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New Additions to the Lichenicolous Mycota of India

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ABSTRACT

The present study reports seven lichenicolous fungi and one lichenicolous lichen as new records for India from high-altitude regions of Uttarakhand. The newly documented lichenicolous fungi include *Arthonia xanthoparmeliarum* Etayo (on *Xanthoparmelia* sp.), *Didymocyrtis slaptonensis* (D. Hawksw.) Hafellner & Ertz (on *Xanthoria* sp.), *Endococcus exerrans* Nyl. (on *Rhizocarpon disporum* (Nägeli ex Hepp) Müll. Arg., *Endococcus verrucisporus* Alstrup (on *Protoparmeliopsis muralis* (Schreb.) M. Choisy), *Intralichen baccisporus* D. Hawksw. & M.S. Cole (on *Calogaya* sp.), *Muellerella rhizocarpicola* Brackel (on *Rhizocarpon geographicum* (L.) DC.) and *Stigmidium congestum* (Körb.) Triebel (on *Lecanora* sp.). The new lichenicolous lichen is *Erichansenia epithallina* (Lynge) S.Y. Kondr., Kärnefelt & A. Thell (on *Rhizoplaca* sp.). These findings expand India's lichenicolous mycota checklist to 288 species. An artificial key to all known Indian lichenicolous lichens is provided. The findings emphasize the understudied diversity of lichen-associated fungi in the Himalayas and the need for more surveys in remote Indian regions.

Keywords: Himalaya, Lichenicolous lichen, New records, Teloschistaceae

INTRODUCTION

India exhibits a rich lichen diversity, comprising approximately 3,236 lichen taxa documented across its diverse ecosystems (Sinha *et al*., 2024). In contrast, lichenicolous fungi are those which colonize lichens as parasites, saprotrophs, or commensals, and remained inadequately documented within the country. Worldwide, 2,795 taxa of lichenicolous fungi are currently recognized, encompassing both obligate lichen inhabitants and facultative species across various fungal lineages (Diederich *et al*., 2025). To date, only 281 taxa of lichenicolous fungi have been reported from India, constituting about 10.05% of the world's diversity (*pers. comm.*).

In continuation of our investigations on lichenicolous fungi and lichenicolous lichens of India, we document seven new records of lichenicolous fungi and one lichenicolous lichen from the country.

Lichenicolous lichens, albeit less extensively studied than lichenicolous fungi, warrant particular ecological scrutiny owing to their distinctive host-association mechanisms and photobiont acquisition strategies. For example, a recent Italian study found these taxa to be predominantly crustose, typically associated with coccoid green algal photobionts, and common in dry, sun-exposed habitats, where many function as "algal thieves" by appropriating photobionts from hosts to form independent thalli (Nimis *et al*., 2024). The extent to which Indian taxa conform to analogous ecological patterns remains to be elucidated. Presently, merely 8 lichenicolous lichens are recorded from India (Joshi *et al*., 2016, 2018, 2020, 2024; Falswal and Bhandari, 2020; Maurya *et al*., 2024), in contrast to approximately 257 species documented globally (Diederich *et al*., 2025).

To facilitate taxonomic identification and comparative analysis with extant taxa, we are hereby furnishing an artificial key to the lichenicolous lichens of India.

MATERIALS AND METHODS

The specimens forming the basis of this study were collected from high-altitude regions (3000 – 3400 m.) of Uttarakhand. Voucher specimens are deposited in the herbarium of the Rajasthan University Botanical Laboratory (RUBL), Jaipur, India. Macroscopic features were examined using Olympus stereo zoom dissecting microscope (SZX10), while microscopic examinations were conducted with an Olympus BX53 microscope equipped with differential interference contrast (DIC) optics and an Olympus camera. Thin hand-cut sections were prepared under the dissecting microscope and mounted in water to study structural details and measurements. Ascospores and conidia were measured and recorded as

minimum–maximum values. The standard reagents used for staining and identification included 10% KOH (K), Lugol's iodine (I, applied directly or after KOH pre-treatment, K/I), Lactophenol Cotton Blue (LCB), Brilliant Cresyl Blue (BCr), and Congo Red (CR).

RESULTS

Arthonia xanthoparmeliarum Etayo, Biblioth. Lichenol. 98: 49 (2008) **(Figure 1A)**

Diagnostic characters: Ascomata arthonioid, round to irregular, 1.5–2.5 mm diam., black, without a distinct margin. Epihymenium brown. Hymenium hyline to pale brown. Hypothecium pale brown. Asci 8-spored, clavate to subglobose. Ascospores hyaline, 1-septate, with more or less equal cells, claviform, 10–13 × 3.5–5 µm.

