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Estimation of epiphytic lichen litter fall biomass in three temperate forests of Chamoli district, Uttarakhand, India

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Abstract: Lichen plays an important role in nutrient cycling through litter fall. Currently there is no biomass estimation available on the lichen litter fall from temperate forest of Himalayas. Hence the lichens fallen on the forest floor from canopy and main branches at an altitude in and around 3000 m were studied using 10 randomly-placed, 1 m x 1 m quadrats at each of the three major forest types of the Himalayas in Ghangaria (Valley of Flowers), Chopta and Kanchula Khark Musk Deer Park forest area (Kedarnath Wild Life Sanctuary) of Chamoli district in Uttarakhand. The lichen litter fall biomass was recorded in September 2007. Lichen biomass was highest in the *Quercus semecarpifolia* forest (Oak) of the Chopta area, followed by *Acer oblongum* forest (mixed forest) in Kanchula Kharkh Musk Deer Park and *Pinus wallichiana, Taxus baccata, Abies pindrow* (coniferous forest) of Ghangharia (Valley of Flowers), with values of 1.32 g m^{-2}, 0.71 g m^{-2} and 0.41 g m^{-2}, respectively. It was also observed that foliose lichen (*Parmelia* type) group showed maximum lichen litter fall biomass followed by fruticose (*Usnea* type) in all the three forest stands.

Resumen: Los líquenes juegan un papel importante en el reciclaje de nutrientes por medio de la caída de hojarasca. Actualmente no hay estimaciones disponibles de la biomasa de la hojarasca de liquen para los bosques templados de los Himalayas. Por lo tanto, se estudiaron los líquenes del dosel y las ramas principales caídos al piso del bosque, a una altitud de alrededor de 3000 m, usando 10 cuadros de 1 m × 1 m colocados al azar en cada uno de los tres principales tipos de bosque de los Himalayas en Ghangaria (Valle de las Flores), Chopta y el área forestal del Parque Kanchula Khark del Ciervo Almizclero (Santuario Kedarnath para la Vida Silvestre) del distrito Chamoli en Uttarakhand. La biomasa de la hojarasca de liquen fue registrada en septiembre de 2007. La biomasa de los líquenes tuvo su máximo en el bosque de *Quercus semecarpifolia* (encino) del área Chopta, seguido del bosque de *Acer oblongum* (bosque mixto) en el Parque Kanchula Khark del Ciervo Almizclero, y el de *Pinus wallichiana, Taxus baccata, Abies pindrow* (bosque de coníferas) de Ghangharia (Valle de las Flores), con valores de 1.32 g m^{-2}, 0.71 g m^{-2} y 0.41 g m^{-2}, respectivamente. También se observó que el grupo de los líquenes foliosos (*tipo* Parmelia) mostró la biomasa máxima de hojarasca de liquen, seguido por el grupo de los fruticosos (*tipo* Usnea) en los tres rodales de bosque.

Resumo: O líquen joga um papel importante na reciclagem de nutrientes através da queda de folhada. Actualmente não há uma avaliação da queda de biomassa de líquen nas florestas temperadas dos Himalaias. Foi assim que se procedeu ao estudo da queda de líquen da copa e dos ramos principais no solo da floresta a uma altitude de e à volta dos 3000 m, usando uma quadricula de 1 m x 1 m disposta casualmente em 10 locais em cada uma das três principais tipos de floresta dos Himalaias em Ghangaria (Vale das Flores), Chopta e na área florestal do

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Parque dos Veados Almiscarados em Kanchula Khark (Santuário de Vida Selvagem de Kedarnath) no distrito de Chamoli em Uttarakhand. A queda da folhada de líquen foi registada em Setembro de 2007. A biomassa de líquen foi mais elevada na floresta de *Quercus semecarpifolia* (Carvalho) na área de Chopta, seguida pela da floresta de Acer oblongum (floresta mista) no Parque do Veado Almiscarado Kanchula Kharkh e no *Pinus wallichiana, Taxus baccata, Abies pindrow* (florestas de coníferas) em Ghangharia (Vale das Flores), com valores de 1,32 g m^{-2}, 0,71 g m^{-2} e 0,41 g m^{-2}, respectivamente. Observámos ainda que o grupo do líquen foliáceo (tipo Parmelia) evidenciou a maior queda de folhada seguido pelo líquen arbustivo (tipo Usnea) em todas as três parcelas florestais.

