



Original Article

An annotated catalogue of the lichenicolous fungi of Jammu and Kashmir and Ladakh, India with new records and identification key

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ABSTRACT

This article enumerates 72 species of lichenicolous fungi belonging to 21 families and 43 genera from Jammu and Kashmir and Ladakh. The study is based on published literature and specimens recently collected from some localities of Kishtwar High Altitude National Park, Jammu and Kashmir. Four species viz., *Bachmanniomyces santessonii* Etayo, *Intralichen lichenum* (Diederich) D. Hawksw., and M.S. Cole, *Milospium graphideorum* (Nyl.) D. Hawksw., and *Roselliniella oxyspora* Matzer and Hafellner are reported as new to India, while *Milospium* and *Roselliniella* are new generic records. Brief descriptions of the newly recorded species are presented. The geographical distribution, host lichens, and key to all the species of lichenicolous fungi presently known from Jammu and Kashmir and Ladakh are also provided.

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Introduction

The lichenicolous fungi represent a highly specialized group of fungi that form obligate or facultative associations exclusively with lichens. Some species may induce symptoms, while others appear to grow without causing any damage to the lichens they live on. They include a wide range of pathogens, saprotrophs, and commensals and many are host-specific. They have been described for centuries, but little is known about cellular contact, nutrient exchange, antibiosis, or virulence (Diederich et al. 2018). Globally, 3000–5000 species of lichenicolous fungi are estimated to occur. As of now, 2319 species are described among Ascomycetes (2219 species) and Basidiomycetes (100 species) under 55 orders, 115 families, and 397 genera (Diederich et al. 2018).

Although India is a megadiverse country, its lichenicolous fungi are still insufficiently known. Some publications mentioning the occurrence of lichenicolous fungi prior to the year 2013 are Moreau (1951a, b), Poelt (1961), Awasthi and Singh (1975), Rairkar and Patwardhan (1979) Sherwood et al. (1981), Hertel (1983), Pant and Awasthi (1989), Triebel (1989) Awasthi (1991) Hariharan et

al. (1996), Coppins and Kondratyuk (1998), Alstrup and Ahti (2007). Zhurbenko (2013) published the first checklist of Indian lichenicolous fungi mainly based on the specimens from Jammu and Kashmir and Ladakh which included 42 taxa. Subsequently, several publications by Joshi et al. (2013, 2016a, 2016b, 2016c, 2017a, 2017b, 2017c, 2018, 2020a, 2020b, 2021), Joshi (2018, 2020, 2021), Joseph and Sinha (2015), Singh et al. (2017), Singh and Singh (2019) made some notable contributions toward the knowledge of Indian lichenicolous fungi. To date, 216 species of lichenicolous fungi are known from India (based on the compilation of previously mentioned publications) which represents about 9% of the globally known species (Diederich et al. 2018).

The northernmost part of India has two Union Territories, Jammu and Kashmir and Ladakh, which geographically are located in the Western Himalayan region. Prior to October 2019, both the Union Territories were under a single state Jammu and Kashmir situated between the latitude of 32°17'–37°03' N and longitude of 72°03'–80°20' E. Jammu and Kashmir experiences sub-tropical to a temperate climate with the vegetation of broadleaved, coniferous, and mixed forests. In contrast, Ladakh is a cold desert and has scattered patches of *Populus* and *Salix* vegetation. The varied geography, climate, and vegetation in both regions are suitable for the luxuriant growth of lichens and lichenicolous fungi prefer a temperate climate. However, lichenicolous fungi are underexplored in the region as only a few reports are available

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(Zhurbenko 2013; Joshi et al. 2016a; Joshi et al. 2018; Joshi 2018; Kumar et al. 2021). Therefore, the aim of the present study is to explore these two Union Territories exclusively for lichenicolous fungi, and the study so far resulted in 72 species including four new records.

Material and methods

The present study is based on the compilation of lichenicolous fungi from published literature for Jammu and Kashmir, and Ladakh and a recent collection from some localities of Kishtwar High Altitude National Park (KHANP) located in the district Kishtwar of Jammu and Kashmir. Freshly collected specimens were studied with routine mycological techniques following Hawksworth et al. (2010), Darmostuk et al. (2018), and Etayo (2010). The external morphology was studied under the stereo-zoom microscope (Leica S8APO). Thin hand-cut sections of the fruiting bodies were examined for anatomical features in water, 10 % KOH (K), lactophenol cotton blue, and Lugol's iodine under a compound microscope (Leica DM2500) equipped with camera and image analysis software. All the measurements were taken from water mounts. The systematic arrangement and current nomenclatural status of the species were checked and revised following Diederich et al. (2018). The taxa are presented alphabetically and the newly recorded species for India are denoted by an asterisk (*). The data on species distribution were ascertained from previous literature and a distribution map was prepared in QGIS 3.6 (Figure 3). The species with unrecorded geocoordinates have been georeferenced with the help of specimen examined details and Google Earth Pro 7.3. The studied specimens are housed at herbarium LWG of CSIR-National Botanical Research Institute, Lucknow.

Result and discussion

Taxonomic accounts

1. *Abrothallus microspermus* Tul

Locality. Marwah, Kishtwar, KHANP, Jammu and Kashmir (Kumar et al. 2021).

Host. *Punctelia neutralis* (Hale) Krog

Remarks. The species is known from North America (Cole and Hawksworth 2001; Diederich 2003; Kocourková et al. 2012), Romania (Czarnota et al. 2018), Switzerland, Great Britain, southern Ural Mountains (Urbanavichene et al. 2013), South Korea (Kondratyuk et al. 2013), and New Zealand (Longán and Gómez-Bolea 1999).

2. *Acarospora lendemeri* K. Knudsen and Kocourk

Localities. Near Khardung-La pass and Leh (Zhurbenko 2013).

Host. *Candelariella* sp.

Remarks. Zhurbenko (2013) reported it as *Sarcogyne sphaerospora* J. Steiner. Later, Knudsen and Kocourková (2020) found that the taxa belong to the genus *Acarospora* and the name *A. sphaerospora* has already existed for another species. Therefore, they proposed a new name *A. lendemeri*. The species is so far known only from Mongolia and Kashmir (Huneck et al. 1992; Pino-Bodas et al. 2017).

3. *Arthonia clemens* (Tul.) Th. Fr

Localities. Bhaderwah, Ramtund, enroute to Kailash Kund, Jammu and Kashmir (Joshi et al. 2016a).

Host. *Rhizoplaca chrysoleuca* (Sm.) Zopf

Remarks. The species is known from Europe, North Africa, China, Greenland (Alstrup and Hawksworth 1990) and the Caucasus (Zhurbenko and Kobzeva 2016).

4. *Arthonia epiphyscia* Nyl

Locality. Zanskar, Ichar Ladakh (Joshi et al. 2016a).

Host. *Physcia* sp.

Remarks. The distribution of the species is scattered throughout south-eastern Britain and central Scotland (Cannon et al. 2020).

5. *Arthonia molendoi* (Frauenf.) R. Sant

Locality. Zanskar, Rangdeem Ladakh (Joshi et al. 2016a).

Host. *Rusavskia elegans* (Link) SY Kondr and Kärnefelt

Remarks. The species is distributed in Israel (Navrotskaya et al. 1996), Iran (Seaward et al. 2008), Turkey (Hafellner and John 2006), Tajikistan (Kondratyuk and Kudratov 2002) and Russia (Zhurbenko and Hafellner 1999).

6. **Bachmanniomyces santessonii* Etayo (Figure 1A and B)

Description. Conidiomata pycnidia, black, aggregate, immersed and finally erumpent, 0.1–0.2 mm in diameter. Conidiophores absent. Conidiogenous cells simple, sub-cylindrical to ampulliform, hyaline, 10.0–12.0 × 2.0–3.0 μm. Conidia simple, narrowly ellipsoid, slightly wider toward the ends, hyaline, 8–10.0 × 2.0–3.0 μm.

