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Original research article

A comprehensive floristic account of the lichen flora across various forest stands in the Kumaun Himalaya

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Abstract: The Indian Himalayan region, especially Kumaun Himalaya, hosts diverse forest ranges from tropical to alpine zones, offering extensive habitats for various lichen species. Lichen is a symbiotic association of an alga and a fungus, living together in a close, interdependent relationship. They are pioneers in forest succession, colonizing disturbed areas and aiding soil formation by breaking down substrates and trapping organic matter. Lichens serve multiple ecological and practical purposes. Some birds utilize them as nesting material, while musk deer and tailless mice used as silage among lichens in alpine regions. Additionally, various lichen species are valued for their applications in spices, dyes, perfumery and traditional medicine. This study examined lichen diversity across five forest stands in Kumaun, identifying 40 species from 17 genera and 8 families. The highest diversity was found in the high-altitude *Quercus floribunda* forest, with 31 species, followed by *Q. leucotrichophora*, which had 18 species. After *Q. floribunda*, followed by *Q. leucotrichophora* forest and *Alnus nepalensis* were preferred by lichen taxa. The study concluded that within the altitudinal range of 1200m to 2200m, *Q. leucotrichophora* forest and *Alnus nepalensis* (Nepalese Alder) were identified as important alternative tree phorophytes for lichen taxa.These two species supported a higher diversity of lichen growth compared to other tree species across the five forest stands examined in the study area, likely due to their bark characteristics and microhabitat conditions that influence lichen colonization. This finding underscores the ecological importance of these tree species in supporting lichen diversity and conservation within mid-altitude Himalayan forests.

Keywords: Conservation, ecological significance, forest types, Kumaun Himalaya, lichens.

Introduction

Lichens are a unique life form of symbiosis between two components i.e. fungi (mycobiont) and algae (photobiont). They are considered to be the most primitive colonizers of terrestrial habitats of the earth. Lichens are included in the fungal kingdom, but have members of other two kingdoms; Bacteria and Chromista (Cavalier-Smith *et al.* 2016). The peculiar structure and distinctive physiology of lichens enables them to colonize in various climatic conditions. Many secondary metabolites are synthesized by the fungus, which are unique to lichen symbiosis. Recently, Spribille, *et al.* (2016) defined lichens are constituted of not two but three symbiotic partners- an ascomycetous fungus, a photosynthetic alga and unexpectedly, a basidiomycetous yeast. Tournefort in 1700 A.D. proposed lichen (a Greek word) as one of the genera of plant entities. Lichen refers to the superficial growth on the bark of olive trees. It is estimated that about 25,000 species of

lichens inhibit over 10% of the terrestrial surfaces from arctic to tropical regions and from plains to the mountain peaks on the earth (Muggia, *et al.,* 2013). In India, mostly Himalayan region from temperate to alpine area lichens grow luxuriantly on bark of trees (corticolous), rocks (saxicolous) and on soil surface (terricolous). On the basis of their morphological features or growth forms, lichens are foliose (leafy, branched, lobed and spread over the substratum); fruticose (branched, long hair-like structure, hanging from the trees and attached with the substratum with a single attachment), crustose forms (crust like structure); squamous forms (powdery) etc.

Lichens are economically important as spices, perfumery, dyes, medicines, and in some beverage. Some species of lichens are used as fodder particularly for musk deer, tail less mouse and also certain birds use lichen to make their nests. Lichens are very slow growing plants and play a significant role in forest succession because they are pioneer. Ecologically, lichens are best indicator of air pollution, forest nitrification, acidification, important tool to study climate change and lichenometry. The present study aims to raise awareness among the local community about the ecological significance of various lichen species in five major forest areas of Kumaun and emphasize their importance in lichen conservation.

