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Effect of elevation gradient on the distribution of lichens and mosses of central Himalayan region, Uttarakhand, India

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ABSTRACT

The present investigation aimed to determine the distribution pattern of 27 species of lichens and 7 species of mosses within five altitudinal bands between 3100-4000m near Badrinath area in the Central Himalaya. *Melanelia infumata*, *Xanthoria elegans* were the dominant among the lichens, whereas *Bryum argenteum* was dominant among mosses. The species diversity exhibits a distinct pattern at different altitudinal band. The number of both lichens and moss species decline towards the higher elevation gradient. The rock inhabiting species exhibit their dominance in higher altitude while soil inhabiting lichens dominates in the lower altitudes. The chlorolichens dominates all the sites in lower and higher elevation while cyanolichens have a restricted distribution in the area.

1) INTRODUCTION

E Most of the hills of central Himalayan region are rugged and steep, with its terrain cut by deep rivers and glaciers. A cold alpine climate is observed at higher elevation where summers are cool and winters are severely cold and the area is permanently snow covered during the month of November to February. The varied topography and extreme climate enables only few vascular and majority of the cryptogams to survive. Among the cryptogams lichens and mosses constitutes the majority of terrestrial vegetation at higher altitudes.

Lichens are the unique group of plants that consists of two unrelated organisms a fungus and an alga, growing together in a close symbiotic association. The unique morphology and physiology of lichens enables them to grow luxuriantly in extreme habitats. In general, lichens and mosses are differentially distributed along moisture gradients, however mosses thriving under moisture conditions than lichens [1, 2].

A number of studies on lichens at different altitudinal ranges are available from Himalayas. Baniya et. al.,[3] studied the pattern of torricolous lichen species richness along elevation gradient in Himalayas. Pinokiyo et. al., [4] investigated diversity and distribution of lichens in relation to altitudes within protected biosphere hotspot, north east India. Devkota [5] studied the lichens in different altitudinal gradient of Phulchowki (1500-2700m) of the Nepal Himalayas and observed that the members of lichens families were dominant on different altitudinal gradients.

Grytnes [6] conducted the analysis of standardized species richness data sets from transects in order to evaluate simultaneously the potential drivers of elevation diversity gradients. The central Himalayan region is well known for its rich plant diversity, including lichens. Though the account of lichens from Badrinath area are available [7] but their distribution pattern at different altitudinal gradient were not known. Similarly, the mosses of the area are meagerly studied so far. The present investigation is aimed to study the lichen and moss diversity from lower to higher altitudinal gradients of the Badrinath area. The diversity at lower and higher altitude regions of central Himalaya will elucidate the usefulness of lichens and mosses from Uttarakhand hills not only for taxonomical aspects but also for their probable use in biomonitoring field studies because lichens and mosses are the sensitive group of plants, any change in distribution and richness indicates changes in environmental conditions and effects of anthropogenic activities.

2) MATERIALS AND METHODS

***Study area*:** The study was conducted in nearby localities of Badrinath, a famous pilgrimage of Hindus (Badrinath Forest Division) of central Himalaya, Chamoli district in Uttarakhand. The Badrinath Forest Division is located in

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northern (N 30^0 44' 413 E 79^0 27' 832 to N 30^0 47' 137 E 79^0 27' 431), and contains parts of the central Himalayas (Figure 1). The study area exhibits distinct range of elevation from 3151m (10,337.9ft) to 4048m (13,280ft).

***Sampling of lichens and mosses*:** More than 100 samples were collected from study area; enroute from Mana to Vashudhara (Figure 1, Table 1) during 1st June to 30th June 2010, by sampling 1m×1m quadrate and 25cm×25cm sub-quadrate according to Vetaas [8]. The species on each site were selected randomly in ten quadrates of $25cm^2$ and in each quadrate; number of individuals of small, medium and large lichens, moss (colony) were counted and noted properly.

The elevation and location of mountain hills were measured using GPS (GPS 12 Fc S/N 36979983 Garmin, Olathe, KS, USA). The frequency, density and abundance of lichen and moss species were calculated following the standard methodology of Curtis and McIntosh [9].

