

Lichenicolous fungi colonising members of the lichen-forming family Teloschistaceae in India

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Summary. This paper gives an account of lichenicolous fungi colonising members of the lichen-forming family Teloschistaceae from India. A new species, *Lichenochora ajaysinghii*, colonising *Caloplaca saxicola* is described and a key to so-far-known lichenicolous fungi colonising Indian Teloschistaceae taxa is provided.

Key Words. *Caloplaca*, Himalaya, key, new species, taxonomy.

Introduction

The cosmopolitan lichen-forming family Teloschistaceae exhibits considerable morphological and ecological heterogeneity across genera and species groups and currently encompasses 97 genera, although many are not widely accepted (Wijayawardene *et al.* 2020), but in total with more than 1000 species (Kondratyuk *et al.* 2017), is divided into four subfamilies: Brownlielloideae, Caloplacoideae, Teloschistoideae and Xanthorioideae (Gaya *et al.* 2012; Arup *et al.* 2013; Kondratyuk *et al.* 2015; Jaklitsch *et al.* 2016).

Like many other mainly lichen-forming families, this family is also a home for lichenicolous fungi. The family has been revised twice in India: 1) Y. Joshi (2008) mentioning 83 species placed in six genera, and recently, 2) Mishra *et al.* (2019) reported 111 species distributed amongst 35 genera. However, except for a few sporadic publications (Zhurbenko 2013; Joshi *et al.* 2016, 2018; Joshi 2018) no actual comprehensive record of lichenicolous fungi colonising members of this family is available from India.

The aim of this paper is to provide brief information on lichenicolous fungi colonising teloschistacean taxa along with detailed description of a new species, *Lichenochora ajaysinghii*, and a key to the so-far-known lichenicolous fungi colonising Indian teloschistacean taxa. Further, the records of *Cercidospora epicarphinea* (Nyl.) Grube & Hafellner on *Caloplaca* sect. *Gasparrinia* described earlier by Joshi *et al.* (2016) probably do not belong to that species and so is excluded from the present study.

Materials and Methods

Molecular studies carried out in the Teloschistaceae have resulted in the recognition of 97 genera by some workers; identifying them with a morphotaxonomic approach has become painstaking and tedious and such excessive splitting is out-of-step with practices in other large lichen-forming families, such as Cladoniaceae. For example, Schumm & Aptroot (2019a, b, c, d) in their book *Images of the lichen genus Caloplaca Vol. I – IV*, treated *Caloplaca* Th.Fr. in its broader sense. We have therefore decided to follow those authors and retain the broader concepts of *Caloplaca* and *Xanthoria*. However, for reference, the newer names proposed are placed in parentheses. The specimens we studied are deposited in the herbaria of CSIR-National Botanical Research Institute (LWG) which includes the personal herbarium of the late Dr D. D. Awasthi (AWAS) and Lucknow University (LWU), and Kumaun University Almora (ALM) and were examined under a stereozoom dissecting microscope (Olympus SZ61). Thin hand-cut sections were made for studying the anatomy of the sporophores and examined under a compound microscope (Olympus BX53) equipped with Olympus differential interference contrast optics. Microscopical examination was made in water, 10% KOH (K), lactophenol cotton blue (LCB), and Lugol's iodine (directly I), or after a KOH pre-treatment (K/I). Ascospore measurements are presented as: arithmetic mean - standard deviation, arithmetic mean, and arithmetic mean + standard deviation, flanked by the minimal and maximal measurements in parentheses, and the

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length/breadth ratio (l/b) is presented in the same way, followed by the number of measurements (n). Values in italics (e.g., $-11.83-$) are arithmetic means.

