RESEARCH ARTICLE

New Records and Checklist of Lichens from Punjab, India

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Abstract

The paper enumerates a total of 68 species of lichens belonging to 31 genera and 19 families from the state of Punjab, of these *Chaenotheca brunneola* and *Phaeophyscia insignis* are new records for Indian lichen biota. The study utilizes visual aids such as a heatmap with dendrogram, depicting the presence or absence of lichen species and families across different districts of Punjab. A polar heatmap with dendrogram illustrates the distribution of lichen taxa across these districts, while a pie chart with distinct radius spokes showcases the presence of lichen taxa within different elevation ranges. In the present study an attempt has been made to provide a comprehensive checklist of lichens from Punjab along with the identification key and detailed description of new records.

Keywords: Biodiversity, cryptogam, distribution, taxonomy.

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Introduction

Punjab is one of the prominent northern agrarian states of India. The state recognized as the "land of five rivers," stands as a border state in northwest India, positioned between latitudes 29°30'N and 32°32'N and longitudes 73°55'E and 76°50'E. The state shares its boundaries with Pakistan to the west and the neighboring regions of Jammu and Kashmir, Himachal Pradesh, Haryana and Rajasthan (Fig. 1). The Punjab State is divided into three regions: Majha, Doaba and Malwa. The state encompasses a mere 6.49% of forested land, including 2.98% of tree cover outside of forests and 3.56% of actual forest cover (Singh *et al*., 2014). Geographically, the state can be categorized into four landform types such as Shivalik hills, Kandi, Alluvial Plain, and South-Western Sand Dune Studded Region (Gosal, 2004). The major forested areas of Punjab include the Shivalik forest, comprising sub-mountainous zones and undulating land beneath the hills in various districts. The Shivalik hills boast remarkable biodiversity, forming a broad natural green belt along the state's northeastern border adjacent to the Himalayan foothills (Gajarmal *et al*., 2020). This area accounts for about 77% of the total forest area in the state, along with the Bir Forest in Patiala and Sangrur districts and the Mand Forest, primarily surrounding wetlands in districts like Kapurthala, Rupnagar and Tarn Taran (Singh *et al*., 2014).

Lichens are renowned for their pivotal role as ecosystem pioneers and their contribution to several significant ecosystem services, such as pollution monitoring. However, lichens face threats due to habitat loss, increasing air pollution, shifting microclimates, and uncontrolled harvesting. These factors have contributed to the dearth of prior lichen diversity records in Punjab. According to Champion and Seth (1968), major regions of Himachal Pradesh (Dalhousie, Dharamshala, Chinni and Kilba Bashahr division, Kullu division, Shimla and Tosnal Parbatti valley) and Haryana (Ambala, Hisar and Karnal) were historically part of the Punjab state. Early research from the state documented only three lichen species - *Endocarpon pusillum* Hedw., *Peltigera membranacea* (Ach.) Nyl. and *Ramalina sinensis* Jatta (Singh and Sinha, 2010). Later on, 21 lichen species were reported from the Shivalik region of the state by Jerath *et al*. (2006, 2012).

Despite Punjab's limited forest cover, it sustains a rich variety of plant life, encompassing 397 algae, 948 fungi, 34 bryophytes, 48 pteridophytes and 1897 angiosperms species as documented by Edake (2015). The Punjab State Council for Science and Technology, Chandigarh (PSCST), Biodiversity Strategy Action Plan (BSAP), Punjab Biodiversity Board and Department of Forestry & Wildlife Preservation of Punjab, along with other bodies, diligently collected biodiversity data (floral and faunal) from the state during their respective tenures. However, there were no consolidated data on lower cryptogams like lichens from the state (Jerath *et al*., 2002, 2006, 2012). To establish baseline data for future lichenological research, this study provides a comprehensive checklist of lichen species from Punjab, with the key of their identification.

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Material & Methods

The present study is based on the fresh collections from the different localities of Punjab state during 2021-2023 and published literature. The specimens were collected from the Shivalik hill region ranging in elevation from 180 m to 600 m. The specimens were examined morphologically, anatomically and chemically. The morphological examination was done under a stereo zoom microscope (Leica S8APO) and the anatomical study was done by thin hand-cut sections observed under a compound microscope (Leica DM500). For

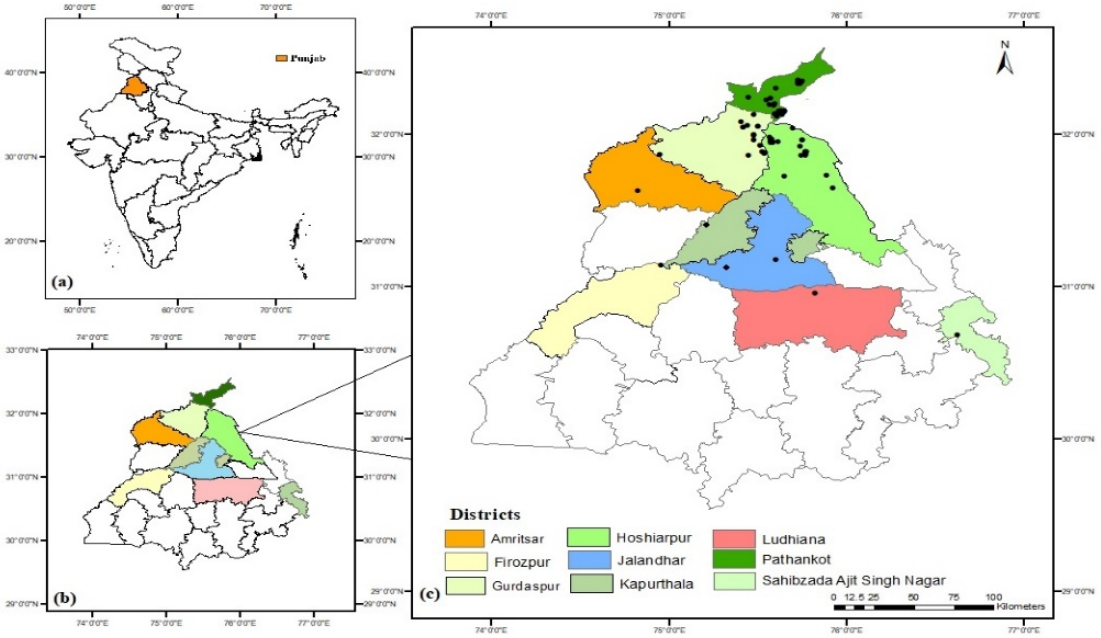


Fig. 1: A map of Punjab state showing different collection sites.

the chemical study, spot tests were performed using routine reagents K, C and P. For K test, 10% KOH solution was used. For the C test, calcium hypochlorite and for P test, Para-phenylenediamine were used. The thin layer chromatography (TLC) was performed in solvent system A (Toluene: 1, 4-dioxane: acetic acid: 180: 60: 8), following the techniques of Orange *et al.,* (2001). The specimens were identified up to the species level with the help of publications of Awasthi (1991, 2007) and followed by Wijayawardene *et al.*, (2022) for classification. All the identified specimens are housed at herbarium LWG of CSIR-National Botanical Research Institute, Lucknow. The distribution map for the species was obtained using Google Earth Map and Arc GIS 10.8 software.

