Diversity and distribution of lichenized fungi on some historical monuments of Kumaun Himalaya, Uttarakhand

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Key words: Historical monuments, inventory, Kumaun Himalaya, lichens, species richness.

Abstract: Monuments and cultural assets are substantial personification of historical, scientific and ecological communications between past and present. These are very unique and undisturbed sites for growth of various biotic communities forming a separate ecosystem. In the present study an extensive work regarding diversity of lichens colonizing 46 monuments of Kumaun Himalaya was undertaken to know actual diversity of lichens colonizing these monuments. Lichens were collected in and around the monuments and identified with the help of various lichenological techniques. The study revealed a total of 71 lichens species belonging to 39 genera and 21 families. Hierarchal cluster analysis identifies monuments of Jageshwar, Shiva Temple Khark Karki, Baleshwar, Sun Temple and Fort of Banasur as the best monuments for the lichen diversity. Besides hosting common lichen species, these monuments also act as best substratum for the recently newly described species *Heterodermia himalayana* and *H. upretii* and some new records. Since there are both positive and negative attributes of lichenized fungi colonizing monuments, it is also a matter of discussion and a challenging task for us to take a decision whether these organism colonizing monuments should be preserved (because of ecological prospective) or eradicated.

Zusammenfassung: Denkmäler und Kulturgüter sind eine wesentliche Personifizierung der historischen, wissenschaftlichen und ökologischen Kommunikation zwischen Vergangenheit und Gegenwart. Sie sind einzigartige und ungestörte Standorte für das Wachstum verschiedener Biozönosen und bilden ein separates Ökosystem. In der vorliegenden Studie wurde eine umfangreiche Erhebung der Flechtendiversität auf 46 Denkmälern von Kumaun Himalaya durchgeführt. Flechten wurden in und auf den Denkmälern gesammelt und mit Hilfe verschiedener lichenologischer Techniken bestimmt. Die Studie ergab insgesamt 71 Flechtenarten in 39 Gattungen und 21 Familien. Die hierarchische Clusteranalyse identifizierte die Denkmäler Jageshwar, Shiva Tempel, Khark Karki, Baleshwar, Sonnentempel und Fort von Banasur als die besten für die Flechtenvielfalt. Neben der Bereitstellung eines Lebensraumes für häufige Flechtenarten wirken diese Denkmäler auch als Wuchsunterlage für die kürzlich neu beschriebenen Arten *Heterodermia himalayana* und *H. upretii* und für einige neue Nachweise für Indien. Da lichenisierte denkmalsbesiedelnde Pilze sowohl positive als auch negative Eigenschaften haben, ist es auch eine Diskussionsfrage und eine anspruchsvolle Aufgabe die Entscheidung zu treffen, ob diese denkmalbesiedelnden Organismen bewahrt (aus ökologischer Perspektive) oder entfernt werden sollen.

Historical and cultural assets are not only the symbol of ancient civilization, but also provide the most tangible and illuminating insights into our past conveying historical information from generation to generation. These may be considered as an ecosystem where both biotic (bacteria, algae, fungi, bryophytes, lichens and higher plants) and abiotic components meet together (NIMIS 2001) and there are several publications available on diversity of these biotic components colonizing monuments across the world (NIMIS & al. 1987, ORTEGA-MORALES & al. 2006, MACEDO & al. 2009, PANDEY & al. 2011, VERMA & al. 2014). Amongst these biotic forms, lichens are pioneer colonizers which have the capability to cope up with extreme desiccation and temperature and these qualities confer their well establishment over the rock surface (i.e. epilithic) or inside the rock (i.e. endolithic).

A lot of studies on lichen flora colonizing monuments and their effect on various historical monuments and artifacts have been conducted worldwide (PRIETO & al. 2000, CARBALLAL & al. 2001, MARCOS 2001, RIGAMONTI 2008, NATTAH & al. 2012). In India, investigation of lichen diversity colonizing monuments was initiated in the eighties describing effects of lichens on granite (GAYATHRI 1980). Later on various monuments of the country were visited to study the floristic composition of lichens on monuments (SINGH & UPRETI 1991; CHATTERJEE & al. 1995, 1996; SINGH & al. 1999; SAXENA & al. 2004; JOSHI & UPRETI 2007a, b, 2008; UPRETI & al. 2010; BAJPAI & UPRETI 2014).

However, for Uttarakhand, which is a part of central Himalayan region and famous for its cultural assets made up of stone, wood and other construction materials and housing more than 500 monuments, few studies are available so far (TRIPATHI & al. 2013, JOSHI & al. 2014). Hence, the present paper focuses on diversity and distribution of lichenized fungi on Kumaun Himalayan monuments.

Materials and methods

Study area: The study was carried out on 46 monuments including some Naula (small water reservoir used for surface water harvesting in Uttarakhand, typically made with stone artifacts) of Kumaun region of Uttarakhand situated between an altitude of 812–2243 m a.s.l. (Tab. 1).

