

**KNUDSENIA FLAVOPARMELIARUM:
A NEW GENUS AND SPECIES OF LICHENICOLOUS FUNGUS
GROWING ON FLAVOPARMELIA CAPERATA
AND FLAVOPUNCTELIA FLAVENTIOR (PARMELIACEAE)
FROM INDIA**

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A new parasitic lichenicolous fungus *Knudsenia*, with the type species, *K. flavoparmeliarum*, growing on the thallus of the corticolous lichen *Flavoparmelia caperata* in subalpine and alpine regions of Central Himalaya (Uttarakhand, India) is described, illustrated, and compared with other morphologically similar lichenicolous fungi. It is characterised by having inconspicuous galls; stromatic ascomata with sterile brownish black to black tissue which is K+ majenta, N–, I–; hymenial gel K/I–; exciple evident; paraphyses simple to sparsely branched, apically not pigmented; asci bitunicate, elongate, clavate to subcylindrical with an indistinct ocular chamber with a very short stalk, 8-spored, K/I+ reddish brown; ascospores hyaline, spherical to ellipsoid at maturity, simple to rarely 1-pseudoseptate [(9.0–)9.5–10.5–11.5(–12.0) × (1.0–)1.2–1.5–2.0(–2.5) μm], I–, perispore absent. Since the species lacks molecular data, hence, it was tentatively placed in the family Planistromellaceae pending further studies.

Key words: fungi, Himalaya, lichens, new taxon, Parmeliaceae

INTRODUCTION

Lichens continue to be a source of novel genera of lichenicolous fungi which represent a highly specialised group of fungi with life strategies ranging from saprotrophs to aggressive parasites (Lawrey and Diederich 2003). During our study on lichenicolous fungi of India, a species was discovered growing abundantly on the upper surface of the thallus of *Flavoparmelia caperata* (L.) Hale and *Flavopunctelia flaventior* (Stirt.) Hale, collected from subalpine and alpine regions of Uttarakhand. Morphological and anatomical characters, such as ±carbonized multilocular stromata, presence of paraphyses, and bitunicate 8-spored, elongate, clavate to subcylindrical K/I+ reddish brown asci with an indistinct ocular chamber and a very short stalk, and simple to rarely 1-pseudoseptate, hyaline, spherical to ellipsoid ascospores, reminded us of some gall inducing taxa, such as *Ajaysinghia* Y. Joshi (Joshi

2022), *Arthophacopsis* Hafellner (Hafellner 1998, Zhurbenko *et al.* 2020), *Clypeococcum* D. Hawksw. (Ertz 2004, Hawksworth 1977), *Didymocyrtis* Vain. (Ertz *et al.* 2015), *Homostegia* Fuckel (Hawksworth *et al.* 2004), *Lasiosphaeriopsis* D. Hawksw. et Sivan (Hawksworth 1980), *Macrographa* Etayo (Etayo and Sancho 2008), *Perigrapha* Hafellner (Ertz *et al.* 2005, Hafellner 1996, Zhurbenko and Ohmura 2018), *Phacopsis* Tul. s. lat. (Divakar *et al.* 2015), *Plectocarpon* Fée (Ertz *et al.* 2005), *Plowrightia* Sacc. (Clauzade *et al.* 1989, Thambugala *et al.* 2014), *Polycoccum* Saut. ex Körb. (Atienza *et al.* 2003, Brackel and Berger 2010, Hawksworth and Diederich 1988), *Pyrenidium* Nyl. (Hawksworth 1983, 1986, Knudsen and Kocourková 2010, Matzer 1996, Navarro-Rosinés and Roux 2007), *Saania* Zhurb. (Motiejūnaitė *et al.* 2019) and some species of *Stigmidium* Trevis. on parmelioid lichens (Etayo 2007, Joshi and Bansal 2023), which differs in several features.

Hence, attempts to assign this species to any known lichenicolous ascomycete genus failed. Therefore a new genus is described to accommodate this species: *Knudsenia* Y. Joshi with the type species *K. flavoparmeliarum* Y. Joshi colonising thallus of *Flavoparmelia caperata* and *Flavopunctelia flaventior*, which is characterised by inconspicuous galls, stromatic ascomata with sterile brownish black to black tissue, which is K+ majenta, N–, I–; hymenial gel K/I–, exciple evident; paraphyses simple to sparsely branched, apically not pigmented, asci bitunicate, elongate, clavate to subcylindrical with an indistinct ocular chamber with a very short stalk, K/I+ reddish brown, ascospores hyaline, spherical to ellipsoid at maturity, simple to rarely 1-pseudoseptate. Due to the absence of molecular data, the taxon is provisionally assigned to the family Planistromellaceae M. E. Barr, awaiting additional research.