Specimen examined. India, Jammu and Kashmir, Kishtwar district, KHANP, Marwah, on *Sticta* sp. colonizing on bark, 33°41'5.262" N 75°41'13.4016" E, elev. 2630 m, 26 viii 2017, Vishal Kumar and Y.P. Sharma 17-035710 (LWG).

Distribution. Earlier, the species was reported only from Peru (Etayo 2010). It is a new record for India.

Host. *Sticta* sp.

Remarks. The species is closely related to *Bachmanniomyces pseudocyphellariae* Etayo, but differs due to the different morphology of their galls (small and stipitate in *B. santessonii* versus convex, wide and non-stipitate in *B. pseudocyphellariae*). The conidiogenous cells in *B. pseudocyphellariae* have characteristic basal enlargements that are missing in *B. santessonii*. Also, the conidia are more irregular and usually sickle-shaped in *B. pseudocyphellariae* while in case of *B. santessonii*, they are simple and slightly wider at the ends (Etayo 2010).

7. *Buelliella protoparmeliopsis* Etayo and Pérez-Ortega

Localities. Gulmarg and Srinagar (Dachigam National Park) Jammu and Kashmir (Joshi et al. 2016a).

Host. *Protoparmeliopsis muralis* (Schreb.) M. Choisy

Remarks. The species is known from South America (Perez-Ortega and Etayo 2010).

8. *Carbonea aggregantula* (Müll. Arg.) Diederich and Triebel

Locality. Pahalgam, Jammu and Kashmir (Joshi et al. 2016a).

Host. *Protoparmeliopsis muralis*

Remarks. The species is widely distributed in Europe, Asia, Macaronesia, Northern America, Southern America and Antarctica (Hafellner 2018a).

9. *Carbonea vitellinaria* (Nyl.) Hertel

Locality. Chaprot, Ladakh (Poelt 1961; Hertel 1983).

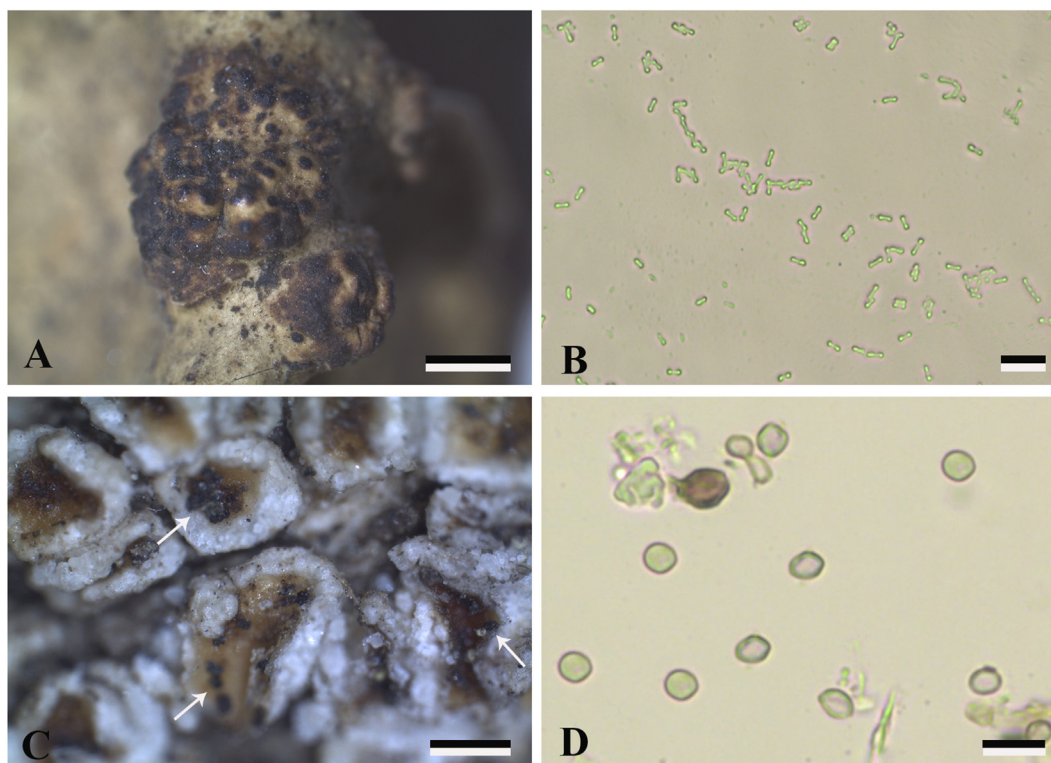


Figure 1. A, *Bachmanniomyces santessonii* infecting thallus of *Sticta* sp.; B, Conidia of *B. santessonii* in water; C, Mycelia of *Intralichen lichenum* infecting apothecia of *Lecanora* sp. (arrows); D, Conidia of *I. lichenum* in water. <scale bar: 1 mm (A); 20 μ m (B); 0.2 mm (C); 10 μ m (D)>

Host. *Candelaria vitellina* (Hoffm.) A. Massal.

Remarks. The species is cosmopolitan in distribution and is known from Europe, North and South America, Oceania and Asia (Hertel and Zhao 1982; Obermayer 2004; Galloway 2007; Etayo and Sancho 2008; Chambers et al. 2009; Zhurbenko 2009).

10. *Capronia triseptata* (Diederich) Etayo

Locality. Baisaran, Jammu and Kashmir (Joshi 2018).

Host. *Physcia* sp.

Remarks. The species was reported as *Muellerella triseptata* Diederich, by Joshi (2018). The distribution of the species is known from Luxembourg, France and Austria (Berger 1996), Switzerland (Matzer and Hafellner 1990) and Italy (Nimis and Tretiach 1999).

11. *Cercidospora caudata* Kernst

Locality. Near Defence Institute of High-Altitude Research, Chunthang valley, Sorinsa Ladakh (Joshi et al. 2016a).

Host. *Rusavskia elegans*

Remarks. The species is known from arid and Mediterranean regions to boreal and arctic regions of the world (Navarro-Rosinés et al. 2004).

12. *Cercidospora macrospora* (Uloth) Hafellner and Nav.-Ros

Localities. Kargil, Ladakh (Zhurbenko 2013), Shankaracharya Hill, Jammu and Kashmir (Joshi et al. 2016a).

Hosts. *Lecanora* sp., *Protoparmeliopsis muralis*

Remarks. The species is known all over the northern hemisphere and from the Himalayas including Nepal and Pakistan (Calatayud et al. 2013).

13. *Cercidospora melanophthalmae* Nav.-Ros

Localities. Near Khardungla pass Ladakh (Zhurbenko 2013), Sourire, Suru, Panikar, Changla Leh, Ladakh (Joshi et al. 2016a).

Hosts. *Rhizoplaca chrysoleuca*, *R. melanophthalma* var. *obscura* (J Steiner) Leuckert and Poelt and *R. peltata* (Ramond) Leuckert and Poelt.

Remarks. The species is known to occur in Syria, Armenia, Afghanistan and Pakistan (Calatayud et al. 2013).

14. *Cercidospora wernerii* Nav.-Ros., Calat. and Hafellner

Locality. Changla Leh, Ladakh (Joshi et al. 2016a).

Host. *Aspicilia* sp.

Remarks. The distribution of the species is known from Lebanon, Spain, France, Greenland (Navarro-Rosinés et al. 2009) and Turkey (Candan and Halici 2011).

15. *Cercidospora xanthoriae* (Wedd.) R. Sant

Localities. Leh, Ladakh (Zhurbenko 2013), Hemis National Park, Rumbak valley, Spandin Ladakh (Joshi et al. 2016a).

Host. *Rusavskia elegans*

Remarks. The species is known from Russia (Zhurbenko 2009) and Turkey (Hafellner and John 2006).

16. *Cercidospora* sp.

Localities. Near Khardung La Pass, Leh, Ladakh (Zhurbenko 2013)

Host. *Lecanora* sp.