Lichen collection and identification: Monuments of district Bageshwar (Bag) and Pithoragarh (Pth) were visited during September 2013 to March 2014 while that of Almora (Alm) and Champawat (Cham) were visited during July 2014 to January 2015. The lichen samples colonizing in and around the monuments and various shrines were collected in plastic bags with the help of snapper without damaging the monument. The crustose lichen species which the authors were unable to collect from the monument were identified only up to the generic level with the help of good photography. Morphological examinations were carried out using a stereo-zoom dissecting microscope (Olympus SZ2-ILST) and anatomical studies of handmade sections were done using a research microscope (CX21iLEDFS1). Spot test reactions on thalli, medulla, and fruiting bodies were tested with the standard reagents: 10 % potassium hydroxide (K), sodium hypochlorite (C) and *para*-phenylenediamine (Pd). Thin Layer Chromatography was performed as per ORANGE & al. (2001) and the specimens were identified with AWASTHI (1991, 2007), DIVAKAR & UPRETI (2005), and SINGH & SINHA (2010) and are deposited in herbarium of Kumaun University (KU).

Quantitative analysis: Alpha diversity was analysed using SHANNON-WIENER diversity index (SHANNON & WIENER 1963) while concentration of dominance was analysed using Simpson's index (SIMPSON 1949).

Tab. 1. Qualitative and quantitative characteristics of studied Kumaun Himalayan monuments. [*SR* number of lichen species or species richness, *F* number of families, *H'* SHANNON-WIENER Index or alpha diversity, *D'* SIMPSON's Diversity index, *CD* Concentration of dominance (SIMPSON's index)].

SN	Name of Monument	District	Latitude (N)	Longitude (E)	Altitude (m a.s.l.)	SR	F	H'	D'	CD
1	Ram Temple	Alm	29°35.321'	79°39.292'	1593	11	9	2.146	8.964	0.124
2	Patal Devi	Alm	29°36.514'	79°39.380'	1525	5	5	1.609	5.000	0.2
3	Narayan Kali	Alm	29°38.227'	79°42.329'	1306	6	5	1.561	4.933	0.222
4	Sun Temple	Alm	29°38.194'	79°36.561'	1300	19	12	2.406	11.95	0.097
5	Nanda Devi	Alm	29°35.431'	79°39.211'	1567	7	6	1.748	5.952	0.184
6	Gurjar Dev	Alm	29°46.585'	79°25.863'	1414	10	7	1.834	6.911	0.180
7	Maniyan	Alm	29°46.660'	79°25.634'	1422	14	10	2.206	9.945	0.122
8	Badrinath Chhatgulla	Alm	29°44.881'	79°24.514'	1400	15	6	1.657	5.848	0.209
9	Mrityunjaya	Alm	29°46.503'	79°25.685'	1375	6	6	1.792	6.000	0.167
10	Kachahari	Alm	29°46.705'	79°25.675'	1428	5	4	1.332	3.900	0.280
11	Ratan Dev	Alm	29°45.005'	79°24.593'	1491	5	3	1.055	2.800	0.360
12	Vandev	Alm	29°41.661'	79°33.075'	1352	9	6	1.735	5.917	0.185
13	Badrinath	Alm	29°46.507'	79°25.629'	1377	8	6	1.733	5.929	0.188
14	Chudakaran Mahadev	Alm	29°49.981'	79°17.074'	833	13	9	2.058	8.923	0.148
15	Bharsoli Temple	Alm	29°53.603'	79°13.339'	960	12	7	1.864	6.909	0.167
16	Chamyadi Temple	Alm	29°54.723'	79°13.489'	1087	10	6	1.748	5.956	0.180
17	Titri Temple	Alm	29°52.844'	79°13.689'	898	8	4	1.213	3.750	0.344
18	Narsingh Dev	Alm	29°41.154'	79°33.396'	1299	9	7	1.889	6.944	0.160
19	Madkeshwar Temple	Alm	29°46.276'	79°29.483'	1253	8	6	1.733	5.929	0.188
20	Jageshwar	Alm	29°38.141'	79°51.155'	1832	22	16	2.689	15.97	0.074
21	Binsar	Alm	29°41.573'	79°44.587'	2208	10	6	1.696	5.889	0.200
22	Lakhudiyar	Alm	29°38.338'	79°42.550'	1365	6	5	1.561	4.933	0.222
23	Someshwar Temple	Alm	29°46.781'	79°36.270'	1390	8	7	1.906	6.964	0.156
24	Vriddha Jageshwar	Alm	29°39.010'	79°50.481'	2243	5	4	1.332	3.900	0.280
25	Naula Dwarahat I	Alm	29°46.701'	79°25.628'	1420	6	5	1.561	4.933	0.222
26	Naula Dwarahat II	Alm	29°46.699'	79°25.715'	1420	3	3	1.099	3.000	0.333
27	Naula Chhatgulla	Alm	29°45.005'	79°24.589'	1388	2	2	0.693	2.000	0.500
28	Naula Parkot	Alm	29°46.459'	79°29.796'	1255	3	3	1.099	3.000	0.333
29	Naula Vibhandeshwar	Alm	29°46.508'	79°25.627'	1022	4	4	1.386	4.000	0.250
30	Naula Paniyali	Alm	29°49.758'	79°17.146'	812	3	3	1.099	3.000	0.333
31	Baijnath	Bag	29°54.147'	79°36.934'	1117	7	5	1.475	4.857	0.265
32	Shiva Temple Khark Karki	Cham	29°19.420'	80°05.276'	1558	22	10	2.022	9.870	0.169
33	Fort of Banasur	Cham	29°24.273'	80°02.596'	1817	19	12	2.288	11.92	0.125
34	Kotwali Chabutra	Cham	29°20.036'	80°05.073'	1701	11	7	1.894	6.927	0.157
35	Shiva Temple Nadbora	Cham	29°19.596'	80°04.541'	1550	9	6	1.735	5.917	0.185
36	Shiva Temple Majhpipal	Cham	29°23.080'	80°15.014'	1249	14	9	2.069	8.923	0.143
37	Sun Temple	Cham	29°25.345'	80°12.111'	1419	8	6	1.733	5.929	0.188
38	Baleshwar	Cham	29°20.047'	80°07.014'	1561	20	11	2.233	10.92	0.125
39	Ek Hathiya	Pth	29˚49.354'	80˚09.012'	1081	14	8	1.946	7.901	0.163
40	Baleshwar Thal	Pth	29°49.497'	80°08.460'	819	12	8	2.023	7.939	0.139
41	Chamunda Devi	Pth	29°41.350'	80°05.501'	1637	11	7	1.846	6.909	0.174
42	Pungeshwar Mahadev	Pth	29°46.521'	80°03.842'	1262	17	9	2.038	8.904	0.149
43	Ancient group of temple, Gangolihat	Pth	29°39.386'	80°02.386'	1645	7	6	1.748	5.952	0.184
44	Laxmi Narayan	Pth	29°32.535'	80°13.480'	1448	7	5	1.55	4.905	0.224
45	Vishnu Temple	Pth	29°34.520'	80°14.401'	1429	8	7	1.906	6.964	0.156
46	Sun Temple Chopta	Pth	29°41.466'	80°13.268'	1197	12	8	1.979	7.924	0.153