Key words: Biomass, epiphytic, litter fall, macrolichen, temperate, western Himalayas.

Introduction

Lichens play an important role in the nutrient cycling of forest ecosystem through litter fall and decay. They also contribute to structural complexity, ecological function and biodiversity (Baucher & Nash 1990; Essen *et al.* 1996; Knops *et al.* 1996; Pike 1978). Lichen litter fall studies provide a basis to understand canopy lichen diversity (often overlooked due to inaccessibility) as well as the preferred substrate of each species (mature branches/twigs), their growth patterns, and the physical and biological factors (including anthropogenic) leading to their litter fall. Essen (1985) estimated the litter fall of epiphytic macrolichens in two old *Picea abies* forests in Sweden. According to Essen & Renhorn (1998), high biomass of epiphytic lichens is a characteristic feature of many old growth forest ecosystems in temperate area. Lichens are ecologically important as food, shelter and nesting materials for a variety of wild animals (Mc Cune & Geiser 1997). A few studies of lichen diversity and distribution regarding Himalayan lichens are available (Negi & Upreti 2000; Pinokiyo *et al.* 2008). However, lichen litter fall biomass data from the Himalayas are so far not available. The present communication is a preliminary study of the epiphytic lichen biomass from selected sites from the temperate Himalayan forests.

Materials and methods

The study was carried out in three different forest sites situated in the Chamoli district of Uttarakhand in the inner Himalayan region, at an altitude of 3000 m above mean sea level. The Ghangharia site is located in the Valley of Flowers, between 30º41´ to 30º48´ N and 79º33´ to 79º46´ E, whereas Chopta forest and Kanchula Khark Musk Deer Park forest (Kedarnath Musk Deer Sanctuary) lie between 28º43´ N to 31º27´ N and 77º 34´ E to 81º02´ E (Fig. 1). The temperature in all the three forests ranges between 7º C to 24º C during summer, with maximum winter temperature ranging between below 0º C to 20º C. The Ghangharia forest area is dominanted by coniferous trees, such as *Abies pindrow* (Royle ex D. Don) Royle, *Pinus wallichiana* A. B. Jacks, *Taxus baccata* L. and *Cedrus deodara* (Roxb.) Loud. The Chopta area is dominated by *Quercus semecarpifolia* Sm. (Oak) in association with *Prunus cornuta* (Wall. ex Royle) Stend. and *Rhododendron campanulatum* D. Don. The dominant tree species in Kanchula Khark Musk Deer Park forest are *Acer oblongum* Wall. with *Q. leucotrichophora* L.A. Camus, *Alnus nepalensis* D. Don, *Q. floribunda* Lindle. ex A. Camus, and *Ilex dipyrena* Wall. in Roxb.

During September 2007, ten 1 m x 1 m quadrats were randomly laid in forest floor at each of the study sites, and the biomass of macrolichen litterfall from trees was collected for analysis (Fig. 2). The lichens were weighed after removing the twig or any other foreign material and drying at 70º C (Stephen & Sillett 1995).

Lichen species were identified on the basis of their morphological, anatomical and chemical features (Awasthi 1988, 2000; Divakar & Upreti 2005; Nayaka 2004). The secondary chemistry of the collected lichen specimens were identified by colour spot tests (K, C, Pd) followed by thin-layer chromatography (TLC) using a solvent system of toluene: 1-4 dioxane: acetic acid, 180:60:8 (v/v/v) (Walker & James 1980).