Statistical Analysis

The statistical analysis was done using Origin Pro Graphing and Analysis software. The information regarding lichen families and species across various districts was encoded into binary format (0 or 1; 0 depicts absence while 1 depicts presence), subjected to Pearson correlation analysis and visualized through heatmaps and Polar heatmaps with dendrograms. Furthermore, pie charts were utilized to illustrate lichen taxa across different elevation ranges, where each spoke's length represents the elevation and the color indicates the respective taxa present.

Result & Discussions

A total of 68 lichen species belonging to 31 genera and 19 families (Table 1), were documented across the 23 districts of Punjab. This study also includes two species (*Chaenotheca brunneola* (Ach.) Müll. Arg. and *Phaeophyscia insignis* (Mereschk.) Moberg as new distributional records for India lichen biota (Fig. 5). The presence of different lichen taxa across different districts of the Punjab region was analyzed using a Polar heat map featuring a dendrogram. In this polar heat map, the presence or absence of different lichen taxa can be seen in districts. The district with an absence of a particular lichen taxon is colored white and the presence is represented by red color (Fig. 2). The districts such as Pathankot (50 spp.), Hoshiarpur (34 spp.) and Gurdaspur (12 spp.) of Majha and Doaba regions exhibit higher species count and represented by red color in the polar heat map, attributed to their elevated altitudes and minimal pollution exposure. These districts are situated near the Himalayan foothills and the biodiverse Shivalik hills benefit from heavy rainfall, fostering favorable conditions for lichen growth.

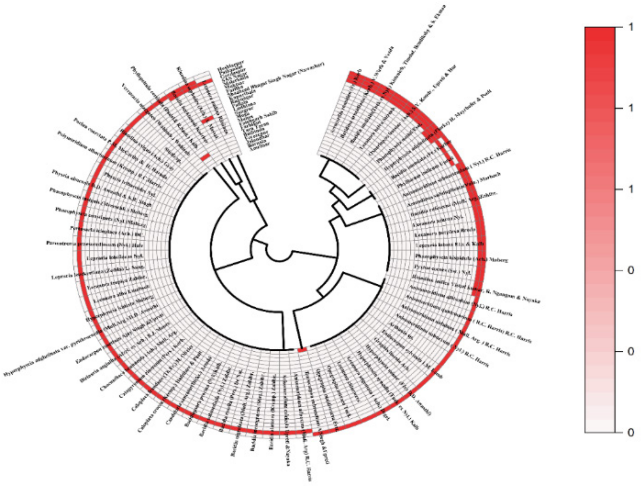


Fig. 2: A polar heatmap featuring a dendrogram displays the presence or absence of different lichen taxa across different districts of the Punjab region.

Table 1: A list of lichens taxa in the Punjab state along with their distribution in India.

S. No.	Name of lichen taxa	Families	GF	SUB	Districts in the state							Field Numbers	Distribution in India	Remarks
					1	2	3	4	5	6	7			
1.	*Acrocordia conoidea* (Fr.) Korb	Monoblastiaceae	Cr	C	-	-	+	+	-	+	-	23-368290, 23-367730, 23-367741	PB	Naincy *et al*., (2024)
2.	*Amandinea subduplicata* (Vain.) Marbach	Caliciaceae	Cr	S	-	-	-	+	-	+	-	23-367873, 21-367770	MP, RJ, TN, UK	Mishra *et al*., (2016) and Uppadhyay *et al*., (2016)
3.	*Anisomeridium adnexum* (Müll. Arg) R.C. Harris	Monoblastiaceae	Cr	C	-	-	-	-	-	+	-	22-367735	GJ, KA, UP, UK	Mishra *et al*., (2024)
4.	*A. albisedum* (Nyl.) R.C. Harris	Monoblastiaceae	Cr	C	-	-	-	+	-	-	-	23-368269	MH, UK	Bajpai and Upreti (2011) & Mishra *et al*., (2016)
5.	*A. calcicola* Upreti & Nayaka	Monoblastiaceae	Cr	S	-	-	-	-	-	+	-	23-368434	UP	Nayaka and Upreti (2013)
6.	*A. nidulans* (Müll. Arg.) R.C. Harris	Monoblastiaceae	Cr	C	-	-	-	+	-	-	-	23-367792	UP	Nayaka and Upreti (2013)
7.	*A. subnectendum* (Nyl.) R.C. Harris	Monoblastiaceae	Cr	C	-	-	-	+	-	+	-	23-368289, 22-367739	KA	Mishra *et al*., (2024)
8.	*A. subnexum* (Nyl.) R.C. Harris	Monoblastiaceae	Cr	C	-	-	-	+	-	-	-	23-368270	A & N Island, GA	Singh and Sinha (2010) & Randive *et al*., (2021)
9.	*A. quaternarium* (R.C. Harris) R.C. Harris	Monoblastiaceae	Cr	C	-	-	-	+	-	-	-	23-368271	UP	Mishra *et al*., (2024)
10.	*Arthonia sp.*	Arthoniaceae	Cr	C	-	-	-	+	-	-	-	23-367714	AS, KT, MN, WB	Awasthi (1991)
11.	*Bacidia alutacea* (Kremp.) Zahlbr.	Ramalinaceae	Cr	C	-	-	-	-	-	+	-	23-367714	J&K, MN, OR, SK, TN, UP	Singh and Sinha (2010), Nayaka and Upreti (2013), Devi *et al*., (2015), Nayak *et al*., (2016), Goni and Sharma (2015)
12.	*B. beckhausii* Koerber	Ramalinaceae	Cr	C	-	-	+	-	-	+	-	23-367895, 23-368204	UP	Nayaka and Upreti (2013)
13.	*B. incongruens* (Stirt.) Zahlbr.	Ramalinaceae	Cr	C	-	-	-	-	-	+	-	22-367683	KA, MN, TN, UP, WB	Singh and Sinha (2010), Nayaka and Upreti (2013), Devi *et al*., (2015)
14.	*B. nigrofusca* (Müll. Arg.) Zahlbr.	Ramalinaceae	Cr	C	-	-	-	-	-	+	-	22-368292	AR, SK, UK	Singh and Sinha (2010)
15.	*B. rosella* (Pers.) De Not.	Ramalinaceae	Cr	C	-	-	-	-	-	+	-	22-367619	HP	Singh and Sinha (2010)

