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Colonization Dynamics of Lichens Along Altitudinal Gradients in the Kumaun Himalaya, India

Pooja Bisht[1] **and Balwant Kumar**[1]*

[1]*Department of Botany, SSJ University Campus, Almora-263 601, India*

*Corresponding Author. Email: drbalwantkumararya@gmail.com

https://orcid.org/0009-0001-5584-7386 (Pooja Bisht)
https://orcid.org/0000-0001-6566-2302 (Balwant Kumar)

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ABSTRACT: Despite ecological relevance and susceptibility to environmental change, the Kumaun Himalaya, a biologically rich region of Uttarakhand, has received scant attention on the diversity and dynamics of lichens. In this context, the goal of this study was to examine the distribution and variety of lichens in the Hawalbagh block region of Kumaun Himalaya. For this purpose, lichen samples were collected between 1400 and 2200 m in altitude to document their diversity and distribution patterns using a stratified random sampling method. The study area was categorized into three elevation zones: lower elevation (1000-1400 m) dominated by pure pine forest; middle elevation (1400 - 1800 m) was characterized by pine-oak mixed forest, and the higher elevation (100-2200) forest zone was dominated by oak trees. An extensive field survey was conducted to collect primary data. During the study, a total of 46 species of lichen belonging to 29 genera and 12 families were encountered. Maximum 60.87% species were found as foliose, followed by crustose (19.57%) and fruticose (15.22 %) lichens. Whereas dimorphic, squamulose, and fruticose forms of lichen contributed 2.17 %, respectively. A single species of dimorphic type (*Cladonia verticillata*) was observed on the soil surface in the higher region. During the field survey, it was also observed that lopping of *Quercus* trees for fuel and fodder, increasing tourism activity, construction of motorable roads and resorts, particularly in the high-altitude region at Shitlakhet-Syahi Devi, frequent occurrence of forest fire, and grazing at middle and lower altitudes in pine forests, provide a threat to the lichen taxa of the region. Besides heavy anthropogenic activities, lichens on soil and rock surfaces, even on lower regions of tree trunks, are also threatened by their survival. This study suggests that habitats should be protected to support the lichen flora along with other vegetation of the region. It would be helpful to prevent the colonisation of several terricolous and saxicolous lichens on ground and rock surfaces, which are declining due to frequent occurrence of forest fires in the lower reaches of the study area.

Keywords: Lichen diversity, Forest types, Altitudinal gradient, Bioindicators, Kumaun Himalaya.

1. INTRODUCTION

The Indian Himalayan region, which spans a large altitudinal gradient and is home to a broad range of flora and animals, is one of the world's most ecologically varied and geologically dynamic mountain ranges (Ellis et al., 2025). In the context of Kumaun Himalaya in the east and the Garhwal Himalaya in the west, the two main administrative and biogeographical divisions of Uttarakhand's Central Himalaya are the Kumaun Himalaya and the Garhwal Himalaya. The Kumaun Himalaya, which includes districts such as Almora, Nainital, Bageshwar, and Pithoragarh, is distinguished by a variety of forest types ranging from subtropical to alpine, offering ideal habitats for a broad range

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of cryptogamic diversity, including lichens (Tamta et al., 2024). Lichens are special symbiotic relationships that create a self-sustaining composite creature between a mycobiont (fungus) and a photobiont (green alga or cyanobacterium).