Remarks. This species is closer to *C. macrospora* and also resembles *C. crozalsiana* (H. Oliver) Nav.-Ros., Cl. Roux and Casares but

differ in having exciple colorless or slightly green-blue in its lower half and somewhat smaller ascospores (Zhurbenko 2013). This partially identified species may represent an undescribed species which needs further examination.

17. **Cladosporium licheniphilum** Heuchert and U. Braun

Locality. Near Wullar Lake, Jammu and Kashmir (Zhurbenko 2013).

Host. *Polycauliona candelaria* (L.) Frödén, Arup and Söchting

Remarks. The species was reported from Russia (Heuchert and Braun 2006).

18. **Corticifraga peltigerae** (Fuckel) D. Hawksw. and R. Sant

Localities. Tangmarg and near Wullar Lake, Jammu and Kashmir (Zhurbenko 2013).

Hosts. *Peltigera elisabethae* Gyeln. and *Peltigera ponojensis* Gyeln.

Remarks. The species was reported from Russia (Zhurbenko 2009).

19. **Didymocyrtis epiphyscia** Ertz and Diederich

Locality. Near the Department of Environmental Science, behind the gas plant, Jammu and Kashmir (Joshi et al. 2018).

Host. *Physcia crispa* Nyl.

Remarks. So far, the species has been known from Europe (Belgium, France Germany, Italy and Luxembourg) (Ertz et al. 2015) and Asia (Zhurbenko 2009).

20. **Diplolaeviopsis ranula** Giralt and D. Hawksw

Locality. Pahalgam, Anantnag, Jammu and Kashmir (Joshi et al. 2018).

Host. *Lecanora indica* Zahlbr.

Remarks. It has been reported in Georgia and Kentucky (Diederich 2003) and California (Etayo et al. 2007).

21. **Echinothecium reticulatum** Zopf

Locality: Unknown

Host. *Flavoparmelia caperata* (L.) Hale

Remarks. The species was reported by Joshi et al. (2020b) from Jammu and Kashmir without its precise locality, specimen examined details and herbarium deposition. The species has a wide distribution especially in the boreal zone of Europe, Greenland, North and South America (Triebel et al. 1991) and Antarctica (Halici and Barták 2019).

22. **Endococcus incrassatus** Etayo and Breuss

Locality. Near Tawi river, Jammu and Kashmir (Zhurbenko 2013).

Host. *Endocarpon pusillum* Hedw.

Remarks. The species has been reported in California (Etayo and Breuss 2001) and Asia (Zhurbenko 2013).

23. **Endococcus physciae** Y. Joshi

Locality. Sondar, Kishtwar, KHANP, Jammu and Kashmir (Joshi 2018).

Host. *Physcia* sp.

Remarks. So far, the species is known from India (Joshi 2018).

24. **Endococcus rugulosus** (Leight.) Nyl

Locality. Tangmarg, Jammu and Kashmir (Zhurbenko 2013).

Host. *Aspicilia* sp.

Remarks. Earlier, the species has been known from Iran (Seaward et al 2008), Turkey (Halici et al. 2007a) and Russia (Zhurbenko 2009).

25. **Heterocephalacria physciacearum** (Diederich) Millanes and Wedin

Locality. Sonmarg, Jammu and Kashmir (Joshi et al. 2018).

Host. *Physcia grisea* (Lam.) Zahlbr.

Remarks. The species is widely distributed in Austria, Great Britain, Ethiopia, and Canada (Diederich 1996).

26. **Intralichen christiansenii** (D. Hawksw.) D. Hawksw. and M.S. Cole

Locality. Khardung-La pass Ladakh (Zhurbenko 2013).

Host. *Candelariella aurella* (Hoffm.) Zahlbr.

Remarks. The species is widely distributed in Israel (Temina et al. 2005), Iran (Seaward et al. 2008), Turkey (Hafellner and John 2006), Russia (Zhurbenko and Hafellner 1999) and China (Hawksworth and Cole 2003).

27. ***Intralichen lichenum** (Diederich) D. Hawksw. and M.S. Cole (Figure 1C and D)

Description. Mycelium brown, septate, not constricted at septa. Conidiophores not separated from vegetative hyphae, branched, pale brown, septate, constricted at septa, $22.0\text{--}35.0 \times 1.5\text{--}2.5 \mu\text{m}$. Conidiogenous cells monoblastic, not distinguished from conidiophore cells, subcylindrical to ellipsoid, pale brownish, conidia simple brownish, aseptate, in chains, $3.5\text{--}4.5 \times 2.5\text{--}3.5 \mu\text{m}$.

Specimen examined. India, Jammu and Kashmir, Kishtwar district, KHANP, Sonder, on *Lecanora* sp. colonizing twigs of *Cedrus deodara* $33^\circ 28' 22.6272'' \text{N}$ $75^\circ 50' 17.52'' \text{E}$, elev. 2116 m, 20 April 2019, Vishal Kumar and Y. P. Sharma 19-035711 (LWG).

Distribution. Earlier, the species was reported in the British Isles (Hawksworth 1994), New Guinea (Aptroot et al. 1997), the USA (Cole and Hawksworth 2001), the Republic of Adygea, Russia (Zhurbenko and Kobzeva 2016), European Russia (Tsurukau and Korchikov 2017). It is a new record for India.

Host. *Lecanora* sp.

Remarks. The species is close to *Intralichen christiansenii* but readily gets distinguished in having aseptate conidia (Hawksworth and Cole 2002).

28. **Lichenochora ajaysinghii** Y. Joshi

Locality. Baltal, Anantnag, Jammu and Kashmir (Joshi et al. 2020a).

Host. *Caloplaca saxicola* (Hoffm.) Nordin

Remarks. So far, the species is known only from India only (Joshi et al. 2020a).

29. **Lichenochora verrucicola** (Wedd.) Nik. Hoffm. and Hafellner

Locality. Leh, Ladakh (Joshi et al. 2016a).

Host. *Aspicilia* sp.

Remarks. This species is known from Europe (France, Spain, the Netherlands) and North America (Sparrius et al. 2002; Knudsen 2006).

30. *Lichenocodium lecanorae* (Jaap) D. Hawksw

Locality. Sonder, Kishtwar, KHANP, Jammu and Kashmir (Kumar et al. 2021).

Host. *Lecanora* sp.

Remarks. So far, it is known from Great Britain, Ireland, Canary Island, Spain (Hawksworth et al. 2010), and Ukraine (Darmostuk 2019a).

31. *Lichenocodium usneae* (Anzi) D. Hawksw

Locality. Pahalgam, Jammu and Kashmir (Zhurbenko 2013).

Host. *Flavoparmelia caperata*

Remarks. The species has been reported from Turkey (Hafellner and John 2006), Russia (Zhurbenko 2009), and Iran (Sohrabi and Alstrup 2007).

32. *Lichenocodium xanthoriae* M.S. Christ

Locality. Tangmarg, Jammu and Kashmir (Zhurbenko 2013).

Host. *Melanelixia subargentifera* (Nyl.) O. Blanco et al

Remarks. The species has been reported in Austria (Etayo and Berger 2009), the USA (Haldeman 2019), Russia (Himmelbrant et al. 2013), and Italy (Brackel 2008).

33. *Lichenodiplis lecanorae* (Vouaux) Dyko and D. Hawksw

Localities. Pahalgam and Gulmarg, Jammu and Kashmir (Zhurbenko 2013).

Hosts. *Caloplaca cerina* (Hedw.) Th. Fr., *Polycauliona candelaria* and *Porpidia crustulata* (Ach.) Hertel and Knoph.

Remarks. The species has been reported from Russia (Zhurbenko et al. 2012) and Turkey (Hafellner and John 2006).

34. *Lichenostigma alpinum* (R. Sant., Alstrup and D. Hawksw.) Ertz and Diederich

Locality. Tangmarg, Jammu and Kashmir (Zhurbenko 2013).