16.	*B. rufescens* (Mùll. Arg.) Zahlbr.	Ramalinaceae	Cr	C	-	-	-	+	-	+	-	23-368424, 23-368429	MP, MN, TN	Singh and Sinha (2010), Devi *et al*., (2015)
17.	*B. submedialis* (Nyl.) Zahlbr.	Ramalinaceae	Cr	C	-	-	-	-	-	+	-	23-367897	AR, GA, J&K, KA, MH, MN, OR, TN, UP, WB	Singh and Sinha (2010), Devi *et al*., (2015), Goni and Sharma (2015), Nayak *et al*., (2016)
18.	*Bacidina arnoldiana* (Korb.) V. Wirth & Vëzda	Ramalinaceae	Cr	C, S	-	-	+	+	-	+	-	23-368235, 23-368297, 22- 367772	MP, UK, UP	Singh and Sinha (2010)
19.	*B. inundata* (Fr.) Vězda	Ramalinaceae	Cr	S	-	-	+	+	-	-	-	23-367720, 23-368295	UK	Singh and Sinha (2010)
20.	*B. medialis* (Tuck ex Nyl.) Kistenich *et al*.	Ramalinaceae	Cr	C	-	-	+	+	-	+	-	22-367900, 23-368203, 22-367893	HP, J&K, KL, LD, OR, TN, WB	Singh and Sinha (2010), Goni and Sharma (2015)
21.	*Bacidiopsora psorina* (Nyl.) Kalb.	Ramalinaceae	Cr	C	-	-	-	-	-	+	-	22-367678	AR, HP, KL, TN, UP, WB	Singh and Sinha (2010)
22.	*Caloplaca crocea* (Kremp.) Hafellner & Poelt	Teloschistaceae	Cr	C	-	-	-	-	-	+	-	22-368206	TN	Singh and Sinha (2010)
23.	*C. ferrugines* (Th.Fr.) H. Olivier	Teloschistaceae	Cr	S	-	-	-	-	-	+	-	22-367649	HP, UK	Mishra *et al*., (2020)
24.	*Candelaria concolor* (Dicks.) Arnold	Candelariaceae	Fo	C	-	-	-	-		+	-	23-367839	HP, J&K, KA, MN, NL, SK, UK	Singh and Sinha (2010), Nayak *et al*., (2016)
25.	*Catapyrenium cinereum* (Pers.) Korb.	Verrucariaceae	Cr	S	-	-	-	-	-	+	-	23-367653	MH	Singh and Sinha (2010)
26.	***Chaenotheca brunneola* (Ach.) Mùll. Arg.**	Coniocybaceae	Cr	C	-	-	-	-	-	+	-	22-367679	PB	In Present Paper
27.	*Dirinaria aegialita* (Afzel. ex Ach.) B.J. Moore	Caliciaceae	Fo	C	-	-	-	-	-	+	-	23-367697	A&N Island, AR, CG, J&K, KL, MP, OR, TN, WB	Singh and Sinha (2010), Nayak *et al*., (2016), Sharma *et al*., (2019)
28.	*Endocarpon rosettum* Ajay Singh &Upreti	Verrucariaceae	Cr	S	-	-	-	-	-	+	-	23-368296	MP, UP	Singh and Sinha (2010)
29.	*E. subrosettum* A.Singh &Upreti	Verrucariaceae	Cr	S	+	-	-	+	-	-	-	23-368266, 23-368432	GA, HP, J&K, MP, UK, UP	Singh and Sinha (2010), Randive *et al*., (2021)
30.	*E. sylvicalum I.M.* Lamb	Verrucariaceae	Cr	C	-	-	-	+	-	-	-	23-368291	UP	Nayaka *et al*., (2023)
31.	*Graphis lineola* Ach.	Graphidaceae	Cr	C	-	-	-	+	-	-	-	23-367726	AP, J&K, KA, MN, TN, UK, WB	Singh and Sinha (2010), Goni and Sharma (2015), Devi *et al*., (2015)

32.	*Hyperphyscia adglutinata var. adglutinata* (Florke) H. Mayrhofer & Poelt	Physciaceae	Fo	C	-	-	+	+	-	+	+	23-367875, 23-368252, 23-367656, 23-367604	HP, J&K, UK	Singh and Sinha 2010
33.	*H. adglutinata var. pyrithrocardia* (Mùll. Arg.) D.D. Awasthi	Physciaceae	Fo	C	-	-	-	-	-	+	-	22-367794	TN, UK, UP	Singh and Sinha (2010), Mishra *et al*., (2016)
34.	*H. isidiata* Moberg	Physciaceae	Fo	C	-	-	-	-	-	+	-	22-367804	HP	Singh and Sinha (2010)
35.	*H. minor* (Fée) D.D. Awasthi)	Physciaceae	Fo	C	-	-	-	+	-	-	-	23-368275	UP	Nayaka and Upreti (2013)
36.	*H. syncolla* (Tuck. ex Nyl.) Kalb	Physciaceae	Fo	C	-	-	-	+	-	-	-	23-368256	HP, MP, MH, UP	Singh and Sinha (2010)
37.	*Lecanora achroa* Nyl.	Lecanoraceae	Cr	C	-	-	-	+	-	+	-	23-368256	HP, J&K, MN, SK, UP, UK	Singh and Sinha (2010), Goni and Sharma (2015)
38.	*L. alba* Lumbsch	Lecanoraceae	Cr	C	-	-	-	-	-	+	-	23-368208	AR, HP, J&K, UP, UK	Singh and Sinha (2010), Goni and Sharma (2015)
39.	*L. andina* Räsänen	Lecanoraceae	Cr	C	-	-	+	-	-	-	-	23-368212	HP, MH	Singh and Sinha (2010)
40.	*L. argentata* (Ach.) Degel.	Lecanoraceae	Cr	C	-	-	-	+	-	-	-	23-368437	A&N Island, AP, J&K, MH, MN, OR, UK, WB	Singh and Sinha (2010)
41.	*L. chlarotera* Nyl.	Lecanoraceae	Cr	C	-	-	-	+	-	-	-	23-368438	J&K, KA, MH, MN, NL, RJ, TN, UP, UK, WB	Singh and Sinha (2010), Nayaka and Upreti (2013)
42.	*L. helva* Stizenb.	Lecanoraceae	Cr	C	-	-	+	+	-	+	-	23-368226, 23-367716, 22-367626	AS, GA, HP, J&K, KL, MP, MH, TN	Singh and Sinha (2010), Goni and Sharma (2015)
43.	*L. perplexa* Brodo	Lecanoraceae	Cr	C	-	-	-	+	-	+	-	23-368224, 22-368229	AR, AS, J&K, KA, KL, MP, OR, RJ, TN, UP, UK	Singh and Sinha (2010)
44.	*L. tropica* Zahlbr.	Lecanoraceae	Cr	C	-	-	-	-	-	+	-	22-367616	HP, J&K, KA, MP, MN, OR, TN, UP, UK, WB	Singh and Sinha (2010), Goni and Sharma (2015), Devi *et al*., (2015)
45.	*Lepraria leuckertiana* (Zedda) L. Saag.	Stereocaulaceae	Cr	C	-	-	-	-	-	+	-	23-367876	KA, HP, MP, J&K, MZ, RJ UK	Bajpai & Upreti (2018)
46.	*L. lobata* Elix & Kalb	Stereocaulaceae	Cr	C	-	-	-	+	-	+	-	23-367890, 22-367627	HP, KA, MH, TN, UK	Bajpai & Upreti (2018)
47.	*L. lobificans* Nyl.	Stereocaulaceae	Cr	C	-	-	-	-	-	+	-	23-368207	HP, J&K, KA, MP, MH, OR, RJ, TN, UK	Singh and Sinha (2010), Bajpai & Upreti (2018)