Lichens are among the pioneers of terrestrial ecosystems and constitute a unique group of plants consisting of two unrelated organisms, an alga and a fungus, living together in a tight symbiotic relationship (Awasthi, 2000). At the global level, lichens are an important component of terrestrial biodiversity, with thousands of species spread across several biomes, from polar to tropical locations. Their ecological significance is generally acknowledged, especially as bioindicators of environmental quality, biomonitors of air contaminants, and contributors to ecosystem stability. However, anthropogenic factors such as deforestation, urbanisation, habitat degradation, and climate change are jeopardising lichen diversity, leading to localised losses of vulnerable species (Rawat & Kumar, 2025). The Himalayan region is regarded as a lichen biodiversity hotspot because of its altitudinal complexity and diverse microclimatic conditions. Several investigations conducted in the Kumaun region have found a significant variety of lichens. Mishra & Upreti (2016) identified 246 macrolichen species from the Kumaun region, with foliose forms and families such as Parmeliaceae and Physciaceae predominating. Similarly, Maurya & Mishra (2023) also reported 199 lichen taxa in the Almora district across multiple forest locations, demonstrating high species richness and geographic variation. Studies in surrounding areas, such as the Darma Valley and Kumaun's sacred groves, have also revealed diverse lichen assemblages, highlighting the roles of host tree diversity, altitude, and microclimatic variables in lichen dispersion (Joshi et al., 2018; Chandra & Joshi, 2018). Various morphological as well as physiological characteristics of lichens and the presence of their secondary metabolites allow them to bloom in varied substrata at different localities. Muggia et al. (2013) reported approximately 25,000 species of lichens worldwide, and the Indian Himalayan region accounts for 10% of this global diversity. Based on their habitat, lichens grow over the rock surface (saxicolous, on tree bark (corticolous), and on soil (terricolous). Lichens play a significant ecological role in forest succession, species composition, and as bioindicators (Upreti, 1980). Besides, economically, they are very useful as food (spices), fodder, dyes, perfumery, cosmetics, medicines, etc. Thus, the goal of this study was to examine the distribution and diversity of lichens in the Hawalbagh block of the Kumaun Himalaya. This study aims to minimise the current research gap and to identify ecological factors that reflect lichen diversity, particularly in the Himalayan region.

2. MATERIALAND METHODS

2.1. Study Area

The current collection was made from three distinct elevation zones of a temperate forest of the Almora district, Kumaun Himalaya (Uttarakhand). These sites are located between 29°30′-30°20′N latitude and 79°20′-80°20′E longitude and range from 1000-2200 m altitude along the Almora-Ranikhet state highway. This region is well known for its diverse vegetation and various ecological conditions. The dominant forest types of the region are pure pine, pine-oak mixed, and oak mixed forests, respectively. The entire forest comes under the reserve forest and is managed by the forest department. More than 200 villages have benefited from this reserve forest. The local inhabitants collect fuelwood, fodder, litter, and some NTFPs for their own use (Figure 1).

2.2. Lichen sampling and strategy for data collection

An extensive field survey was conducted using random and stratified sampling (Upreti et al., 2015) across the three selected forest sites to document the region's lichen diversity of the region. Lichen specimens were systematically collected from a variety of substrata, including tree bark (corticolous), rocks (saxicolous), and soil (terricolous). Sampling was conducted following the standard field methods described by Awasthi (2007). For each specimen, detailed field notes were recorded, including growth form, substratum type, altitude, GPS coordinates, date of collection, and name of the collector (Figure 1). Preliminary field identification and examination of thallus morphology were performed using a 10× hand lens. At the same time, a chisel and hammer were used of carefully remove saxicolous and firmly attached specimens to avoid damage. All collected samples were air-dried and preserved in properly labelled paper packets (17×10 cm) for subsequent laboratory examination and taxonomic analysis (Figure 2).

2.2.1. Lower elevation zone (1000-1400 m)

This forest site is located at Kosi along the Ranikhet-Almora Road, approximately 12 km from Almora town (Figure 3). The area experiences substantial anthropogenic Pressure because of its proximity to human areas and traffic networks. The site is characterised by a predominantly monospecific *Pinus roxburghii* forest stand (Singh et al, 2023).

2.2.2. Middle elevation zone (1400-1800m)

The site represents a middle-elevation transition zone located approximately 18 km from Almora town along the Ranikhet-Almora and Sun Temple roads (Figure 3). The vegetation is characterized by a mixed pine-oak forest dominated by *Pinus roxburghii* and *Quercus leucotrichophora*, with a sub-canopy layer comprising *Rhododendron arboreum* and *Pyrus pashia*. Due to its proximity to transit routes and religious landmarks, the site is subject to significant anthropogenic pressure, including habitat disturbance and biomass extraction (Kumar & Khanduri, 2024).