Host: on thallus of *Xanthoparmelia* sp.

Ecological nature: It is a weak to moderate parasitic species as slight necrosis and discolouration was visualized on the thallus.

World distribution: Chile (Etayo and Sancho, 2008), Italy (Brackel and Puntillo, 2023), Luxembourg (Eichler *et al*., 2010), Mongolia (Zhurbenko *et al*., 2020), North America (Haldeman, 2022), U.S.A. (Kocourková, 2009).

Specimens examined: India, Uttarakhand, Uttarkashi district, Nelong valley, near Kharcha, 31°04'40"N, 78°57'53"E, alt. 3393 m, on thallus of *Xanthoparmelia* sp. colonising rock, 23 May 2025, Sunita Bisht 00415 (RUBL 21972); ibid, 00421 (RUBL 21975).

Didymocyrtis slaptoniensis (D.Hawksw.) Hafellner & Ertz **(Figure 1B)**

Diagnostic characters: Ascomata perithecioid, scattered or in small groups, immersed, globose to broadly oval 170–250 µm diam., wall red-brown. Paraphyses 1.5–2 µm wide. Asci fissitunicate, narrowly cylindrical, 80–100 × 7–10 µm, 8-spored. Ascospores 1-septate, uniserate, pale brown, verriculose, 12–15 × 5–7 µm. Conidiomata pycnidial, 80–120(–150) µm diam., globose. Conidia hyaline, non-septate, ellipsoid, 6–9 × 2–3.5 µm, guttule at each end.

Host: on thallus and apothecial disc of *Xanthoria* sp.

Ecological nature: It is a parasitic species as distinct necrotic spots were visualized on the thallus and apothecial disc.

World Distribution: Austria (Berger *et al*., 2015), Belgium (Ertz *et al*., 2008), Canary Islands (van den Boom and Clerc, 2015), England (Hafellner, 2015), Estonia (Aptroot *et al*., 2005), France (Gardiennet, 2012), Germany (Brackel, 2009, Cezanne *et al*., 2013, Cezanne and Eichler, 2015), Great Britain (Hawksworth, 1994), Italy (Brackel, 2008b), Liechtenstein (Ertz *et al*., 2015), Luxembourg (Diederich *et al*., 2014), Morocco (Werner, 1939), Portugal (van den Boom and Giralt, 2012), Spain (Etayo, 2010a, 2010b), Sweden (Santesson, 1993), Switzerland (Ertz *et al*., 2015), Ukraine (Darmostuk and Sira, 2022).

Specimen examined: Uttarakhand, Chamoli district, Malari, on way to Sumna, Near four points., alt. 2901, 30°71'03"N 79°85'01"E, on thallus and apothecial disc of *Xanthoria* sp. colonizing rocks, 25 May 2023, Sunita Bisht 00072 (RUBL 21452).

Endococcus exerrans Nyl., Flora 62: 360 (1879) (**Figure 1C)**

Diagnostic characters: Ascomata perithecioid, perithecia more or less immersed, black, 100–150 µm. Asci 8-spored, narrowly clavate. Ascospores brown, oblong, 1-septate, 13–16 × 3–5 µm.

Host: on thallus of *Rhizocarpon disporum*

Ecological nature: It is a mild parasitic species as slight discolouration was observed on the thallus.

World distribution: Canary Islands (van den Boom *et al*., 2015), Estonia (Suija and Randlane, 2009), France (Roux, 2012), Germany (Schiefelbein, 2013), Great Britain (Hawksworth, 2003), Greece (Christensen and Alstrup, 2013), Italy (Brackel, 2008a), Netherlands (Aptroot *et al*., 2008), Russia (Stepanchikova *et al*., 2019), Sweden (Thell *et al*., 2014), Turkey (Halici, 2008), Denmark, Israel, Northern Ireland, U.S.A. (GBIF 2026).

Specimen examined: India, Uttarakhand, Chamoli district, Malari village, upside Malari along an old canal, 30°40'45"N, 79°54'08"E, alt. 3350 m, on thallus of *Rhizocarpon disporum* colonising rock, 24 May 2023, Sunita Bisht 00108 (RUBL 21915).