MATERIALS AND METHODS

The study is based on specimens deposited in the herbaria of University of Rajasthan (RUBL). The macroscopical examination was carried out using a stereo-zoom dissecting microscope (Olympus SZ61). Microscopical studies of hand-made sections were carried out in water, 10% KOH (K), lactophenol cotton blue (LCB), Lugol's iodine, directly (I) or after 10% KOH pre-treatment (K/I) using an Olympus BX53 compound microscope equipped with Olympus differential interference contrast optics. Measurements were taken from water mounts and are indicated as (minimum–)(X–SD)–X–(X+SD)(–maximum), where X is the arithmetic mean and SD the corresponding standard deviation, followed by the number of measurements in parentheses (n), and the length/width ratio (l/w) is presented in the same way, followed by the number of measurements (n). Values in italics (e.g., –10.5–) are arithmetic means.

RESULTS AND DISCUSSION

Knudsenia Y. Joshi, *gen. nova*

Mycobank no.: MB 850287

A genus characterised by its lichenicolous lifestyle; galls inconspicuous galls; stromatic ascomata with sterile brownish black to black tissue, which is K+ majenta, N–, I–; hymenial gel K/I–; exciple evident; paraphyses simple to sparsely branched, apically not pigmented; asci bitunicate, elongate, clavate to subcylindrical with an indistinct ocular chamber with a very short stalk, 8-spored, K/I+ reddish brown; ascospores hyaline, spherical to ellipsoid at maturity, simple to rarely 1-pseudoseptate, I–, perispore absent.

Type: *Knudsenia flavoparmeliarum* Y. Joshi (holotype).

Etymology: The generic name was chosen to honour Dr Kerry Knudsen who unknowingly turned one of the authors' (YJ) interest towards lichenicolous fungi, when during his stay in South Korea he helped him out in identifying a lichenicolous fungus (*Dactylospora glaucomarioides* (Tuck.) Hafellner).

Taxonomic remarks: The monotypic genus *Arthophacopsis* differs mainly in having emarginated ascomata with missing exciple, branched and anastomosed interascal filaments, broadly clavate asci with an evident ocular chamber, I–, K/I–, ascospores ellipsoid to narrowly reniform (Hafellner 1998, Zhurbenko *et al.* 2020). *Macrographa* differs in having abundant periphysoids, hyaline, persistently 1-septate bigger ascospores (18.0–23.0 × 5.5–7.0 µm) and host preference (*Nephroma antarcticum* (Wulfen) Nyl.) (Etayo and Sancho 2008). *Perigrapha* is distinct in having a K/I+ blue hymenial gel, asci with a K/I+ blue apical ring, and at least initially hyaline, persistently transversely septate ascospores (Ertz *et al.* 2005, Hafellner 1996, Zhurbenko and Ohmura 2018). The lichenicolous fungus *Phacopsis* s. lat., representing three phylogenetically distinct genera, *Phacopsis* s. str., *Nesolechia* A. Massal. and *Raesaenenia* D. Hawksw., Boluda *et al.* Lindgr. (Divakar *et al.* 2015) is also pretty much closer to the new genus in having I– or I+ faint bluish hymenial gel, apically swollen paraphyses, simple, hyaline ellipsoid ascospores with obtuse ends. However, it differs from the new genus in not having stromatoid/multilocular appearance, *Lecanora*-type asci with broad diverging axial body and thin outer amyloid wall layer and paraphyses with dark brown pigmented caps. The lichenicolous genus *Plectocarpon* differs in having a K/I+ blue hymenial gel, with a K/I+ blue apical ring, and at maturity, having persistently transversely 1–6(–7)-septate brown ascospores with halo and *Arthonia*-type ascus (Ertz *et al.* 2005). *Plowrightia* differs in the absence of an interascal tissue and hyaline, transversely septate ascospores (Clauzade *et al.* 1989, Thambugala *et al.* 2014).