2.2.3. Higher elevation zone (1800-2200m)

The site is situated within the temperate belt of the Kumaun Himalaya, encompassing the Shitlakhet-Syahi Devi forest range, approximately 45 km from the town of Almora. Unlike the mid-elevation zones, this site is

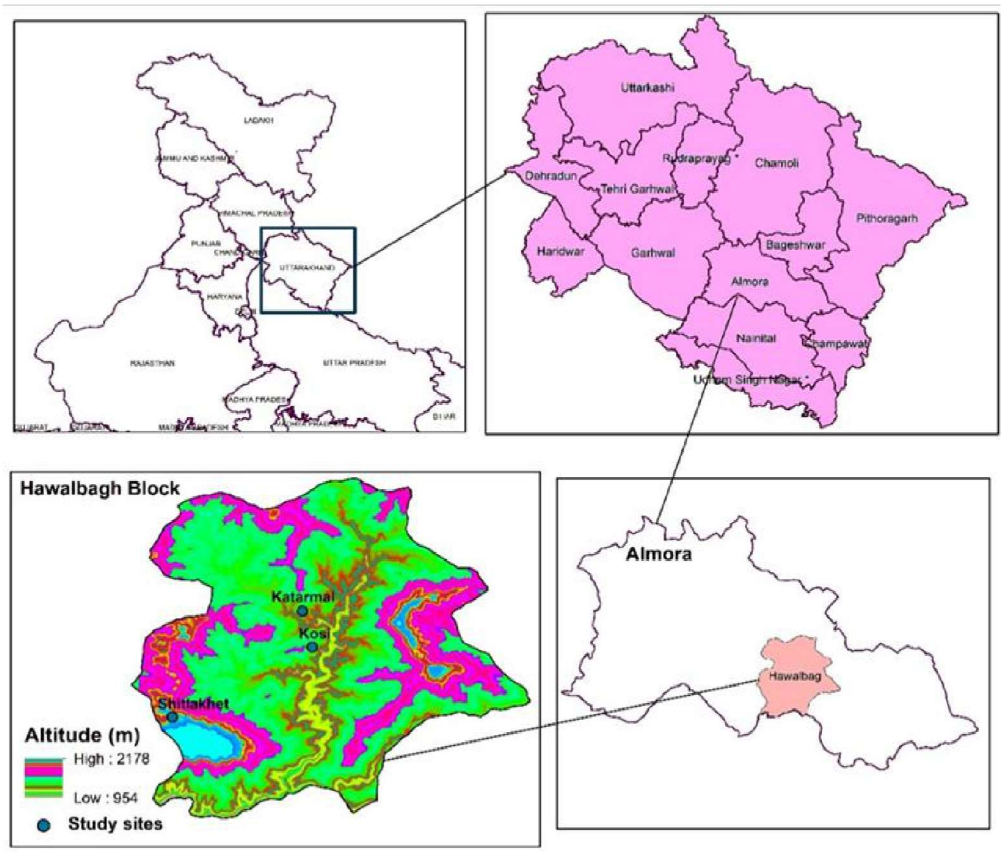

Figure 1. Location map of the study area showing the Hawalbag block of the Almora district

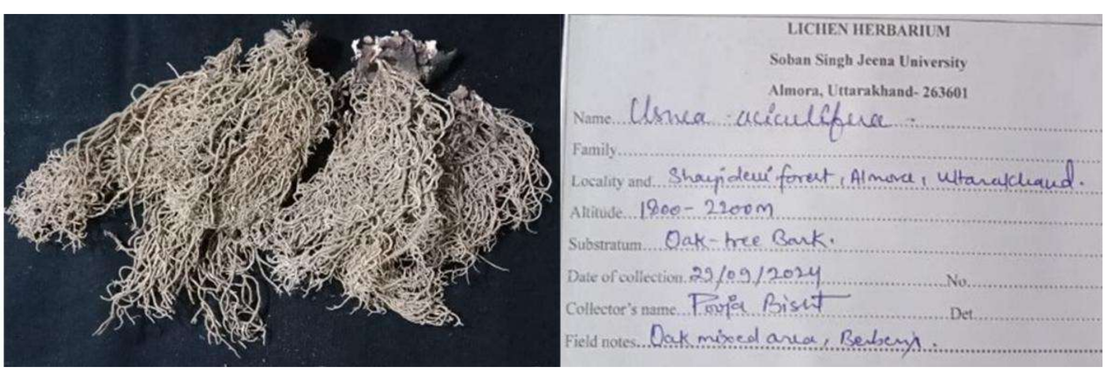

Figure 2. Herbarium sample of *Usnea aciculifera* collected from the study area

characterised by its relatively undisturbed status, largely protected by its religious significance (Syahi Devi temple) and geographical isolation, resulting in a more preserved forest structure (Figure 3).