Tab. 2. Distribution of lichen species in the studied monuments of Kumaun Himalaya.

Taxon	Monuments of Kumaun Himalaya																																												
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46
Acarospora fusca				+	+										+							+																+				+				
Aspicilia calcarea														+						+																		+								
Bacidia sp.				+																+	+			+									+						+							
Buellia sp. 1		+	+	+			+	+			+	+	+	+	+	+	+	+	+	+	+	+											+	+	+	+	+	+	+	+	+			+		
Buellia sp. 2			+																		+													+							+	+				+
Bulbothrix isidiza																						+														+						+				
Byssoloma subdiscordans																				+																										
Caloplaca cinnabarina						+		+						+										+	+				+		+	+	+			+	+					+				
C. flavovirescens	+							+		+				+	+	+				+	+		+				+			+	+	+	+		+	+				+	+	+				
C. ochroplaca																																+														
C. subbassiae		+	+	+	+	+	+	+	+	+				+	+		+	+	+		+			+	+						+					+	+			+					+	+
C. subsoluta																				+															+							+		+		
Candelaria concolor	+			+		+	+	+		+		+			+				+	+					+				+			+	+		+		+	+		+	+	+	+			+
Candelariella sp.				+			+	+					+																									+								
Canoparmelia texana																																+														
Cladonia sp.	+																																+										+			
Chrysothrix sp.				+																																										
Collema crispum																																						+								
Dirinaria consimilis								+						+			+							+								+				+						+			+	+
Dermatocarpon vellereum	+			+			+																															+	+	+	+					
Diploschistes actinostomus								+																									+													
Dimelaena oreina			+	+	+	+	+	+	+					+	+		+	+															+			+	+			+						
Endocarpon rosettum		+		+			+		+	+		+		+				+		+	+											+	+			+								+		
Flavoparmelia caperata																				+																										
Heterodermia diademata																+				+		+										+											+			
H. himalayana												+																											+							
H. japonica	+																																						+	+						
H. obscurata																																+														
H. pseudospeciosa	+															+	+		+																			+	+			+				
H. speciosa																																										+				

Tab. 2. Continued.

Taxon	Monuments of Kumaun Himalaya																																												
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46
H. upretii																																	+													
Hyperphyscia adglutinata				+																+																										
Lecanora sp.1	+	+	+	+		+	+	+			+	+	+	+	+	+		+		+	+		+		+						+	+	+	+				+		+				+	+	+
Lecanora sp. 2																			+		+																					+				+
Lecidella carpathica															+								+									+							+				+	+	+	+
L. stigmatea																+																+								+	+					+
Lepraria sp.	+			+	+		+		+				+	+		+		+		+			+	+	+	+	+	+	+	+	+	+	+	+	+			+	+	+		+	+			
Leptogium sp.																				+																		+								
Mycobilimbia philippina																				+																+										
Myelochroa aurulenta	+																																													
Parmotrema andinum						+		+			+							+																			+	+								
P. crinitum															+	+						+											+													+
P. grayanum																																+		+												
P. hababianum					+																																									
P. praesorediosum				+	+	+	+	+	+		+		+	+				+	+				+		+			+				+		+	+	+		+	+		+	+	+			
P. melanothrix																																+														
P. mesotropum																																										+				
P. reticulatum																										+				+			+													
P. tinctorum												+				+					+											+	+			+		+	+	+	+					+
Pertusaria indica															+					+		+										+	+	+				+								
P. leucosora																																		+											+	
Phaeophyscia hispidula				+								+	+	+					+	+			+									+			+		+	+	+	+		+	+	+	+	
P. orbicularis							+																																		+					
Physcia caesia				+		+																																+								
P. dubia																																						+								+
Porpidia albocoerulescens																				+																										
Punctelia borreri	+			+								+																				+														
P. subrudecta													+							+															+			+			+					
Pyxine cocoes							+	+							+																															
P. sorediata				+	+	+	+		+	+	+	+	+	+		+		+	+		+		+			+			+		+		+		+		+	+	+				+	+		
P. berteriana var. *hima-laica*	+																+											+					+							+						

Tab. 2. Continued.