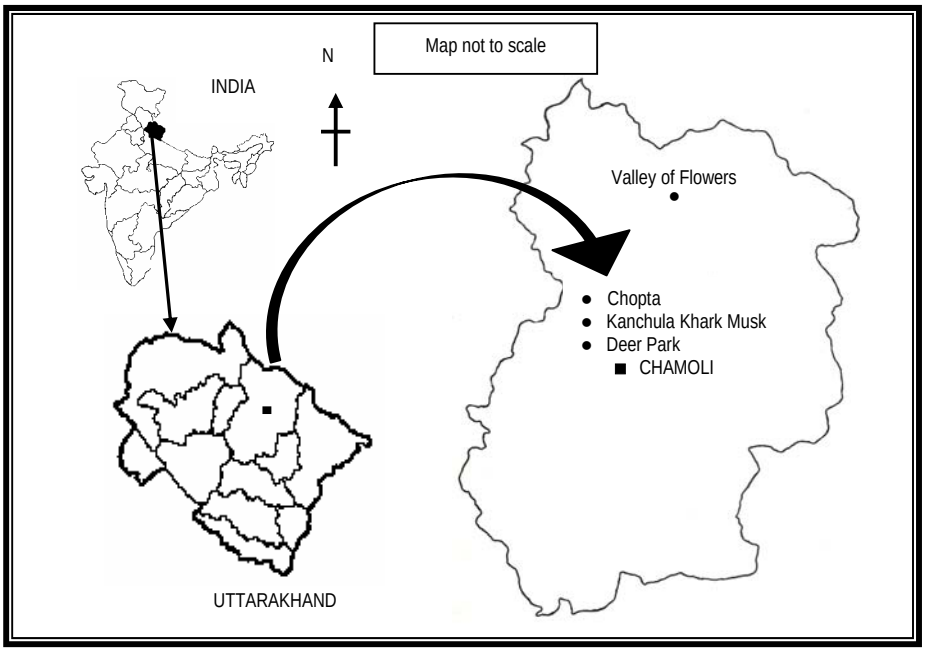

Fig. 1. Map showing the location of collection sites in Uttaranchal, surveyed for epiphytic lichen litter fall biomass collection.

Results

A total of 29 macrolichen species were recorded from all three sites. The study sites had more 'typical foliose' growth form (*Parmelia* type), with 11 genera and 13 species followed foliose-laciniate growth form (*Physcia* type) 3 genera with 5 species (both growth forms collectively referred to as *Parmelia* type in this study) and 'fruticose' growth form *Usnea/Ramalina* type (referred as *Usnea* type in this study) with 1 genus and 4 species.

Out of the three forest sites, their highest lichen dry biomass (1.323 g m^{-2}) was recorded in Chopta forest, followed by Kanchula Khark Musk Deer Park forest and 'Valley of Flowers', with lichen dry biomass of 0.708 g m^{-2} and 0.410 g m^{-2}, respectively (Table 1).

The biomass of both *Parmelia* type and *Usnea* type lichen in the Chopta area were 1.128 g m^{-2} and 0.147 g m^{-2}, respectively. In Kanchula Khark Musk Deer Park forest the *Parmelia* type and *Usnea* type lichens were represented by the biomass of 0.495 g m^{-2} and 0.008 g m^{-2}. In the 'Valley of Flowers' *Parmelia* type had a dry biomass of 0.282 g m^{-2}, with 0.036 g m^{-2} of *Usnea* type lichens. The highest biomass of cyanolichens (0.115 g m^{-2}) was recorded from the 'Valley of Flowers' area. In all the three forests *Parmelia* type lichens contributed the maximum biomass, 0.432 g m^{-2}, of *Nephromopsis pallescens* in Chopta, 0.271 g m^{-2} of *Parmotrema nilgherrense* in Kanchula Kharkh Musk Deer Park (Kedarnath Wild Life Sanctuary), and 0.052 g m^{-2} of *Punctelia subrudecta* in 'Valley of Flower'.