2.3. Identification of Lichen Taxa

Lichen specimens were processed following standard herbarium protocols. Morphological, anatomical, and chemical characteristics were examined using standard lichenological techniques in the laboratory of the Botany Department at SSJ University Campus, Almora (Uttarakhand) (Figure 2). Taxonomic identification was done using keys and descriptions provided by Awasthi (2007), Divakar & Upreti (2005), and Nayaka (2004). To validate species identity, chemical analyses were performed using thin-layer chromatography (TLC) with solvent systems A and C, following the standardised methods of Orange et al. (2001).

2.4. Data Analysis

Lichen diversity was assessed by calculating species richness and distribution across altitudinal zones and forest types. For the graphical representation of the data, R software version 4.5.0 and Microsoft Excel were used. Lichen taxa were grouped by family, genus, and growth form (crustose, foliose, fruticose, and dimorphic). Comparative analyses were used to examine variation in diversity patterns across the sites.

3. RESULTS AND DISCUSSIONS

A total of 46 lichen species belonging to 29 genera and 12 families were recorded across the three forest sites of the study area (Table 3). Out of which the predominance of foliose lichens accounted for 28 species (60.87%) of the whole diversity. Besides, nine species (19.57%) of crustose lichens and seven species (15.22%) of fruticose lichens were also recorded from the area (Table 2). Squamulose and dimorphic growth types, on the other hand, were underrepresented, with only a single species, i.e., Cladonia fruticulosa, contributing 2.17% to each (Table 1). Similar observations on the distribution of different lichen species were reported by Maurya & Mishra (2023) and Mishra & Upreti (2016) from other parts of the Kumaun Himalaya. The pattern of microclimatic conditions, such as moderate humidity, optimal light availability, and stable substrates, promotes the development of larger, more physiologically complex thalli. In addition, about 19.56% of crustose forms are also contributors to the lichen colonization of the region.

Figure 3. (A). Far view of Syahi Devi forest (B). Under forest view of Syahi Devi (C). Syahi Devi Temple Forest (D). Katarmal forest far view (E). Lichen growth on the wall along the road (F). A sacred site, Suntemple at Katarmal (G). Far view of the Kosi region (H). *Drinaria aegialita* lichen on walls along the Kosi- Ranikhet road (I). Kosi River Dam in the Kosi region

Table 1. Occurrence of various lichen species in different altitudinal zones of the study area