48.	*Opegrapha astraea* Tuck.	Opegraphaceae	Cr	C	-	-	-	+	-	-	-	23-367692	UP	Nayaka and Upreti (2013)
49.	*O. maldiveana* Ertz.	Opegraphaceae	Cr	C	-	-	-	+	-	-	-	23-367766	UP	Nayaka and Upreti (2013)
50.	*Oxneriopsis bassiae* (Ach.) S.Y. Kondr., Upreti & Hur	Teloschistaceae	Cr	C	-	-	+	+	-	+	-	23-368280, 23-368286, 23-367625	AR, AS, BR, HP, J&K, JH, MP, OR, RJ, SK, TN, UK, UP	Mishra *et al*., (2020)
51.	*Parmotrema praesorediosum* (Nyl.) Hale	Parmeliaceae	Fo	C	-	-	-	-	-	+	-	22-367698	AP, AS, HP, J&K, KA, KL, MP, MH, MN, NL, OR, RJ, SK, TN, UK, UP, WB	Singh and Sinha (2010)
52.	*Pertusaria leioplaca* (Ach.) DC.	Pertusariaceae	Cr	C	-	-	-	-	-	+	-	22-367882	MN, NG, WB	Singh and Sinha (2010)
53.	*Phaeophyscia constipata* (Nyl.) Moberg	Physciaceae	Fo	C	-	-	-	+	-	+	-	23-367727, 22-367769	HP, J&K, UK, UP	Singh and Sinha (2010), Nayaka and Upreti (2013)
54.	*P. hispidula* (Ach.) Moberg	Physciaceae	Fo	C	-	-	-	+	-	+	-	23-368263, 23-368259	AR, AS, HP, J&K, KA, KL, MP, MH, MN, MZ, NL, RJ, SK, TN, UK, UP, WB	Singh and Sinha (2010), Maurya *et al*., (2024)
55.	***P. insignis* (Mereschk.) Moberg**	Physciaceae	Fo	C	-	-	-	-	-	+	-	23-368430	PB	In present paper
56.	*P. nashii* Essl.	Physciaceae	Fo	C	-	-	+	+	-	+	-	23-367832, 23-367729, 22-368238	PB	Maurya *et al*., (2024)
57.	*Phylliscum indicum* Upreti	Lichinaceae	Cr	S	-	-	+	+	-	-	-	23-367602, 23-368435	J&K, MP, UP	Singh and Sinha (2010)
58.	*Phyllopeltula corticola* (Budel & R. Sant.) Kalb.	Peltulaceae	Fo	C	-	+	+	+	-	+	-	23-367886	UP	Nayaka and Upreti (2013)
59.	*Physcia abuensis* D.D. Awasthi & S.R. Singh	Physciaceae	Fo	C	-	-	-	-	-	+	-	23-367724	RJ	Singh and Sinha (2010)
60.	*P. tribacoides* Nyl.	Physciaceae	Fo	C	-	-	-	-	-	+	-	22-367779	AR, HP, MP, MH, MN, NL, SK, TN	Singh and Sinha (2010)
61.	*Polymeridium albocinereum* (Kremp.) R.C. Harris	Trypetheliaceae	Cr	C	-	-	-	-	-	+	-	23-368293	HP	Singh and Sinha (2010)
62.	*Porina coarctata* P.M. McCarthy & H. Harada	Pertusariaceae	Cr	S	-	-	-	-	-	+	-	23-368205	PB	Naincy *et al*., (2024)

63.	*Pyxine cocoes* (Sw.) Nyl.	Caliciaceae	Fo	C	-	-	-	+	-	+	-	23-368236, 22-367798	AS, GA, KA, KL, MP, MH, MN, OR, TN, UP, WB	Singh and Sinha (2010)
64.	*Rinodina exigua* (Ach.) Gray	Physciaceae	Cr	C	-	-	-	-	-	+	-	23-368207	MN, UP	Singh and Sinha (2010)
65.	*R. indica* Vishal Kumar, R. Ngangom & Nayaka	Physciaceae	Cr	C	-	-	-	+	-	+	-	23-368237, 23-367870	UP	Kumar *et al*., (2021)
66.	*R. sophodes* (Ach.) A. Massal	Physciaceae	Cr	C	-	-	+	-	+	+	-	23-368234, 23-368433, 22-367635	AP, HP, J&K, MP, SK, UP, WB	Singh and Sinha (2010), Goni and Sharma (2015)
67.	*Stictis sp.*	Stictidaceae	Cr	C	-	-	-	-	-	+	-	23-367622	KA, TN	In present paper
68.	*Verrucaria margacea* (Wahlenb.) Wahlenb	Verrucariaceae	Cr	S	-	-	-	-	-	+	-	23-367764	J&K, MN, UP	Singh and Sinha (2010), Nayaka and Upreti (2013), Goni and Sharma (2015)