Materials and Methods

Study area: The study was conducted in five forest types of Almora district, Kumaun Himalaya, located between 29°30'N to 30°20'N and 79°20'E to 80°20'E at altitudes of 1200 m-2200 m. Almora, a hilly district in mid-Kumaun, Uttarakhand, is known for its rich cultural traditions and diverse plant use. The forest types studied include *Quercus floribunda, Q. leucotrichophora, Pyrus pasia, Alnus nepalensis,* and *Pinus roxburghii*, situated in the Lamgara and Hawalbag blocks of Almora (Figure 1). Lichen samples were collected from *Quercus floribunda* (Tilonj oak/green oak) stand which is located in Morunaula forest, Lamgara block, at 1800m-2200m altitude, about 65km from Almora. This protected area is dominated by *Q. floribunda*, with vegetation including *Cedrus deodara*, *Rhododendron arboreum*, and *Alnus nepalensis*. Samples were also collected from an *Alnus nepalensis* (Utis/alder) stand at Dol Ashram, along the Almora-Lamgara Road, about 45 km from Almora, as well as from a *Pyrus pasia* (Mehal) stand in Kasar Devi, near Kasar Jangal on the Almora-Takula Road, at 1500m-1800m altitude. A *Quercus leucotrichophora* (Banj oak/white oak) forest was studied at Shitalakhet (1400m-1600m altitude) in the Hawalbag block, 45 km from Almora, with accompanying species including *Myrica esculenta*, *Pyrus pasia*, and *Rhododendron arboreum*. A *Pinus roxburghii* (Chir-pine) dominated forest was also studied at Katarmal area on the Almora-Ranikhet Road, at 1200m-1400m altitude, about 30 km from Almora.

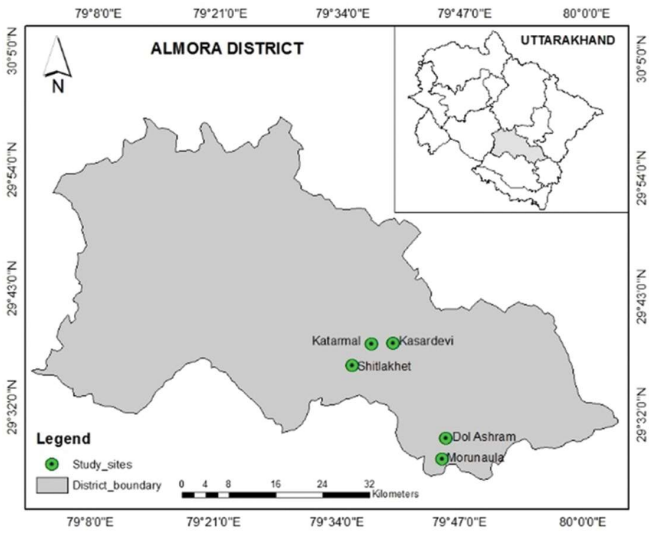
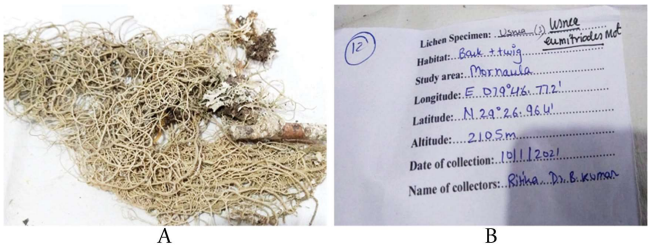


Fig. 1. Location map of collection sites.

Collection of lichen specimens: Field surveys were conducted across five forest stands to inventory macrolichen taxa. Lichen specimens were collected from tree phorophytes, rocks, and soil, with all collection sites marked by GPS. The sampling method followed Awasthi (2007). Although macrolichen are visible to the naked eye, a 10x hand lens was used to examine the lichen thallus structure to confirm identification during collection (Figure 2A). A chisel and hammer were used for precise extraction of specimens. All samples were placed in 6x12 inch polyethylene bags for transport. Specimens were gathered for herbarium preparation and later identification. Major tree and shrub species hosting



A B

Fig. 2. Lichen herbarium- A: Sample of *Usnea eumitrioides* collected from Mornaula forest; B: Herbarium packet (17 cm x 10 cm).