Endococcus verrucisporus Alstrup, Fródskaparrit 40: 90 (1994) **(Figure 1D)**

Diagnostic characters: Ascomata perithecioid, fully to semi-immersed, scattered, black, 100–150 µm in diam. Asci 8-spored, narrowly clavate.

Ascospores brown, broadly ellipsoid, 1-septate, 10–12 × 5–7 µm, with verrucose walls.

Host: on thallus of *Protoparmeliopsis muralis*

Ecological nature: It is a mild parasitic species as slight discolouration was observed on the thallus.

World distribution: Belgium (Sérusiaux *et al*., 1999), Czech Republic (Kocourková and Van den Boom, 2005), Denmark (Alstrup *et al*., 1992), England, Ireland, Wales (Orange, 2002), Iceland (Brackel, 2010) Norway (Alstrup, 1997), Portugal (Berger and Zimmermann, 2016), Russia (Zhurbenko *et al*., 2016), Scotland (Coppins, 2000), Great Britain and Northern Ireland, Åland Islands, France (GBIF 2026).

Specimen examined: India, Uttarakhand, Chamoli district, Badrinath, Nar mountain, alt. 3134 m, on thallus of *Protoparmeliopsis muralis* colonising rock, 18 June 2023, Sunita Bisht 00224 (RUBL 21965).

Erichansenia epithallina (Lynge) S.Y. Kondr., Kärnefelt & A. Thell, Acta Bot. Hung. 62 (1-2): 120 (2020) **(Figure 1E)**

Diagnostic characters: Thallus crustose, endosubstratic to inapparent. Ascomata apothecioid, often clustered in small groups, sessile, dark orange to rusty red. Exciple 40–100 µm wide. Epithecium yellowish orange to ferruginous red, K+ purple-red. Hymenium hyaline, 50–60 µm high, non-amyloid. Paraphyses septate, branched in the upper part, swollen at tips. Asci *Teloschistes*-type, clavate, 8-spored. Ascospores polarilocular, hyaline, 1-septate, ellipsoid, 10–12 × 6–7 µm.

Host: on thallus of *Rhizoplaca* sp.

Ecological nature: Since it is growing on the thalllus of another lichen without producing any symptoms, hence is a commensalistic species.

Chemistry: Thallus K–, C–, KC–, P–; apothecia K+ purple-red, C+ purple. Chemistry: 7-Cl-emodin, parietin, emodin, 7-Cl-emodinal.

World distribution: Bulgaria (Denchev *et al*., 2022), North America (Brodo *et al.*, 2001), Russia (Khodosovtsev *et al*., 2004), Austria, Canada, Cabo Verde, France, Greenland, North Macedonia, Norway, Switzerland, U.S.A. (GBIF 2026).

Specimen examined: India, Uttarakhand, Uttarkashi district, Nelong valley, near Kharcha, 30°4'38"N, 78°57'54"E, alt. 3403 m, on thallus of *Rhizoplaca* sp. colonising rock, 23 May 2025, Sunita Bisht 00383 (RUBL 21919) ibid, 00384 (RUBL 21961); ibid, alt. 3520 m, 30°06'35"N 79°00'44"E, 21 May 2025, Sunita Bisht 00390 (RUBL 21960).

.**Remarks:** Although lichen family Teloschistaceae has been revised twice from India (Joshi, 2008; Mishra *et al*., 2020), neither this genus nor this species has been reported previously. It is documented here for the first time as a lichenicolous lichen.

Key to the lichenicolous lichens of India

1. Thallus squamulose, isidiate, isidia globose to cylindrical; fruiting bodies absent; on *Phaeophyscia hispidula* (Ach.) Moberg……***Phyllopsora phaeophysciae*** P. Maurya, G.K. Mishra & D.K. Upreti

1. Thallus crustose, non-isidiate; fruiting bodies present; on other lichens ……..…...2

2. Ascomata perithecioid; ascospores simple, hyaline, ellipsoid to narrow-ellipsoid, 12–16 × 5–7 µm; on *Caloplaca saxicola* (Hoffm.) Nordin and *Calogaya pusilla* (A. Massal.) Arup, Frödén & Søchting...……***Verrucaria latericola*** Erichsen

2. Ascomata apothecioid.....……...3

3. Asci 4-spored; apothecia urceolate, sessile, slightly pruinose; ascospores muriform, brown, ellipsoid, 20–35 × 10–13 µm; on *Cladonia fimbriata* (L.) Fr…...***Diploschistes muscorum*** (Scop.) R. Sant. Asci more then 4-spored……4