Discussion

The quadrats in 'Valley of Flowers' showed the lowest biomass of lichen litter fall compared to the other two sites. One reason for lower lichen litter fall biomass in the forest may be due to animal rearing, high human activity, construction and tourism. The 'Valley of Flowers' is situated enroute to Hemkund Sahib, a famous holy place of Sikhs. Every year thousands of pilgrims trek through the Ghangaria area. In this study site *Punctelia borreri* recorded its maximum biomass of 0.052 g m^{-2}. The total litter fall biomass of lichens (0.410 g m^{-2}) recorded in the study area is lower than the biomass of lichens in coniferous forest of central Finland (9.0 g m^{-2}) as mentioned by Chunjiang *et al.* (2000). The lower biomass in our study site as compared to coniferous forest of central Finland may be due to the fact that the study area has lower precipitation and high human activity.

The reason for lower lichen literfall biomass in Valley of Flower forest area is directly related with the various factors responsible for loss of lichen

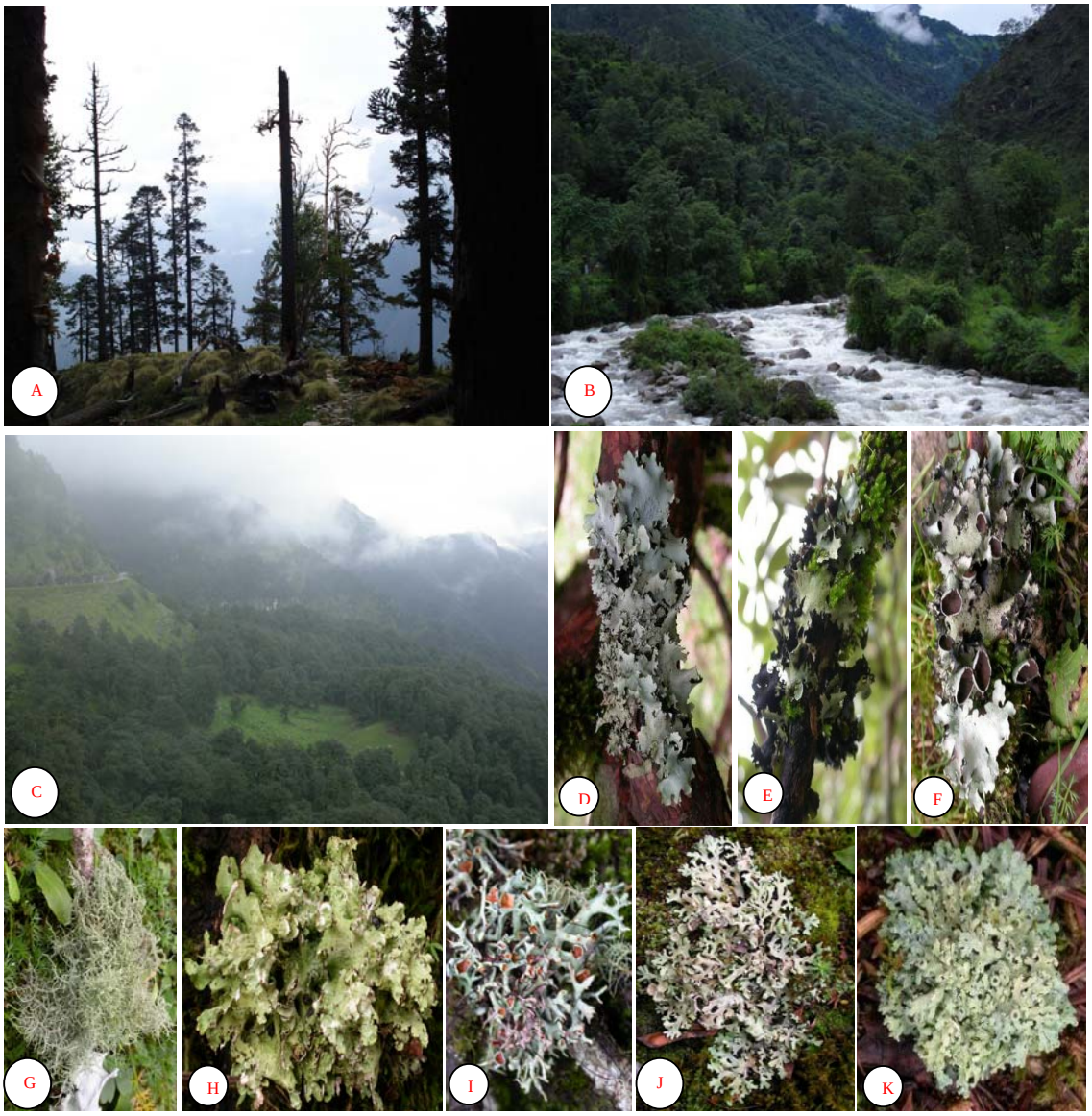

Fig. 2. A. Coniferous forest in Valley of Flower, B. *Acer oblongum* forest in Kanchula Khark Musk Deer Park, C. *Quercus semecarpifolia* forest in Chopta, D. *Rimelia reticulata* (Taylor) Hale & Fletcher, E. *Parmotrema nilgherrense* (Nyl.) Hale, F. *Cetrelia cetrarioides* (Del. Ex Duby) W. Culb. & C. Culb., G. *Usnea longissima* Ach., H. *Nepromopsis pallescens* (Schraer) Park., I. *Everniastrum cirrhatum* (Fr.) Hale, J. *Heterodermia speciosa* (Wulfen) Trevison, K. *Heterodermia diademata* (Taylor) D. D. Awasthi. (D-K Fallen lichen species on forest floor and twigs.)

diversity. Upreti (1996) assessed the different factors responsible for loss of lichen diversity in India. Important factors include the change in the ecological conditions, forest cover and loss of habitat and increase of the urban and industrial areas. The various activities of human in hilly regions of India such as 'Jhum cultivation' or Shifting agriculture, agriculture, mineral extraction, tourism, hydroelectric and road building projects are other factors leading to the rapid deterioration of lichen-rich habitats. Over exploitation and selective removal of economically important lichens by local people have now become the major threats to the lichen flora of India.