Host. *Lepra albescens* (Huds.) Hafellner

Remarks. The distribution of the species is known from China (Hawksworth and Cole 2003), Iran (Sohrabi and Alstrup 2007), Russia (Zhurbenko 2009), and Turkey (Halici et al. 2007b).

35. *Lichenostigma cosmopolites* Hafellner and Calat

Localities. Near Wullar lake, Jammu and Kashmir (Zhurbenko 2013), Kishtwar, Sarthal forest area, Kukernag, Jammu and Kashmir (Joshi et al. 2016a).

Hosts. *Xanthoparmelia mexicana* (Gyeln.) Hale, *X. stenophylla* (Ach.) Ahti and D. Hawksw. and *X. conspersa* (Ehrh. ex Ach.) Hale

Remarks. The species has been reported from Turkey, Iran, Georgia, Nepal, China and Japan (Hafellner and Calatayud 1999; Aptroot and Sipman 2001; Hawksworth and Cole 2003; Sohrabi and Alstrup 2007).

36. *Lichenostigma cf. elongatum* Nav.-Ros. and Hafellner

Locality. Leh, Ladakh (Zhurbenko 2013).

Hosts. *Lecanora* sp., *Lobothallia praeradiosa* (Nyl.) Hafellner

Remarks. The distribution of the species is known from Syria (John et al. 2004), Iran (Valadbeigi and Sipman 2010), Russia (Zhurbenko 2009), and Turkey (Hafellner and John 2006).

37. *Lichenostigma maureri* Hafellner

Locality. In between Pahalgam and Lidderwat, Jammu and Kashmir (Joshi et al. 2016a).

Host. *Xanthoparmelia stenophylla*

Remarks. The species is widespread in the Northern and Southern hemispheres (Calatayud et al. 2004).

38. *Lichenostigma* sp.

Locality. Leh, Ladakh (Zhurbenko 2013).

Host. *Seiophora contortuplicata* (Ach.) Frödén

Remarks. Zhurbenko (2013) reported this taxon as *Lichenostigma* subgen. *Lichenogramma* sp. In the recent classification by Diederich et al. (2018), the genus is placed under *Lichenostigma*.

39. *Marchandiomyces corallinus* (Roberge) Diederich and D. Hawksw

Locality. Near Wullar Lake, Jammu and Kashmir (Zhurbenko 2013).

Hosts. *Physcia aipolia* (Ehrh. ex Humb.) Fűrnr., and *Polycauliona candelaria*

Remarks. The species is known from China (Hawksworth and Cole 2003) and Russia (Zhurbenko 2008).

40. **Milospium graphideorum* (Nyl.) D. Hawksw (Figure 2A–B)

Description. Conidiomata sporodochia, brown to black, often aggregated on the host thallus, 0.15–0.25 mm in diameter. Conidiophores simple to irregularly branched, hyaline to brownish, septate, 2.5–3.5 µm in diameter. Conidiogenous cells monoblastic, hyaline to pale brown, 6–11 × 3–4 µm. Conidia irregularly subglobose to ellipsoid, brown to dark brown, simple but superficially appearing muriform in heavily lobed conidia, 5–12 × 4–8 µm.

Specimens examined. India, Jammu and Kashmir, Kishtwar district, KHANP, Loharna, on *Graphis scripta* (L.) Ach. Colonizing bark of a tree, 33°34'21.90" N, 75°50'43.73" E, elev. 2550 m, 26 August 2021, Vishal Kumar 21-045901, 21-045902 (LWG); KHANP, Palmar, on *Lepraria* sp. Colonizing on soil, 33°27'20.01" N, 75°41'5.65" E, elev. 2413 m, 10 November 2020, Vishal Kumar and Y.P. Sharma 21-036827 (LWG).

Distribution. It is known from Portugal (Hawksworth 1975), Bulgaria (Otte 2005), Khodosovtsev et al. (2007), England, Ireland, Channel Island, Canary Island, Spain (Hawksworth et al. (2010), Caucasus Russia (Urbanavichus and Ismailov 2013) and France (Hafellner 2018a). It is a new record for India.

Hosts. *Graphis scripta* (L.) Ach. and *Lepraria* sp.

Remarks. Previously, *Milospium graphideorum* was always reported on lichens having *Trentepohlia* as photobiont. However, in the present study, in addition to *Graphis* sp., we also found it growing on *Lepraria* sp., which has *Asterochloris* as photobiont. This species differs from the rest of the species of the genus because most of these have septate spores with differently thickened walls (Crous et al. 2015).

41. *Monodictys epilepraria* Kukwa and Diederich

Locality. Tangmarg, Jammu and Kashmir (Zhurbenko 2013).

Host. *Lepraria* sp.

Remarks. The species has been reported from Great Britain, Scotland (Kukwa and Diederich 2005) and Ukraine (Kapets and Kondratyuk 2019).

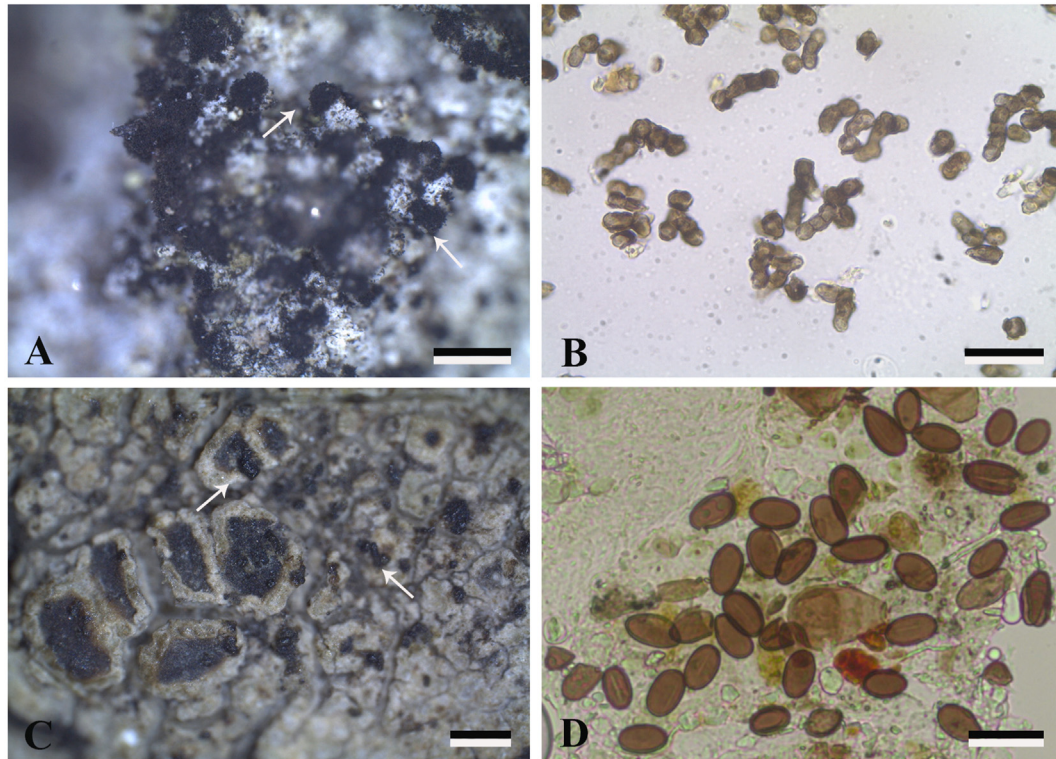


Figure 2. A, Colonies of *Milospium graphideorum* infecting thallus of *Lepraria* sp. (arrows); B, irregularly folded conidia of *M. graphideorum* in water; C, Perithecia of *Roselliniella oxyspora* on thallus and an apothecial disc of *Lecanora* sp. (arrows); D, brown ascospores of *R. oxyspora* in water. <scale bar: 0.5 mm (A); 10 μ m (B); 0.5 mm (C); 20 μ m (D)>