Name of species	Family	Growth forms	Lower altitude (1000-1400m)	Middle altitude (1400-1800m)	Higher altitude (1800-2200m)
Allectraria oakesiana (Tuck) Randl. & thell	Parmeliaceae	Fruticose	-	on bark	-
Aspicilia	Megasporaceae	Crustose	-	on rock	-
Biatora vernalis	Ramalinaceae	Crustose	on rock	-	-
Blastenia ferruginea	Teloschistaceae	Crustose	-	on bark	
Buellia almorensis	Caliciaceae	Crustose	-	on bark	-
B. betulinoides	Caliciaceae	Crustose	-	on bark	on bark
Bulbothrix isidiza (Nyl.) Hale	Parmeliaceae	Foliose	-	-	bark & rock
B. setschwanensis (Zahlbr.) Hale	Parmeliaceae	Foliose	-	on bark	Bark
Caloplaca bassiae (Ach.) Zahlbr.	Teloschistaceae	Crustose	on rock	on rock	on rock
Canomaculina subtinctoria (Zahlbr.) Elix	Parmeliaceae	Foliose	-	-	on bark
Canoparmelia pustulescens (Kurok.) Elix	Parmeliaceae	Foliose	on bark	-	-
Catellaria nilgiriensis	Catellariaceae	Crustose		on rock	on rock
Cetrelia olivetorum (Nyl.) W.l. Culb. And C.F. Culb.	Parmeliaceae	Foliose	-	-	on bark &twig
Cladonia fruticulosa Kremp.	Cladoniaceae	Dimorphic	-	on soil	-
C. verticillata	Cladoniaceae	Squamulose & fruticose	-	-	on soil
Dermatocarpon vellereum	Verrucariaceae	Crustose	-	on rock	-
Dirinaria aegialita (Afzel. ex Ach.) B.J. Moore	Caliciaceae	Foliose	-	on rock	on rock
Flavoparmelia caperata (L.) Hale	Parmeliaceae	Foliose	-	on bark	on bark
Flavopunctelia borrerioides Kurok	Parmeliaceae	Foliose	-	-	on bark and twig
Hypotrachyna cirrhatum (E.Fries*).*	Parmeliaceae	Foliose	-	-	on bark
H. nepalense (Taylor) Hale ex Sipman	Parmeliaceae	Foliose	-	-	on bark
Heterodermia diademata (Taylor) D.D. Awasthi	Physciaceae	Foliose	-	-	on soil
H. japonica (M. Sato) Swinscow and Krog	Physciaceae	Foliose	-	-	on soil
H. obscurata (Nyl.) Trevis.	Physciaceae	Foliose	on rock	-	on rock
H. podocarpa (Bel.) D.D. Awasthi	Physciaceae	Foliose	-	-	on twig
Lecanora tropica Zahlbr.	Lecanoraceae	Crustose	on rock	on rock	-
Leucodermia boryi	Physciaceae	Foliose	-	-	on bark
Lobaria retigera var. retigera (Bory) Trevis.	Lobariaceae	Foliose	-	-	on soil
Nephromopsis leii	Parmeliaceae	Foliose	-	-	on bark
Parmotrema austrosinense (Zahlbr.) Hale	Parmeliaceae	Foliose	on rock	on rock	-
P. myelochroa	Parmeliaceae	Foliose	on bark	-	-
P. nilgherrense (Nyl.) Hale	Parmeliaceae	Foliose	-	on bark	-
P. reticulatum (Taylor) M. Choisy	Parmeliaceae	Foliose	on bark	on bark	on bark
P. tinctorum (Despr. Ex Nyl.) Hale	Parmeliaceae	Foliose	on bark	on bark	-
Peltigera canina	Peltigeraceae	Foliose	-	-	on soil
P. rufescense	Peltigeraceae	Foliose	-	-	on soil
Phaeophyscia hispidula (Ach.) Essl.	Parmeliaceae	Foliose	-	-	on rock
Punctelia rudecta (Ach.) Krog	Parmeliaceae	Foliose	-	-	on rock
P. subrudecta (Nyl.) Krog	Parmeliaceae	Foliose	-	-	on bark
Ramalina Conduplicans Vain.	Ramalinaceae	Fruticose	-	-	on twig
R. hossei Vain.	Ramalinaceae	Fruticose	-	-	on twig
R. sinensis	Ramalinaceae	Fruticose	-	on bark	on bark
Usnea aciculifera Vain.	Parmeliaceae	Fruticose	-	-	on bark & twig
U. florida	Parmeliaceae	Fruticose	-	on twig	-
U. orientalis Motyka	Parmeliaceae	Fruticose	-	-	on bark
Xanthoparmelia antleriformis (Elix) Elix and J. Johnst.	Parmeliaceae	Foliose	-	on rock	-

Crustose lichens are responsible for ecological tolerance and surface formation across distant habitats in forest areas (Gupta et al., 2014). As per their habitat basis, corticolous (bark-inhabiting) lichens accounted 41.30% for all the species, and also preferred to grow on various substrata. With a contribution of 26.09%, saxicolous (rock-inhabiting) lichens constitute the second largest group (Figure 4). It was followed by terricolous (soil-inhabiting) lichens about 15.22%. However, 6.52% of the species were ramicolous, meaning they colonize on host twigs (Table 2). In addition, 10.87% of the species were found to be common on tree bark and twigs (Table 2). Upreti et al. (2015) also explored the lichen flora of the Padder valley of the Jammu & Kashmir region. The study revealed the Parmeliaceae as a dominant family, represented by 110 species of lichens, including corticolous forms. Similar observations were made by Sharma & Sheikh (2010) in the J&K region. Several studies have also been carried out on factors such as bark characteristics, texture, moisture retention capacity, and chemical composition responsible for lichen establishment in temperate regions (Lõhmus et al., 2023; Borge & Ellis, 2025). Besides, the lichen family Parmeliaceae was also found to be rich in the Nanda Devi Biosphere Reserve of the Kumaun Himalaya (Rawat, 2021). However, the families Physciaceae and Ramalinaceae contribute little to the lichen diversity of the region (Awasthi, 2007; Bajpai & Upreti, 2012). The lichen family Parmeliaceae played a major role in shaping lichen diversity, contributing 50% of the region's total lichen diversity of the region (Table 1). It was followed by Physciaceae and Ramalinaceae, represented by 10.87% and 8.70%, respectively. Teloschistaceae, Peltigeraceae, and Cladoniaceae each accounted for 4.35%, while Caliciaceae comprised 6.52%. Besides, the families Catillariaceae, Megasporaceae, Lobariaceae, Lecanoraceae, and Verrucariaceae shared very few species (2.17%) of the overall diversity of lichens.