Results and Discussion

Our study revealed 21 species, including one new species (*Lichenochora ajaysinghii*), belonging to 17 genera colonising thallus, apothecial disc and soralia of 16 different species of teloschistacean taxa distributed in nine states of India. Of these 21 taxa, 14 are obligate i.e. so far known only from teloschistacean members (*Arthonia molendoi*, *Buelliella inops*, *Cercidospora caudata*, *Cercidospora xanthoriae*, *Cladosporium licheniphilum*, *Lichenochora ajaysinghii*, *Lichenostigma* subgen. *Lichenogramma* sp., *Opegrapha gyalolechia*, *Phoma* sp., *Polycoccum clauzadei*, *Polycoccum tinantii*, *Stigmidium cerinae*, *Verrucula latericola* and *Zwackhiomyces coepulonus*), while seven are facultative and are found colonising various taxa (*Intralichen christiansenii*, *Lichenocodium xanthoriae*, *Lichenodiplis lecanorae*, *Marchandiomyces corallinus*, *Muellerella erratica*, *Muellerella lichenicola*, *Muellerella pygmaea*).

Among the lichenised species examined, it was *Xanthoria elegans* (syn. *Rusavskia elegans*) which was infected by the most lichenicolous fungi (12) followed by *Caloplaca saxicola* (syn. *Calogaya saxicola*) and *Caloplaca flavorubescens* (syn. *Gyalolechia flavorubescens*) (with four each). It has also been observed that out of these 21 taxa, 15 species colonise saxicolous lichens, five corticolous lichens, and one colonises both saxicolous and corticolous lichens.

Taxonomic Treatment

Lichenochora ajaysinghii Y. Joshi sp. nov. Type: India, Jammu & Kashmir, Anantnag distr., Baltal, alt. 2700 m, on thallus of *Caloplaca saxicola* colonising rocks, 29 Aug. 1982, A. Singh 13921 (holotype LWG 11577; isotype RUBL).

Mycobank no.: MB 834996

Fungus commensalistic, not inducing gall formation. *Hyphae* hyaline, inconspicuous. Fungus lichenicolous on thallus and rarely on apothecial disc of *Caloplaca saxicola*. *Ascomata* perithecioid, arising singly or aggregated in small clusters, $110 - 165 \times 130 - 220$ ($- 250$) μm , sessile, black, slightly glossy, rough, subglobose to pyriform, constricted at the base, ostiole $30 - 45$ ($- 50$) μm diam. Exciple wall $10 - 15$ μm thick, textura angularis, consisting of two portions: an outer dark reddish brown, K+ deep olive-brown, $13 - 25$ ($- 35$) μm thick, consisting of 6 – 8 layers of cells, and the inner one, pale brown to colourless, $6 - 9$ ($- 11$) μm thick, with very narrow cells. No papillae or hyphal

appendages observed. *Hamathecium* colourless, I+ reddish brown, K/I- with abundant lipid droplets, $1 - 4$ ($- 6$) μm diam., made up of periphyses and paraphyses. *Periphyses* hyaline, persistent, mostly unbranched, septate, abundant along the ostiolar channel, $10 - 15 \times 2 - 3$ μm . *Paraphyses* hyaline, $3 - 4$ μm thick, septate, straight to slightly flexuose, simple or ramified, often markedly constricted at the septa, KI-, only visible among immature asci, degenerating and becoming evanescent before the asci are completely mature. *Asci* subcylindrical-clavate, wall without visible structures at the apex, stalk to $6 - 8$ ($- 10$) μm long, 6 – 8-spored, I-, except cytoplasm which becomes orange-red, K/I-, $(40 -) 49 - 65 - 82$ ($- 86$) \times $(8 -) 10 - 11.8 - 13.5$ ($- 14$) μm ($n = 25$). *Ascospores* uniseriately to biseriately arranged, narrowly ellipsoid to somewhat soleiform, 1-septate, with lipid droplets, smooth, at first hyaline, rarely pale grey-olive to medium olive-brown, with obtuse to slightly tapering ends, straight or rarely slightly curved, slightly constricted at the septum, with a subtle torus along the septum, slightly heteropolar, $(12 -) 15 - 18.4 - 21.4$ ($- 24$) \times $(3 -) 3.5 - 4.5 - 5.5$ ($- 6$) μm ($n = 25$), $l/b = (2.8 -) 3.5 - 4.2 - 5.1$ ($- 6$), perispore absent, ascospores filled with oil droplets, walls $0.2 - 0.5$ μm thick. Conidiomata not observed. Fig. 1.

