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Estimation of Epiphytic Macrolichen Biomass in Binsar Wildlife Sanctuary (BWS), Almora, Uttarakhand, India

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ABSTRACT

The lichen litter fallen on the forest floor from canopy and main branches between elevations of 900-2500 m was estimated for the Binsar Wildlife Sanctuary (BWS) of Almora district in Uttarakhand, India. The forest of the sanctuary was divided in 5 major forest stands, *viz.*, *Quercus*, *Alnus*, *Pinus*, *Rhododendron* and Mixed. At each stand ten, 1-m^2 quadrats were randomly placed and the lichen litter was collected in April 2013. Lichen biomass was highest in *Quercus* stand (2.55 g m^{-2}) followed by *Alnus* (2.33 g m^{-2}), Mixed stand (2.00 g m^{-2}), *Rhododendron* (0.82 g m^{-2}), and *Pinus* with the lowest lichen litter biomass (0.21 g m^{-2}). The highest biomass was recorded for Matrix lichens (0.8944 g m^{-2}), followed by Forage lichens (0.6976 g m^{-2}) and Cyanolichens (0.0064 g m^{-2}).

1) INTRODUCTION

Epiphytes constitute 6-15% of the non-woody biomass and up to 20% the above-ground nutrient capital in terrestrial ecosystem [1, 2]. Besides contributing to structural complexity, ecological function and biodiversity [3-6], epiphytes play an important role in nutrient cycling in forest ecosystems through litter fall and decay.

Lichen community data (e.g. species richness and community composition) are easily collected, but do not necessarily reflect the contribution of these species to forest ecosystem function. It is important to understand the distribution of lichen biomass in the forest landscape, since the contributions of lichens, such as nitrogen fixation and provision of forage to reindeers, are likely proportional to their biomass [6]. Hence, accurate estimates of lichen biomass in forests are needed to reasonably estimate annual nitrogen fixed by lichens and to better understand lichen contributions to forage and other functions [6].

A large number of studies regarding lichen-litterfall biomass across the world have been published [2, 7-20]. However, the investigation of lichen-litterfall biomass in India was initiated recently, and a very little information on this aspect is available, particularly for the Garhwal Himalaya region [21]. Owing to the rich lichen diversity in Himalaya, studies on this aspect have a wide scope for investigation. The present work is the first step towards more systematic studies in Kumaun Himalaya, by quantifying lichen-litterfall biomass in the BWS. Furthermore we evaluate patterns by epiphytic macrolichen biomass by functional group as they relate to stand age, remnant tree retention, and lichen communities.

2) MATERIALS AND METHODS

2.1 Study area

The study was carried out in BWS, situated between 29°37′56″ N and 79°20′15″ E, in the Almora and Bageshwar districts of Uttarakhand (Fig. 1). It is spread over an area of 45.59 km^2. The altitude ranges from 900 to 2500 m, with an average value of 2412 m. The area is rich in its flora and fauna, and has been declared as an Important Bird Area by Bird Life International (http://www.birdlife.org/). The flora is rich in lichens, bryophytes, pteridophytes, and wild flowers, along with trees such as *Rhododendron* sp., *Myrica esculenta*, *Pinus* sp., *Quercus* sp., *Alnus nepalensis*, *Aesculus indica* [22].

2.2 Lichen litter fall collection and identification

On the basis of dominant plant species, the forest was divided into 5 major stand types: (i) Mixed species (ii) *Rhododendron* (iii) *Alnus* (iv) *Quercus*, and (v) Pinus (Fig. 2-5). During the