Taxon	Monuments of Kumaun Himalaya																																													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46
Ramalina conduplicans																				+																										
Rinodina oxydata		+															+																			+						+				
Sarcogyne cf. *novomexicana*							+																																							
Staurothele fissa																	+						+											+					+		+	+			+	+
Tephromela khatiensis																				+																										
Trapelia coarctata																																+		+		+			+						+	+
Verrucaria coerulea																				+																										
Xanthoparmelia antleriformis								+																																						
X mexicana			+	+		+		+							+																	+	+													
X. coreana																															+															

Name of monuments: 1 Ram Temple, 2 Patal Devi, 3 Narayan Kali, 4 Sun Temple, 5 Nanda Devi, 6 Gurjar Dev, 7 Maniyan, 8 Badrinath Chhatgulla, 9 Mrityunjaya, 10 Kachahari, 11 Ratan Dev, 12 Vandev, 13 Badrinath, 14 Chudakaran Mahadev, 15 Bharsoli Temple, 16 Chamyadi Temple, 17 Titri Temple, 18 Narsingh Dev, 19 Madkeshwar Temple, 20 Jageshwar, 21 Binsar, 22 Lakhudiyar, 23 Someshwar Temple, 24 Vriddha Jageshwar, 25 Naula Dwarahat I, 26 Naula Dwarahat II, 27 Naula Chhatgulla, 28 Naula Parkot, 29 Naula Vibhandeshwar, 30 Naula Panyali, 31 Baijnath, 32 Shiva Temple Khark Karki, 33 Fort of Banasur, 34 Kotwali Chabutra 35 Shiva Temple Nadbora, 36 Shiva Temple Majhpipal, 37 Sun Temple, 38 Baleshwar, 39 Ek Hathiya, 40 Baleshwar Thal, 41 Patalbhuwaneshwar, 42 Pungeshwar Mahadev, 43 Ancient group of temple, Gangolihat, 44 Laxminarayan, 45 Vishnu Temple, 46 Sun Temple Chopta.

Tab. 3. Distribution of families in all the monuments of Kumaun Himalaya

Family name	Number of species in different monuments of Kumaun Himalaya																																												
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46
Acarosporaceae	0	0	0	1	1	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0
Caliciaceae	1	1	2	2	2	1	3	4	1	1	2	2	2	3	3	2	4	2	2	1	3	1	1	1	0	1	0	1	1	0	1	1	4	2	2	2	2	2	2	2	2	2	1	2	1	2
Candelariaceae	1	0	0	2	0	1	2	2	0	1	0	1	1	0	1	0	0	0	1	1	0	0	0	0	1	0	0	0	1	0	0	1	1	0	1	0	1	2	0	1	1	1	1	0	0	1
Chrysothricaceae	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cladoniaceae	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0
Collemataceae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0
Lecanoraceae	1	1	1	1	0	1	1	1	0	0	1	1	1	1	2	2	0	1	1	1	2	0	2	0	1	0	0	0	0	0	1	3	1	2	0	1	0	1	1	2	1	1	0	2	2	3
Lecideaceae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Megasporaceae	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Parmeliaceae	2	0	1	3	2	3	1	4	1	0	2	2	2	1	2	2	0	2	1	2	1	2	1	0	1	1	0	1	0	1	1	7	4	2	2	3	1	4	2	1	3	3	1	0	0	2
Pertusariaceae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	1	1	2	0	0	0	1	0	0	0	0	0	0	1	0
Pilocarpaceae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Porpidiaceae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Physciaceae	2	1	0	3	0	1	1	0	0	0	0	2	1	1	0	2	2	0	2	3	0	1	1	0	0	0	0	0	0	0	0	3	1	0	1	1	1	4	4	2	1	4	2	1	1	1
Ramalinaceae	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0
Stereocaulaceae	1	0	0	1	1	0	1	0	1	0	0	0	1	1	0	1	0	1	0	1	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	0	0	1	1	1	0	1	1	0	0	0
Tapelariaceae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	1	0	1	0	0	1	0	0	0	0	0	1	1
Teloschistaceae	1	1	1	1	0	2	1	3	1	2	0	0	0	3	2	1	1	1	1	2	2	0	1	2	2	0	1	0	1	1	3	3	2	0	2	3	2	0	0	2	1	3	0	1	1	1
Tephromelataceae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0
Thelotremataceae	0	0	1	1	1	1	1	1	1	0	0	0	0	1	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Verrucariaceae	1	1	0	2	0	0	2	0	1	1	0	1	0	1	0	0	1	1	0	2	1	0	1	0	0	0	0	0	0	0	0	1	1	1	0	1	0	1	2	1	2	1	0	1	1	1