***Identification of lichen species*:** Collected specimens were identified with the help of Lichenology Laboratory of National Botanical Research Institute (CSIR-NBRI) Lucknow and a voucher specimen of each species is deposited in the herbarium of the CSIR-NBRI (LWG).

3) RESULT AND DISCUSSION

The study sites revealed, the occurrence of 27 species of lichens belonging to 18 genera (14 families) and 7 species of mosses belonging to 6 families. The members of lichens belonging to family Parmeliaceae, Umbilicariaceae, Acarosporaceae, Teloschistaceae, and Physciaceae, dominates the study area and contributes more than 0.80% of each of all species mostly in higher altitudes around 4000m. Among the different lichen genera *Umbilicaria* exhibit the highest frequency of 60, 100, 20 and 100 at sites 1, 3, 4 and 5 respectively. At site 3, *Xanthoria elegans*, *Xanthoria paritiena* and *Xanthoria candelaria* exhibit 80, 90 and 60% of frequency; 6, 9 and 2.8 of density and abundance of 7.5, 10 and 9.3 respectively (Table 2).

Since the sites mostly devoid of trees, the exposed rock surfaces provide the suitable habitat to lichens for colonization, therefore out of the 27 species of lichens, 18 species are rock inhabiting. The *Acarospora fusca*, *Acarospora gwynnii*, *Acarospora macrospora*, *Dermatocarpon miniatum*, *Lasallia pustulata*, *Rhizocarpon geographicum*, *Rhizoplaca chrysoleuca*, *Rhizoplaca melanopthalma*, *Stereocaulon foliolosum*, *Umbilicaria aprina*, *Umbilicaria indica*, *X. elegans*, *X. parietina*, and *X. candelaria* are the species of lichens growing directly on rocks. Some species of lichens exhibit their restricted distribution such as *X. elegans* exhibit its wide distribution from 3151 to 3321m altitude with 60%, 40%, 80% and 50% frequency at site 1, 2, 3 and 4 respectively, while at an altitude of 4048m (site 5) it exhibits complete absence. The highest richness of both lichens and mosses represented by the sites located between 3321 and 3648m altitudes (Figure 1). In the harsh climatic regimes of low pressure, high wind velocity, subzero atmospheric temperature and high soil activity only the tolerant soil and rock lichen species have an ability to colonize [10].