Abbreviations: G.F: Growth form, SUB: Substratum, Cr: Crustose, Fo: Foliose, C: Corticolous, S: Saxicolous
1. Amritsar 2. Ferozepur 3. Gurdaspur 4. Hoshiarpur 5. Ludhiana 6. Pathankot 7. Sahibzada Ajit Singh Nagar
A&N Island: Andaman & Nicobar Island, AP: Andhra Pradesh, AR: Arunachal Pradesh, AS: Assam, BR: Bihar, CG: Chhattisgarh, GA: Goa, GJ: Gujrat, HP: Himachal Pradesh, J&K: Jammu & Kashmir, JH: Jharkhand, KA: Karnataka, KL: Kerela, KT: Kolkata, LD: Lakshadweep, MP: Madhya Pradesh, MH: Maharashtra, MN: Manipur, MZ: Mizoram, NL: Nagaland, OR: Orissa, PB: Punjab, RJ: Rajasthan, SK: Sikkim, TN: Tamil Nadu, UK: Uttarakhand, UP: Uttar Pradesh, WB: West Bengal

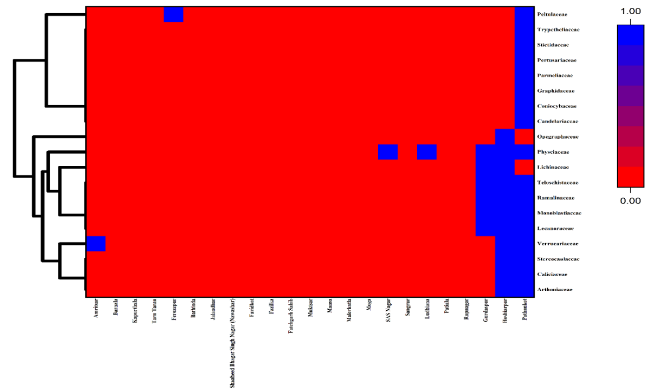


Fig. 3: A heatmap featuring a dendrogram displays the presence or absence of lichen families across different districts of the Punjab region.

Conversely, districts like Amritsar, Ludhiana, Ferozepur and Sahibzada Ajit Singh Nagar reported the lowest species count, each with only a single species represented by red color. The sparse lichen presence in these areas is likely due to heavy urbanization, limited rainfall, high temperature, and extensive agricultural activity, which disrupts suitable substratum for lichen colonization. In districts such as Jalandhar and Kapurthala, only a few lichen species were observed and photographed, while the remaining districts of the Malwa region completely lack lichens and are represented by white color in the polar heat map. The probable reason for the poor or absence of lichens in this region may be due to lower elevation ranges, lack of a suitable host, harsh environmental conditions and higher anthropogenic activities such as intensive agriculture, stubble burning, excessive fertilizer use, industrial waste, heavy vehicular emissions and pollution from brick kilns (Kaur and Singh, 2022).

A heat map with a dendrogram was prepared to show the presence or absence of lichen families across different districts of the Punjab region. In which the blue color depicts the presence and the red color depicts the absence of families (Fig. 3). Among the 20 lichen families documented in the state, the Physciaceae demonstrates its dominance with 14 species, followed by Ramalinaceae (10 spp.), Monoblastiaceae (8 spp.), Lecanoraceae (8 spp.) and Verrucariaceae (6 spp.) are represented by blue color region in the heat map. The families Arthoniaceae, Candelariaceae, Coniocybaceae, Graphidaceae, Lichinaceae, Parmeliaceae, Pertusariaceae, Peltulaceae, Stictidaceae, Trypetheliaceae are each represented by a single species. Within Physciaceae, four genera are present. Verrucariaceae, Caliciaceae and Ramalinaceae each contain two genera. Most of the Malwa region districts show complete absence of lichen families which are represented by the red color region in the heat map.

The availability of suitable substrate primarily influences lichen distribution. In the present study, the most lichen (57 spp.) were corticolous, followed by saxicolous (11 spp.). The Shivalik Hill's green belt, characterized by diverse phorophytes, harbors a significant number of corticolous lichens. These are predominantly found in the state due to the favorable conditions in this region. Conversely, the absence of appropriate substrata in other districts is attributed to extensive anthropogenic activities and intensive agricultural practices, which hinder lichen growth.