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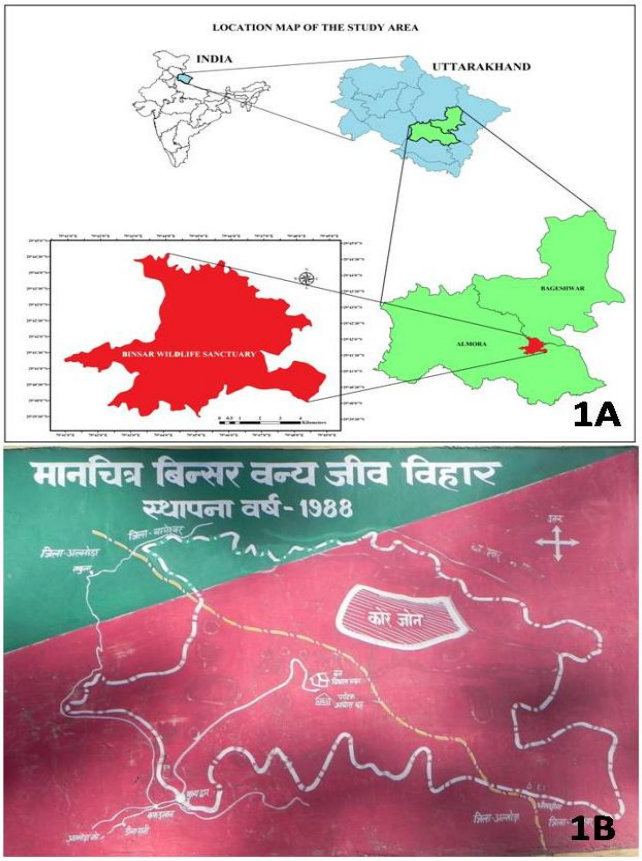

Fig. 1: **A)** Location map of study area (source NRDMS, Almora), **B)** Map indicating various localities and zonation in BWS (source Forest Department, Almora).

month of April 2013, ten 1m x 1m quadrats were randomly laid in the forest floor of each forest stand type, and the litter fall of macrolichen was collected for biomass estimation as per McCune [13]. The whole samples of the lichens were oven dried at 70^0C for 24 h and then weighed to calculate biomass.

Epiphytic macrolichens were divided into three functional groups based on their roles in the forest ecosystem [12]. These groups include 'Cyanolichens', which bears cyanobacteria as either the primary or secondary photobiont; the only contributor of this group within study site was *Leptogium*. 'Forage lichens' consist of all pendulous fruticose lichens. These are used for forage by wildlife, primarily the genera *Ramalina* and *Usnea.* 'Matrix lichens', account for all remaining green-algal macrolichens, primarily foliose in growth form. This group was represented by the genera *Everniastrum, Flavoparmelia*, *Heterodermia* and *Parmotrema.*

Lichen species were identified on the basis of their morphological, anatomical and chemicals features as per published floras [23, 24].

3) RESULTS

A total of 10 macrolichen species [*Everniastrum nepalense* (Taylor) Hale *ex* Sipman, *Flavoparmelia caperata* (L.) Hale, *Heterodermia boryi* (Fée) Kr. P. Singh & S.R. Singh, *H. diademata* (Taylor) D.D. Awasthi, *H. incana* (Stirton) D.D. Awasthi, *Leptogium* sp., *Parmotrema reticulatum* (Taylor) Choisy, *P. tinctorum* (Nyl.) Hale, *Ramalina conduplicnas* Vain., *Usnea* sp.] were present in the lichen litter from the sanctuary. Out of the 5 stand types, the highest epiphytic lichen biomass was recorded in the *Quercus* stand (2.57 gm^{-2}), followed by *Alnus* (2.33 g m^{-2}), Mixed (2.00 g m^{-2}),