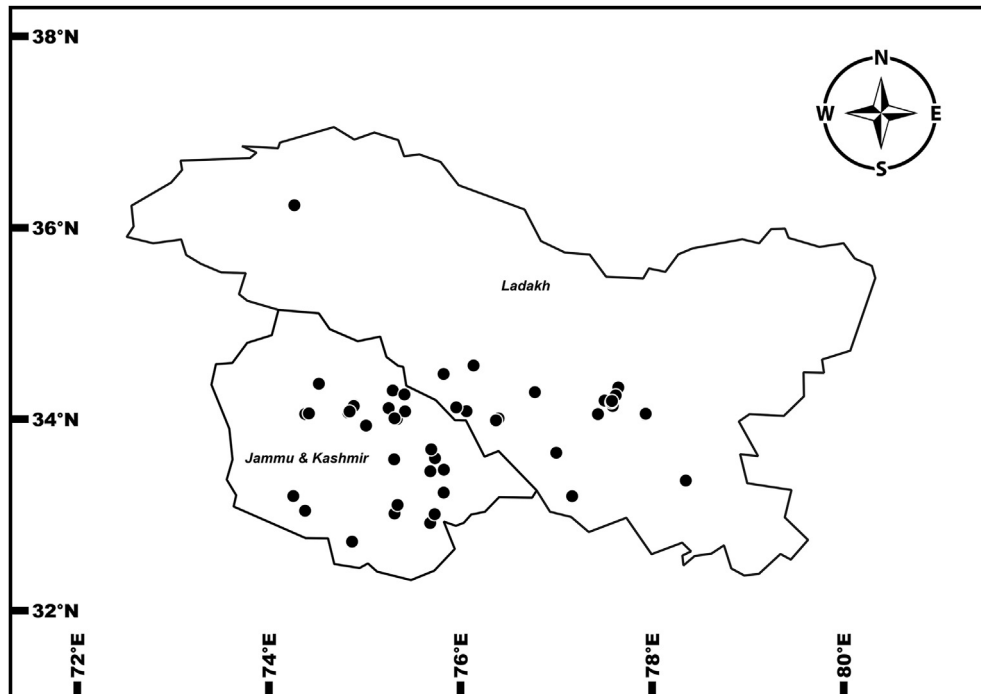


Figure 3. Distribution map of lichenicolous fungi in Jammu and Kashmir, and Ladakh.

42. *Muellerella erratica* (A. Massal.) Hafellner and V. John

Localities. Near Khardung-La pass Hemis National Park, Rumbak valley, Gandala, Panikar, Suru valley, Zanskar, Changla, Ladakh

(Zhurbenko 2013), Pahalgam, Jammu and Kashmir (Joshi et al. 2016a).

Hosts. *Aspicilia maculata* (H. Magn.) Oxner, *Aspicilia caesiocinerea* (Nyl. ex Malbr.) Arnold, *Lecanora* sp., *Lecidea lapicida* (Ach.) Ach.,

Pertusaria sp., *Protoparmeliopsis muralis*, *Rhizoplaca melanophthalma* and *Rusavskia elegans*.

Remarks. The species is known from Nepal (Triebel 1989), Iran (Seaward et al. 2008), Russia (Zhurbenko 2009), China, Pakistan (Poelt and Grube 1993) and Turkey (Hafellner and John 2006).

43. ***Muellerella lichenicola*** (Sommerf.) D. Hawksw

Locality. Fyang, Leh, Ladakh (Joshi et al. 2016a).

Host. *Rusavskia elegans*

Remarks. The species is known from Northwestern European Russia (Himmelbrant et al. 2018), Murmansk Region (Urbanavichus et al. 2008), Norway, Sweden, and Finland (Westberg et al. 2021).

44. ***Muellerella pygmaea*** (Körb.) D. Hawksw

Localities. Lamayuru and Leh, Ladakh (Zhurbenko 2013).

Hosts. *Acarospora* sp. and *Rusavskia elegans*

Remarks. The distribution of the species is known from China (Hawksworth and Cole 2003), Turkey (Hafellner and John 2006), Iran (Seaward et al. 2008), Tajikistan (Kondratyuk and Kudratov 2002) and Russia (Triebel 1989; Zhurbenko 2009).

45. ***Muellerella ventosicola*** (Mudd) D. Hawksw

Locality. Rangdum Leh, Ladakh (Joshi et al. 2016a).

Host. *Rhizocarpon disporum* (Nägeli ex Hepp) Müll. Arg.

Remarks. The species is known from Turkey (Yazici and Etayo 2014) and Ukraine (Nadyeina and Halici 2011).

46. ***Nectriopsis lecanodes*** (Ces.) Diederich and Schroers

Localities. Tangmarg and near Wullar Lake, Jammu and Kashmir (Zhurbenko 2013).

Hosts. *Peltigera elisabethae* and *Peltigera scabrosa* Th. Fr.

Remarks. The occurrence of this widespread species is known from Europe, Lithuania (Motiejūnaitė et al. 2006) and Greece (Hafellner 2018b).

47. ***Phacothecium varium*** (Tul.) Trevis

Locality. Harwan, Dachigam National Park, Jammu and Kashmir (Joshi 2018).

Host. *Xanthoria parietina* (L.) Th.

Remarks. So far, it has been recorded from Austria (Poetsch and Schiedermayr 1872), Germany (Arnold 1868), Italy (Jatta 1882), Ukraine (Kondratyuk and Khodosovtsev 1997) and Israel (Navrotskaya et al. 1996).

48. ***Phoma* sp.**

Locality. Gulmarg, Jammu and Kashmir (Zhurbenko 2013).

Host. *Rusavskia elegans*

Remarks. This partially identified species needs further re-examination.

49. ***Polycoccum clauzadei*** Nav.-Ros. and Cl. Roux

Locality. Leh, Ladakh (Zhurbenko 2013).

Host. *Rusavskia elegans*

Remarks. The species is known from Russia (Zhurbenko 2009) and Iran (Sohrabi and Alstrup 2007).

50. ***Polycoccum ibericum*** Etayo and van den Boom

Locality. Harwan, Dachigam National Park, Jammu and Kashmir (Joshi 2018).

Host. *Rinodina* sp.

Remarks. The species is known from Spain and Portugal (Van den Boom and Etayo 2014).

51. ***Polycoccum pulvinatum*** (Eitner) R. Sant

Locality. Tangmarg, Jammu and Kashmir (Zhurbenko 2013).

Host. *Physcia dubia* (Hoffm.) Lettau

Remarks. The species is known from Russia (Zhurbenko 2009) and Iran (Sohrabi and Alstrup 2007).

52. ***Polysporina subfuscescens*** (Nyl.) K. Knudsen and Kocourk

Localities. Chumthang Valley, Ganglas area of Leh, Ladakh and Srinagar, Jammu and Kashmir (Joshi et al. 2016a).

Hosts. *Candelariella aurella* and *Carbonea* sp.

Remarks. The species is widely distributed in North America, Europe, Asia, in the northern hemisphere (Knudsen and Kocourkova 2008).

53. ***Pyrenidium actinellum*** Nyl

Locality. Tangmarg, Jammu and Kashmir by (Zhurbenko 2013).

Hosts. *Peltigera elisabethae* and *Peltigera praetextata* (Flörke ex Sommerf.) Zopf

Remarks. The occurrence of the species is known from Russia (Zhurbenko 2009) and Turkey (Halici et al. 2007c).

54. ***Rosellinula frustulosae*** (Vouaux) R. Sant

Locality. Leh, Ladakh (Zhurbenko 2013).

Host. *Lecanora frustulosa* (Dicks.) Ach.

Remarks. The species is known from Mongolia (Hafellner 1985), Kyrgyzstan (Nadyeina and Halici 2011), Turkey (Halici et al. 2007d) and Iran (Sohrabi and Alstrup 2007).

