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Original Research Article

Lichen Biomass Distribution in Different Forest Stands of Kumaun Himalaya

Ritika Tamat, Pooja Bisht and Balwant Kumar*
Department of Botany, S.S.J. University Campus, Almora (Uttarakhand)- 263601, INDIA
Corresponding author: drbalwantkumararya@gmail.com
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Abstract: Lichens are vital components of forest ecosystems, serving as indicators of environmental quality and contributing to nutrient cycling and habitat complexity. This study assesses lichen biomass across different forest stands in the Kumaun Himalaya, a region known for its rich biodiversity and varying ecological zones. Quantitative biomass estimation was conducted in representative forest types, including pine (*Pinus roxburghii*), oak (*Quercus leucotrichophora*) and mixed broadleaf stands. Standardized sampling techniques, including stratified random sampling and destructive harvesting methods, were employed to quantify epiphytic lichen biomass. Results revealed significant variations in biomass distribution across forest types, with the highest biomass recorded in undisturbed oak-dominated forests, followed by mixed and pine stands. Factors influencing lichen biomass included canopy cover, bark texture, moisture availability, and anthropogenic disturbance. The study exhibits the ecological importance of conserving native broadleaf forests to maintain lichen diversity and biomass, which in turn support broader ecosystem functions. This study also provides a baseline for long-term monitoring of lichen dynamics in response to climate change and forest management practices in the Himalayan region.
Keywords: Lichens, biomass, forest types, altitude, Kumaun Himalaya.

Introduction

The Kumaun Himalaya, a significant section of India's Central Himalayas, is home to a variety of forest types, including temperate and subalpine coniferous stands as well as subtropical deciduous forests. A wide variety of lichen species that are suited to particular microclimatic and edaphic conditions are supported by this ecological variability (Negi, 2002). There are few quantitative evaluations of the lichen biomass in these forests, despite the known diversity. In order to comprehend the ecological contribution of lichens in terms of productivity, nutrient retention, and habitat complexity, biomass estimation is a crucial parameter (Johanson, *et al.*, 2006). In temperate and subalpine regions, the predominant forest vegetation consists of mixed oak and coniferous woods. The luxuriant growth of epiphytic lichens on the trunk (bole), branches, and twigs of both the tree phorophytes makes a substantial contribution to the biomass of litter fall on the forest floor. The Himalayas, especially the higher elevations of the Kumaun and Garhwal region, are home to a profusion of lichens. According to Upreti and Joshi (2010) more than 1200 lichen species known to exist in the Himalayas are found in Uttarakhand. The Himalayan lichens have also been the subject of several taxonomic investigations. The collection and trade of lichens provide a significant source of livelihood for communities in the high-altitude regions of Uttarakhand, such as Garhwal and Kumaun. The process begins with local collectors who collect the lichens and sell them to regional

traders. These traders then bring the produce to major markets, where it is auctioned off to large-scale traders and manufacturers for various commercial uses. However, lichens are extremely slow-growing organisms, often requiring several years to establish and form noticeable biomass. They are also highly sensitive to environmental changes, particularly air pollution, which directly affects their growth, survival, and distribution. This ecological vulnerability makes their natural regeneration rate very low. Consequently, the availability of lichen biomass, along with the known availability of commercially valuable lichen species in the region, becomes a critical issue. It not only raises concerns for biodiversity conservation but also poses challenges for the sustainable livelihood of local communities who traditionally depend on lichens for food, spices, medicinal, and economic purposes. Additionally, they are extremely vulnerable to environmental disruptions, especially air pollution, which can have a negative impact on their survival, growth, and geographic dispersion. Lichens' natural regeneration rate is still quite modest because of these biological limitations. As a result, there are serious ecological issues raised by the region's growing demand for and extraction of commercially valuable lichen species. In addition to endangering local biodiversity, the diminishing supply of lichen biomass presents problems for the long-term viability of traditional livelihood systems that rely on lichens for food, spices, medicine, and financial gain.