RECOGNITION. Similar to *Lichenochora tertia* in ascospore shape and size as in that species they measure $(12 -) 15 - 16.5 - 18$ ($- 20$) \times $(4 -) 4.9 - 5.3 - 5.7$ ($- 6.5$) μm and presence of a subtle torus, which however, differs in having semi-immersed bigger perithecia (200 μm diam.) with papillae, asci with a shorter stalk (5 μm), $(0 -) 1$ -septate hyaline, ellipsoid ascospores with a smaller l/b ratio $(2.2 -) 2.8 - 3.2 - 3.6$ ($- 4.5$), and a different host (*Xanthoria elegans*) growing in alpine regions.

DISTRIBUTION & HABITAT. Known only from the type locality and forming numerous ascomata on the thallus and rarely on the apothecial disc of *Caloplaca saxicola*, and seems to be commensalistic as no damage to the host lichen was observed.

ETYMOLOGY. The epithet is named after the late Dr Ajay Singh, a renowned lichenologist of India, who collected the type material.

NOTES. The almost cosmopolitan lichenicolous pyrenomycete genus *Lichenochora* is generally characterised by a hamathecium of paraphyses and periphyses; 2 – 8-spored asci bearing hyaline to rarely greyish-brown, simple to 5-transseptate ascospores (Navarro-Rosinés *et al.* 1998; Hoffmann & Hafellner 2000; Hafellner & Navarro-Rosinés 2004). The genus is represented by 44 species across the world (Diederich *et al.* 2018) of which 12 colonise Teloschistaceae (Diederich *et al.* 2018).

Based on the width of the spores, all these 12 species can be broadly divided into two groups: one with narrower spores ($4 - 8$ μm , i.e. *Lichenochora caloplacae*, *L. elegantis*,