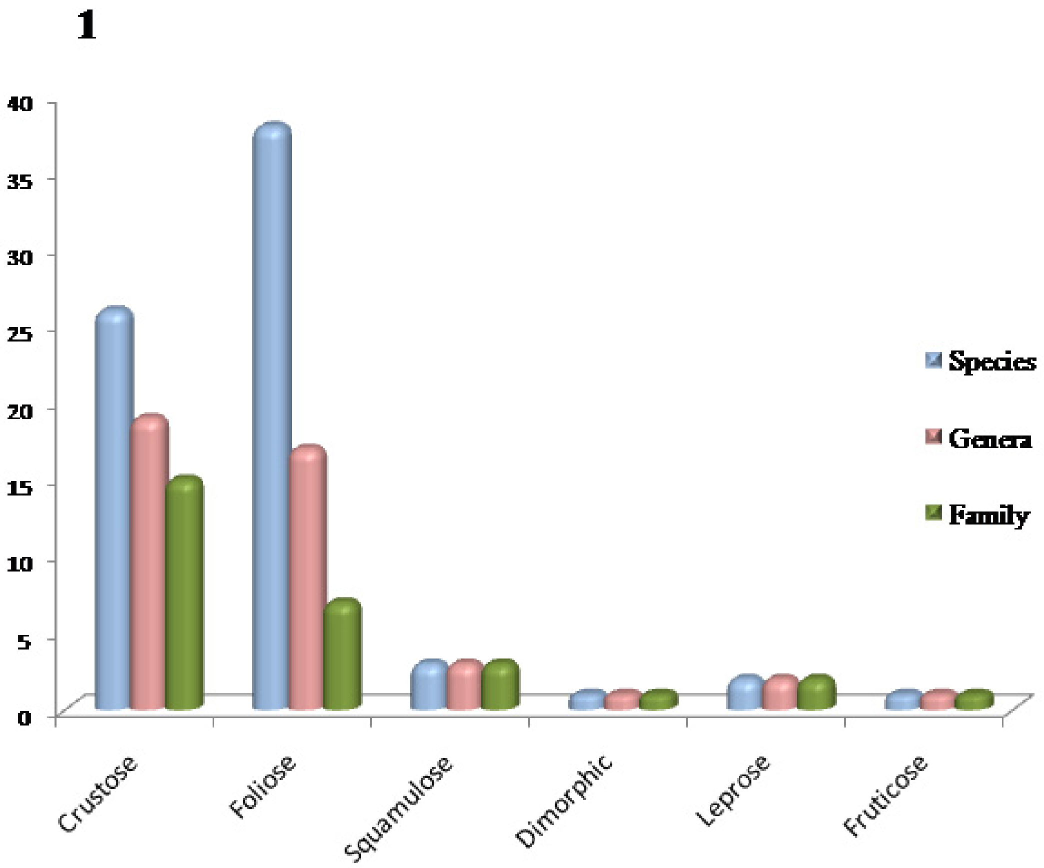

Fig. 1. Different growth form of lichens in the studied monuments.

To determine the compositional differences between the monuments, hierarchal cluster analysis was performed with the help of PAST software (HAMMER & al. 2001).

PEARSON's correlation coefficient was performed by using SPSS software 16.0 version for knowing the relationship between altitude and species richness, number of families, alpha diversity, Simpson's diversity and concentrations of dominance. Polynomial regression analysis was performed by using PAST software for knowing the relationship between altitude and species richness (HAMMER & al. 2001).

Results

Species composition of the monuments: The study revealed the occurrence of 71 lichens species belonging to 39 genera and 21 families with various growth forms of lichens (Tabs. 2–3, Fig. 1). *Parmeliaceae* was the dominant family with 25.35 % (18 species) followed by *Physciaceae* (18.30 %; 13 species), *Caliciaceae* (9.85 %; 7 species) and *Teloschistaceae* (7.04 %; 5 species) (Tab. 3).

Jageshwar monument shows the maximum diversity of lichens (22 species belonging to 16 families). In contrast, minimum diversity of lichens was noticed in Chhatgulla Naula, Almora (2 species) (Tab.1).