55. ****Roselliniella* cf. *oxyspora*** Matzer and Hafellner (Figure 2C and D)

Description. Ascomata perithecia, dark brown to black, globose to subglobose, immersed to erumpent, scattered, 0.15–0.2 mm in diam. Paraphyses septate and branched, not thickened at the apex. Asci clavate, unitunicate, thin-walled, 8-spored, I–, K/I–. Ascospores simple, brown, ovate to narrowly ellipsoid, sometimes with pointed apices, with small guttules, 11.5–14.5 × 6.5–8.5 μm.

Specimen examined. India, Jammu and Kashmir, Kishtwar district, KHANP, Sonder, on *Lecanora* sp. Colonizing twigs of *Cedrus deodara* 33°28'19.80" N, 75°49'24.03" E, elev. 2030 m, 21 April 2019, Vishal Kumar and Y. P. Sharma 19-035724 (LWG).

Distribution. This species is known only from Brazil and Tanzania (Matzer and Hafellner 1990). It is a new record for India.

Host. *Lecanora* sp.

Remarks. The species is reported so far only from *Coccocarpia* sp. (Matzer and Hafellner 1990) and its current report from *Lecanora* sp. is interesting. Due to the unavailability of the additional specimens for the time being, we are treating this species under *Roselliniella* cf. *oxyspora*.

56. ***Sclerococcum saxatile*** (Schaer.) Ertz and Diederich

Locality. Bhaderwah, Jammu and Kashmir.

Host. *Pertusaria* sp.

Remarks. Joshi et al. (2016a) reported it as *Dactylospora saxatilis* (Schaer.) Hafellner, however, according to Diederich et al. (2018) the species is synonym under *Sclerococcum saxatile*. The species is

so far known from Europe, Asia, North Africa, North America (U.S.A. Greenland) and Australia (Hafellner 2004).

57. *Sphaerellothecium contextum* Triebel

Locality. Unknown

Host. *Rhizoplaca* sp.

Remarks. Joshi et al. (2020b) reported the occurrence of this species in Jammu and Kashmir without mentioning its precise locality and herbarium deposition. Its occurrence is known from Europe and North America (Cáceres and Triebel 2004).

58. *Sphaerellothecium propinquellum* (Nyl.) Cl. Roux and Triebel

Locality. Awantipura, Srinagar, Jammu and Kashmir (Joshi et al. 2016a).

Host. *Protoparmeliopsis muralis*

Remarks. The species is so far known to occur on *Lecanora carpinea* (L.) Vain. and allied species (Roux and Triebel 1994; Zhurbenko et al. 2020). Joshi et al. (2016a) reported the occurrence of this species growing on *Protoparmeliopsis muralis*. The species is known from Europe and North America (Cáceres and Triebel 2004).

59. *Sphaerellothecium pumilum* (Lettau) Nav.-Ros., Cl. Roux and Hafellner

Localities. Tangmarg Jammu and Kashmir (Zhurbenko 2013) and Pahalgam, Jammu and Kashmir (Joshi et al. 2016a).

Hosts. *Phaeophyscia ciliata* (Hoffm.) Moberg and *Physcia caesia* (Hoffm.) Fűrnr.

Remarks. Zhurbenko (2013) and Joshi et al. (2016a) reported the species as *Stigmidium pumilum* (Lettau) Matzer and Hafellner, but according to Diederich et al. (2018) the species is now treated under *Sphaerellothecium*. The occurrence of this species is known from Europe, New Zealand, South America and North America (Triebel and Cáceres 2004).

60. *Sphaeropezia cf. lecanorae* (Diederich and G. Marson) Baloch and Wedin

Locality. Tangmarg, Jammu and Kashmir (Zhurbenko 2013)

Host. *Protoparmeliopsis muralis*

Remarks. The species is known from the Austrian Alps and the USA (Diederich et al. 2002).

61. *Spirographa fusisporella* (Nyl.) Zahlbr. s.l

Locality. Baltal, Anantnag, Jammu and Kashmir (Joshi et al. 2016a).

Host. *Protoparmeliopsis muralis*

Remarks. Flakus et al. (2019) reported this species growing in the hymenium of *Fissurina* and *Graphis* in Brazil, Cuba, Europe and Cantabria (northern Spain) indicating it to be specific to Graphidaceae. Whereas from India, the species was reported on *Protoparmeliopsis muralis* by Joshi et al. (2016a). Therefore, it might be a species complex, and the Indian specimens may belong to an undescribed species of *Spirographa*.

62. *Stigmidium fuscatae* (Arnold) R. Sant

Localities. Deharna, Sonder, KHANP Jammu and Kashmir (Joshi et al. 2018).

Hosts. *Acarospora fuscata* (Ach.) Arnold, *Acarospora* sp.

Remarks. The species is widely distributed in Europe, Africa (South Africa), and North America and Mexico (Triebel and Cáceres 2004).

63. *Stigmidium gyrophorarum* (Arnold) D. Hawksw

Locality. Tangmarg, Jammu and Kashmir (Zhurbenko 2013).

Host. *Umbilicaria vellea* Hoffm.

Remarks. The species has been reported from Russia (Zhurbenko and Santesson 1996), Turkey (Halici et al. 2007e), and Tajikistan (Kondratyuk and Kudratov 2002).

64. *Stigmidium squamariae* (B. de Lesd.) Cl. Roux and Triebel

Localities. Bhaderwah, Marwah and Sonder, KHANP. Jammu and Kashmir (Joshi et al. 2018).

Host. *Protoparmeliopsis muralis*

Remarks. The species has been reported from Europe, Africa (Morocco), U.S.A. and Mexico (Triebel and Cáceres 2004).

65. *Stigmidium tabacinae* (Arnold) Triebel

Localities. Sonmarg, Jammu and Kashmir (Zhurbenko 2013) and Lamayuru, Leh, Ladakh (Joshi et al. 2016a).

Hosts. *Toninia tristis* (Th. Fr.) Th. Fr. and *Toninia tristis* ssp. *asiae-centralis* (H. Magn.) Timdal

Remarks. It is known from Russia (Zhurbenko 2009), Iran (Sohrabi and Alstrup 2007) and Turkey (Hafellner and John 2006).

66. *Stigmidium xanthoparmeliarum* Hafellner

Locality. Shankaracharya Hill, Jammu and Kashmir (Joshi et al. 2016a).

Host. *Xanthoparmelia stenophylla*

Remarks. The species is known from Austria and Switzerland (Hafellner 1999), and Spain (Calatayud and Triebel 1999), Great Britain (Hawksworth 2003) and Iran (Sohrabi and Alstrup 2007).

67. *Tetramelas pulverulentus* (Anzi) A. Nordin and Tibell

Localities. Leh district, Chumathang valley, Somreri, Ladakh (Joshi et al. 2018).

Host. *Physcia* sp.

Remarks. Most of the records of the species are known from Europe Asia, northern Africa Macaronesia, Northern America, Southern America, and Antarctica (Hafellner 2018b).

68. *Vouauxiella lichenicola* (Linds.) Petr. and Syd

Localities. Pahalgam and Gulmarg, Jammu and Kashmir (Zhurbenko 2013) and Gulmarg (Joshi et al. 2016a).

Host. *Lecanora* cf. *subrugosa* Nyl.

Remarks. The species is widely distributed in Europe, northern Africa, North America (Diederich 2004) and Turkey (Etayo and Breuss 1998).

69. *Xenonectriella subimperspicua* (Speg.) Etayo

Locality. Bhaderwah Doda, Jammu and Kashmir (Zhurbenko 2013).

Host. *Punctelia borreri* (Turner) Krog

Remarks. The species was reported as *Pronectria subimperspicua* (Speg.) Lowen by Zhurbenko (2013) but as per Diederich et al. (2018), the species is now treated under *Xenonectriella*

subimperspicua. It has been reported from Argentina, Brazil, Ecuador, Germany, New Zealand and Spain (Brackel 2007; Motiejūnaitė and Grochowski 2014; Etayo and Pérez-Ortega 2016; Etayo 2017).

70. *Zwackhiomyces coepulonus* (Norman) Grube and R. Sant

Locality. Leh, Ladakh (Zhurbenko 2013).