The Syahi Devi region (higher-elevation zone) *Quercus leucotrichophora* forest exhibited the highest number of lichen species, with 29 (63.04%). The assemblage was dominated by foliose and fruticose lichens, including Bulbothrix isidiza, Hypotrachyna cirrhata, Punctelia rudecta, Lobaria retigera, Peltigera canina, Ramalina hossei, and Usnea orientalis (Figures 5 and 6). The presence of multiple fruticose (Usnea and Ramalina) and foliose (Lobaria and Peltigera) taxa reflects relatively undisturbed nature and mesic microclimatic conditions of the higher region of the study area. The region provides a suitable habitat for the best association of all the growth forms of lichens, particularly for a dimorphic (*C. verticillata*), which was not observed in the middle and lower altitudinal zones. The mid-altitudinal region of Katarmal supported 20 species of 12 genera and 7 families. This community included both

Table 2. Occurrence (%) of different lichen families, genera and species of the study area

Families	Genera (%)	Species (%)
Parmeliaceae	48.28	50
Physciaceae	6.90	10.87
Ramalinaceae	6.89	8.70
Calciaceae	6.89	6.52
Teloschistaceae	6.89	4.35
Peltigeraceae	3.44	4.35
Cladoniaceae	3.44	4.35
Catellariaceae	3.44	2.17
Megasporaceae	3.44	2.17
Lobariaceae	3.44	2.17
Lecanoraceae	3.44	2.17
Verrucariaceae	3.44	2.17

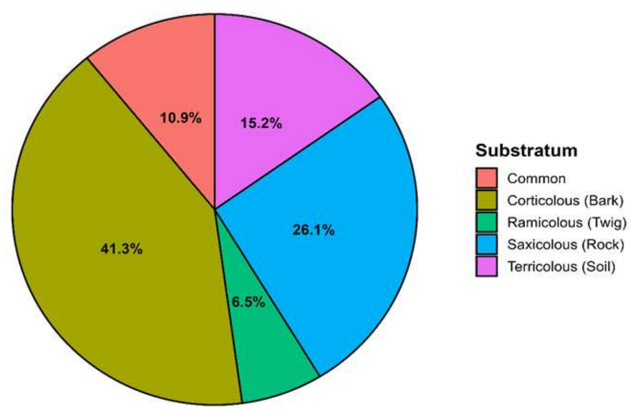

Figure 4. Illustration of species composition as per their habitat preference

Table 3. Contribution (%) of different growth forms of lichens of the study area

Growth forms	Species
Foliose	60.86
Crustose	19.56
Fruticose	15.21
Squamulose	2.17
Dimorphic	2.17

Figure 5. (A). *Dermatocapon. vellereum.* (B). *Parmotrema. austrosinense*. (C). *Dirinaria aegialita.* (D). *Nephromopsis leii.* (E). *Parmotrema reticulatum*. (F). *Heterodermia diademata*. (G). *Leucodermia boryi* (H). *Xanthoparmelia australasia*. (I). *Parmotrema nilgherrense*. (J). *Peltigera rufescense*. (K). *Usnea aciculifera*. (L). *Parmotrema tinctorum*