4. Apothecia orange to rusty red, K+ purple-red, C+ purple; ascospores polarilocular, 1-septate, hyaline, ellipsoid, 10–12 × 6–7 µm; on *Rhizoplaca* sp.……***Erichansenia epithallina*** (Lynge) S.Y. Kondr., Kärnefelt & A. Thell

4. Apothecia not orange to rusty red, K–, C–; ascospores not polarilocular……5

5. Ascospores predominantly muriform, curved/sickle-shaped, brown, 14–25 × 6–10 µm; on *Polyozosia dispersa* (Pers.) S.Y. Kondr., Lőkös & Farkas…….***Diplotomma epipolium*** (Ach.) Arnold

5. Ascospores never muriform, simple or 1-septate.……...……...…….6

6. Ascospores 1-septate, brown; asci *Buellia* type; apothecia black, lecideine, with mostly carbonized thalline margin; on *Aspicilia* sp., *Circinaria* sp., *Myriospora* sp.…...……***Buellia badia*** (Fr.) A. Massal.

6. Ascospores simple, hyaline……...7

7. Thallus prominent, pale brown; apothecia glossy black with persistent concolorous margin, ascospores ellipsoid to ovoid, hyaline, 8–15 × 5–9 µm on *Lecanora subimmersa* (Fée) Vain.……..….....***Carbonea assimilis*** (Hampe ex Körb.) Hafellner & Hertel

7. Thallus endolithic to inconspicuous, pale grey; apothecia pale brown to black, margin white; ascospores hyaline, 8–12 × 5–6 µm; on *Acarospora* sp. and *Dermatocarpon* sp.……..***Polyozosia dispersa*** (Pers.) S.Y. Kondr., Lőkös & Farkas

Intralichen baccisporus D. Hawksw. & M.S. Cole, Fungal Diversity 11: 89 (2002) **(Figure 1F)**

Diagnostic characters: Lichenicolous hyphomycete. Mycelium growing throughout the medulla and hymenium of the host lichen. Conidia multicellular, subglobose that aggregate and form chains or amorphous masses, brown, individual conidia at first non-septate and later becoming 1–3-septate, 6–12 × 7–9 µm.

Host: on apothecial disc of *Calogaya* sp.

Ecological nature: Since no visible symptoms were observed and the species is colonizing inside the apothecial disc, it is a commensalistic species.

World distribution: Austria, Belgium, Luxembourg, Netherlands (Sérusiaux *et al*., 2003), Channel Islands National Park (Knudsen and Kocourková, 2012), France (Roux, 2012), Germany (Brackel, 2014; Rettig, 2016), Italy **(**Brackel, 2020), North America (Hawksworth and Cole, 2002), Russia (Himelbrant *et al*., 2021), Great Britain, Northern Ireland, Spain, Ukraine and U.S.A. (GBIF 2026).

Specimen examined: India, Uttarakhand, Chamoli district, Kailashpur village, roadside, 30°42'21"N, 79°52'18"E, alt. 3038 m, on apothecial disc of *Calogaya* sp. colonising rock, 14 December 2023, Sunita Bisht 00235 (RUBL 21918).

Muellerella rhizocarpicola Brackel, Arch. Lichenol. 35: 10 (2023) **(Figure 1G)**

Diagnostic characters: Ascomata perithecioid, immersed, globose to pyriform, 210–350 µm in diam., wall brown to black. Periphyses present, 1.7–2.6 µm in diam. Asci 32(–64)-spored, clavate to subcylindrical, 42–60 × 14–18 µm. Ascospores 1-septate, smooth, pale brown to dark brown, broadly ovoid, 6.5–9 × 4.5–6 µm, thin-walled.

Host(s): on thallus of *Rhizocarpon geographicum*

Ecological nature: Since no visible damage was observed on the host, it is a commensalistic species.

World distribution: Germany, Italy (Brackel, 2023), Austria, Canada, France, Great Britain and Northern Ireland, Norway, Sweden, Switzerland, U.S.A. (GBIF 2026).