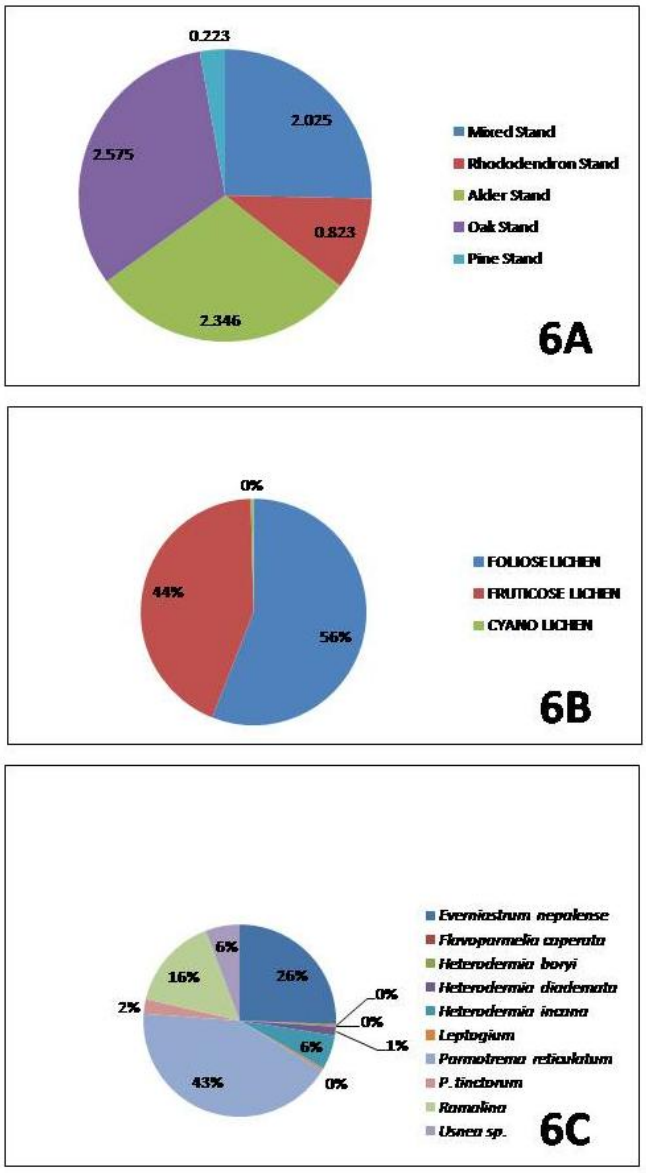

Fig. 6: **A)** Graphical representation of macrolichen biomass estimates among 5 different forest stand types in BWS, **B)** Graphical representation of biomass estimates of matrix, forage and cyanolichens in BWS, **C)** Graphical representation of biomass estimates of examined lichen species acting as litter in BWS.

Rhododendron (0.82 g m^{-2}) and *Pinus* (0.21 g m^{-2}) [Table 1-5, Fig. 6A].

The Mixed stand type had the highest Matrix lichen biomass (1.876 g m^{-2}), whereas the maximum Forage lichen biomass was found in the *Alnus* stand (1.701 g m^{-2}). Cyanolichens were found only in the *Quercus* stand (0.032 g m^{-2}) and were absent in the other 4 stand types [Table 7, Fig. 6B].

The biomass for individual lichen species was also calculated, and it was highest for *Parmotrema reticulatum* (0.6798 g m^{-2}), followed by *Everniastrum nepalense* (0.4084 g m^{-2}), *Ramalina*