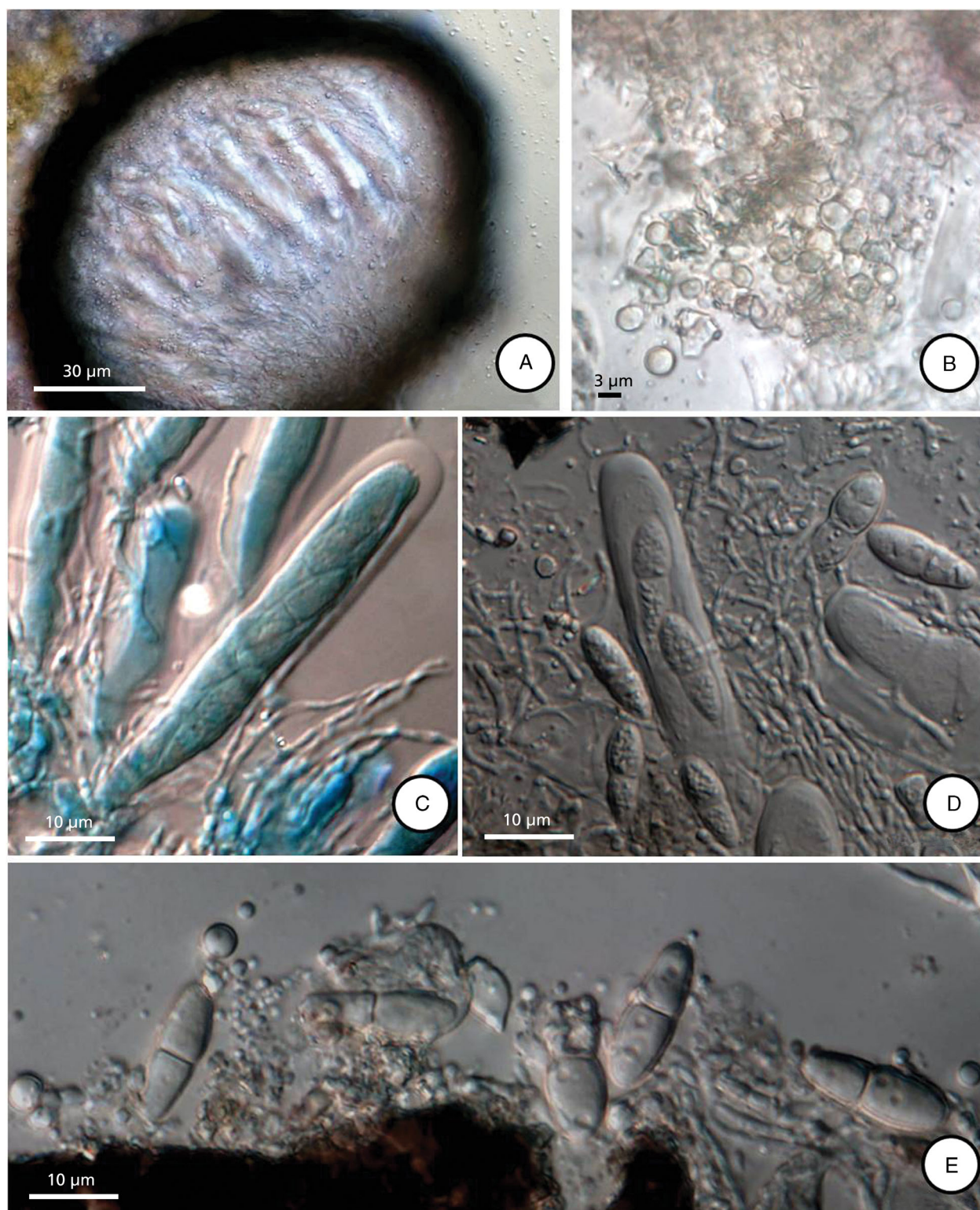


Fig. 1. *Lichenochora ajaysinghii*. A transverse section through a perithecium; B oil droplets; C ascus with ascospores stained in LCB; D ascospores with oil within ascus magnified; E mature ascospores.

L. epimarmorata, *L. pyrenodesmiae*, *L. sinapispermae* and *L. tertia*) and the other with broader spores (7 – 12 µm,

i.e. *L. constrictella*, *L. epidesertorum*, *L. epifulgens*, *L. epinashii*, *L. wasserii* and *L. xanthoriae*).

The new species is characterised by 1-septate ascospores which are at first hyaline and later rarely pale grey-olive to medium olive-brown, rounded to somewhat pointed at the apices, slightly heteropolar, and falls in the category of narrower spores and is unlikely to be confused with others of the genus.

The most similar species is *Lichenochora tertia* in ascospore shape and size which in that species is reported as (12 –) 15 – 16.5 – 18 (– 20) × (4 –) 4.9 – 5.3 – 5.7 (– 6.5) µm, and having a subtle torus, but, differs in having semi-immersed bigger perithecia (200 µm diam.) with papillae, asci with a shorter stalk (5 µm), (0 –) 1-septate hyaline, ellipsoid ascospores with a smaller l/b ratio of (2.2 –) 2.8 – 3.2 – 3.6 (– 4.5) and a different host (*Xanthoria elegans*) growing in alpine regions. *Lichenochora caloplacae* differs from the new taxon in having comparatively bigger spores measuring (14 –) 17.4 – 22.8 (– 27) µm and which are narrowly ellipsoid to fusiform with rather acute ends and lack a perispore, have comparatively bigger perithecia (170 – 310 × 125 – 270 µm) and