Material and methods

Study area: At elevations of 1200 m to 2200 m, the study was carried out in five different types of forest stands in the Almora district of the Kumaun Himalaya. The region is situated between 29°30'N and 30°20'N and 79°20'E and 80°20'E. In Uttarakhand's mid-Kumaun, the hilly area Almora is renowned for its many plants uses and rich cultural traditions. *Quercus floribunda, Q. leucotrichophora, Pyrus pasia, Alnus nepalensis,* and *Pinus roxburghii* are among the forest types that were examined. These forest stands are located in the Lamgara and Hawalbag blocks of Almora district. *Q. floribunda* (Tilonj oak/green oak) stands situated the Morunaula forest, at higher elevation of 1800 m-2200 m. *Rhododendron arboreum*, *A. nepalensis*, and *Cedrus deodara* are among the vegetation found in this protected region, which is primarily dominated by *Q. floribunda*. A *P. pasia (Mehal*) stand in Kasar Devi, next to Kasar Jangal on the Almora-Takula Road, at an elevation of 1500 m-1800 m, and an *A. nepalensis* (Utis/alder) stand in Dol Ashram, along the Almora-Lamgara Road, approximately 45 km from Almora, were also sampled. In the Hawalbag block, 45 km from Almora, near Shitalakhet (1400 m-1600 m altitude), a *Q. leucotrichophora* (Banj oak/ white oak) forest was investigated. *Myrica esculenta*, *P. pasia,* and *R. arboreum* are among the auxiliary species. At an elevation of 1200 m–1400 m, approximately 30 kilometers from Almora, a forest dominated by *P. roxburghii* (Chir-pine Forest) was also examined in the Katarmal area along the Almora–Ranikhet Road.

Collection of lichen samples: A field investigation was carried out to inventory macrolichen species in five selected forest stands. Lichen samples were collected from different substrates such as tree phorophytes, rocks, and soil of the study area. Each collection location was marked with GPS. Samples were taken in accordance with Awasthi (2007). During the field survey, the lichen thallus structure was examined using a 10x hand lens to verify identification, even though macrolichens are apparent to the unaided eye. The specimens were carefully removed from the substratum. Polyethylene bags measuring 6 by 12 inches were used to transport all of the samples. The specimens were collected in order to prepare the herbarium and then identify them. A wide range of forest stands, altitudinal zones, and substrate types were used to gather specimens in order to guarantee a thorough depiction of the local lichen variety.

Herbarium preparation and identification of lichen samples: For every lichen species, a 17 cm by 10 cm herbarium packet was prepared and labelled with information about the species, growth type, date of collection, name of collector, host/substratum type, latitude, longitude and altitude. All of the lichen specimens were identified in the laboratory by analyzing their morphology, anatomy and chemical

characteristics. For this purpose, lichen identification key was consulted (Awasthi, 2007).

Data collection

Sampling of tree phorophyte: A systematic sampling strategy was used to assess lichen biomass across five distinct forest stands (Kumar, 2008). The study focused on five ecologically significant and abundant phorophyte species viz. *Q. floribunda*, *Q. leucotrichophora*, *P. pasia*, *A. nepalensis*, and *P. roxburghii*. Thus, a total of ten replicates of each tree phorophytes were selected randomly in each of the forest stands for collecting their lichens (Table 1). This approach helped in evaluating how tree age and surface area might affect lichen distribution and abundance. Once selected, the trees were carefully examined for the presence of lichens. Lichen samples were collected from a standardized height on the tree trunk (usually at breast height or 1.37 meters from the ground) to maintain consistency in sampling. The collected lichens were then carefully scraped using sterile tools, ensuring minimal damage to the tree bark. The biomass of the collected lichen samples was measured after oven-drying them under controlled laboratory conditions and Kumar (2008) method was employed. This method provided accurate estimates of lichen biomass per tree and allowed for comparison across species and diameter classes. This sampling protocol was designed to offer a representative understanding of lichen biomass across varying tree species and their diameter size classes, thereby providing valuable insights into lichen ecology and its relationship with host trees in different forest ecosystems.