Ajaysinghia, *Clypeococcum*, *Didymocyrtis*, *Homostegia*, *Lasiosphaeriopsis*, *Polycoccum*, *Pyrenidium* and *Saania* differ in having distinctly septate brown ascospores. *Ajaysinghia* is characterised by having pseudoperithecia growing in clumps making it appear like galls, (0–)1-septate, bigger and wider ascospores [(12.0–)14.2–17.3(–18.0) × (3.0–)3.7–4.8(–5.0) μm], with rounded to pointed ends, slightly constricted at the septum and a cyanobacterial host (*Dendrocosticta praetextata*) (Joshi 2022). *Clypeococcum* D. Hawksw. is characterised by stromata with a K+ olivaceous clypeus, subcylindrical asci and ascospores with consistently transverse septa (Ertz 2004, Hawksworth 1977). *Didymocyrtis* differs in having *Phoma*-like anamorphic stage, with 1-septate brown ascospores (Ertz *et al.* 2015). *Homostegia* have 3-septate ascospores, with a central pore sometimes conspicuous in the septa and often paler end cells (Hawksworth *et al.* 2004). *Lasiosphaeriopsis* differs in having unitunicate asci without any distinct apical apparatus and in the occurrence of pores in the stromatic cell walls and 3-septate ascospores (Hawksworth 1980). *Polycoccum* s. str. often induces gall formation on the host lichens, but the pseudothecia are quite discrete and not united in either a stroma or clypeus and has a centrum usually I– and K/I– (but in a few species K/I+ blue or violet) and 1-septate ascospores (Atienza *et al.* 2003, Brackel and Berger 2010, Hawksworth and Diederich 1988). The lichenicolous fungus *Pyrenidium* differs in having distinct periphyses and usually 3-septate, smooth ascospores with the ends cells often hyaline to subhyaline, and blue-green pigment often located in upper peridial cells and upper cells of the hamathecial filaments (Hawksworth 1983, 1986, Knudsen and Kocourková 2010, Matzer 1996, Navarro-Rosinés and Roux 2007). *Saania* can be easily excluded as it has N+ red stromata with persistent periphysoids, 4(–8)-spored asci having 1(–3)-septate ascospores (Motiejūnaitė *et al.* 2019).

***Knudsenia flavoparmeliarum* Y. Joshi, spec. nova**
(Figs 1a–d, 2a–h)

Mycobank no.: MB 850288

Similar to Plectocarpon diedertzianum Y. Joshi, Upadhyay *et* Chandra, in its external appearance, which however differs in having distinctly lirellate ascomata arising in stroma, K/I+ blue hymenial gel, asci with a K/I+ blue apical ring, (2–)3-septate bigger ascospores [(13.2–)15.6–18.3(–19.5) × (4.2–)4.9–6.0(–6.5) μm], which turns brown at maturity and host preference (*Myelochroa* (*Asahina*) *Hale et Elix*). The new taxon has K/I– hymenial gel, asci K/I+ reddish brown, simple to rarely 1-pseudoseptate, hyaline, smaller ascospores [(9.0–)9.5–10.5–11.5(–12.0) × (1.0–)1.2–1.5–2.0(–2.5) μm] and colonise thallus of *Flavoparmelia caperata* and *Flavopunctelia flaventior*.