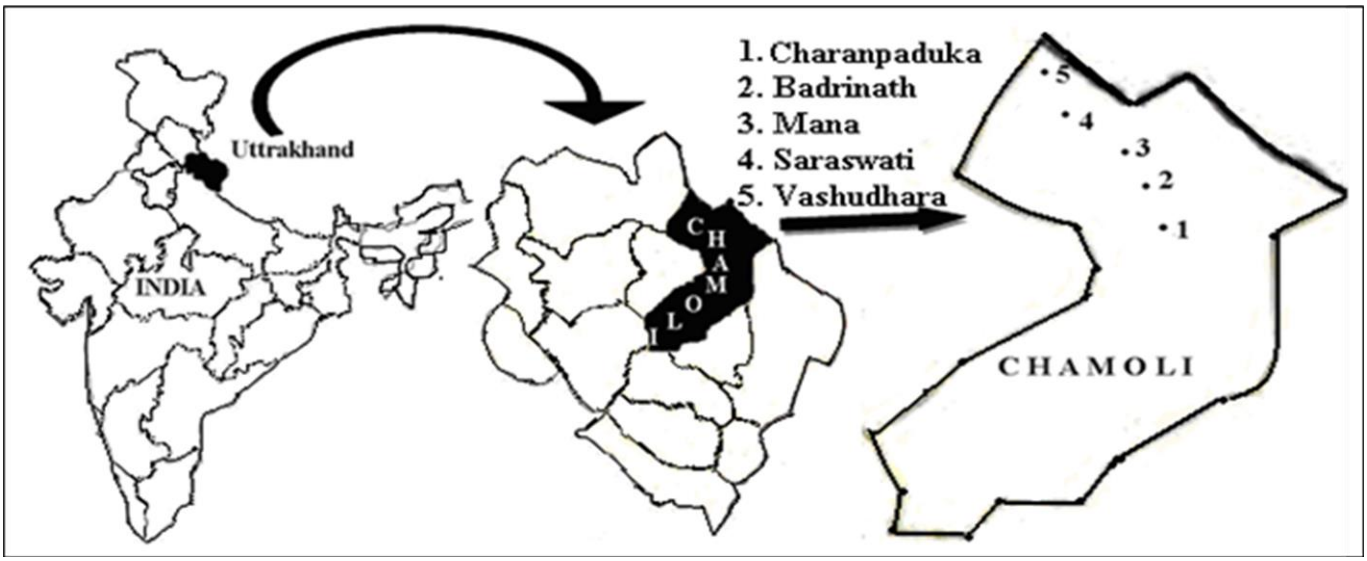

Figure 1: Sampling sites at different altitudes in central Himalaya, India

Table 1: GPS locations, altitude and type of vegetation at different sites in central Himalaya region, India

Sites	Name of the site	GPS Locations	Altitude (m)	Vegetation
1	Origin of Saraswati River (Mana)	N 30^0 44' 578 E 79^0 29' 628	3151	Lichens and moss dominated
2	Mt. Narayan Foot Hills (Charanpaduka)	N 30^0 44' 413 E 79^0 27' 832	3226	Exposed rocks
3	Mt. Nar Foot Hills (Badrinath)	N 30^0 44' 316 E 79^0 29' 930	3321	Vascular plants dominated
4	Way of Mana to Vashudhara (Saraswati)	N 30^0 47' 238 E 79^0 27' 130	3648	Exposed rocks
5	Mt. Kuber foot Hills (Vashudhara)	N 30^0 47' 137 E 79^0 27' 431	4048	Exposed rocks

Table 2. Lichens and mosses growing at different sites of higher altitudes of central Himalaya, Uttarakhand, India

S.No	Lichens	Site-1 (3151m)			Site-2 (3226m)			Site-3 (3321m)			Site-4 (3648m)			Site-5 (4048m)		
		F	D	A	F	D	A	F	D	A	F	D	A	F	D	A
1	*Acarospora fusca*				40	8	20							60	5.5	9.1
2	*Acarospora gwynnii*	90	3	3.3	50	6.5	7							60	5.5	9.1
3	*Acarospora macrospora*				70	7	10							40	4.5	11.2
4	*Candelaria concolor*				40	4.5	11	10	0.8	8						
5	*Coccocarpia erythroxyli*	60	4.5	7.5	60	3.5	5.8									
6	*Collema sp.*	10	1.4	4.6				50	1.2	1.3						
7	*Dermatocarpon miniatum*	30	0.8	2.6	60	6	10				80	3.2	4			
8	*Diploschistes muscorum*				80	4.5	5.6	50	4	8						
9	*Endocarpon subramulosum*				30	7.5	2.5	40	1.8	6				60	2.5	4.1
10	*Flavoparmelia caperata*	20	2	1	40	4	4	40	1.8	6						
11	*Lasallia pustulata*							30	1.5	5	90	4.5	5			
12	*Lichinella stipatula*										60	3	5			
13	*Lichinella cerebriformis*										30	.6	2			
14	*Melanelia olivacea*				30	2.5	6				80	1.6	2			
15	*Melanelia infumata*				50	10	20	20	0.6	3	10	.1	1	60	7.5	12.5
16	*Physcia tenella*	80	2.4	3	10	2.5	12.5									
17	*Physcia apolia*				60	3	5	70	1.4	4.6						
18	*Parmelia sulcata*				20	9.5	3.1				40	1.6	4	50	5	10
19	*Rhizocarpon geographicum*	70	6.5	9.2												
20	*Rhizoplaca chrysoleuca*				70	4	4.4									
21	*Rhizoplaca melanophthalma*	60	1.8	3	70	3.5	5									
22	*Stereocaulon foliolosum*													70	6.5	9.2
23	*Umbilicaria aprina*	60	5.5	9.1										100	10	1
24	*Umbilicaria indica*							100	2	2	20	1.6	8			
25	*Xanthoria candelaria*				40	5.6	14	60	2.8	9.3				100	3.5	3.5
26	*Xanthoria elegans*	60	1.2	3	40	7	1.7	80	6	7.5	50	4	8			
27	*Xanthoria parietina*							90	9	10	70	2.8	4			
S.No	**Mosses**	**Site-1** (3151m)			**Site-2** (3226m)			**Site-3** (3321m)			**Site-4** (3648m)			**Site-5** (4048m)		
		F	**D**	**A**	**F**	**D**	**A**	**F**	**D**	**A**	**F**	**D**	**A**	**F**	**D**	**A**
1	*Abietinella brandisii*				60	6.5	7.8							80	3	4.2
2	*Bryum argenteum*	60	2.8	9.3				60	2.8	9.3	40	3.2	8			
3	*Grimmia apiculata*	60	1.2	3												
4	*Leskea perstricta*							100	2	2	30	2.7	9			
5	*Pogonatum aloides*							30	1.5	5						
6	*Syntrichia princeps*	80	2.4	3										80	6	7.5
7	*Thuidium assimile*				50	3.5	7									