Table 1. Lichen biomass in three temperate forest of Chamoli districts, Uttarakhand, India.

Lichen Taxa	Valley of Flowers										Chopta										Musk Deer Park									
	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10
Canoparmelia sp.			.03																											
Cetrelia braunsiana (Müll. Arg.) W. Culb. & C. Culb.																			.05				.09			.13				
Cetrelia cetrarioides (Del.ex Duby) W. Culb. & C.Culb.															.02															
Dermatocarpon miniatum (L.) Mann	.01																													
Everniastrum cirrhatum (Fr.) Hale							.12				.74	.63	.66	.61	.20	.08	.23	.01	.57	.09	.03	.02	.11	.1	.16	.66			.07	
Heterodermia diademata (Taylor) D. Awasthi												.02	.02		.10											.03				
Hetrodermia leucomela (L.) Poelt															.08															
Hetrodermia speciosa (Wulfen) Trevisan				.03																										
Leptogium askotense D. Awasthi & Akhtar														.23									1.15			.02				
Leptogium saturninum (Dickson) Nyl.	.04								.04																					
Lobaria pindarensis Räsänen					.05																									
Myelochroa xantholepis (Mont. & Bosch) Elix & Hale																				.44										
Nephromopsis pallescens (Schaer.) Park.																4.32														
Parmelaria thomsonii (Stirton) D. Awasthi																										.11				
Parmelinella wallichiana (Taylor) Elix & Hale						.05	.03												.03							.04				
Parmotrema nilgherrense (Nyl.) Hale			.10	.01		.08					.95	.18	.18	.28	.06	.12		.81	.04		.35			.09	.28	2.71			.06	.02
Phaeophyscia hispidula (Ach.) Moberg		.20																												
Physcia stellaris (L.) Nyl.		.15																												
Physcia tribacia (Ach.) Nyl.		.20						.01																						
Punctelia borreri (Sm.) Krog	.08	.13	.11	.09		.02	.46		.07																					
Punctelia subruducta (Nyl.) Krog		.52	.01			.09	.03	.06																	.02					
Ramalina conduplicans Vainio																					.37				.38					