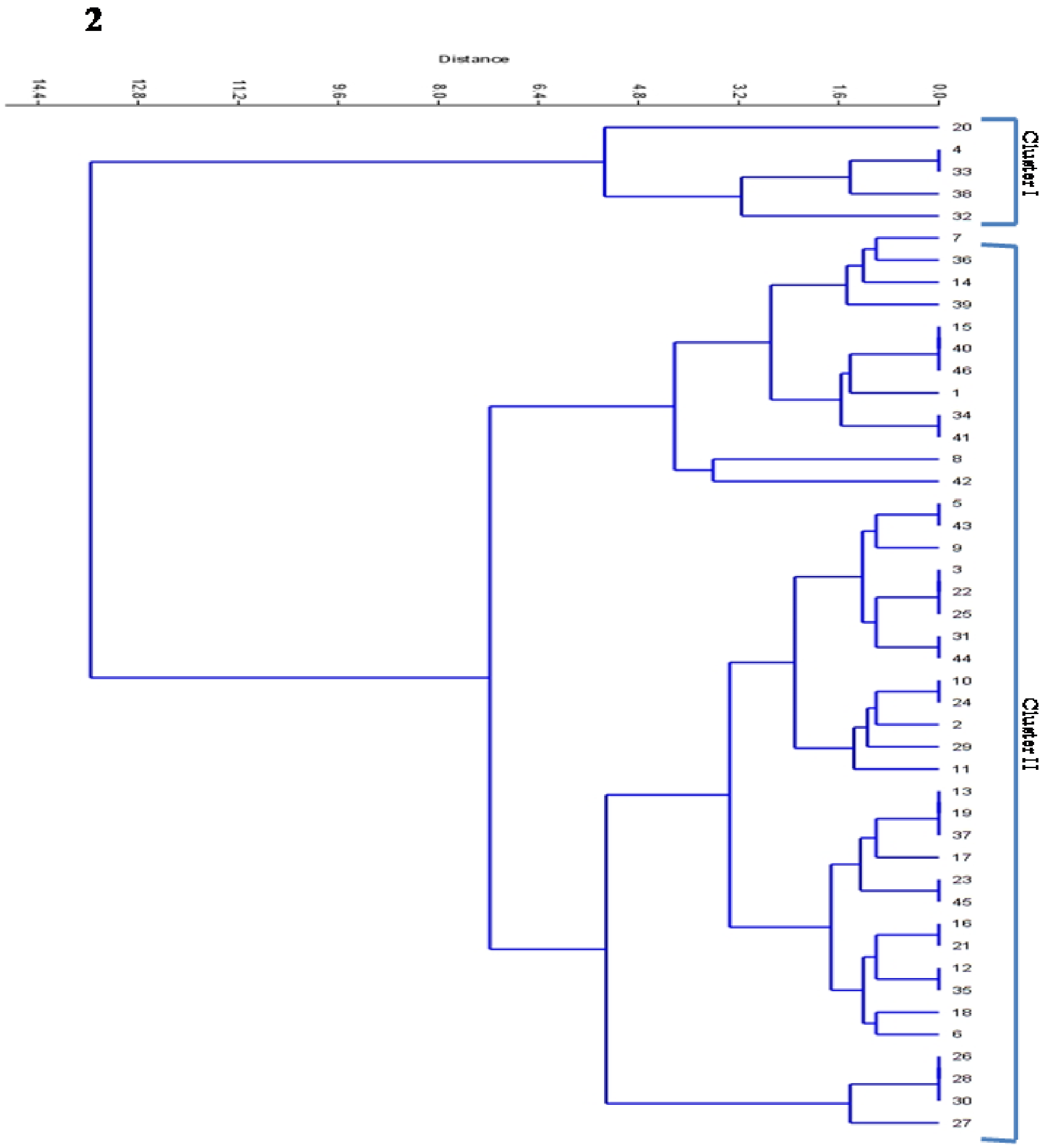

Fig. 2. Hierarchal cluster analysis between species richness of lichens on all the monuments and number of lichen families for the determination of compositional difference between monuments.

Eighteen species, viz. *Byssoloma subdiscordans* (Nyl.) P. JAMES, *Porpidia albocoerulescenes* (WULFEN) HERTEL & KNOPH, *Ramalina conduplicans* VAIN., *Tephromela khatiensis* (RÄSÄNEN) LUMBSCH and *Verrucaria coerulea* (RAMOND) DC. (20), *Caloplaca ochroplaca* POELT & HINTER. and *Canoparmelia texana* (TUCK.) ELIX & HALE (32), *Chrysothrix* sp. (4), *Collema crispum* (HUDS.) G. H. WEB. (38), *Heterodermia obscurata* (NYL.) TREVIS. (32*), H. speciosa* (WULF.) TREVIS. (42), *H. upretii* Y. JOSHI, S. UPADHYAY & K. CHANDRA (33), *Myelochroa aurulenta* (TUCK.) ELIX & HALE (1), *Parmotrema hababianum* (GYELN.) HALE (5), *P. melanothrix* (MONT.) HALE (31), *P. mesotropum* (Müll. ARG.) HALE (42), *Xanthoparmelia anteliformis* (ELIX) ELIX & J. JOHNST. (8) and *X. coreana* (GYELN.) HALE (30), were found colonizing only a single monument, i.e. they are unique to those monuments, while *Lepraria* was the only genus recorded from almost all the monuments and it showed its presence both inside and outside the monuments. Jageshwar monument have the maximum number of unique lichen species (5 species, 27.77 %) followed by Shiva temple Khark Karki (3 species, 16.66 %), Pungeshwar Mahadev (2 species, 11.11 %), Sun Temple, Baleshwar, Fort of Banasur, Ram Temple, Nanda Devi, Baijnath, Badrinath Chhatgulla, Naula Paniyali (1 species each, 5.55 % each) (Tab. 2).

Two recently newly described species of lichens viz. *Heterodermia himalayana* Y. JOSHI, K. CHANDRA & M. TRIPATHI (Joshi & al. 2014a) and *H. upretii* (JOSHI & al. 2014b) were also recorded from Ek Hathiya temple and Fort of Banasur, respectively. Besides this, some lichen species (*Parmotrema andinum* (MÜLL. ARG.) HALE, *P. crinitum* (ACH.) M. CHOISY*, P. hababianum, P. melanothrix,* and *Pyxine berteriana* D. D. AWASTHI) were also reported for the first time as saxicolous on monuments across the nation and are also showing habitat extension since these species were previously reported corticolous from the Indian subcontinent.

Quantitative analysis: Quantitative analysis shows that the alpha diversity and Simpson's index **(**D') varies from 0.693 (Naula Chhatgulla) to 2.689 (Jageshwar) and 2 (Naula Chhatgulla) to 15.97 (Jageshwar), respectively. However, the value of concentration of dominance ranges between 0.074 (Jageshwar) to 0.5 (Naula Chhatgulla) (Tab. 1).