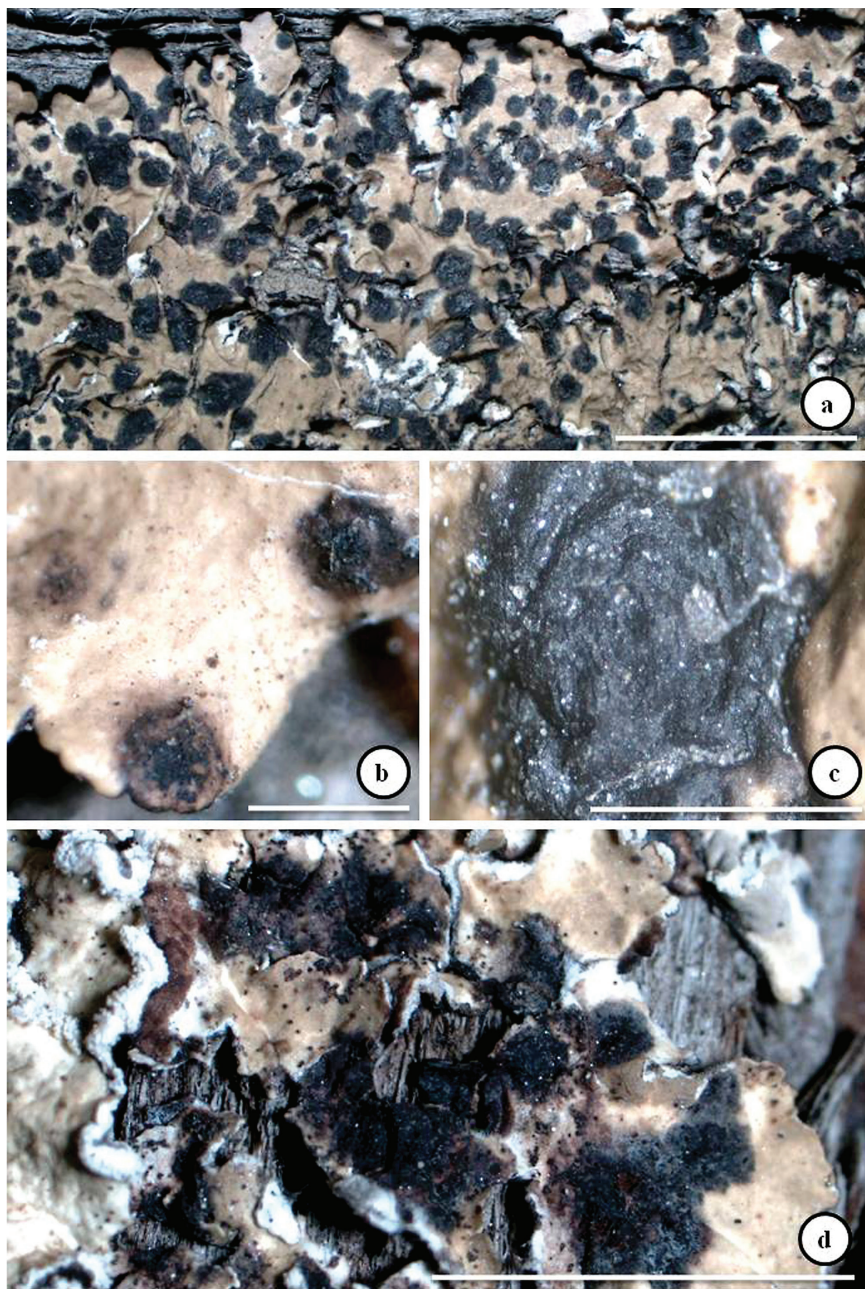


Fig. 1. *Knudsenia flavoparmeliarum*. a = Heavily infected thallus of *Flavoparmelia* (scale bar = 5 mm); b = Juvenile stage (scale bar = 1 mm); c = Ascomata of *P. flavoparmeliarum* aggregated into galls with labyrinthiform ornamentation (scale bar = 1 mm); d = Severe infection caused by the fungus (scale bar = 5 mm)

Type: India. Uttarakhand, Pithoragarh district, Munsyari, Bilzu, alt. 3,300 m, 30° 23.126' N, 80° 10.322' E, on upper side of thallus of *Flavoparmelia caperata* colonising *Juniperus* bark, 22 September 2017, Kapil Bisht s.n. (holotype: RUBL 21427).