Assessment of lichen biomass: Lichen biomass (g/tree) was calculated by first counting the total number of branches on each selected tree. Three branches per tree were then randomly selected for removing their lichens. All lichens were carefully collected from all three randomly selected branches, as well as from the main trunk (bole), and packed in polybags for transport to the laboratory. To achieve consistent dry biomass, collected lichens were cleaned, allowed to air dry, and then oven-dried for 48 hours at 60°C. An analytical balance (precision ±0.001 g) was used to measure their biomass (Figure 1). The sampled trees were categorized into six different diameters at breast height (dbh) size classes to ensure variability and capture the influence of tree girth on lichen colonization and biomass. The following formula was used to calculate the biomass:

Lichen biomass on canopy region a tree phorophyte = Total biomass of lichens collected from all the three selected branches of a sampled phorophyte / Total number of branches of the sampled phorophyte

Average lichen biomass on canopy region of a tree phorophyte = Total biomass of lichens collected from all the three sampled phorophyte / Total number of sampled phorophyte

Average lichen biomass on a tree phorophyte = Average lichen biomass recorded on canopy region + Average biomass recorded on trunk portion of the phorophyte

Statistical analysis: Standard statistical protocols were used to analyze the data**.** Calculations were also done using excel software.

Fig. 1. Lichen sampling and biomass assessment.

Results

A total of 40 lichen species representing 17 genera and 8 families were recorded across five forest type in the Kumaun Himalaya (Tamta, *et al.*, 2025). During the study, lichen biomass has been studied in a total of five different forest stand types

(Table 1). Where a total of 214.3 fresh lichen biomass and 181.3 lichen dry biomass have been estimated from the 10 replicates of five different forest stands (Table 1). Among the dimeter classes, the highest biomass of lichen taxa was found on tree phorophytes having dbh class 37. 6 to 43.5cm (Figure 2). Similarly, luxuriant biomass of macrolichens was also recorded from *Q. leucotrichophora* stand which contributed by 22 macrolichen species such as *Bulbothrix setschwanensis, Cetrelia cetrarioides, Canoparmelia texana, Cladonia cartilaginea, C. coniocraea, C. fruticulosa, C. furcata, C. pyxidata, C. subradiata, C. verticillata, Everniastrum cirrhatum, E. nepalense, Flavoparmelia caperata, Heterodermia boryi, H. comosa, H. diademata, Parmotrema austrosinense, P. reticulatum, P. tinctorum, Ramalina conduplicans, R. sinensis, Usnea eumitrioides, U. orientali.* The second forest stand *A. nepalensis* has also highest biomass was found in the diameter range 37.6-43.5 cm by lichen species such as *H. himalayensis, P. hababianum, P. praesorediosum, P. ravum, Punctelia rudecta, P. subrudecta, Pyxine berteriana var. himalaica, P. sorediata, R. sinensis.* The third forest stand *Q. leucotrichophora* has less biomass recorded in the diameter range 37.6-43.5 cm. which was estimated near around 18.48 gm fresh weight and 16.51gm dry weight. The lichen species recorded in this study include *F. caperata*, *H. diademata*, *P. austrosinense*, *P. praesorediosum*, *R. conduplicans*, and *R. sinensis*. Among the phorophytes, the fourth tree stand (*P. pasia*) contributed a considerable amount of biomass, recorded within the diameter range of 37.6-43.5 cm, with approximately 11.11 g fresh weight and 8.91 gm dry weight of lichens. In contrast, the fifth tree stand (*P. roxburghii*) showed relatively poor lichen biomass within the diameter range of 49.6-55.5 cm, representing about 15.11 gm fresh weight and 12.51 gm oven dry weight of the above-mentioned species.

Phorophyte preference drives biomass dynamics in lichen communities

(a) At high-altitude *Quercus floribunda* stand: This forest type, exhibited the highest lichen diversity among the studied sites represented by 31 species (Tamta, *et al.*, 2025). The site 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 (Figure 3). A sum of 45.79 g fresh weight (Fw) and 40.55 g oven dry weight (Odw) of lichen was estimated from the high-altitude *Q. floribunda* stand. No lichen biomass was found on trees of *Q. floribunda* having more than 60.6cm dbh (diameter at breast height).

(b) Biomass on *Alnus nepalensis*: A total of 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 favorable environment for a variety of lichen species. A total fresh biomass about 30.83g and 23.08 g dry weight was estimated from the 10 different diameter trees of *A. nepalensis*.

(c) Biomass on *Quercus leucotrichophora* stand: From this forest type, 18 species of macrolichen were recorded. *Quercus leucotrichophora* estimated a total of 60.11 g fresh weight and 54.49 g oven dry weight. The second-highest diversity was observed in this mid altitude *Q. leucotrichophora* stand. 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 lichen communities, possibly due to its specific microclimatic conditions and substrate availability.