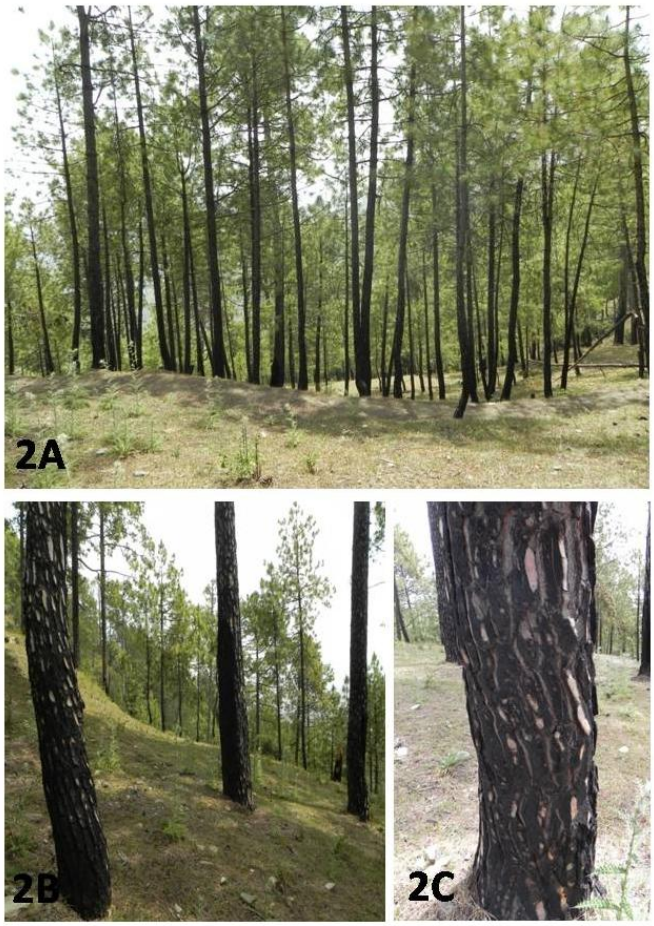

Fig. 2: **A)** *Pinus* stand, **B** & **C)** Burnt *Pinus* tree trunks.

Fig. 3: **A)** *Quercus* stand, **B & C)** Lichen litter fall in *Quercus* stand.

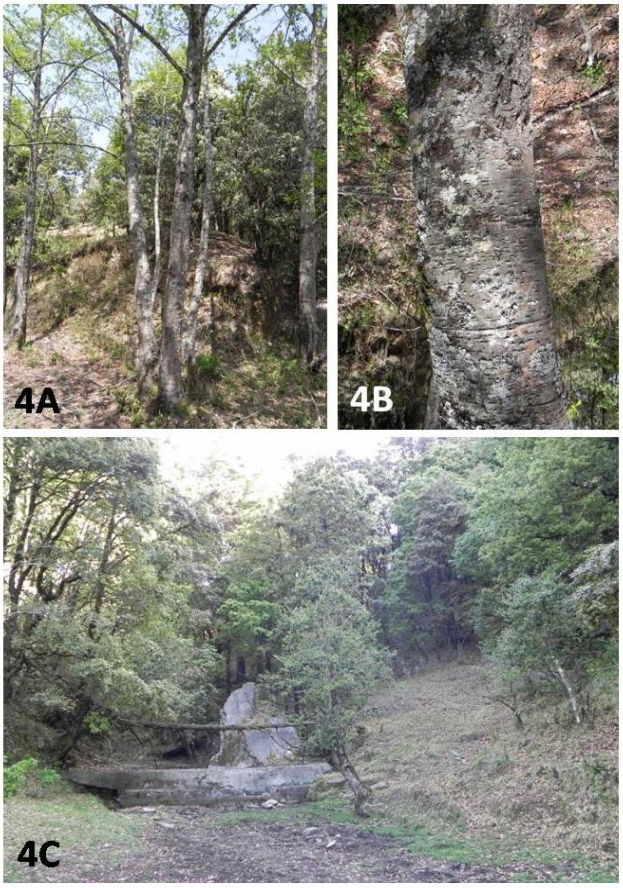

Fig.4: **A)** *Alnus* stand, **B)** *Alnus* tree trunks laden with macrolichens, **C)** Mixed stand.

Fig.5: **A)** *Rhododendron* stand, **B** & **C)** Trunks with mattress of moss.

conduplicans (0.2500 g m^{-2}), *Usnea* sp. (0.0918 g m^{-2}), *Heterodermia incana* (0.0916 g m^{-2}), *Parmotrema tinctorum* (0.0394 g m^{-2}), *Heterodermia diademata* (0.0236 g m^{-2}), *Leptogium* sp. (0.0064 g m^{-2}), *Heterodermia boryi* (0.0050 g m^{-2}), and *Flavoparmelia caperata* (0.0024 g m^{-2}) [Table 8, Fig. 6C]. The family Parmeliaceae, with four representative genera (*Everniastrum*, *Flavoparmelia*, *Parmotrema* and *Usnea*), contributed the highest lichen litter biomass (76.438%), followed by Ramalinaceae (15.640%), Physciaceae (7.520%) and Collemataceae (0.400%) [Table 8]. *Everniastrum nepalense* and *Parmotrema reticulatum* were present at the highest frequency (54% each) in all the 5 stand types, followed by *Ramalina conduplicans* (50%), *Usnea* sp. (30%), *Heterodermia incana* (20%), *Parmotrema tinctorum* (8%), *Flavoparmelia caperata* and *Heterodermia diademata* (4% each), whereas *Heterodermia boryi* and *Leptogium* were present at the lowest frequency (2% each) [Table 6].