Table 1. Continued.

Lichen Taxa	Valley of Flowers										Chopta										Musk Deer Park									
	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10
Ramalina sinensis Jatta		.14																		.01										
Rimelia reticulata (Taylor) Hale & Fletcher	.16	02				.06	.08	.26		.15																				
Usnea eumitrioides Mot.																										.01				
Usnea longissima Ach.	.01									.06																				
Usnea orientalis Mot.											.15	.05	.05	.17	.16	.10	.27		0.5	.02		.05				.02				
Usnea subflorida Stirton			.19		.02			.08																						
Xanthoria perietina (L.) Th.Fr.	.01		.01	.02						.01																				
Total (g m^{-2})	.31	1.36	.45	.15	.07	.30	.26	.86	.01	.33	1.84	.88	.91	1.29	.62	4.62	.50	.82	1.19	.56	.75	.07	1.35	.19	.87	3.70	0	0	.13	.02
Average biomass (g m^{-2})	0.41										1.32															0.71				

Of the three forest sites, the Kanchula Khark Musk Deer Park (Kedarnath Wild Life Sanctuary) has lower lichen biomass than the Chopta area. The biomass of 0.708 g m^{-2} may be attributed to the presence of *Acer oblongum* trees which provided suitable substrate for few foliose and fruticose lichens on the twigs. Precipitation, density, age and forestry management (Essen *et al.* 1996; Mc Cune 1993) and environmental factors such as air pollution (Kuusinen *et al.* 1990), likely controlled the quantity and distribution pattern of lichen biomass in a particular forest stand.

The Chopta forest area, with the highest biomass (1.32 g m^{-2}) among all the three sites, has old mature tree of *Quercus semecarpifolia* growing sparsely and lacking any understorey vegetation, thus providing wide open areas on the forest floor which receive more litter fall of lichens from the canopy. The moist and humid climates of the forest also help colonization by many lichen. According to Wein & Spener (1975) windswept treeless plateaus exhibit more epiphytic lichen biomass than areas having dense tree growth. All three forest sites in our study have dense tree canopy except the Chopta forest where, due to old mature trees growing sparsely and lacking understory young tree and other vegetation, there were more open areas under the forest and had a higher lichen biomass. According to Lehmkuhl (2004) lichen literfall biomass increases with increasing stand complexity and moisture. The open pure pine stands has less literfall biomass than the young mixed and mature-mixed species stands. However, in the present study all the three forest have pure stands of *Quercus semecarpifolia, Acer oblongum* and *Cedrus deodara* but the moisture contents were higher in *Quercus semecarpifolia*, resulting in the maximum lichen litter fall biomass (Kumar 2008).

According to Rawat *et al.* (2007) *Quercus semecarpifolia* is an excellent host tree for lichen growth in temperate Himalayas, as the dense, dome-shaped canopy of the tree provide ample amount of shade and moisture on main trunk and branches, which are suitable for colonization by lichens and many other epiphytes. In all the experimental sites, no record of lichen exploitation by human has been recorded; however, in Kanchula Kharkh Musk Deer Park site the musk deer feed on some lichens (Negi 1996).

In summary, our results clearly indicate that the *Quercus semecarpifolia* forest contributes the maximum lichen litter fall biomass to the forest as compared to coniferous and *Acer* forest in temperate Himalayas.

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