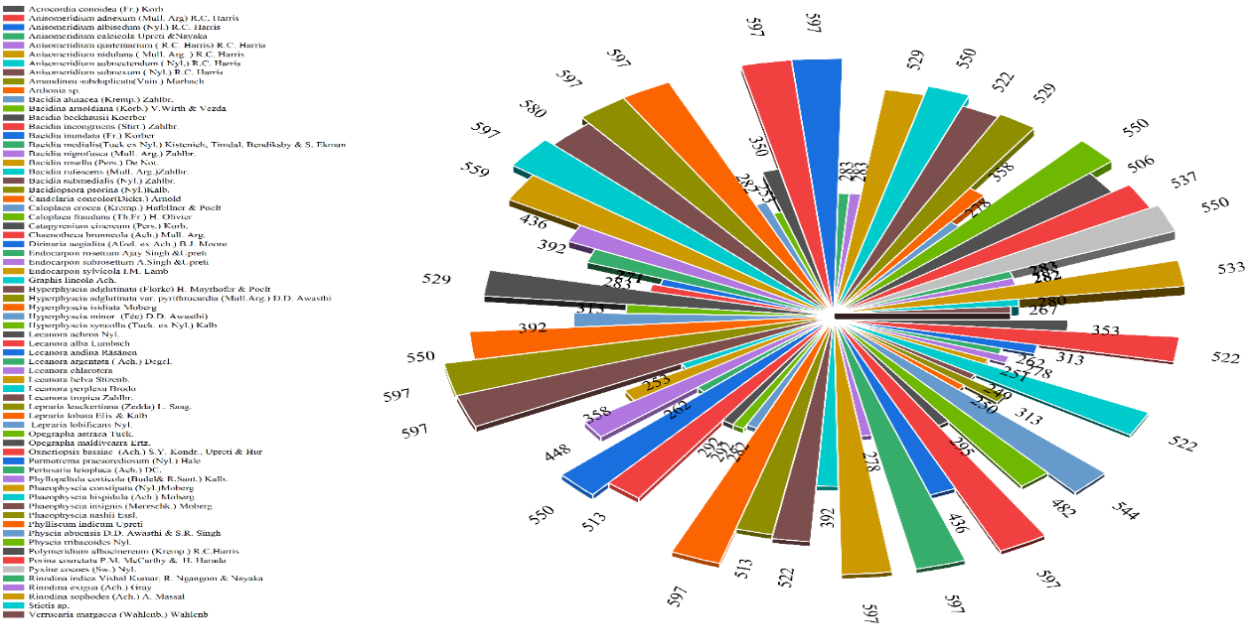


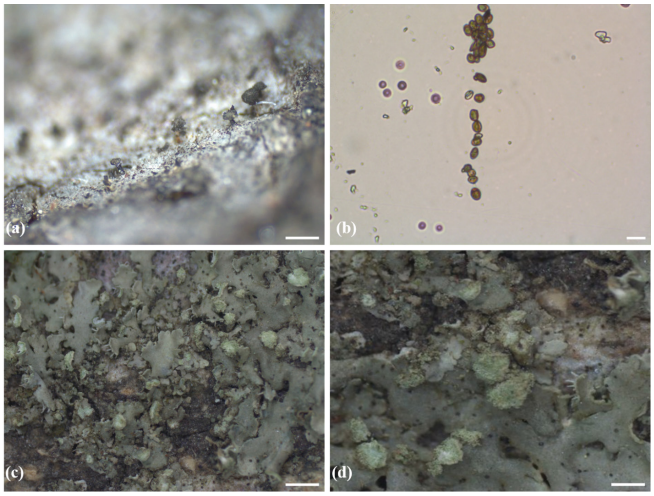
Fig. 4: A pie diagram with different radius spokes represents the presence of lichen taxa across different elevation range.

Lichen growth forms serve as significant indicators of the surrounding environmental conditions. The Variations in growth forms across different districts of the state can be attributed to the varying rainfall patterns, with higher precipitation near the Shivalik hills and lower rainfall in the western desert regions. This study indicates that crustose (50 spp.), are predominant in the area, followed by foliose (15 spp.) and leprose (3 spp.). The state experiences a tropical, semi-arid climate, with a subtropical monsoon season characterized by cold winters and scorching summers, and total rainfall ranges between 250 to 1000 mm, which contributes to the dominance of crustose lichens. The lichens are known to endure high humidity conditions and simultaneously exhibit mechanisms to prevent over-saturation (Lakatos *et al*., 2006). The prevalent foliose growth forms in the region are primarily represented by *Hyperphyscia* (5 spp.) and *Phaeophyscia* (4 spp.). The genera *Bacidia* (9 spp.), *Lecanora* (8 spp.), and *Anisomeridium* (7 spp.) also exhibit a significant presence. *Lepraria* (3 spp.*)* is the sole genus representing the leprose growth type. Fruticose lichens are absent due to inadequate conditions in the lower elevation regions of the state.

The variations in the distribution of growth forms indicate the dynamic nature of the area's ecosystem. The elevation ranges provide insight into the growth forms of lichen species. The state is surrounded by the Shivalik hill region, ranging in elevation from 180 to 600 m. To showcase the presence of lichen taxa within different elevation ranges a pie chart with distinct radius spokes was made. The length of the spoke represents the elevation range and the color indicates the different lichen species. The longer the spoke, the higher the elevation range, representing the presence of lichen species across different elevations in the pie chart (Fig. 4).

The present exploration of the state is the first attempt after years of research gap, to get a clear picture of lichen diversity. Therefore, the present findings are valuable in context to the availability of lichens and their distribution within the state. Future exploration in the major Shivalik hill ranges and phorophyte-diverse regions of the state will undoubtedly increase the known lichen diversity. This study also provides a baseline date for future environmental pollution monitoring studies in Punjab.

Despite a long history of lichenological studies in India, few reports of lichen species from Punjab were known. This study addresses this research gap by providing an updated and comprehensive checklist of lichens from the state. Additionally, this study provides consolidated reports on lichens from the state to the Department of Forest and Wildlife Preservation and the State Biodiversity Board of the Government of Punjab



Scale: (a–c) = 2 mm and (b) = 10 µm (d) = 1mm.
Fig. 5: (a, b) *Chaenotheca brunneola* (c,d) *Phaeophyscia insignis*

Taxonomic Accounts

Table 2: Key to the lichens of Punjab state

1. Thallus foliose or squamulose……2
   – Thallus crustose or leprose……17
2. Thallus squamulose and photobiont blue green alga……*Phyllopeltula corticola*
   – Thallus foliose and photobiont green alga……3
3. Upper surface of thallus yellow color……*Candelaria concolor*
   – Upper surface of thallus otherwise……4
4. Hypothecium brown to dark brown……5
   – Hypothecium hyaline to pale yellow……6
5. Thallus adnate to the substratum, rhizines lacking……*Dirinaria aegialita*
   – Thallus loosely attached to the substratum, rhizines present……*Pyxine cocoes*
6. Lobes larger, lower surface black in center and rhizinate, brown towards margin and lacking rhizines ……*Parmotrema praesorediosum*
   – Lobes small, lower surface black, rhizines present thought-out the surface……7
7. Lower cortex of thallus paraplectenchymatous or prosoplectenchymatous……8
   – Lower cortex of thallus prosoplectenchymatous or absent……13
8. Thallus containing atranorin, upper cortex K+ yellow……9
   – Thallus lacking atranorin, upper cortex K-……10
9. Lobes 1–2 mm wide, upper surface whitish grey, soredia marginal to laminal……*Physcia abuensis*
   – Lobes 3–10 mm wide, upper surface grey, soredia marginal only……*Physcia tribacoides*
10. Thallus having soredia, lower surface whitish to pale brown to brown……11
    – Thallus lacking soredia, lower side pale brown……*Phaeophyscia constipata*
11. Lobes broader more than 2 mm wide, soredia granular and black long rhizine……*Phaeophyscia hispidula*
    – Lobes narrower less than 2 mm wide, soredia otherwise and rhizines shorter……12
12. Lobes 0.5–1.5 mm wide, upper side greenish grey, lower side white……*Phaeophyscia nashii*
    –Lobes 0.1–0.5 mm wide, upper side grey to grey brown, lower side white to pale brown……*Phaeophyscia insignis*
13. Thallus lacking soredia and isidia……*Hyperphyscia syncolla*
    –Thallus having soredia or isidia……14
14. Thallus having isidia, isidia cylindrical……*Hyperphyscia isidiata*
    –Thallus having soredia……15
15. Prothallus present at lobes margin……*Hyperphyscia minor*
    – Prothallus absent at lobes margin……16
16. Medulla white ……*Hyperphyscia adglutinata* var. *adglutinata*
    – Medulla orange or red……*Hyperphyscia adglutinata* var. *pyrithrocardia*
17. Thallus leprose……18
    – Thallus crustose……20
18. Thallus containing atranorin ……19
    – Thallus lacking atranorin, containing usinic acid and zeorin, atranorin absent……*Lepraria leukertiana*
19. Thallus containg atranorin and zeorin……*Lepraria lobata*
    –Thallus containing atranorin, constictic, stictic acids and zeorin……*Lepraria lobificans*
20. Thallus with blue-green alga……*Phylliscum indicum*
    – Thallus with green alga……21
21. Ascomata apothecia or lirellae……22
    – Ascomata sunken in verrucae or perithecia……53
22. Thallus having apothecia……23
    –Thallus having lirellae……51
23. Apothecia lecanorine……24
    – Apothecia lacideine……34
24. Thallus containing atranorin, K+ yellow……25
    – Thallus lacking atranorin, K-……*Rinodina indica*
25. Ascospores hyaline, simple ellipsoid……26
    – Ascospores brown and 1- septate……33
26. Thallus containing usnic acid……27
    – Thallus lacking usnic acid……28
27. Thallus containing 2′-O-methylperlatolic acid, apothecia pale brown to orange ……*Lecanora achroa*
    – Thallus lacking 2′-O- methylperlatolic acid, apothecia disc red-brown to brown……*Lecanora alba*