The most noticeable fact about these monuments is that they were not only heavily conquered by crustose growth forms of lichens, viz. species of *Acarospora, Aspicilia*, *Buellia, Caloplaca, Diploschistes, Endocarpon, Lecanora, Rinodina* and *Verrucaria* but also house foliose lichen species which were quantitatively higher in comparison than crustose growth forms. Besides this we found a single species of endolithic lichen *Sarcogyne* cf. *novomexicana* also invading some monuments.

Hierarchal cluster analysis, prioritized and identified the monuments (Fig. 2) into two major clusters: Cluster I (monuments no. 4, 20, 32, 33, 38 and 42) with 17 to 22 lichen species: i.e. clusters having higher lichen diversity, and Cluster II (all other monuments) with 2 to 15 lichen species: i.e. clusters having low lichen diversity (Fig. 2). From our study, it becomes clear that altitude of the studied sites does not show any relationship with species richness of lichens, their families, alpha diversity, Simpson's diversity and concentration of dominance (Tab. 4) and this was also confirmed by the Pearson's correlation coefficient analysis. Polynomial regression data sets also revealed that the relation of altitude with species richness was non-linear and non-significant ($Y= -9.096-07x^2+0.0047x+5.052$, $r^2= 0.016$, $p= 0.70$) (Fig. 3). Hence, altitude does not have any major effect on lichen diversity on monuments of Kumaun Himalaya. Rather it is the microclimatic conditions, physical and chemical properties of substratum and architecture pattern of monuments which may be assisting in creating specific habitats for luxuriant growth of lichens. Meanwhile, species richness of lichen shows the significant relation with families of the lichen diversity (0.923**, $p<0.01$), alpha diversity (0.845**, $p<0.01$), SIMPSON'S diversity (0.919**, $p<0.01$), concentration of dominance (–0.730**, $p<0.01$) (Tab. 4). Besides this, number of families also shows the significant relation with alpha diversity (0.936**, $p<0.01$), Simpson's diversity (1.000**, $p<0.01$) and Concentration of Dominance (–0.831**, $p<0.01$) (Tab. 4).

3

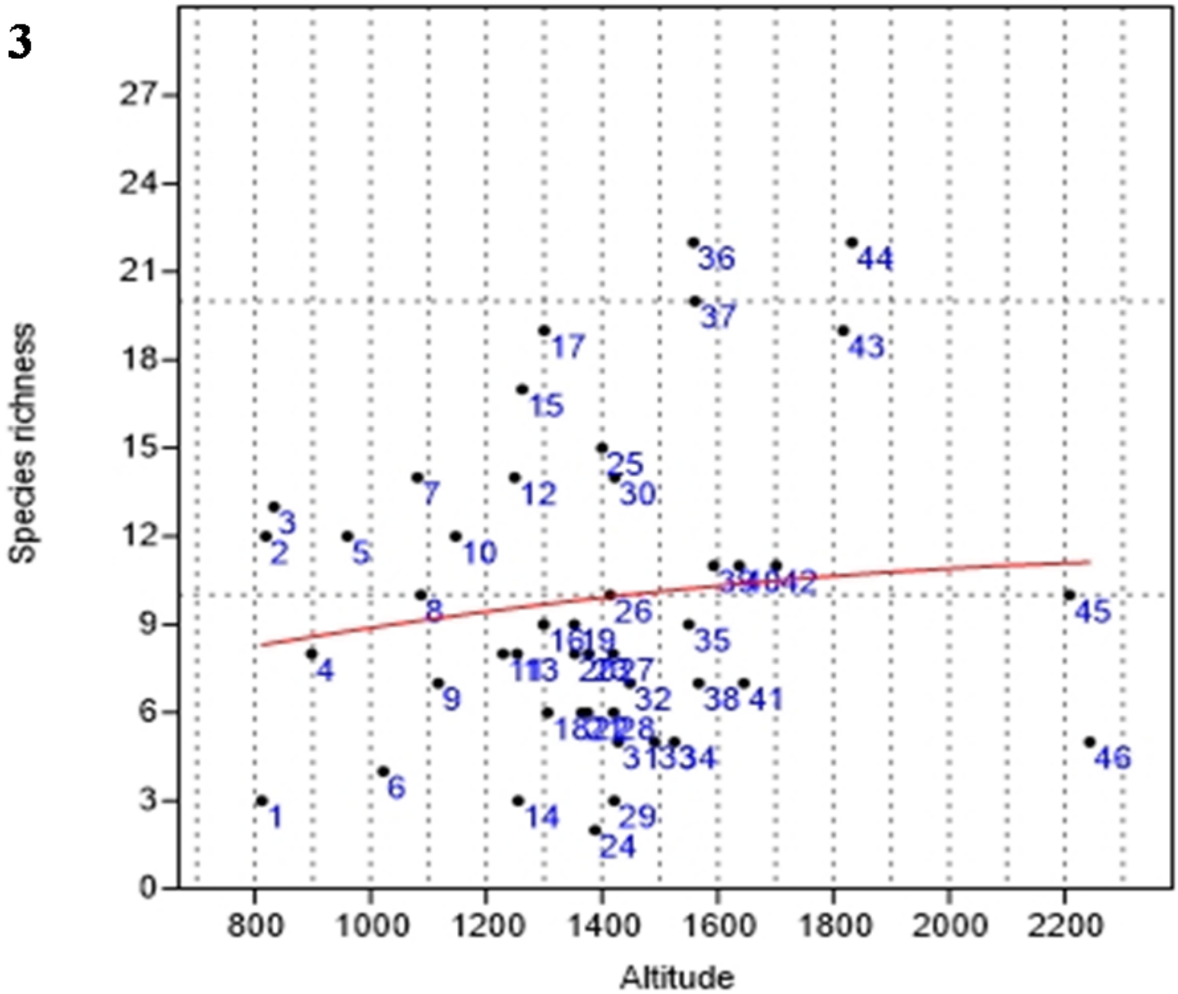

Fig. 3. Polynomial regression analysis between altitude and species richness of lichens (Y = -9.096-07x2+0.0047x+5.052, r2= 0.016, p=0.70).