(d) Biomass on *Pyrus pasia* stand: 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 lichen taxa. 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. *P. pasia* estimated total of 28.24 g fresh biomass and 22.44 g dry biomass of lichens.

(e) Biomass on lower altitude *Pinus roxburghii* stand: This site recorded the lowest diversity, with only six species being found, namely *F. caperata, H. diademata, P. austrosinense, P. praesorediosum, R. conduplicans,* and *R.*

sinensis. The limited plant diversity at this site suggests 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. *P. roxburghii* estimated a total amount of 49.33 g fresh weight and 40.57 dry weight of several lichen species.

Analysis of lichen biomass distribution across tree diameter at breast height (dbh) classes: The study revealed distinct patterns in epiphytic lichen biomass distribution across different diameter classes of host trees, with significant variations observed among tree species. The results provide valuable facts into the optimal tree sizes for lichen colonization and growth in these forest stands (Figure 2). To examine the relationship between tree circumference and lichen production, the trees with known diameters were grouped into different diameter classes (Figure 2). Correspondingly, the lichen biomass associated with each class was recorded and arranged in the same manner. This categorization allowed for a comparative analysis of how tree size influences the availability and accumulation of lichen biomass (Figure 2).

Table 1. Biomass dynamics of lichen communities on different tree phorophytes of the study area.

Tree dbh (cm)	Lichen biomass (g)		Tree dbh (cm)	Lichen biomass (g)		Tree dbh (cm)	Lichen biomass (g)		Tree dbh (cm)	Lichen biomass (g)		Tree dbh (cm)	Lichen biomass (g)	
Q. floribunda	Fw	Odw	*A. nepalensis*	Fw	Odw	*Q. leucotrichophora*	Fw	Odw	*P. pasia*	Fw	Odw	*P. roxburghii*	Fw	Odw
38	7	4.42	35	4.02	3.8	35	5.8	5.42	35	5.45	4.98	35	8.74	7.28
36	4.28	4.08	40	5.86	4.2	38	5.93	5.08	38	3	2.65	40	5.59	5.04
38	5.81	5.1	42	3.81	2.11	40	7.81	7	40	3.76	2.34	46	4.41	3.5
40	3.23	3.31	45	2.1	1.98	42	4.74	4.43	42	4.35	3.92	50	10	8.9
45	6.56	6	48	3.36	3.1	45	8.86	7.8	45	1.92	1.2	55	5.11	3.61
42	5.23	5.02	50	1.531	1.4	49	3.73	2.68	50	2.9	1.5	60	2.05	1.39
50	2.36	2.1	56	2.49	1.33	52	6.31	6.2	54	1.06	0.96	63	1.65	1.4
60	3	2.77	62	2.2	1.1	56	4.94	4.2	60	1.74	1.1	68	2.98	2.2
50	2.77	2.52	67	2.1	1.9	58	4.87	4.6	65	1.8	1.6	70	6.25	5.95
58	5.55	5.23	70	3.36	2.16	62	7.12	7.08	70	2.26	2.19	80	2.55	1.3
Total	45.79	40.55	Total	30.831	23.08	Total	60.11	54.49	Total	28.24	22.44	Total	49.33	40.57

Fw= fresh weight; Odw= Oven dry weight; dbh= diameter at breast height; cm= centimeter; gm=gram

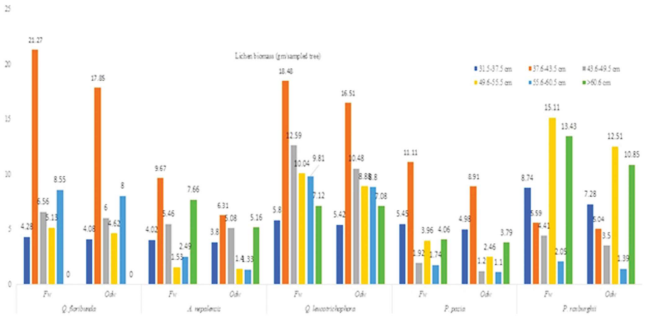

Fig. 2. Variation in lichen biomass across different phorophyte dbh classes.