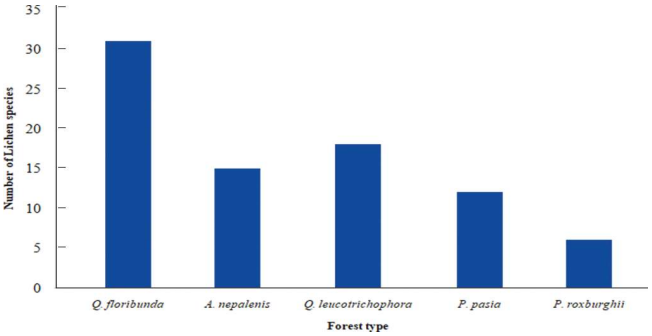


Fig. 3. Lichen species recorded in the study area.

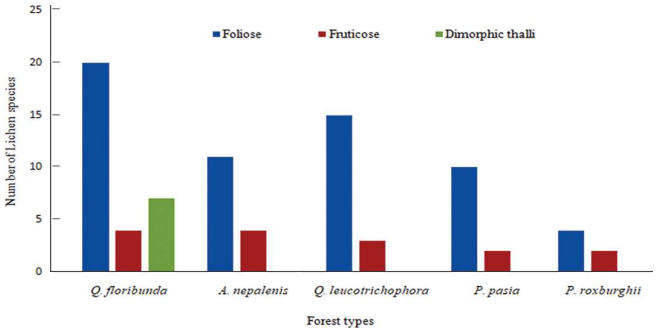


Fig. 4. Lichen species showing there growth forms in the study area.

the lichens were also recorded. Specimens were collected from various forest stands, altitudinal zones, and substrates to ensure a comprehensive representation of the local lichen diversity.

Preparation of lichen herbarium: Herbarium packets (17cm x 10cm) were prepared for each lichen species, labelled with details such as species name, growth form, collection date, collector, host, latitude, longitude, and altitude (Figure 2B). Specimens were identified morphologically using literature, and some were identified using chemical and anatomical techniques. Voucher specimens are preserved at the Biodiversity Conservation Laboratory, Department of Botany, Soban Singh Jeena University, Almora.

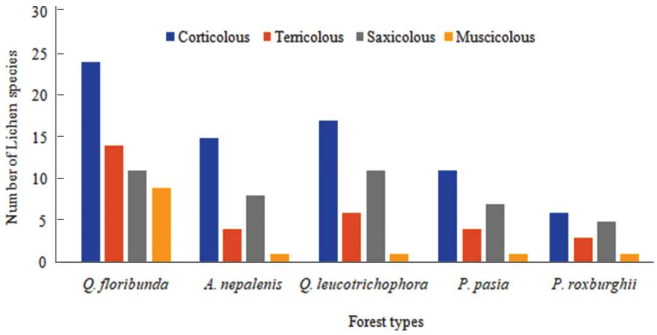


Fig. 5. Lichen species showing their habitat preference in the study area.

Identification of lichen taxa: All collected lichen specimens were identified through the examination of their morphology, anatomy, and chemical properties. Key references for the identification of Indian lichen taxa included Awasthi's works (1988, 1991, 2000, 2007), as well as the comprehensive taxonomic descriptions and identification keys provided by Divakar and Upreti (2005) and Nayaka (2004). In addition to literature-based identification, the specimens were also analysed and verified at the Lichenology Laboratory, CSIR-National Botanical Research Institute in Lucknow, Uttar Pradesh (India).

Data analysis: A standardized ecological method, as described by Ambasht and Ambasht (2002), was employed to analyse the data collected from various forest stands within the study area.