F= Frequency (%), D= Density (ha^{-1}), A= Abundance (ha^{-1}).

Rai et al., [11] recorded higher species count of soil lichens in Himalayan habitats than the other regions of the world. The probable reason for higher species diversity may be due to the lower competition from other ground plant above tree line (>3000m) tolerance of lichens to grazing, trampling, acidic pH and harsh climatic conditions.

The moss species exhibits higher diversity (7 species) at lower altitudes (between 3151 to 3321m), while the higher altitudes between 3648-4048 exhibits occurrence of only 4 species. Out of 7 moss species, *Bryum argenteum* was found at site 1, 3 and 4 with frequency 60, 60 and 40%; density 2.8, 2.8 and 3.3 ha^{-1}; and abundance were 9.3, 9.3 and 8 ha^{-1} respectively between altitude of 3151 to 3648m.

Over twenty thousand species of lichens are known, distributed in different geographical regions of the world. Lichens have diversified extensively during the past 600 million years [12], lichens with mosses form dominant flora of ecosystem covering 10% of the earth terrestrial habitats, particularly higher elevations [13]. Among the lichens, the green photobiont containing (chlorolichens) dominates all the sites while cyanolichens having cyanobacteria/blue green algae exhibit their scanty occurrence in the lower altitudes up to site 3 (3648m). Different photobionts require different conditions for their growth. The *Trebouxia*, a most common photobiont in chlorolichens need temperature of 5-10^{0}C [14] and other green photobionts prefer 18-21^{0}C [15], while

cyanobacteria require 24-30^{0}C [16]. Cyanolichens dominates mostly the niches which have moisture for longer period whereas green algae chlorobionts dominates the rest. Decrease in annual precipitation and temperature are the major factors responsible for poor or scanty growth of lichens at higher altitudes (3500-4000m) as these factors severely limited the growth of photosynthetic organisms.

Similar to the studies of Maier [17], most of the *Grimmia* species exhibit their occurrence in higher altitudes, as in the present study the genus *Grimmia* (Musci, Grimmiaceae) with its six species such as, *G. alpestris*, *G. atrata*, *G. donniana*, *G. fuscolutea*, *G. longirostris*, and *G. ovalis* showed their distribution between the altitudinal ranges of 4500 and 6000m in the Himalayan region. As an adaptive strategy most of the species of lichens and mosses grow for minimum either forming tufts or closely forming cushions at onto the substrate to protect the plant from high wind velocity at exposed higher altitudes and can retain water vapor for longer period.

Fast pace of urbanization due to increasing human activities, construction of buildings, roads, helipads, dams, hydroelectric stations together with higher tourist pressure influences the climate and deteriorating the habitats of lichens and mosses. The diversity of lichens and mosses in central Himalayan region can be useful as biosensors, helping to assess the overall health of an ecosystem. Lichens and mosses being the most sensitive plant groups to microclimatic changes indicate such anthropogenic activities distinctly.

