	Species*site	65.35	8	8.16	3.55**
	Species*date	85.85	20	4.29	1.86*
	Site*date	21.64	10	2.16	0.94 ns
	Species*site*date	166.58	40	4.16	1.81ns
	Error	413.81	180	2.29	
Nitrogen	Species	19.35	4	4.83	189.82***
	Site	0.34	2	0.17	6.71**
	Date	0.051	5	0.01	0.400ns
	Species*site	2.80	8	0.35	13.72***
	Species*date	1.45	20	0.07	2.85***
	Site*date	0.65	10	0.65	2.559**
	Species*site*date	2.83	40	0.07	2.77***
	Error	4.58	180	0.025	
CN ratio	Species	35673.49	4	8918.37	401.95***
	Site	18.24	2	9.12	0.41ns
	Date	53.77	5	10.75	0.48ns
	Species*site	1727.39	8	215.92	9.73***
	Species*date	1027.70	20	51.38	2.31**
	Site*date	380.40	10	38.04	1.71*
	Species*site*date	1476.82	40	36.92	1.66ns

	Error	3993.75	180	22.18	
Lignin	Species	4436.71	4	1109.18	237.30***
	Site	92.45	2	46.22	9.89***
	Date	61.23	5	12.24	2.63*
	Species*site	421.65	8	52.70	11.27***
	Species*date	374.17	20	18.70	4.003***
	Site*date	240.08	10	24	5.13***
	Species*site*date	394.91	40	9.87	2.11***
	Error	841.33	180	4.674	
Lignin:N	Species	9436.39	4	2359.09	209.20***
	Site	109.11	2	54.55	4.83**
	Date	74.18	5	14.83	1.31ns
	Species*site	1735.17	8	216.89	19.23***
	Species*date	536.94	20	26.84	2.38**
	Site*date	122.72	10	12.27	1.08ns
	Species*site*date	777.53	40	19.43	1.72**
	Error	2029.81	180	11.27	

Table 5: Correlation matrix among litter carbon (Lit-C), litter nitrogen (Lit-N), CN ratio(C: N), Lignin (Lig), Lignin: nitrogen ration (Lig: N) and mass loss (M Loss) across treatment plots for two cropping seasons. (n=90). * significant at p<0.05, **p<0.01, ***p<0.001, NS indicates correlation coefficients are not significant at p<0.05. Data are correlation coefficients (r-values).

Variable	Lit-C	Lit-N	C:N	Lig	Lig:N	M Loss
Lit-C	1	0.20*	0.60**	0.34**	0.02 NS	0.21**
Lit-N		1	-0.58**	0.15**	-0.66**	-0.05NS
C:N			1	0.20**	0.60**	0.17**
Lig				1	0.57**	0.13*
Lig:N					1	**0.18****
M Loss						1

Fig. 1a. Cumulative mass loss (%) of different litter types at Deothala

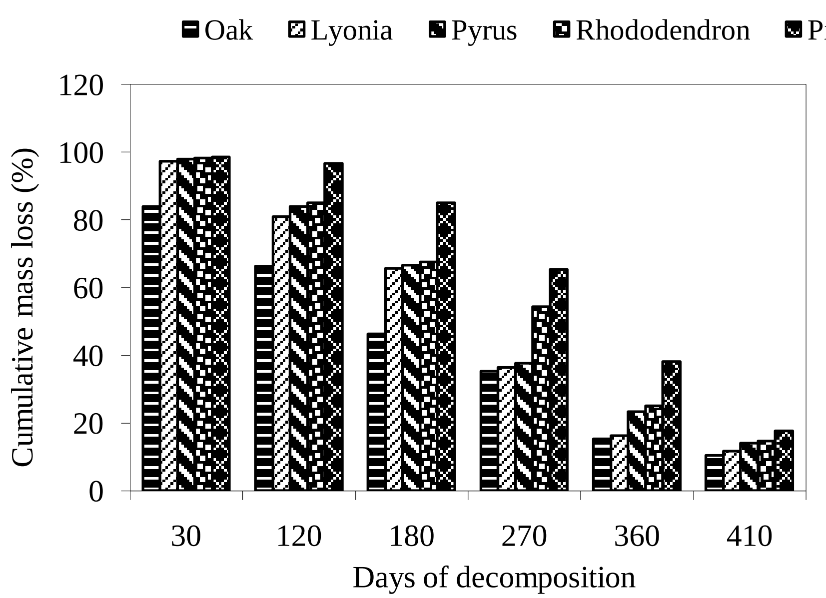

Fig 1a. Cumulative mass loss (%) of different litter types at Deothala.

Fig. 1b. Cumulative mass loss (%) of different litter types at SodaSaruli

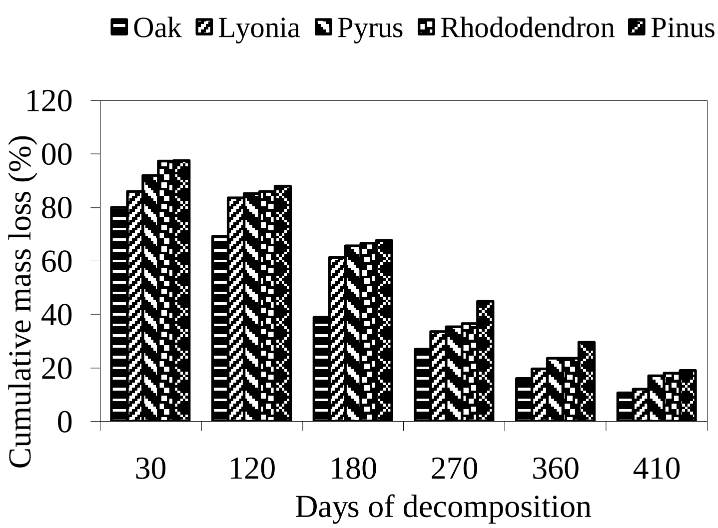

Fig 1b.Cumulative mass loss (%) of different litter types at SodaSaruli.