Tab. 4. Pearson's Correlation Coefficient between different variables. *ALT* Altitude, *SR* number of lichen species or species richness, *F* number of families, *H'* SHANNON-WIENER Index or alpha diversity, *D'* SIMPSON's Diversity index, *CD* Concentration of dominance (Simpson's index)].

	ALT	SR	F	H'	D'	CD
ALT	1.000					
SR	0.125	1.000				
F	0.137	**0.923****	1.000			
H'	0.051	**0.845****	**0.936****	1.000		
D'	0.135	**0.919****	**1.000****	**0.935****	1.000	
CD	-0.062	**-0.730****	**-0.831****	**-0.945****	**-0.831****	1.000

**Correlation is significant at the 0.01 level (2- tailed)

The floristic composition of lichens over the monuments shows same pattern of distribution in majority of monuments. The microlichens were found growing abundantly up to 1–1.5 m from basal part and top most part of the monuments, while some scattered patches were also observed in the middle vertical part of the monuments. Macrolichens were found considerably in higher amounts and growing all over the monuments in both vertical as well as horizontal surfaces which are exposed to sun.

Though the distribution of lichens was observed from bottom to top of the monuments at outer portion of each wall, the majority of monuments showed that distribution and diversity of lichens were comparably higher at east facing walls. In most of

Fig. 4. Unequal distribution of lichens in different faces of Badrinath Chhatgulla temple. a. East face, b. South face.

the monuments distribution of lichens was confined to three faces/sides (viz. east, west, north) while the fourth face/side (south) was rarely colonized by lichens. The presence of lichens on a particular face/side is simply due to light availability, moisture content and wind blow directions which create a gradient of microclimatic conditions and are responsible for varying number of lichens in different faces/sides (Fig. 4).

Discussion

The detrimental effect of lichens on stone work is generally accepted across the world – a phenomenon reputedly first reported by the Scottish lichenologist LINDSAY in 1856 (NIMIS & al. 1992), and scientists and conservationists are pretty concerned over the effects of lichens on architecturally important buildings and monuments (NIMIS & al. 1992). It is well known that all the monuments dwelling biota either they are thallophytes or higher plants perform the deteriorative activity and contribute in the irreversible loss of substrates by means of physical and chemical alterations. A number of publications regarding monuments and lichens suggest their biodeteriorative activities on monuments (SEAWARD 1988; TIANO 1993, 1998; RÍOSA & al. 2009). But a question raised by the geologist GEIKE back in 1893 (MOTTERSHEAD & LUCAS 2000), whether a stone deteriorates less rapidly with lichen cover than without it, has opened a debate, whether we should eradicate lichens from the monuments or leave them there. Besides being protected by lichen cover, these monuments also provide shelter to several interesting species which have chosen these cultural heritages as their home. Hence, the big question what to be conserved – either the lichen (biodiversity) or the monument (cultural heritage) – has raised a conflict between the nature conservationists and the monument conservators.

Consequently, it is a quite challenging task whether the lichen diversity should be preserved on monuments as these are the home for new species and new records, or the significant cover of common lichens such as *Lecanora*, *Buellia* and *Caloplaca*, on historical monuments needs to be eradicated by appropriate methods without any damage to these monuments.

As part of the natural environment monuments will be affected by consistent activity of biotic and abiotic components when exposed, and that will definitely assault the integrity and intactness of monuments, which is beyond our control. Lichens, which are treated as culprits of monuments, will perform this role very efficiently because of their capability of succession on bare surface at first. This capability of lichens supported by favourable surrounding environment, undisturbed substrate and habitat conditions, makes their survivorship longer when living on monuments. Hence, in our opinion the presence of lichens on monuments can be considered in a positive way since they attract not only the scientists and historians but also laymen to the confluence of ecological heritage and cultural heritage and this understanding and approach of laymen to get to know and understand science, substantiate the actual meaning of science. Besides this, these cultural heritages are acting as a treasure house of several interesting species.

Conservators are quite anxious to preserve our architectural heritage by either vigorously removing lichen cover or treating the monuments with chemicals; but in both ways they are accelerating erosion rather than safeguarding that which they are most anxious to protect. In India Archaeological Survey of India (ASI) has all the rights to conserve and protect cultural heritages of India from biotic stresses; the process of eradicating the lichens from the monuments by chemicals or other means has never came out as a successful tool and re-colonization of lichens was noticed after sometime. Even Environmental Impact Assessment (EIA) needs to be done before eradicating any organisms from the monuments, because like in our study, a monument can be a home for some new species or new records.

To overcome this challenge it is highly required to discuss this matter at the same table among monument conservators as well as lichen experts and nature conservationists to develop any technique and its implementation in welfare of both, monuments and lichens, i.e. cultural and ecological heritage.

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