Results

A total of 40 lichen species, representing 17 genera and 8 families, were recorded across five forest types in the Kumaun Himalaya (Table 1). The highest diversity was found in the high-altitude *Q. floribunda* forest represented by 31 species at 1800m-2200m altitude, followed by the *Q. leucotrichophora* forest (18 species) at 1400m-1600m altitude. Two forest stands- *A. nepalensis* and *P. pasia* located at the same altitude range of 1500m-1800m in different areas were found to harbor 15 and 12 species of lichens, respectively. The lowest diversity was in the *Pinus roxburghii* stand at 1200m-1400m, with only six species recorded (Figure 3). Of the 40 lichen species recorded, the majority (29 species) exhibited foliose growth forms, followed by seven with dimorphic thalli and four with fruticose forms (Figure 4).

Table 1. Occurrence of different lichen species in various forest strands of the study area.

Name of species	Family	Substratum	Growth form	Occurrence of lichen species in different forest stands				
				Q. floribunda	*A. nepalensis*	*Q. leucotrichophora*	*P. pasia*	*P. roxburghii*
Bulbothrix setschwanensis (Zahlbr.) Hale	Parmeliaceae	C, S, T	Foliose +	+	+	+	-	
Cetrelia cetrarioides (Del. ex Duby) W. Culb. & C. Culb.	Parmeliaceae	C	Foliose +	+	-	-	-	
Canoparmelia texana (Tuck.) Elix and Hale	Parmeliaceae	C	Foliose +	+	-	-	-	
Cladonia cartilaginea Müll. Arg.	Cladoniaceae	C, M	Dimorphic thallus	+	-	-	-	-
C. coniocraea (Flörke) Spreng.	Cladoniaceae	C, M	Dimorphic thallus	+	-	-	-	-
C. fruticulosa Kremp.	Cladoniaceae	M, T	Dimorphic thallus	+	-	-	-	-
C. furcata (Huds.) Schrader	Cladoniaceae	M, T	Dimorphic thallus	+	-	-	-	-
C. pyxidata (L.) Hoffm.	Cladoniaceae	M, T	Dimorphic thallus	+	-	-	-	-
C. subradiata	Cladoniaceae	T	Dimorphic thallus	+	-	-	-	-
C. verticillata (Hoffm.) Schaerer	Cladoniaceae	T	Dimorphic thallus	+	-	-	-	-
Dermatocarpon vellereum Zschacke	Verrucariaceae	S	Foliose -	-	-	+	-	
Everniastrum cirrhatum (Fr.) Hale ex Sipman	Parmeliaceae	C	Foliose +	+	+	+	-	
E. nepalense (Taylor) Hale ex Sipman	Parmeliaceae	C	Foliose +	+	+	+	-	
Flavoparmelia caperata (L.) Hale	Parmeliaceae	C, S, T	Foliose +	+	+	+	+	
Heterodermia boryi (Fée) Kr.P. Singh & S.R. Singh	Physciaceae	C, M, T	Foliose +	-	-	-	-	
H. comosa (Eschw.) Follmann & Redón	Physciaceae	C, S	Foliose +	+	+	+	-	
H. diademata (Taylar) D. D. Awasthi	Physciaceae	C, S, T, M	Foliose +	+	+	+	+	
H. himalayensis (D.D. Awasthi) D.D. Awasthi	Physciaceae	C, S	Foliose +	-	+	-	-	
H. hypocaesia (Yasuda) D.D. Awasthi	Physciaceae	C, S, T	Foliose +	-	-	-	-	
H. incana (Stirt.) D. D. Awasthi	Physciaceae	C. M	Foliose +	-	-	-	-	
Leptogium burnetiae C.W. Dodge	Collemataceae	C, M	Foliose +	-	-	-	-	
Myelochroa aurulenta (Tuck.) Elix and Hale	Parmeliaceae	C, S	Foliose +	-	-	-	-	
Parmotrema austrosinense (Zahlbr.) Hale	Parmeliaceae	C,S,T	Foliose +	+	+	+	+	
P. hababianum (Gyeln.) Hale	Parmeliaceae	C	Foliose -	-	+	-	-	
P. praesorediosum (Nyl.) Hale	Parmeliaceae	C	Foliose -	-	-	-	+	
P. rampoddense (Nyl.) Hale	Parmeliaceae	C	Foliose -	-	-	+	-	
P. ravum (Krog and Swinscow) Sérus.	Parmeliaceae	C	Foliose -	-	+	-	-	