Specimens examined: India, Uttarakhand, Chamoli district, Malari, on way to Sumna, near four point, alt. 2901 m, 30°22'01"N 79°22'33"E, on thallus of *Rhizocarpon geographicum* colonising rock, 21 June 2023, Sunita Bisht 00053 (RUBL 21976); Badrinath, Mana Valley, near mata murti temple alt. 3240 m, 30°46'15"N 79°29'22"E, on thallus of *Rhizocarpon geographicum* colonising rock, 21 June 2023, Sunita Bisht 00140 (RUBL 21977); ibid, 3080 m, 30°78'72"N 79°45'38"E, 21 June 2023, Sunita Bisht 00169 (RUBL 21978); on way to Vasudhara falls, 3240 m, 30°46'26"N 79°29'20"E, on thallus of *Rhizocarpon* sp. colonising rock, 19 June 2023, Sunita Bisht 00156 (RUBL 21413); ibid, 3200 m, on thallus of *Rhizocarpon geographicum* colonising rock, 21 June 2023, Sunita Bisht 00161 (RUBL 21980); Uttarkashi, district, Nelong valley, near Nelong, alt. 3590 m, 31°6'34"N 79°00'44"E, on thallus of *Rhizocarpon geographicum* colonising rock, 21 May 2025, Sunita Bisht 00377 (RUBL 21979).

Remarks: Indian collections previously reported as *Muellerella ventosicola* (Mudd) D. Hawksw. from Ladakh and Uttarakhand (Joshi *et al*., 2016, 2020ab) were re-examined after consulting (Brackel, 2023) and based on host specificity and morphological characters, these specimens should be better referred to *Muellerella rhizocarpicola*, occurring on *Rhizocarpon geographicum* instead of *M. ventosicola*.

Stigmidium congestum (Körb.) Triebel, Mycotaxon 42: 290 (1991) **(Figure 1H)**

Diagnostic characters: Ascomata perithecioid, globose, 40–70 µm, black. Ascomatal wall approximately 5–12 µm thick, entirely medium brown to dark brown. Periphyses and pseudoparaphyses 5–9 × 1–2 µm. Asci 25–30 × 10–15 µm, generally cylinder-like, clavate. Ascospores hyaline, 1-septate, ellipsoidal or more often oblong, 12–14 × 2.5–4 µm.

Host: on apothecial disc of *Lecanora* sp.

Ecological nature: It is a parasitic species, as black necrotic spots were observed on the apothecial discs of the host.