colonise different hosts, viz. *Caloplaca ammiospila* (syn. *Blastenia ammiospila*), *C. cerina* and *C. tetraspora* (syn. *Bryoplaca tetraspora* (Zhurbenko & Brackel 2013)). *Lichenochora elegantis* has longer ascospores measuring 28 – 33 µm, 4-spored asci, much bigger perithecia (300 – 400 µm) and also a different host (*X. elegans*) (Hafellner *et al.* 2008). *Lichenochora sinapispermae* differs in having smaller spores measuring (11.5 –) 12 – 15.5 (– 17.5) µm; l/b ratio = (1.6 –) 1.9 – 2.5 (– 2.8), with a torus, bigger perithecia (230 – 300 × 200 – 250 µm) and a different host (*C. sinapisperma* (syn. *Bryoplaca sinapisperma*) (Etayo & Navarro-Rosinés 2008)). *Lichenochora pyrenodesmiae* also has smaller spores (10.5 –) 12 – 16.5 (– 17) µm with a l/b ratio = (1.5 –) 1.9 – 2.9 (– 3.4) and a host *C. variabilis* (syn. *Pyrenodesmia variabilis*) (Etayo & Navarro-Rosinés 2008). *L. epimarmorata* also has simple to septate, smaller spores (10 – 14 × 5 – 7) µm with l/b ratio = 1.5 – 2 (– 2.2) and again occurs on a different host (*C. marmorata* (= *Xanthocarpia marmorata*)) (Etayo & Navarro-Rosinés 2008).

Key to the lichenicolous fungi colonising Indian Teloschistacean taxa (*Caloplaca* s.l., *Xanthoria* s.l., *Seiropora* s.s.)

1. Spores produced in asci 2
1. Spores not produced in asci..... 16
2. Ascromata arthonioid; ascospores hyaline, 1-septate, 11 – 14 × 5 – 6 µm; on thallus and apothecia of *Caloplaca biatorina* (syn. *Calogaya biatorina*), *C. saxicola*, *Xanthoria elegans* colonising rocks in temperate and alpine regions of Himachal Pradesh, Jammu & Kashmir, Ladakh. Ref.: Grube (2007); Zhurbenko (2013); Fleischhacker *et al.* (2016); Joshi *et al.* (2016) **Arthonia molendoi**
2. Ascromata not arthonioid..... 3
3. Ascromata lirelliform; ascospores hyaline, (1 –) 2 – 3-septate, (8 –) 11.69 – 13.92 – 16.16 (– 17) × (3 –) 3.46 – 4.28 – 5 (– 5.1) µm; on thallus and rarely apothecial disc of *Caloplaca flavorubescens* colonising bark in temperate regions of Himachal Pradesh, Uttarakhand. Ref.: Joshi (2018)..... **Opegrapha gyalolechia**
3. Ascromata not lirelliform 4
4. Ascromata apothecioid; ascospores hyaline to pale brown, 1-septate, (12 –) 14 – 16 (– 18) × 6 – 8 µm; on thallus of *Caloplaca flavorubescens* colonising bark in alpine regions of Uttarakhand. Ref.: Hafellner (2004); Joshi *et al.* (2018)..... **Buelliella inops**
4. Ascromata perithecioid..... 5
5. Perithecia associated with superficial, black, richly ramified, ornamented hyphal strands; ascospores hyaline then medium olive-brown and finally dark brown, broadly obovoid, (9 –) 10 – 12 × 6 – 7.5 (– 8.5) µm; on thallus and apothecial disc of *Seiropora contortuplicata* (syn. *Xanthaptychia contortuplicata*) colonising rocks in alpine regions of Ladakh. Ref.: Zhurbenko (2013) **Lichenostigma** subg. **Lichenogramma** sp.
5. Perithecia with hyaline hairs or smooth..... 6
6. Ascospores brown 7
6. Ascospores hyaline 11
7. Asci multispored 8
7. Asci 8-spored 10
8. Perithecia >0.15 mm diam., more or less superficial, immersed in lower part only. Asci <64 spored. Ascospores 4 – 6 µm broad 9
8. Perithecia <0.15 mm diam., more or less immersed. Asci >64 spored; ascospores (4.5 –) 5 – 6 (– 7) × (2 –) 2.5 – 3 (– 4) µm; on thallus and apothecial disc of *Caloplaca saxicola*, *C. lithophila*, *C. trachyphylla* (syn. *Golubkovia trachyphylla*), *C. flavorubescens*, *C. flavovirescens* (syn. *Gyalolechia flavovirescens*), *C. subsoluta* (syn. *Squamulea subsoluta*), *C. variabilis*, *Xanthoria elegans* colonising bark and rocks in tropical, temperate and alpine regions of Himachal Pradesh, Jammu & Kashmir, Ladakh, Tamil Nadu, Uttarakhand. Ref.: Triebel & Kainz (2004); Joshi