P. reticulatum (Taylor) M. Choisy	Parmeliaceae	C	Foliose	+	+	-	-	-
P. tinctorum (Despr. ex Nyl.) Hale	Parmeliaceae	C	Foliose	+	+	+	+	-
Peltigera canina (L.) Willd.	Peltigeraceae	T	Foliose	+	-	-	-	-
P. praetextata (Flörke) Zopf	Peltigeraceae	T	Foliose	+	-	-	-	-
Phaeophyscia hispidula (Ach.) Moberg	Physciaceae	C, T	Foliose	+	-	-	-	-
Punctelia rudecta (Ach.) Krog	Parmeliaceae	C, S, T	Foliose	-	-	+	-	-
P. subrudecta (Nyl.) Krog	Parmeliaceae	C, S, T	Foliose	-	-	+	-	-
Pyxine berteriana var. *himalaica* D.D. Awasthi	Physciaceae	C	Foliose	-	-	+	-	-
P. sorediata (Ach.) Mont.)	Physciaceae	C	Foliose	-	-	+	-	-
Ramalina conduplicans Vain.	Ramalinaceae	C, S	Fruticose	+	+	+	+	+
R. sinensis Jatta	Ramalinaceae	C, S	Fruticose	+	+	+	+	+
Usnea eumitrioides Motyka	Parmeliaceae	C	Fruticose	+	+	-	-	-
U. orientalis Motyka	Parmeliaceae	C, S	Fruticose	+	+	+	-	-

where C=Corticolous, T= Terricolous, S= Saxicolous, M= Muscicolous

Lichen diversity across different forest stands of the study area:

High Altitude Quercus floribunda stand: This forest type, located at a high altitude, exhibited the highest lichen diversity among the studied sites. Total 31 species were recorded here, indicating that the environmental conditions at this altitude are particularly conducive to lichen growth. The dominant species found in this area reflect the adaptability of lichens to cooler and potentially more humid conditions typically found at higher altitudes.

Alnus nepalensis stand: 15 species of lichens were recorded in the *A. nepalensis* forest. This intermediate altitude forest stand supports a moderate diversity of lichens, indicating that while it is not as rich in species as the high-altitude *Q. floribunda* forest, it still offers a favourable environment for a variety of lichen species.

Quercus leucotrichophora stand: In this forest type, 18 species of macrolichen were recorded. The second highest diversity was observed in this mid altitude *Q. leucotrichophora* forest. The presence of a significant number of species advocates that this forest type, despite being at a middle altitude, provides a suitable habitat for a variety of lichens, possibly due to its specific microclimatic conditions and substrate availability.

Pyrus pasia stand: In this site, 12 species of lichen were recorded. Following *Quercus* species, *Pyrus pasia* also supports a rich association of 12 lichen species. In the Himalayan region, particularly in temperate zones, *P. pasia* is often cultivated, and its rough bark provides an ideal substrate for epiphytic lichens. The study also observed that the sun-facing sides of older *P. pasia* trees exhibit a luxuriant growth of corticolous lichens, indicating the tree's significance in fostering lichen diversity.

Low altitude Pinus roxburghii stand: This site recorded the lowest diversity, with only six species being found, namely *Flavoparmelia caperata*, *Heterodermia diademata*, *Parmelia austrosinense*, *Parmelia praesorediosum*, *Ramalina conduplicans*, and *Ramalina sinensis*. The limited diversity at this site proposes that the *P. roxburghii* stand may not offer ideal conditions for lichen growth, potentially due to factors such as lower humidity, limited substrate availability, or other ecological constraints. Here the lower diversity observed compared to other sites could be attributed to specific ecological factors or the distinct characteristics of the bark of *P. roxburghii* trees, which may not provide optimal conditions for supporting lichen diversity, apart from a few foliose species. No Usneoid lichens were observed in this lower-altitude forest.