28. Thallus containing 2′-O-methylperlatolic acid, apothecia disc pale brown to orange……..*Lecanora helva*
– Thallus lacking 2′- O-methylperlatolic acid, apothecia otherwise ……29
29. Thallus containing chloroatranorin (PD+ yellowish orange), apothecia sessile……..*Lecanora andina*
– Thallus lacking chloroatranorin (PD-)……30
30. Epihymenial pigment dissolving in K……..*Lecanora chlarotera*
– Epihymenial pigment not dissolving in K……31
31. Thallus containing gangleodin, apothecia disc pale to dark reddish brown……*Lecanora argentata*
– Thallus lacking gangleodin, apothecia disc pale to dark reddish brown……32
32. Apothecia smaller (0.3–1.0 mm in diam.) and large crystals present in amphithecium ……*Lecanora perplexa*
– Apothecia larger (1.3–3.2 mm in diam.) and small and large crystal present……*Lecanora tropica*
33. Ascospore locules simple wall uniformly thickened……*Rinodina sophodes*
– Ascospore locules mischobastimorphic, wall irregularly thickened……*Rinodina exigua*
34. Apothecia with stalk……..*Chaenotheca brunneola*
– Apothecia without stalk……35
35. Ascospore pale brown to dark brown, 1- septate to submuriform……*Amandinea subduplicata*
– Ascospore hyaline, septate or otherwise……36
36. Thallus containing parietin, ascospores polaribilocular to trilocular…… ……37
– Thallus lacking parietin, ascospores otherwise……39
37. Thallus isidiate, yellow orange to yellowish grey……*Oxneriopsis bassiae*
– Thallus lacking isidia, whitish grey……38
38. Thallus UV+ orange, ascospores trilocular, thalline margin persistent……*Caloplaca crocea*
– Thallus UV-, ascospores polaribilocular, thalline margin absent……*Caloplaca ferrugines*
39. Thallus non-lichenized fungus, ascomata urceolate, rounded, chroodiscoid……*Stictis* sp.
– Thallus lichenized fungus, ascomata otherwise……40
40. Thallus ecorticated ascocarps, sunken in the thallus……..*Arthonia* sp.
– Thallus corticated, ascocarps not sunken in the thallus……41
41. Thallus growing on rock, ascospores 30–46 × 0.8–1.6 µm long……*Bacidina arnoldiana*
– Thallus growing on bark, ascospores different size……42
42. Ascospore rod shape to fusiform, transversely 2 –5 septate……..*Bacidia incongruens*
– Ascospore otherwise……43
43. Thallus granulose, furfuraceous, ascospore, 3 –5 transversely septate……*Bacidina medialis*
– Thallus otherwise, ascospore more than 3– septate……44
44. EpitheciumK+Violet……45
– Epithecium K-……46
45. Hypothecium pale yellow, ascospores 9 –15 septate……*Bacidia alutacea*
– Hypothecium hyaline, ascospores 3 – 7 septate……*Bacidia beckhausii*
46. Hypothecium hyaline……47
– Hypothecium pale yellow to pale brown……48
47. Thallus yellowish green, ascospores 3 septate, 27– 45 ×1.6 –2.4 µm long……*Bacidina inundata*
– Thallus grey, ascospores 10-15 septate, 54–80 × 3.2–4 µm long……*Bacidia rosella*
48. Hypothecium pale yellow……49
– Hypothecium pale brown……50
49. Thallus greyish, ascospores fusiform, 5–7 septate, 25–32 × 3.0–3.5µm long……..*Bacidia nigrofusca*
–Thallus greenish grey, ascospores acicular, 6 –12 septate, 40–64 × 2–6 µm long……*Bacidiospora psorina*
50. Apothecial disc yellow brown to reddish brown, ascospores red shaped, 20–25 × 3–3.5 µm……..*Bacidia rufescens*
– Apothecial disc pale brown, ascospores acicular, 31 – 40 × 3 – 4 µm……*Bacidia submedialis*
51. Lirellae partially or completely covered by thallus, hymenium with oil globules ……*Graphis lineola*
– Lirellae completely naked, hymenium otherwise ……52
52. Lirellae white pruinose, ascospores acicular to fusiform, 4 –5 septate, 12–15 × 4–5 µm long……..*Opegrapha astracea*
–Lirellae epruinose, ascospore acicular, 3 septate, 16–20 × 6 –7 µm long……*Opegrapha maldiveana*
53. Thallus verrucose, ascomata sunken in verrucae……..*Pertusaria leioplaca*
– Thallus otherwise……54
54. Thalluscorticolous……55
– Thallus saxicolous or calcicolous ……63
55. Ascospore brown and muriform……..*Endocarpon sylicalum*
– Ascospore hyaline and 1–11 septate……56
56. Ascospore 7 – 11 septate, 30–64 × 6–12 µm long……..*Polymeridium albocinerum*
– Ascospore 1 –3 septate, 9–52 × 4–24 µm long ……57