4) DISCISSION

The *Pinus* stand had the lowest biomass of lichen litter fall compared to the other 4 stand types. Lower lichen litter fall biomass may be due to forest fire. When the sanctuary was visited in the month of April, the boles of the *Pinus* trees were heavily burnt (Fig. 2). Other possible reasons include animal rearing, human activity and tourism. The *Pinus* stand is situated at lower altitude, where it is within the reach of local people, and is getting exploited for lichens because of its economic importance, as lichens are being used as spices. In addition, the local people collect shed pine needles and sell them to the Uttarakhand Forest Department and other Non Governmental Organization's for setting up gasfire-based energy production plants and briquettes (coal derived from pine needles). During this entire practice the lichens also get exploited, since these fallen lichens are carried along with pine needles.

The *Quercus* stand has the highest lichen biomass among all the 5 stands studied. This stand is comprised of old mature trees growing sparsely and lacking any understory vegetation, thus providing wide open areas on the forest floor which receives more litter fall of lichens from the canopy (Fig. 3). In addition, Rawat *et al.* [21] reported that *Quercus semicarpifolia* is an excellent host tree for lichens in temperate Himalaya, since the dome-shaped canopy of the trees provides sufficient shade and moisture on the main trunk and branches for colonization by lichen and other epiphytes.

Although the *Quercus* stand harbored the highest lichen biomass among all the 5 stands, the contribution of lichen biomass in the *Alnus* stand cannot be neglected (Fig. 4). If we compare lichen biomass of an individual tree in BWS, then *Alnus* tree has the highest epiphytic macrolichen biomass in comparison to other trees. It is an excellent host of lichens in comparison to *Quercus* trees, which hosts a large amount of mosses.

The *Rhododendron* stand was very poor in lichen biomass, as the entire trunk of *Rhododendron* trees were heavily laden with moss mat, not allowing lichens to colonize bark of these trees (Fig. 5).

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Table 1. Lichen litter biomass in a Mixed species stand of Binsar Wildlife Sanctuary, Almora, Uttarakhand, India.

MIXED STAND												
SPECIES	Q1 (g/m^2)	Q2 (g/m^2)	Q3 (g/m^2)	Q4 (g/m^2)	Q5 (g/m^2)	Q6 (g/m^2)	Q7 (g/m^2)	Q8 (g/m^2)	Q9 (g/m^2)	Q10 (g/m^2)	TOTAL ($g/10\ m^2$)	AVG. BIOMASS (g/m^2)
Everniastrum nepalense	0.43	2.16	0.00	0.00	2.26	0.00	1.07	0.00	0.00	0.00	5.92	0.59
Flavoparmelia caperata	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.00	0.11	0.01
Heterodermia boryi	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H. diademata	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.18	0.00	0.18	0.01
H. incana	0.05	0.00	0.00	0.00	2.16	0.00	0.00	0.00	0.00	0.00	2.21	0.22
Leptogium sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Parmotrema reticulatum	0.35	0.08	0.00	0.00	7.07	0.00	0.08	0.00	0.00	2.76	10.34	1.03
P. tinctorum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ramalina conduplicans	0.22	0.83	0.00	0.00	0.00	0.00	0.07	0.00	0.34	0.03	1.49	0.14
Usnea sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	**1.05**	**3.07**	**0.00**	**0.00**	**11.5**	**0.00**	**1.22**	**0.00**	**0.63**	**2.79**	**20.25**	**2.00**

Table 2. Lichen litter biomass in a *Rhododendron* stand of Binsar Wildlife Sanctuary, Almora, Uttarakhand, India