Discussion

Overall, the study underscores the significant role of altitude and forest type in shaping lichen diversity in the Kumaun Himalaya. The variation in temperature, humidity, and light availability with increasing altitude creates unique microhabitats that support diverse lichen communities (Kumar *et al* 2022). High-altitude forests, particularly those dominated by *Q. floribunda* (oak), offer the most favorable conditions for a wide variety of lichen species. Two fruticose species, *Cladonia subradiata* and *C. verticillata*, along with two foliose species, *Peltigera canina* and *P. praetextata*, were observed exclusively in the higher-altitude *Q. floribunda* forest. These species were found only on the soil surface. The presence of these four lichen species exclusively in the *Q. floribunda* forest shows their ecological significance as key indicators for the entire study area. Their restricted distribution to this higher-altitude forest, particularly on the soil surface, indicates specific environmental conditions, such as moisture, soil composition, and microclimate, that are unique to this habitat. This finding displays the role of *Q. floribunda* forests in supporting specialized lichen communities particularly terricolous type and evoke that these species could serve as bioindicators of forest health and habitat quality in the region.

The dense canopy, coupled with cooler temperatures and higher moisture retention in particularly oak forests, creates an ideal environment for both epiphytic and terrestrial lichens (Kumar and Upreti, 2008). These findings also thrust the importance of conserving high-altitude oak-dominated forests to preserve lichen diversity, which plays a crucial role in maintaining ecosystem health and stability. Lichen taxa in the study area exhibited a distinct preference for specific habitats, with the highest species diversity observed in the high-altitude *Q. floribunda* forests. Kumar and Upreti (2008) also mentioned that the specific bark characteristics of *Q. floribunda*, create an optimal environment for lichen growth. In contrast, lower diversity was recorded in other forest types, particularly in the *P. roxburghii* stands, indicating that these habitats may offer less favorable conditions for lichen colonization and proliferation.

The study also categorized lichen species based on their substrate preferences (Figure 5). The majority of the identified lichen species (32) were corticolous, meaning they primarily inhabit tree bark, which is consistent with the high diversity observed in forested areas.

A notable portion of the lichen species (16) were terricolous, growing on the soil surface, and another 12 species were saxicolous, preferring rocky substrates. Interestingly, a smaller group of nine species was found growing in association with mosses, a category known as muscicolous lichens, indicating a more specialized ecological niche within the study area. These findings emphasize the importance of substrate type in influencing lichen diversity and distribution within different forest stands.

The higher elevation *Q. floribunda* forest stand supports a notably high diversity of lichens, making it an excellent tree phorophyte in this region. The abundance of corticolous lichens on bark is influenced by factors such as bark texture, nutrient content, and pH (Barkman, 1958; Wirth, 1995). In this study, *A. nepalensis* and *P. pasia* were identified as deciduous species. According to Wirth (1995), the bark of deciduous trees typically has lower acidity compared to evergreen species, though this varies with species, ranging from pH 4.9 to 7.5, which may affect lichen colonization.

Lichens, which grow slowly at rates ranging from less than 1mm to 500mm per year (Seminara, 2018), are particularly vulnerable in this region due to frequent forest fires. These fires pose a significant threat to terricolous (on soil) and saxicolous lichens that inhabit rocks, as well as corticolous species that grow on the bark of tree trunks and shrubs. In addition to the impact of forest fires, the lichen species in this area are also threatened by the regular collection of fodder and fuelwood by local communities. These activities disrupt the delicate balance of the ecosystem and threaten the survival of lichen species, which play a crucial role in forest succession and the overall biodiversity of the region. Therefore, it is essential to raise awareness among local people about the importance of lichen flora and its contribution to the health and sustainability of forest ecosystems.

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