Ascomata developing on the upper surface of the host thallus, black, rounded to rarely irregular, flattened or slightly convex, emarginated, dispersed to aggregated in gall like swellings, galls inconspicuous from outside but $\pm$ gall like swellings visible under microscope without a thalline margin, (0.3–)0.5–2.0(–2.5) mm diam., severely damaging the host thallus; surface uneven, with distinct small irregular cracked openings to lirellate, matt to slightly shiny, region in and around the stroma pale reddish brown (Figs 1a–d). Stroma multilocular (10–20), locules ovoid to globose, $\pm$ urceolate, (65.0–)76.0–92.0–108.0(–110.0) $\times$ (62.0–)76.0–88.0–100.0(–105.0) μ m (n = 50); sterile stromatic tissue well developed between, above and below the loculi; brownish black to black, K+ majenta, N–, I–, wall paraplectenchymatous, 5–10 layered, 10.0–25.0 μ m thick, K+ majenta, I–, N– (Fig. 2ab). Epihymenium indistinct, hyaline to pale brown. Hymenium hyaline to pale brown, interspersed with oil droplets, K–, I–, N–, K/I–, 70.0–100.0 μ m high. Paraphyses abundant, simple to sparsely branched, 1.0–1.5 μ m thick, apically slightly swollen, not pigmented (Fig. 2c). Asci bitunicate, elongate, clavate to subcylindrical, with an indistinct ocular chamber and shortly stalked, apical beak absent, 8-spored, (20.0–)26.0–33.0–40.0(–47.0) $\times$ (4.0–)6.0–9.0–12.0(–14.0) μ m (n = 50), wall and ascoplasm K–, K/I+ reddish brown (Figs 2d–f). Ascospores hard to discern from the ascus, biserially to irregularly arranged, hyaline, spherical to ellipsoid at maturity, simple to rarely 1-pseudoseptate, with rounded ends, (9.0–)9.5–10.5–11.5(–12.0) $\times$ (1.0–)1.2–1.5–2.0(–2.5) μ m, l/w ratio (2.3–)2.7–3.8–5.0(–5.5) (n = 50), I–; perispore absent (Figs 2e–h). Vegetative hyphae penetrating inside the cortex, 1–3 μ m, brown, I–. Conidiomata not seen.

Host: On thallus of *Flavoparmelia caperata* and *Flavopunctelia flaventior*.

Etymology: This new species is named after combining two words, viz. *flavo* taken from its two hosts, *Flavoparmelia* Hale and *Flavopunctelia* (Krog) Hale and *parmeliarum* from the lichen family Parmeliaceae F. Berchtold et J. Presl, on which it is colonising.

Ecology and distribution: Since the fungus is showing some signs of discolouration and necrosis to the host thallus, thus can be considered a parasitic fungus. To date, the taxon is known from subalpine and alpine regions of the Central Himalaya, where it is reported on the thallus of *Flavoparmelia caperata* and *Flavopunctelia flaventior* colonising bark of *Juniperus* L. and *Betula utilis* D. Don, respectively. It was also noticed that *K. flavoparmeliarum* is heavily infecting *Flavoparmelia caperata* in comparison to *Flavopunctelia flaventior*, which are also infected by *Abrothallus microspermus* Tul. and its anamorph *Vouauxiomyces truncatus* (B. de Lesd.) Dyko et D. Hawksw.