57. Both cells of ascospores equal in size, ascospores with warted epispore……..…*Acrocordia conoidea*
– Both cells of ascospores unequal in size and ascospores without warted epispore ……..…..……..…..58
58. Ascospore small 9 – 15 × 4 –5 µm……..…*Anisomeridium albisedum*
– Ascospore larger 15 –52 × 5–24 µm……..……..…59
59. Ascospore 3– septate……..……..…..……..…*Anisomersdium quaternarium*
– Ascospore 1– septate ……..……..…60
60. Ascospores ornamented and oval to pyriform……..…*Anisomeridium adnexum*
–Ascosporesotherwise……..……..…..…61
61. Ascospores biseriate by arranged in ascus……..……..……..…..…..…62
– Ascospores uniseriate by arranged in ascus, ascospore 20–30 × 7–12 µm ……*Anisomeridium subnectendum*
62. Ascospores broadly ovoid, 42–52 × 20–24 µm……..……..……..*Anisomeridium nidulans*
– Ascospores fusiform, 26–34 × 8–11 µm……..…..…*Anisomeridium subnexum*
63. Ascospores transversely 1– 3 septate……..……..…..……..…64
– Ascospores simple or muriform……..……..…..…65
64. Ascospores 1-septate, spindle shape, 15–19 × 5–8 µm ……*Anisomeridium calcicola*
– Ascospores 3-septate, fusiform to fusiform cylindrical, 15–19 × 3–5 µm……..…..…..*Porina coartata*
65. Ascosporesbrownandmuriform……..……..……..…..66
– Ascospores hyaline, simple, 18–32 × 9–12 µm……..……..……*Verrucaria margacea*
66. Squamules upto 7 mm across, lower side of thallus pale, ascospores oblong ……..*Endocarpon rosettum*
–Squamules upto 2.5 mm across, lower side of thallus black, ascospores globose to ellipsoidal……*Endocarpon subrosettum*

1. Chaenotheca brunneola (Ach.) Müll. Arg., Mém. Soc. Hist. Genève 16(2): 360 (1862) (Coniocybace) (Fig. 5a-b)
≡ *Calicium brunneolum* Ach., Kongl. Vetensk.– Acad. Nya Handl. 4: 279 (1816).

- *Description*

Thallus corticolous, immersed, rarely episubstratic, grey to greenish-grey and granular; ascomata apothecia stalked, stalk black shiny, sometimes branched and carrying 2– 5 capitula, capitulum spherical to obconical, mazaedium brown; asci 8-spored, variable shape, estipitate, with uni- to biseriately arranged spores, produced in chains with hooks or cylindrical, well–stalked with uniseriate spores; ascospores spherical-ellipsoidal- cylindrical, smooth or with irregular fissures, spore wall pale brown to brown 11–13 × 2–3.5 µm.

- *Chemistry*

Thallus K+ yellow-red, C –, KC –, P –; UV+; Baeomycesic acid and squamatic acid present in TLC.

- *Representative material examined*

India: Punjab: Pathankot district, village Phangtoli, elev. 515 – 540 m, on bark, 26.02.2022, *Naincy*, 22-367679 (LWG).

- *Distribution and ecology*

The species was collected from the Pathankot district of Punjab state and found growing on bark at an elevation of 515 –540 m. *Chaenotheca brunneola* was first reported from Japan after that it is widely reported from both temperate and cool temperate areas of both hemispheres such as Africa, Australia, Eurasia, North America, Central and South America (Tibell *et al*., 1982). It is now reported as a new record for Indian lichen biota.

- *Remark*

Chaenotheca brunneola is a quite variable species characterized by its small spores, medium-sized ascomata, the association with a trebouxioid photobiont, and the usually P + yellowish to yellowish red thallus. The thallus may be immersed or superficial and granular to farinaceous. *Chaenotheca ferruginea* differs in having a grey thallus which frequently is provided with yellow to red spots and by having larger spores whereas *Chaenotheca trichialis* differs in having a P – thallus and *Stichococcus* as photobiont (Tibell, 1996).

2. Phaeophyscia insignis (Mereschk.) Moberg, Bot. Not. 131(2): 261 (1978).
(Physciaceae) (Figs. 5c-d)
≡ *Physcia insignis* Mereschk., Annuaire Conserv. Jard. Bot. Genève 21: 191 (1919).

- *Description*

Thallus corticolous, foliose; lobes loosely attached to the substratum, 0.1–0.5 mm wide; upper surface whitish grey to pale grey-brown, epruinose; sorediate**,** soralia laminal to submarginal; ascomata apothecia rare, lecanorine, upto 1.5 mm across, thalline margin sometimes with a corona of rhizines; asci 8-spored; ascospores brown, 1- septate, ellipsoid, 17– 24 × 8– 9 µm, *Physcia*- type. Pycnidia not observed.

- *Chemistry*

Medulla K–, C–, KC–, P–; UV–; No lichen substance presents in TLC.

- *Representative materials examined*

India, Punjab: Punjab, *Pathankot district,* village Phangtoli, elev. 514 – 522 m, on bark, 08.10.2022, *Naincy,* 23-368430, 23-368431 (LWG).

- *Distribution and ecology*

The species was collected from Pathankot district of Punjab state and found growing on bark at an elevation of 514–522 m. Earlier, this species was known from North America and Europe (Moberg, 1995). It is now reported as a new record for Indian lichen biota.

- *Remark*

Phaeophyscia insignis is closely resemblance to *Phaeophyscia nashii* Essl., in having white lower surface but the former species differs in having minute lobes of size 0.1– 0.5 mm. *Phaeophyscia constipata* (Nyl.) Moberg, is also close with the present species with white lower surface but the *P. constipata* lacks vegetative propagules.

Conclusion

As per previous records, there were only 24 species of lichens were known from punjab state .The present study further added 64 species to the lichen biota of Punjab which includes Chaenotheca brunneola (Ach.) Müll. Arg. and supports total 88 species of lichen diversity from the punjab state and Phaeophyscia insignis (Mereschk.) Moberg as new records for India lichen biota. The occurrence of 68 species with in the state clearly indicates the topography of the area. The extensive survey of lichens in the adjoining areas will definitely contribute more taxa to the lichen flora of the region and definitely explore more endemic lichens from the areas. The present enumeration of lichens will act as a baseline data will be helpful in carrying out future lichen resource survey in the area.

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Conflict of Interest

The authors declare that they have no conflict of interest.

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