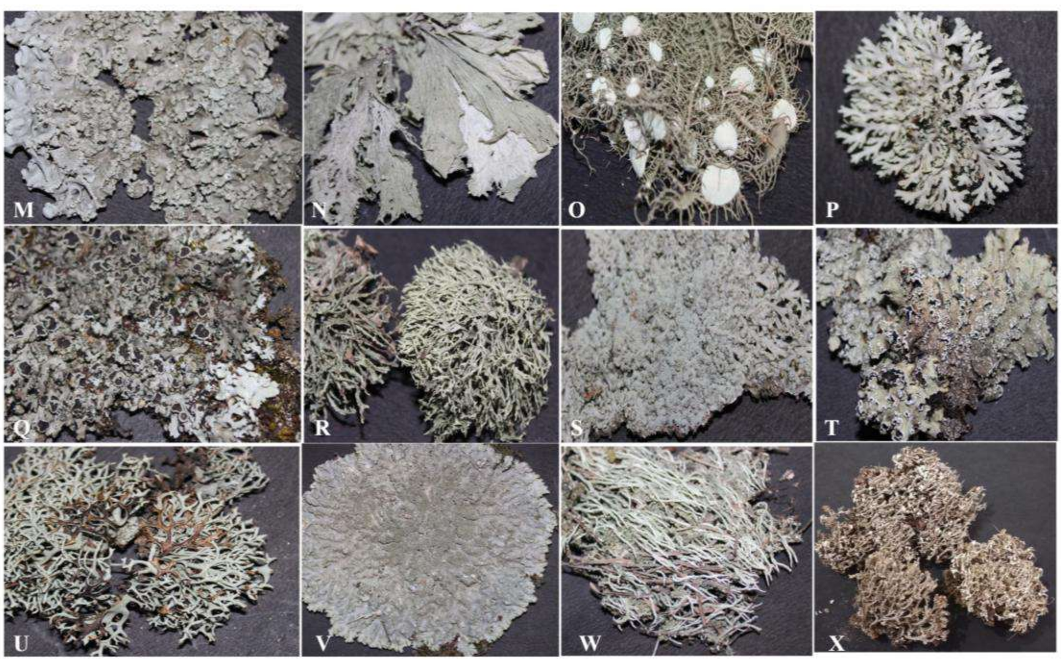

Figure 6. (M). *Flavoparmelia caperata.* (N). *Ramalina sinensis.* (O). *Usnea orientalis*. (P). *Heterodermia obscurata*. (Q). *Phaeophyscia hispidula.* (R). *Ramalina conduplicans.* (S). *Heterodermia japonica*. (T). *Flavopunctelia borrerioides*. (U). *Everniastrum nepalensis*. (V). *Punctelia rudecta*. (W). *Cladonia Fruticulosa.* (X). *Cladonia verticillata*

foliose and crustose lichens, with representatives such as *Dirinaria aegialita*, *Parmelia saxatilis*, *Heterodermia diademata*, and *Physcia tribacia* (Figures 5 and 6). Furthermore, the excellent occurrence of lichens across multiple substrates indicates ecological heterogeneity, particularly in the high-altitude region at Syahi Devi. The coexistence of pine and oak phorophytes created a mosaic of habitats that supported intermediate lichen diversity. The lower altitudinal region contributes the lowest diversity, with only nine species across six genera of four families of lichen. The assemblage was dominated by crustose and a few foliose forms, such as Lecanora tropica and Phaeophyscia hispidula. However, fruticose forms were absent in the lower-altitude region. Therefore, limited diversity was attributed to higher anthropogenic disturbance, including fuelwood collection, grazing, and tourism pressure. It was also observed that the foliose forms were found abundant, followed by fruticose and crustose forms. Fruticose lichens occurred almost exclusively at higher elevations, whereas crustose taxa were observed in higher numbers at low-altitude regions. The mid-altitude pine-oak mixed forest exhibited a transitional composition, whereas the low-altitude pine forest was depauperated. No fruticose lichens were found in the lower elevation zone. Likewise, the number of species increase with elevation, peaking in the high-altitude oak forest region. During the study, poor colonisation of squamulose and dimorphic forms was also shown. However, ecologically, these growth forms are essential for creating niches that support better colonisation and the region's overall vegetation of the region.

3.1. Higher Elevation Region (1800-2200m at Syahi Devi forest)

This forest was dominated by *Quercus* species, particularly *Q. leucotrichophora*, *Rhododendron arboreum,* and *Myrica esculenta* trees. This region exhibits the highest lichen diversity and is represented by 29 (63.04%) species of lichens. The region provides a suitable habitat for the best association of all the growth forms of lichens, particularly for a dimorphic (*Cladonia verticillata*), which was not observed in the middle and lower altitudinal zones.

3.2. Mid-elevation Region Pine-oak Mixed Forest (1400-1800m, Katarmal)

The transitional mixed forest supported 20 species (43.47%) from 12 genera (41.37%) and 7 families (58.33%). This community included both foliose and crustose lichens, with their representatives such as Dirinaria aegialita, Parmelia saxatilis, Heterodermia diademata, and Physcia tribacia. The coexistence of pine and oak phorophytes created a mosaic of habitats that supported intermediate lichen diversity.