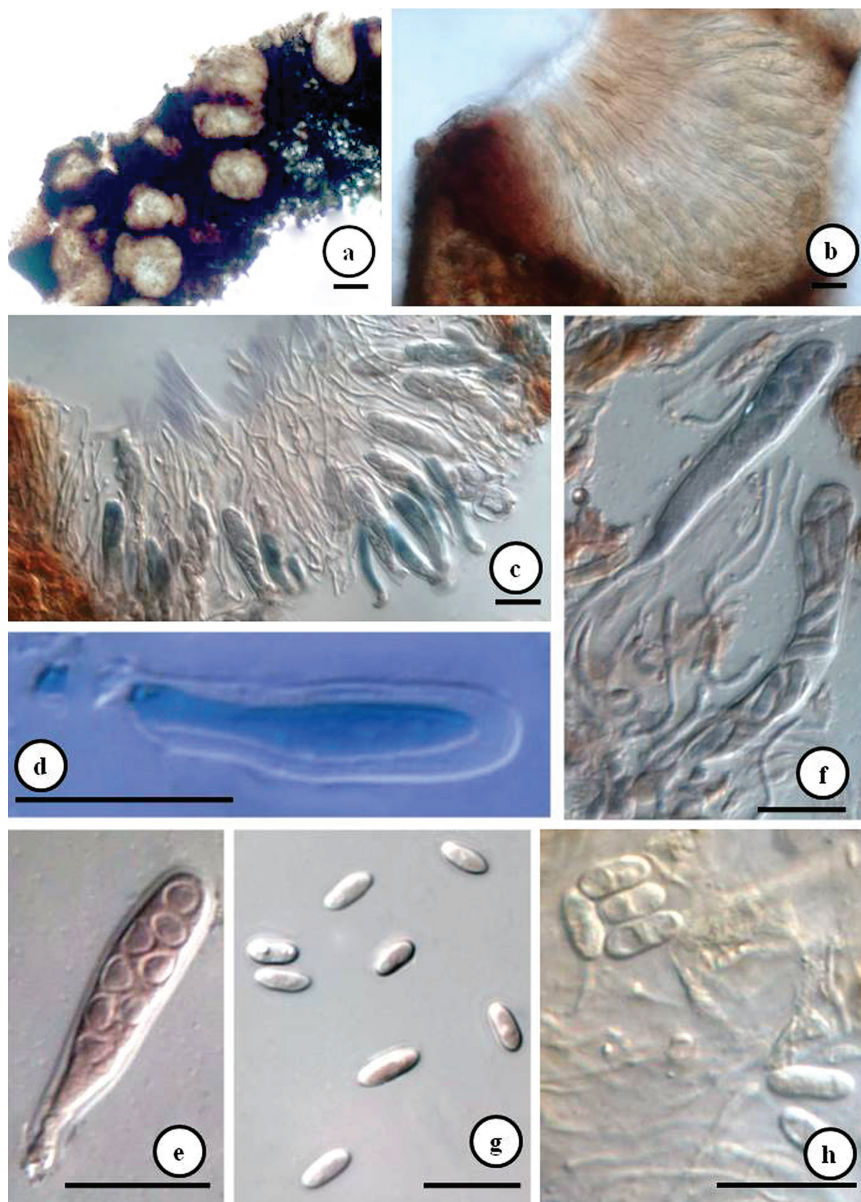


Fig. 2. *Knudsenia flavoparmeliarum*. a = Section through gall showing several ascomata 10× (scale bar = 100 µm); b = A single ascomata 60× (scale bar = 20 µm); c = Hymenium with ascus and paraphyses in LCB 60× (scale bar = 20 µm); d = Asci without ascospores in LCB 60× (scale bar = 20 µm); e = Asci with spherical ascospores in LCB under DIC 60× (scale bar = 20 µm); f = Asci with spherical and ellipsoid ascospores in LCB under DIC 60× (scale bar = 20 µm); g = Mature simple ascospores in DIC 60× (scale bar = 20 µm); h = Ascospores with pseudosepta under 60× (scale bar = 20 µm)

Taxonomic remarks: In comparison to lichen genus *Flavopunctelia* on which to date only 2 lichenicolous species *viz.* *Abrothallus microspermus* Tul. (Tulasne 1852) and *Phacopsis thallicola* (A. Massal.) Triebel et Rambold (Cole and Hawksworth 2001, Diederich *et al.* 2018, Zhurbenko 2017) were found, the lichen genus *Flavoparmelia* is a good host of lichenicolous fungi and is being infected by 13 species, *viz.* *Actinocladium rhodospurum* Ehrenb., *Abrothallus microspermus*, *Arthonia coronata* Etayo, *Burgella flavoparmeliae* Diederich et Lawrey, *Calongeomyces gibelluloides* (D. Hawksw. et Etayo) D. Hawksw. et Etayo, *Didymocyrtis cladoniicola* (Diederich, Kocourk. et Etayo) Ertz et Diederich, *Homostegia hertelii* D. Hawksw., V. Atienza et M. S. Cole, *Niptera lichenicola* (Speg.) Sacc., *Phacopsis thallicola*, *Plectocarpon diedertziaenum* Y. Joshi, Upadhyay et Chandra, *Sclerococcum olivaceum* Etayo et F. Berger, *Sphaerellothecium reticulatum* (Zopf) Etayo and *Trimmatostroma glebarum* Brackel (Diederich *et al.* 2018, Halici and Barták 2019). With *Knudsenia flavoparmeliarum*, the number reaches to 3 and 14 species of lichenicolous fungi colonising lichen genus *Flavopunctelia* and *Flavoparmelia*, respectively.