Lichen biomass distribution in the 31.5-37.5cm dbh class: This range of tree diameter showed moderate lichen biomass across all studied tree species. *P. roxburghii* exhibited the highest biomass values in this class (8.74 g fresh weight; 7.28 g dry weight per sampled tree), suggesting early suitability for lichen establishment in this coniferous species. *Q. leucotrichophora* followed closely (5.8 g Fw, 5.42 g Odw), while *P. pasia* showed comparable values (5.45 g Fw, 4.98 g Odw). The lower biomass on *A. nepalensis* (4.02 g Fw, 3.8 g Odw) and *Q. floribunda* (4.28 g Fw, 4.08 g Odw) indicates these species may require larger diameters to develop optimal conditions for lichen growth.

Fig. 3. Illustration of some habitat specific lichens of the study area.

Lichen biomass distribution in the 37.6-43.5cm dbh class: This range of tree diameter emerged as the most favorable for lichen biomass accumulation across multiple species. *Q. floribunda* showed high values (21.27 gm Fw, 17.85 gm Odw), followed by *Q. leucotrichophora* (18.48 g Fw, 16.51 g Odw) in this dbh class. *P. roxburghii* maintained substantial biomass (15.11 g Fw, 12.51 g Odw), while *P. pasia* (11.11 g Fw, 8.91 g Odw) and *A. nepalensis* (9.67 g Fw, 6.31 g Odw) showed relatively lower but still significant values. This diameter class appears to represent an optimal balance of bark stability, moisture retention, and surface area for lichen colonization.

Lichen biomass distribution in the 43.6-45.5cm dbh class: Biomass values generally declined in this class, though *Q. leucotrichophora* maintained relatively high levels (12.59 g Fw, 10.48 g Odw). The sharp decrease in *P. pasia* biomass (1.92 g Fw, 1.2 g Odw) suggests this species may become less suitable for lichen growth as it exceeds 43.5 cm diameter. *P. roxburghii* showed intermediate values (4.41 g Fw, 3.5 g Odw), while *A. nepalensis* and *Q. floribunda* maintained moderate biomass levels.

Lichen biomass distribution in the 49.6-55.5cm dbh class: *P. roxburghii* showed a resurgence in this class (15.11 g Fw, 12.51 g Odw), indicating a second peak of suitability for lichen growth. *Q. leucotrichophora* maintained substantial biomass (10.04 g Fw, 8.88 g Odw), while other species showed declining trends. Notably, *A. nepalensis* exhibited minimal lichen biomass (1.531 g Fw, 1.4 g Odw) in this size range, suggesting potential changes in bark characteristics that make it less hospitable for lichens.

Lichen biomass distribution in above 55.6-60.5cm dbh class: The largest diameter classes showed species-specific patterns. *P. roxburghii* maintained high biomass in the largest class (13.43 g Fw, 10.85 g Odw), demonstrating continued suitability for lichen growth at advanced ages. *Q. leucotrichophora* showed moderate values (9.81 g Fw, 8.8 g Odw in 55.6-60.5 cm; 7.12 g Fw in above 60.6 cm), while *Q. floribunda* exhibited a complete absence of lichens in the largest diameter class, suggesting potential age-related changes in bark chemistry or physical properties that inhibit lichen growth.

Key characteristics responsible for lichen colonization, distribution and biomass variation:

1. Lower diameter of samplings and trees contributes best lichen species association.
2. The 37.6-43.5cm diameter range represents the optimal size class for lichen biomass across most species (tree phorophyte)
3. *P. roxburghii* shows bimodal peaks of lichen suitability (31.5-37.5cm and 49.6-55.5 cm).
4. *Q. floribunda* becomes unsuitable for lichen growth in the largest diameter class (>60.6 cm).
5. Biomass patterns suggest species-specific relationships between tree diameter and lichen colonization potential.

Discussion

Previous studies have documented the importance of bark characteristics in supporting diverse lichen communities. Kumar and Upreti (2008) specifically observed that the smooth twigs and branches of oak species (*Quercus* spp.) serve as