Host. *Rusavskia elegans*

Remarks. The distribution of the species is known from Russia (Zhurbenko 2009), Israel (Navrotskaya et al. 1996), Turkey (Hafellner and John 2006) and Mongolia (Huneck et al. 1992).

71. *Zwackhiomyces cf. kizskianus* D. Hawksw. and Miądl

Locality. Tangmarg, Jammu and Kashmir (Zhurbenko 2013).

Host. *Peltigera elisabethae*

Remarks. The species is known only from Germany (Zhurbenko 2013) and Asian Russia (Zhurbenko 2017).

72. *Zwackhiomyces lecanorae* (Stein) Nik. Hoffm. and Hafellner

Locality. Zangla, Ladakh (Joshi et al. 2016a).

Host. *Lecanora* sp.

Remarks. The species is scattered in Europe and New Zealand (Bielczyk et al. 2005), Turkey (Halici et al. 2007a) and Ukraine (Darmostuk 2019b).

The present study includes a checklist of 72 species belonging to 43 genera and 21 families. The lichenological survey in some localities of KHANP yielded some interesting species viz., *Bachmanniomyces santessonii*, *Intralichen lichenum*, *Milospium graphideorum*, and *Roselliniella oxyspora* which are reported for the first time from India. Whereas *Milospium* and *Roselliniella* represent new generic records for India. The study revealed that lichenicolous fungi *Cercidospora melanophthalmae*, *Lichenodiplis lecanorae*, and *Muellerella erratica* occur on a wide range of hosts. The most speciose genus in the study region is *Cercidospora* with six species while *Lichenostigma* and *Stigmatidium* are the genera each being represented by five species. As far as the most hospitable host genera are concerned, it was *Rusavskia* being infected by nine species of lichenicolous fungi followed by *Lecanora*, *Physcia*, and *Protoparmeliopsis* that are infected by eight species each.

The lichenicolous fungi are being reported on 69 host lichens in Jammu and Kashmir, and Ladakh which relatively is a small number compared to the total number of lichens reported from the region i.e. 447 species (Kumar et al. 2021) This suggests that a greater number of lichenicolous fungi might be discovered in the near future. It is not yet known why some lichens are more prone to lichenicolous fungi while others are not. The plausible explanation would be the presence of different secondary metabolites in lichens favoring or avoiding the growth of lichenicolous fungi (Asplund et al. 2015). Further, the knowledge of lichenicolous fungi is far from complete as a large number of new species are still being discovered. As per a recent estimate, only 8% of the world's fungi are known so far (Hawksworth and Lücking 2017)

The present study provides detailed information on lichenicolous fungi known to occur in both the union territories of Western Himalaya indicating the area as a potential 'hotspot' of lichenicolous fungal diversity. This can be justified by the fact that this region harbors some of the unique species of lichenicolous fungi as in the case of *Bachmanniomyces santessonii* (Etayo 2010) and *Roselliniella oxyspora* (Matzer and Hafellner 1990) which earlier

were known only from their type localities. In addition, the lichen mycota of the region is also noteworthy as it exhibits a close relationship with that of Europe (Awasthi and Singh 1970).

Polysporina dubia (H. Magn.) Vězda [= *Sarcogyne lapponica* (Ach. ex Schaer.) K. Knudsen and Kocourk.] growing on the thallus of *Acarospora* sp. reported from N.W. Himalayas by Poelt and Vězda (1981) is excluded from the current checklist because of the inability to trace its precise locality and herbarium deposition. Moreover, the occurrence of *Echinothecium reticulatum* and *Sphaerellothecium contextum* is dubious in Jammu and Kashmir, and Ladakh as these are reported without locality and specimen examined details by Joshi et al (2020c). However, both the species are included in the present list as their incidence is known from neighboring states such as Himachal Pradesh and Uttarakhand, and may find place in future studies.

During the last decade, lichenicolous fungi in India are studied with an increasing intensity. The updated checklist on Indian lichenicolous fungi by Joshi et al. (2016a) reported 105 species. In recent years (2016–2021), 145 new records and 20 novel species have been reported from India. This increase in the number of taxa suggests that Indian lichenicolous biota is still underexplored. Intensive surveys in ecologically interesting habitats and unexplored areas will definitely reveal a greater number of novel species and new records.

Our study highlights that the union territories of Jammu and Kashmir, and Ladakh are one of the biodiversity-rich regions of India due to varied climatic conditions and topographical features. During the last decade, the number of studies focusing on lichenicolous fungi in India has helped to uncover their diversity. However, only a few regions of the country have been explored and still, there is a lot of work remaining to understand the diversity, host specificity, and biology of the lichenicolous fungi particularly in biodiversity-rich areas. Owing to diverse lichen mycota and a wide range of elevation, aspects, slopes, and moisture regime, it is expected that a large number of such fungi may occur in Jammu and Kashmir, and Ladakh. Hence, further exploratory studies particularly for lichens and lichenicolous fungi are needed in different geographical locations of both the union territories.

Key to the species of lichenicolous fungi of Jammu and Kashmir and Ladakh, India

- 1a. Spores produced in asci..... 2
- 1b. Spores not produced in asci..... 56
- 2a. Ascumata arthonioid..... 3
- 2b. Ascumata otherwise..... 5
- 3a. Hypothecium hyaline, ascospores hyaline, 1-septate, obovate, 10–14 × 4–7 μm, on *Rhizoplaca chrysoleuca* colonizing exposed quartzite..... *Arthonia clemens*
- 3b. Hypothecium pigmented..... 4
- 4a. Hypothecium pale yellowish to medium-brown, ascospores hyaline, 1-septate, 11–14 × 5–6 μm, on *Rusavskia elegans* colonizing rocks..... *Arthonia molendoi*
- 4b. Hypothecium olive-brown, ascospores hyaline, 1-septate, obovate, lower cell attenuated, smooth, 14–16 × 5–7 μm, on *Physcia* sp. colonizing rocks..... *Arthonia epiphyscia*
- 5a. Ascumata apothecioid..... 6
- 5b. Ascumata perithecioid..... 17
- 6a. Ascospores simple..... 7
- 6b. Ascospores septate..... 10
- 7a. Asci multispored..... 8
- 7b. Asci 8-spored..... 9