***RHODODENDRON* STAND**												
SPECIES	Q1 (g/m^2)	Q2 (g/m^2)	Q3 (g/m^2)	Q4 (g/m^2)	Q5 (g/m^2)	Q6 (g/m^2)	Q7 (g/m^2)	Q8 (g/m^2)	Q9 (g/m^2)	Q10 (g/m^2)	TOTAL ($g/10\ m^2$)	AVG. BIOMASS (g/m^2)
Everniastrum nepalense	0.00	0.14	0.00	0.32	0.00	0.00	0.00	3.15	0.00	0.01	3.62	0.36
Flavoparmelia caperata	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Heterodermia boryi	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H. diademata	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	1.00	0.10
H. incana	0.00	0.00	0.00	0.48	0.00	0.00	0.00	0.00	0.00	0.11	0.59	0.05
Leptogium sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Parmotrema reticulatum	0.00	1.65	0.00	0.42	0.00	0.00	0.00	0.00	0.00	0.45	2.52	0.25
P. tinctorum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ramalina conduplicans	0.00	0.15	0.00	0.22	0.00	0.00	0.00	0.01	0.00	0.00	0.38	0.03
Usnea sp.	0.00	0.00	0.00	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.12	0.01
Total	**0.00**	**1.94**	**0.00**	**1.56**	**0.00**	**0.00**	**0.00**	**3.16**	**0.00**	**1.57**	**8.23**	**0.82**

Table 3. Lichen litter biomass in an *Alnus* stand of Binsar Wildlife Sanctuary, Almora, Uttarakhand, India.

***ALNUS* STAND**												
SPECIES	Q1 (g/m^2)	Q2 (g/m^2)	Q3 (g/m^2)	Q4 (g/m^2)	Q5 (g/m^2)	Q6 (g/m^2)	Q7 (g/m^2)	Q8 (g/m^2)	Q9 (g/m^2)	Q10 (g/m^2)	TOTAL ($g/10m^2$)	AVG. BIOMASS (g/m^2)
Everniastrum nepalense	0.70	0.62	0.80	0.26	0.20	0.40	0.27	0.41	0.51	0.67	4.84	0.48
Flavoparmelia caperata	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Heterodermia boryi	0.00	0.00	0.00	0.00	0.00	0.00	0.25	0.00	0.00	0.00	0.25	0.02
H. diademata	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H. incana	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Leptogium sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Parmotrema reticulatum	6.60	0.42	0.01	0.49	1.66	1.32	0.00	0.04	1.22	0.16	11.92	1.19
P. tinctorum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ramalina conduplicans	0.72	0.27	0.00	0.41	0.50	0.44	0.00	0.38	0.20	0.38	3.30	0.33
Usnea sp.	0.34	0.24	0.61	0.17	0.01	0.49	0.14	0.08	0.13	0.94	3.15	0.31
Total	**8.36**	**1.55**	**1.42**	**1.33**	**2.37**	**2.65**	**0.66**	**0.91**	**2.06**	**2.15**	**23.46**	**2.33**

Table 4. Lichen litter biomass in a *Quercus* stand of Binsar Wildlife Sanctuary, Almora, Uttarakhand, India.

***QUERCUS* STAND**												
SPECIES	Q1 (g/m^2)	Q2 (g/m^2)	Q3 (g/m^2)	Q4 (g/m^2)	Q5 (g/m^2)	Q6 (g/m^2)	Q7 (g/m^2)	Q8 (g/m^2)	Q9 (g/m^2)	Q10 (g/m^2)	TOTAL ($g/10m^2$)	AVG. BIOMASS (g/m^2)
Everniastrum nepalense	0.35	0.25	0.34	0.00	0.02	0.06	1.86	0.28	0.32	2.56	6.04	0.60
Flavoparmelia caperata	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Heterodermia boryi	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H. diademata	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H. incana	0.00	0.04	0.16	0.16	0.03	0.00	0.00	0.00	0.21	0.35	1.78	0.17
Leptogium sp.	0.32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.32	0.03
Parmotrema reticulatum	0.17	0.16	0.26	2.65	0.20	0.96	0.24	0.21	0.39	1.56	9.21	0.92
P. tinctorum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ramalina conduplicans	0.00	0.71	0.42	1.47	2.21	0.39	0.96	0.24	0.30	0.63	7.33	0.73
Usnea sp.	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.35	1.07	0.10
Total	**0.88**	**1.16**	**1.18**	**5.79**	**2.46**	**1.41**	**5.12**	**0.98**	**1.23**	**5.45**	**25.75**	**2.55**

Table 5. Lichen litter biomass in a *Pinus* stand of Binsar Wildlife Sanctuary, Almora, Uttarakhand, India.