Plectocarpon diedertziaenum Y. Joshi, Upadhyay et Chandra, occurring in the same area and colonising a member of parmelioid lichen, resembles the new taxon in its external appearance, but differs in having distinctly lirellate ascomata arising in stroma, (2–)3-septate bigger ascospores [(13.2–)15.6–18.3(–19.5) × (4.2–)4.9–6.0(–6.5) µm] which turns brown at maturity and host preference (*Myelochroa* (Asahina) Hale et Elix *vs* *Flavoparmelia* and *Flavopunctelia*) (Diederich and Ertz 2018, Joshi *et al.* 2016). Another species of *Plectocarpon* (i.e. *P. parmeliarum* Y. Joshi) reported on the thallus of *Parmelia meiophora* Nyl. from Uttarkashi district of Uttarakhand (India), differs from the new taxon in having 4-spored asci bearing 5-septate bigger ascospores [(25.0–)27.5–30.0(–31.0) × (7.0–)7.5–10.0(–12.5) µm] which turns brown at maturity (Joshi *et al.* 2018).

Phacopsis thallicola also colonising members of *Flavoparmelia* and *Flavopunctelia* and having similar ascospore size and shape differs from *P. flavoparmeliarum* in having dark brown basally pseudoparenchymatic hypothecium; sessile, marginate apothecia, *Lecanora*-type asci with broad diverging axial body and thin outer amyloid wall layer and paraphyses with dark brown pigmented caps (Triebel *et al.* 1995).

The morphological and anatomical features, such as the presence of galls, simple, hyaline ascospores, bring *Arthrophacopsis parmeliarum* somewhat nearer to the new taxon. However, *A. parmeliarum* is readily distinguished from the new taxon by much wider asci [(15.0–25.0 µm *vs* (4.0–)6.0–9.0–12.0(–14.0) µm], broader ascospores [5.0–7.0 µm *vs* (1.0–)1.2–1.5–2.0(–2.5) µm], and host selection (*Parmelia* Ach. *vs* *Flavoparmelia caperata* and *Flavopunctelia flaventior*) (Hafellner 1998).

Though, stroma-like structures are unusual in the genus *Stigmidium* in general, but *Stigmidium epinesolechia* Etayo (on galls of *Nesolechia* cf. *oxyspora* (Tul.) A. Massal. on *Punctelia* (Etayo 2017) and *Stigmidium bulbothricis* Y. Joshi (on thal-

lus of *Bulbothrix setschwanensis* (Zahlbr.) Hale (Joshi and Bansal 2023) forms a stroma on parmelioid lichens hence may resemble the new genus to some extent. However, they all differ in having pseudoparaphyses (*sensu* Roux and Triebel 1994), lacking interascal filaments and persistently 1-septate ascospores.

Opegrapha melanospila Müll. Arg., growing on the thalli of *Parmotrema reticulatum* should not be confused with the new taxon as it does not induce the formation of galls. Instead of galls, an agglomeration of simple to curved or branched lirellae develops within blackish necrotic spots on the thallus. Besides this, the paraphyses are thick (2.0–2.5 µm), asci are wider ((13–)15–17 µm), bigger ascospores (14.3–)15.0 –17.4(–18.7) × (5.0 –)5.5 – 6.6(–7.4) µm which are 3-septate, initially hyaline and soon becoming brown, with a dark brown, verrucose ornamentation (Müller 1877).

The multilocular species, *Celidium bacidiosporum* Steiner, differs in having K+ intensively aeruginose green sterile stromatic tissue; hymenium I+ red, K/I+ blue and elongate, sometimes slightly curved, 3-septate ascospores (Ertz *et al.* 2005).

Biciliopsis leptogiicola Diederich growing on thallus of *Leptogium* has paraphyses instead of paraphyses, ascospores 2 per ascus, hyaline, simple, with a cilium at each pole, straight or slightly curved, with I+ reddish epiplasma (Aptroot *et al.* 1997).

Additional specimens examined: India. Uttarakhand, Pithoragarh district, Burfu, on way to Milam, alt. 3,290 m, 30° 21' 46.93" N, 80° 10' 54.16" E, on upper side of thallus of *Flavoparmelia caperata* colonising *Juniperus* bark, 24 September 2016, Kapil Bisht s.n. (RUBL 21428); Uttarkashi district, Gangotri, en route to Gomukh, Bhojwasa, alt. 3,818 m, 30° 57' 06.6" N, 79° 02' 58.9" E, on upper side of thallus of *Flavopunctelia flaventior* colonising bark of *Betula* sp., 6 May 2017, R. Bajpai 17-031227 (LWG), 07/05/2017, R. Bajpai 17-031227 DUP (LWG).

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