particularly favorable substrates for fruticose lichens. Their study demonstrated that these smooth surfaces provide ideal conditions for lichen attachment and growth, likely due to the combination of favorable texture, pH, and moisture retention properties characteristic of young oak bark. This finding aligns with our observations of lichen distribution patterns across different tree diameter classes, where younger branches with smoother bark consistently supported greater lichen biomass. Lichens have a wide range of functions in ecosystems, but they are particularly significant when they are prevalent, like in temperate forests where their biomass can range from 1 to 4.4 mg/ha (Berryman and McCune, 2006; Boucher and Stone, 1992). Lichens are pioneer organisms and primary producers that provide habitat, water, and nutrients to a vast network of microbes, invertebrates, and vertebrates (Gerson and Seaward, 1977). Lichens absorb nutrients from the atmosphere, including those from sources outside the ecosystem (Pike, 1978). By increasing the availability of prey, lichens' many functions have a cascading effect that links an increase in their biomass to higher abundances of top predators like spiders (Gunnarsson, 1990) and passerine birds (Pettersson, *et al.*, 1995).

Overall, the study exhibits the importance of altitude and forest type in influencing lichen biomass in the Kumaun Himalaya. The difference in temperature, humidity, and light availability with increasing altitude creates a distinct microhabitat that supports varied lichen groups (Kumar, *et al.*, 2022). High-altitude forests, particularly those dominated by *Q. floribunda* (oak), provide the ideal habitat for a diverse range of lichen species. The largest biomass of lichen species recorded in the *Q. leucotrichophora* forest demonstrates their ecological importance as a key indicator for the entire study area.

Their restricted distribution to this higher altitude forest, particularly on the soil surface, indicates distinct climatic factors such as high precipitation, soil compositions, and microclimate.

Lichen taxa exhibited distinct biomass preferences across habitats. The highest biomass was recorded in the high-altitude *Q. leucotrichophora* stand (60.11 g), followed by *P. roxburghii* at lower altitude (49.33 g) and *Q. floribunda* (45.79 g). *A. nepalensis* supported 30.83 g of biomass, while *P. pasia* showed the least (28.24 gm). Similar observations by Kumar and Upreti (2008) studied that the unique bark of *Q. floribunda* provides favorable conditions for lichen growth.

In contrast, lower biomass was determined in other forest types, particularly in the *P. pasia* forest stand at 28.24 g, indicating that these habitats might offer less favourable conditions for lichen colonization and proliferation. The bulk of the lichen biomass found on *Q. leucotrichophora* was corticolous, which means that it mostly lives on tree bark with the specified diameter. The high biomass found in forest areas is in line with this. Because of its exceptionally large biomass of lichen, the higher elevation *Q. leucotrichophora* forest stand is a great tree phorophyte in this area.

Bark texture, nutritional content, and pH are some of the factors that affect the amount of corticolous lichen on bark (Barkman, 1958; Wirth, 1995). The tree stands of *A. nepalensis* and *P. pasia* were determined to be deciduous species in this investigation. Although this varies by species, ranging from pH 4.9 to 7.5, deciduous tree bark generally has lower acidity than that of evergreen species (Writh, 1995). This may have an impact on lichen biomass and colonization.

Due to forest fires, lichen biomass, which grows slowly at rates between less than 1 mm and 500 mm annually is especially vulnerable in this area (Seminara, 2018). These fires are a serious threat to corticolous species that grow on the bark of tree trunks and bushes, as well as terricolous (on soil) and saxicolous lichens that live on rocks.

The frequent gathering of fuelwood and fodder by nearby communities poses a threat to the lichen species in this region in addition to the effects of forest fires.

The survival of lichen species and lichen biomass, which are essential to forest succession and the region's overall biodiversity, are threatened by these activities, which also upset the sensitive ecosystem's equilibrium.

Thus, it is crucial to educate the local population about the value of lichen flora and how it contributes to the sustainability and well-being of the forest environment.

Conclusion

This study exhibits the impact of host tree (phorophyte) characteristics on the distribution of epiphytic lichens by showing notable variation in lichen biomass among five tree stands in the Kumaun Himalaya. Forest management and biodiversity assessment in Himalayan ecosystems depend on an understanding of these trends. The important conclusion of this study was that each of the five tree species had a maximum lichen biomass was recorded on phorophytes having dbh between 37.6-43.5 cm. The forest's health, supported by *Q. leucotrichophora*, is indicated by its rich lichen biomass, which thrives under the dense, moist canopy. However, the absence of lichens on large *Q. floribunda* trees (over 60.6 cm dbh) exhibits the vulnerability of these ecosystems. This underscores the need to conserve high-altitude oak forests to maintain essential lichen biomass and overall ecosystem stability.

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