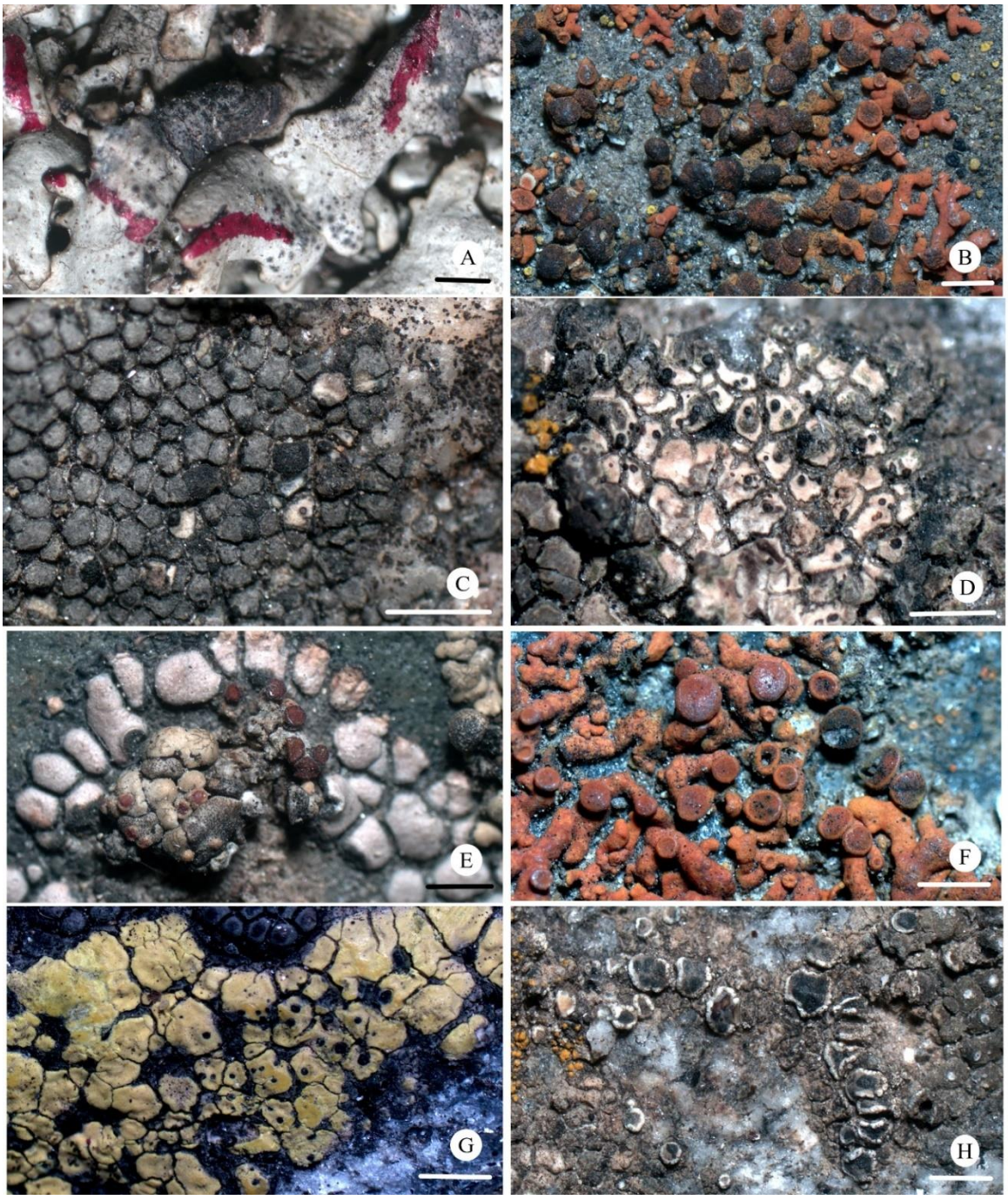

Figure 1: A,Thallus of *Xanthoparmelia* sp. infected by *Arthonia xanthoparmeliarum*; **B**, Thallus and apothecial disc of *Xanthoria* sp. infected by *Didymocyrtis slaptoniensis*; **C**, Thallus of *Rhizocarpon disporum* infected by *Endococcus exerrans*; **D**, Thallus of *Protoparmeliopsis muralis* infected by *Endococcus verrucisporus*; **E**, Thallus of *Rhizoplaca* sp. infected by *Erichansenia epithallina*; **F**, Apothecial disc of *Calogaya* sp. infected by *Intralichen baccisporus*; **G**, Thallus of *R. geographicum* infected by *Muellerella rhizocarpicola*; **H**, Apothecial disc of *Lecanora* sp. infected by *Stigmidium congestum* (Scale bar = 1 mm).

World distribution: Albania (Svoboda *et al*., 2012), Austria, France, Germany, Italy, Spain, Sweden, Switzerland, Turkey (Roux and Triebel, 1994) British Isles (Hitch, 1995), Bulgaria, Croatia (Hafellner, 2018) Canary Island (Hafellner, 1996), Czech Republic (Kocourková, 2000), Finland, Norway (Westberg *et al*., 2021) Greece (Christensen and Svane, 2009), Hungary (Varga *et al*., 2021), Iran (Sohrabi and Alstrup, 2007), Japan (Zhurbenko *et al*., 2015), Montenegro (Strasser *et al*., 2015), Morocco (Hafellner, 1996), Poland (Faltynowicz, 1993), Romania (Zamfir *et al*., 1998), Russia (Zhurbenko, 2017), Slovakia (Vězda, 1963), Slovenia (Grube *et al*., 1995, 1998), Ukraine (Darmostuk and Khodosovtsev, 2017), Great Britain and Northern Ireland, Denmark, Netherlands (GBIF 2026).

Specimen examined: India, Uttarakhand, Chamoli district, Niti village, 30°46'44"N, 79°50'09"E, alt. 3500 m, on apothecial disc of *Lecanora* sp. colonising rock, 10 October 2023, Sunita Bisht 00225 (RUBL 21964).

DISCUSSION

This study contributes seven new records of lichenicolous fungi and one new record of a lichenicolous lichen to India's known flora, raising the national checklist of lichenicolous fungi to 288 species. These discoveries highlight the substantial yet understudied diversity of lichenicolous fungi and lichens in the Himalayan region, especially Uttarakhand.

The artificial key provided facilitates identification of all known Indian lichenicolous lichens and underscores the need for further taxonomic and ecological studies to clarify host associations and biogeographic patterns. These results emphasize the ecological importance of lichenicolous fungi and lichens, particularly their unique strategies of host association and photobiont acquisition. Further surveys in diverse Indian ecosystems are warranted to uncover additional diversity and to elucidate the ecological roles of these specialized organisms.

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