4) CONCLUSION

The distribution of lichens and mosses along with elevation gradient in the study area clearly distinguishes the different sites by varied species richness along with the altitudinal changes, together with marked differences in species. The number and richness of both the plant groups showed a decreasing trend towards the higher elevations. The present distribution pattern of lichens and mosses will be a base line data for carrying out future biomonitoring studies in the area. As the study area is having great human pressure therefore, a regional conservation strategy is needed for effective conservation of lichens and mosses in such fragile areas.

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REFERENCES

1) Frahm, J.P. 2003. Climatic habitat differences of epiphytic lichens and bryophytes cryptogamie. Bryologie 24, 3-14.
2) Sillett, S.C. and Antoine, M.E. 2004. Lichens and bryophytes in forest canopies. (In: M.D. Lowman, M.D., Rinker, H.B. (Eds.), Forest Canopies, 2nd ed. (pp. 151–174). Elsevier Academic Press, New York)
3) Baniya, C.B., Solhoy, T., Gauslla, Y. and Palmer, M.W. 2010. The elevation gradient of lichen species richness in Nepal. The Lichenologist 42, 83-96.
4) Pinokiyo, A., Singh, K.P., and Singh, J.S. 2008. Diversity and distribution of lichens in relation to altitude within a protected biodiversity hot spot, northeast India. Lichenologist 40, 47–62.
5) Devkota, A. 2008. Taxonomic study of lichens of Phulchowki hills, Lalitpur district (Kathmandu Valley). Scientific World 6, 44-51.
6) Grytnes, J.A. 2003, Species-richness patterns of vascular plants along seven altitudinal transects in Norway. Ecography 26, 291-300.
7) Shukla, V. and Upreti, D.K. 2007. Lichen diversity in and around Badrinath, Chamoli district (Uttarakhand). Phytotaxonomy.7, 78-82.
8) Vetaas, O.R. 1997. The effect of Canopy disturbance on species richness in a central Himalayan Oak forest. Plant Ecology 132, 29-38.
9) Curtis, J.T. and McIntosh, R.P. 1950. The interrelation of certain analytic and synthetic physiological parameters. Ecology 31, 434-455.
10) Scheidegger, C. and Clerc, P. 2002. Erdbewohnende Flechten der Schweiz. In: Rote Liste der gefährdeten Arten der Schweiz: Baumund erdbewohnende Flechten, Bern, Bundesamt für Umwelt, Wald und Landschaft BUWAL, Birmensdorf, Eidgenössische Forschungsanstalt WSL, Conservatoire et Jardin botaniques de la Ville de Genève CJBG, pp. 75–108.
11) Rai, H., Upreti, D.K., and Gupta, R.K. 2012. Diversity and distribution of terricolous lichens as indicator of habitat heterogeneity and grazing induced trampling in a temperate alpine shrub and meadow. Biodiversity and Conservation 21, 97–113.
12) Yuan, X., Xiao, S. and Taylor, T.N. 2005. Lichen like symbiosis 600 million years ago. Science 308, 1017-1020.
13) Nash, T.H. and Egan, R.S. 1988. The biodiversity of lichens and bryophytes. In: Lichen, Bryophytes and air quality. Bibleography of Lichenology 30, 11-22.
14) Voytsekhovich, A. and Beck, A. 2016. Lichen photobionts of the rocky outcrops of Karaday massif (Crimean Peninsula). Symbiosis 68, 9-24.
15) Ahmadjian, V. 1993. The lichen symbiosis. Chichester: John Wiely and Sons.
16) Kumar, M., Jyoti, K. and Singh, G.P. 2011. Growth and biopigment accumulation of cyanobacterium *Spiralina platensis* at different light intensities and temperature. Brazilian Journal of Micro-biology 42, 1128-1135.
17) Maier, E. 2002. The genus *Grimmia* (Musci, Grimmiaceae) in the Himalaya. Candollea 57, 143-238.