Fig. 1c. Cumulative mass loss (%) of different litter types at Sainji

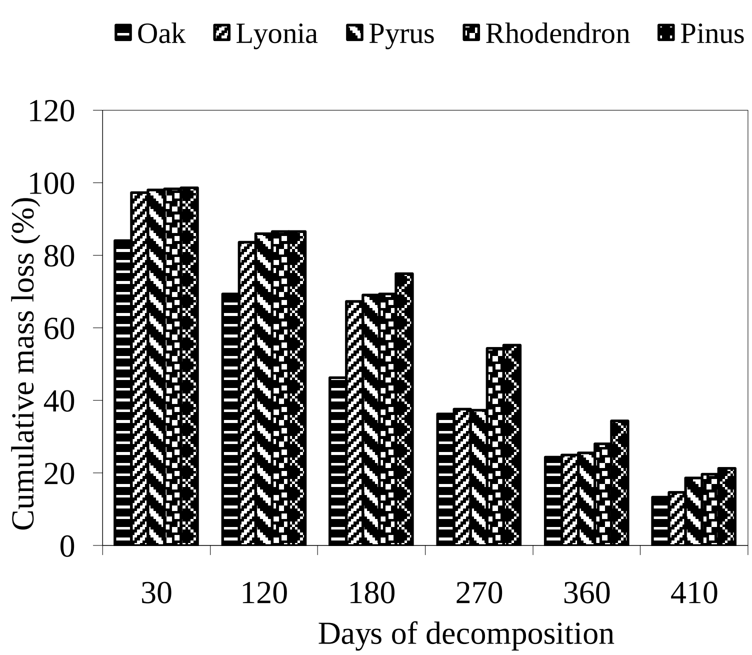

Fig 1c. Cumulative mass loss (%) of different litter types at Sainji.

DISCUSSION:

Litter quality parameters especially lignin, C: N ratio and Lignin:N in all the five species varied significantly within and between species in relation to aspects and slope positions. These intraspecific variations in litter quality could be attributed to differences in soil physical characteristic between these sites. The intraspecific variations in the litter quality could be also explained by differences in the environmental conditions such as light intensity, wind, physical stress like availability of water between these sites. A number of studies have showed that under these extreme conditions most forest trees have the faculty of developing different anatomical structures in their leaves such as smaller surface per unit weight, more palisade tissues, less intercellular space and spongy parenchyma, more supportive and conductive tissues (Roth 1984, 1990, Rollet 1990). In a recent study by Sariyildz and Anderson (2003a), similar differences were observed within species due to the differences in the tree canopy structure which resulted in significant variations in chemical composition of the litters of the same. The results of the present study support the earlier findings that south facing slopes receive more sunlight and are hotter and drier than north facing slopes and ridge tops or upper convex slope surface are exposed to intense solar radiation and experience high wind speeds. Therefore it is reasonable to assume that soil chemical characteristics coupled with the differences in environmental conditions could account for the variation in litter quality differences in the five species between the three sites.

Published studies suggest that plant materials with N>1.7%, Lignin<15%, polyphenol<3% and C: N ratio <20 generally mineralize while those exceeding these limits immobilize N (Palm1995, Constantinides & Fownes 1994, Oglesby & Fownes, 1992, Meyers et al. 1994). Thomas and Asakawa, 1993, reported that lignin to N ratio was the best indicator of organic matter decomposition and N release. Litter with higher initial N concentration usually shows higher mass loss and respiration rates than those with lower N concentration but the importance of initial nitrogen concentration decreased with time. Vestgarden 2001, Ross et al., 2002 concluded that the relationships between litter decomposition and their C: N ratios appear to be complex and species dependent and might not be an appropriate general indicator for changes in decomposition rates. For the present study initial lignin concentrations explained most of the variations in decomposition rates between species and within species for the three sites. The explained variation was higher for the south facing sites and the top slope position suggesting that lignin was exerting a greater control over litter decomposition on the sites with lower nutrient status.Other studies have shown that the influence of initial N and microbial degradation of the holocellulose fraction in early phase of decomposition is strongly dependent upon lignin concentrations in the litter (McClaugherty and Berg, 1987, Rutigliano et al., 1996) because of their intimate physical association and covalent bonding in the cell wall (Monties 1994). Hence it is predictable that as the total lignin concentration increases from 14.82% in Lyonia, 17.83% in Oak, 21.44% in Rhododendron, 23.76% in Pyrus, and 28.61% in Pinus it dominated decomposition rates irrespective of other constituents.

CONCLUSION:

This study shows significant intraspecific variation in the chemical composition of five litters from two aspects and three slope positions. All the five species responded similarly to the environmental conditions and it was found that variation in the chemical compositions especially lignin concentrations largely explained the litter mass losses within and between species. Differences in the decomposition rates of litter on aspects and slope positions illustrate the important point that litter quality may define the potential rates of microbial decomposition but these are significantly influenced by the biotic and abiotic environment in which decomposition takes place. This complex interaction of biotic factors such as litter decomposition and abiotic factors such as energy flux related to aspect and slope position within an ecosystem could therefore affect the soil chemistry, litter quality, nutrient cycling and in turn forest species dynamics and ecosystem development and productivity.

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