- 8a. Ascospores globose to broadly ellipsoid, hyaline, 3–6 × 3–4.5 µm, on *Candelariella* sp. colonizing rocks.....*Acarospora lendemeri*
- 8b. Ascospores narrowly to broadly ellipsoid, hyaline, 3–5 × 1–3 µm, on *Candelariella aurella* and *Carbonea* sp. colonizing rocks.....*Polysporina subfuscescens*
- 9a. Apothecial disc flat, ascospores hyaline, ellipsoid, 7–12 × 5–7 µm, on *Candelaria vitellina* colonizing rocks.....*Carbonea vitellinaria*
- 9b. Apothecial disc convex, ascospores hyaline, ellipsoid, 9–12 × 2–4 µm, on *Protoparmeliopsis muralis* colonizing boulders.....*Carbonea aggregantula*
- 10a. Ascospores consistently 1-septate.....11
- 10b. Ascospores 1–3-septate.....14
- 11a. Ascospores hyaline, slightly sigmoid, not constricted at septum, 22–30 × 1.5–2.5 µm, on *Protoparmeliopsis muralis* colonizing rocks.....*Spirographa fusisporella*
- 11b. Ascospores brownish.....12
- 12a. Hypothecium hyaline, ascospores light brown, constricted at the septum, cells of unequal size, 18–21 × 6–10 µm, on *Protoparmeliopsis muralis* colonizing boulders.....*Buelliella protoparmeliopsis*
- 12b. Hypothecium pale brown.....13
- 13a. Epithymenium and hymenium K–, ascospores smooth, dark brown, 10–15 × 6–10 µm, on *Pertusaria* sp. colonizing bark.....*Sclerococcum saxatile*
- 13b. Epithymenium and hymenium K+ green, ascospores ornamented, brown, 11–14.5 × 4.5–5.5 µm, on *Punctelia neutralis* colonizing bark.....*Abrothallus microspermus*
- 14a. Ascospores brown, ellipsoid, straight or slightly curved, 1–3-septate, 14.5 × 6.5–8.5 µm, on *Physcia* sp. colonizing rocks.....*Tetramelas pulverulentus*
- 14b. Ascospores hyaline.....15
- 15a. Hymenium I–, ascomata black, arising in circular spots on the thallus, ascospores hyaline, (1)–3-septate, without a perispore, 20–24 × 4–7 µm, on *Peltigera elisabethae* and *Peltigera ponojensis* colonizing mossy soil.....*Corticifraga peltigerae*
- 15b. Hymenium I+ blue.....16
- 16a. Ascomata dark brown, disc rounded, margin curved inwards, ascospores hyaline, ellipsoid to narrowly ellipsoid, 3-septate, 10.5–16 × 4.5–7.5 µm, on *Protoparmeliopsis muralis* colonizing rocks.....*Sphaeropezia cf. lecanorae*
- 16b. Ascomata black, elongated, margin not curved, ascospores hyaline, oblong-ovoid, 3-septate, 12–16 × 5–7 µm, on *Xanthoria parietina* colonizing twigs.....*Phacothecium varium*
- 17a. Ascomata stromatic.....18
- 17b. Ascomata not stromatic.....21
- 18a. Ascomata connected to each other by superficial strands of brown hyphae.....19
- 18b. Ascomata not connected to each other by superficial strands of brown hyphae, ascospores hyaline, dark brown at maturity, ellipsoid, 1-septate, 9–12 × 4.5–6 µm, on *Xanthoparmelia stenophylla* colonizing rocks.....*Lichenostigma maureri*
- 19a. Vegetative hyphae single-stranded, ascospores hyaline, becoming brown, 1-septate, halonate, 8–10 × 3–5 µm, on *Xanthoparmelia conspersa* X. *mexicana* and X. *stenophylla* colonizing rocks.....*Lichenostigma cosmopolites*
- 19b. Vegetative hyphae not single-stranded.....20
- 20a. Ascomata subglobose, ascospores hyaline, brown at maturity, smooth-walled, markedly constricted at septum, halonate when young, 1-septate, 9–12 × 6–8.5 µm, on *Seirophora contortuplicata* colonizing rocks.....*Lichenostigma* sp.
- 20b. Ascomata elongated, ascospores hyaline, brown at maturity, granular, not or slightly constricted at septum, halonate when young, 1(–2)-septate, 11–16 × 6.5–9.5 µm, on *Lecanora* sp. and *Lobothallia praeradiosa* colonizing rocks.....*Lichenostigma cf. elongatum*
- 21a. Ascospores brown.....22
- 21b. Ascospores hyaline.....38
- 22a. Ascospores simple.....23
- 22b. Ascospores septate.....24
- 23a. Asci multispored, ascospores, brown, ellipsoid, 5–7.5 × 2–3 µm, on *Lecanora frustulosa* colonizing rocks.....*Rosellinula frustulosae*
- 23b. Asci 8-spored, ascospores brown, ovate to narrowly ellipsoid, 11.5–14.5 × 6.5–8.5 µm, on *Lecanora* sp. colonizing twigs.....*Roselliniella oxyspora*
- 24a. Perithecium wall covered with smooth-walled and stiff brown hyphae, interascal filaments absent, ascospores pale brown, 1–3-septate, 7–11 × 2–3 µm, on *Physcia* sp. colonizing dead wood.....*Capronia triseptata*
- 24b. Perithecium wall without hairs.....25
- 25a. Asci multispored.....26
- 25b. Asci 8-spored.....29
- 26a. Asci > 64 spored, ascomata less than 0.15 mm in diam., usually immersed, ascospores ellipsoid to ovoid–ellipsoid, dark brown, 1-septate, non-constricted, 4.5–7 × 2–4 µm, on *Rusavskia elegans* colonizing rocks.....*Muellerella lichenicola*
- 26b. Asci < 64-spored, ascomata more than 0.15 mm in diameter.....27
- 27a. Asci 32–64-spored, ascospores smooth-walled.....28
- 27b. Asci 20–32-spored, ascospores ornamented, dark brown, 1-septate, ellipsoid to narrowly ellipsoid, 6.5–13.5 × 4–7.5 µm, on *Acarospora* sp. and *Rusavskia elegans* colonizing rocks.....*Muellerella pygmaea*
- 28a. Asci 20–50-spored, ascospores brown, 1-septate, broadly ellipsoid, 6–8.5 × 4–5.5 µm, on *Rhizocarpon disporum* colonizing rocks.....*Muellerella ventosicola*
- 28b. Asci 32–64, ascospores dark brown, 1-septate, ellipsoid to ovoid, 5.5–9.5 × 3–5.5 µm, on *Aspicilia maculata*, *A. caesiocinerea*, *Lecanora* sp., *Lecidea lapicida*, *Pertusaria* sp., *Protoparmeliopsis muralis*, *Rhizoplaca melanophthalma* and *Rusavskia elegans* colonizing rocks.....*Muellerella erratica*
- 29a. Interascal filaments present.....30
- 29b. Interascal filaments absent or poorly developed. Periphyses or periphysoids present or absent.....33
- 30a. Ascospores 1-septate.....31
- 30b. Ascospores 3-septate, ascomatal wall partly blue-green/green near ostiole, ascospores brown to dark brown, sometimes with paler end cells 19–28 × 8.5–11.5 µm, on *Peltigera elisabethae* and *Peltigera praetextata* colonizing mosses over soil.....*Pyrenidium actinellum*
- 31a. Asci 4–6-spored, ascospores dark brown, 1-septate, ellipsoid, 15–22 × 6–10 µm, on *Rusavskia elegans* colonizing rocks.....*Polycoccum clauzadei*
- 31b. Asci 8-spored.....32
- 32a. Ascomata immersed, 50–90 µm in diam., ascospores ellipsoid, brown, brown, 1-septate, ellipsoid, verrucose, 9.5–12.5 × 4–5.5 µm, on *Rinodina* sp. colonizing bark.....*Polycoccum ibericum*
- 32b. Ascomata erumpent, 130–200 µm in diam., ascospores olive-brown to brown, more or less 1-septate, ellipsoid, verrucose, 13.5–17.5 × 7.5–9.5 µm, on *Physcia dubia* colonizing rock.....*Polycoccum pulvinatum*
- 33a. Fungus forming brown to black vegetative hyphae in the host tissue, ascospores frequently hyaline and brown.....34

- 33b. Fungus not forming brown to black vegetative hyphae in the host tissue, ascospores usually brown.....36
- 34a. Ascomata 50–90 μm in diam., ascospores hyaline, becoming light brown at maturity, $11.5\text{--}15 \times 4\text{--}5.5 \mu\text{m}$, on *Prototermeliopsis muralis* colonizing rocks.....
.....*Sphaerellothecium propinquellum*
- 34b. Ascomata 30–80 μm in diam.....35
- 35a. Ascomata 30–70 μm in diam., ascospores hyaline to pale brown at maturity, narrowly obovoid, 1-septate, overmature occasionally 2-septate, constricted at septa, $11\text{--}15.5 \times 4\text{--}4.5 \mu\text{m}$, on *Phaeophyscia ciliata* and *Physcia caesia* colonizing rocks.....
.....*Sphaerellothecium pumilum*
- 35b. Ascomata 40–80 μm in diam., ascospores brown to dark brown at maturity, 1-septate, ellipsoid, apices rounded, constricted at septa, $10\text{--}16 \times 4.5\text{--}8 \mu\text{m}$, on *Rhizoplaca* sp. colonizing rock.....
.....*Sphaerellothecium contextum*
- 36a. Ascospores with rounded ends.....37
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Declaration of competing interest

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