3.3. Low-elevation Region Forest (1000-1400 m, Kosi)

This pine-dominated site recorded the lowest diversity, with only 9 species (19.56 %) across 6 genera (20.68 %) and 4 families (33.33 %) of lichens. The assemblage was dominated by crustose and a few foliose forms, such as Lecanora tropica and Phaeophyscia hispidula. However, fruticose forms were absent here. Therefore, limited diversity was attributed to higher anthropogenic disturbance, including fuelwood collection, grazing, and tourism pressure.

3.4. Lichen Species Colonization

Parmeliaceae was the most dominant family, contributing 23 species (50% of total diversity), followed by Physciaceae (6 species), Ramalinaceae (4 species), and Caliciaceae (3 species). Lichen families such as Cladoniaceae, Peltigeraceae, and additionally, two species of Teloschistaceae were represented, while five families, such as Verrucariaceae, Lecanoraceae, Lobariaceae, Megasporaceae, and Catillariaceae, were each represented by a single species (Table 1). It was also observed that the foliose growth form for lichens was the most abundant, followed by fruticose and crustose forms. Fruticose lichens occurred almost exclusively at higher elevations, whereas crustose taxa dominated at low-altitude pine forests (Table 2). The mid-altitude pine-oak mixed forest exhibited a transitional composition, whereas the low-altitude pine forest was depauperated. No fruticose lichens were found in the lower elevation zone (Table 3). Likewise, species richness increased with elevation, peaking in the high-altitude oak forest. During the study, poor colonisation of squamulose and dimorphic forms was observed due to various man-made disturbances in the region. However, these growth forms are essential for creating an ecological niche in the region to support better colonisation and forest succession.

3.5. Influences of Altitudinal Variation on Lichen Diversity of the Area

Clear variation in species richness and composition was observed along the altitudinal gradient. The lichen community assemblages in the Syahi Devi-Katarmal and Kosi corridor exhibit significant turnover driven by the altitudinal gradient (1000-2200m). However, the lower altitude is dominated by crustose forms and moisture-tolerant foliose lichen taxa. The zone acts as a transition point where anthropogenic stress and higher solar radiation limit the development of macrolichens. The mid-altitude ecotonal zone niches support both subtropical and temperate taxa (e.g. *Heterodermia* and *Bulbothrix)*. However, the higher altitudinal zone provides a high-moisture, low-temperature refugium. This zone harbours the highest number of fruticose lichens *(e.g. Usnea* and *Ramalina)* and diverse foliose communities (e.g., *Parmotrema).* The presence of dense *Quercus* canopies creates a humid microclimate that fosters complex epiphytic colonization. Table 3 depicts variations in lichen species richness along an altitudinal gradient across three sampling sites. A progressive increase in species number is observed with increasing altitude. Site-I (1200 m) recorded the lowest lichen richness, 9 (19.56% species), followed by Site-II (1600 m) with 20 species (43.47%). The highest richness was observed at Site-III (2200 m), where 29 (63.04%) lichen species were recorded. The positive linear trend shows a strong altitudinal influence on lichen diversity, indicating that higher elevations support greater species richness, likely due to more favourable microclimatic conditions and reduced anthropogenic disturbance.

4. CONCLUSION

It is the first altitudinal-based list of the lichens in the Hawalbagh region of the Kumaun Himalaya. The Sahyadri Devi forest has rich plant diversity, highly significant for medicine, fodder, fibre, timber, and wild edible plants. This study has given far-reaching data on the altitudinal distribution of lichens in Syahi Devi, Katarmal, and Kosi region forests, which will be helpful to the plant researchers, organisers, and particularly to the state forest department for developing strategies and action plans for creating procedures and activity plans for the administration of these biodiversity-rich forests. The present study not only corroborates earlier findings from the Kumaun and Western Himalaya but also fills an important gap by providing localised information on lichen diversity and distribution in the Hawalbagh block. The study underscores the importance of this region as a reservoir of lichen diversity, exhibiting the need for further detailed ecological and biomonitoring studies.

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CRediT authorship contribution statement

Pooja Bisht: Field data collection; laboratory work-lichen herbarium preparation, identification; data analysis; data curation; result compilation; writing original draft of the manuscript. Balwant Kumar: Validation; visualisation; review and editing.

Conflict of interest

The authors have declared no conflicts of interest.

Declaration of generative AI and AI-assisted technologies in the writing process

The authors declare that no generative AI or AI-assisted technologies were used to write the text, or to create or modify any figure, visuals, graphics, or data.

Data availability statement

Data collected and/or analyzed during the current investigation are available from the corresponding author upon reasonable request.

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