***PINUS* STAND**												
SPECIES	Q1 (g/m^2)	Q2 (g/m^2)	Q3 (g/m^2)	Q4 (g/m^2)	Q5 (g/m^2)	Q6 (g/m^2)	Q7 (g/m^2)	Q8 (g/m^2)	Q9 (g/m^2)	Q10 (g/m^2)	TOTAL ($g/10\ m^2$)	AVG. BIOMASS (g/m^2)
Everniastrum nepalense	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Flavoparmelia caperata	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
Heterodermia.boryi	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H. diademata	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H. incana	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Leptogium sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Parmotrema reticulatum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
P. tinctorum	0.00	0.73	0.00	0.62	0.00	0.00	0.45	0.00	0.17	0.00	1.97	0.19
Ramalina conduplicans	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Usnea sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.25	0.00	0.25	0.02
Total	**0.00**	**0.74**	**0.00**	**0.62**	**0.00**	**0.00**	**0.45**	**0.00**	**0.42**	**0.00**	**2.23**	**0.21**

Table 6. Frequency of lichen species present in litter in Binsar Wildlife Sanctuary, Almora, Uttarakhand, India

SPECIES	**FREQUENCY (%)**					**AVG. FREQUENCY (%)**
	FOREST STAND TYPE					
	MIXED	***RHODODENDRON***	***ALNUS***	***QUERCUS***	***PINUS***	
Everniastum nepalense	40.00	40.00	100.00	90.00	0.00	54.00
Flavoparmelia caperata	10.00	0.00	0.00	0.00	10.00	4.00
Heterodermia boryi	0.00	0.00	10.00	0.00	0.00	2.00
H. diademata	10.00	10.00	0.00	0.00	0.00	4.00
H. incana	20.00	20.00	0.00	60.00	0.00	20.00
Leptogium sp.	0.00	0.00	0.00	10.00	0.00	2.00
Parmotrema reticulatum	50.00	30.00	90.00	100.00	0.00	54.00
P. tinctorum	0.00	0.00	0.00	0.00	40.00	8.00
Ramalina conduplicans	50.00	30.00	80.00	90.00	0.00	50.00
Usnea sp.	0.00	10.00	100.00	30.00	10.00	30.00

Table 7. Estimates of biomass of Matrix, Forage and Cyanolichens present in lichen litter in different forest stand types in Binsar Wildlife Sanctuary, Almora, Uttarakhand, India.

Lichen group	Stand types					Total
	Quercus (g/10 m^2)	***Alnus*** (g/10 m^2)	**Mixed** (g/10 m^2)	***Rhododendron*** (g/10 m^2)	***Pinus*** (g/10 m^2)	
Matrix lichens	1.703	0.645	1.876	0.050	0.198	4.472
Forage lichens	0.840	1.701	0.149	0.773	0.025	3.488
Cyanolichens	0.032	0.000	0.000	0.000	0.000	0.032
Total (g m^{-2})	2.575	2.364	2.025	0.823	0.223	7.992

Table 8. Estimates of biomass of individual lichens species as well as lichen families present in lichen litter from Binsar Wildlife Sanctuary, Almora, Uttarakhand, India.

Lichens	**Biomass (g/m^2)**	**Family**	**Biomass (g/m^2)**
Everniastrum nepalense	0.4084	PARMELIACEAE	1.2218
Flavoparmelia caperata	0.0024		
Parmotrema reticulatum	0.6798		
P. tinctorum	0.0394		
Usnea sp.	0.0918		
Heterodermia boryi	0.0050	PHYSCIACEAE	0.1202
H. diademata	0.0236		
H. incana	0.0916		
Leptogium sp.	0.0064	COLLEMATACEAE	0.0064
Ramalina conduplicans	0.2500	RAMALINACEAE	0.2500