- et al.* (2016) **Muellerella lichenicola**
9. Asci 32 – 64-spored; ascospores smooth walled, ellipsoid to ovoid, 6 – 8.5 × 3 – 5.5 μm; on thallus of *Xanthoria elegans* colonising rocks in tropical, temperate and alpine regions of Himachal Pradesh, Jammu & Kashmir, Kerala, Ladakh, Uttarakhand. Ref.: Triebel & Kainz (2004); Joshi *et al.* (2016) **Muellerella erratica**
9. Asci 20 – 32-spored; ascospores slightly verrucose and ellipsoid to narrowly ellipsoid, 8 – 10 × 4 – 5 μm; on thallus and occasionally apothecial disc of *Xanthoria elegans* colonising rocks in temperate and alpine regions of Ladakh. Ref.: Triebel & Kainz (2004); Zhurbenko (2013) **Muellerella pygmaea**
10. Ascospores 15 – 20 × 6 – 10 μm, growing on thallus and apothecial disc of *Xanthoria elegans* colonising rocks in temperate and alpine regions of Ladakh, Uttarakhand. Ref.: Navarro-Rosinés & Roux (1998); Zhurbenko (2013); Joshi *et al.* (2016) **Polycoccum clauzadei**
10. Ascospores 18 – 26 × 7.5 – 11 μm, growing on thallus of *Caloplaca flavorubescens* colonising bark in temperate regions of Uttarakhand. Ref.: Diederich (1990); Joshi *et al.* (2018) **Polycoccum tinantii**
11. Ascospores aseptate, ellipsoid to narrow-ellipsoid, occasionally with one concave side, (10.5 –) 14 (– 19) × (4.5 –) 5.8 (– 7.5) μm; on thallus of *Caloplaca saxicola* colonising rocks in temperate region of Uttarakhand. Ref.: Joshi *et al.* (2018) **Verrucula latericola**
11. Ascospores septate 12
12. Interascal filaments absent or indistinct. Ascospores 1-septate, hyaline, light brown when old, 10 – 13 × 3 – 4 μm; on thallus and apothecial disc of *Xanthoria elegans* colonising rocks in temperate region of Uttarakhand. Ref.: Roux & Triebel (1994); Joshi *et al.* (2016) **Stigidium cerinae**
12. Interascal filaments present 13
13. Ascomata in section filled with numerous oil droplets; ascospores narrowly ellipsoid to soleiform, 1-septate, with lipid droplets, at first hyaline, rarely pale grey-olive to medium olive-brown, slightly heteropolar, (12 –) 14.98 – 18.4 – 21.42 (– 24) × (3 –) 3.53 – 4.5 – 5.47 (– 6) μm, l/b = (2.83 –) 3.26 – 4.2 – 5.14 (– 6); on thallus and apothecial disc of *Caloplaca saxicola* colonising rocks in temperate region of Jammu & Kashmir **Lichenochora ajaysinghii**
13. Ascomata in section not filled with numerous oil droplets 14
14. Ascospores with a verrucose wall, hyaline, 1-septate, (15 –) 16 – 20 (– 21) × 5 – 8 μm; on thallus and apothecial disc of *Caloplaca* sp., *C. flavescens* (syn. *Variospora flavescens*), *Xanthoria elegans* colonising rocks in temperate and alpine regions of Himachal Pradesh, Ladakh, Uttarakhand. Ref.: Grube & Hafellner (1990); Zhurbenko (2013) **Zwackhiomyces coepulonus**
14. Ascospores more or less smooth walled. Perithecium wall mainly green, bluish green or brown in upper part, in lower part usually hyaline and indistinctly delimited from the host tissue 15
15. Asci 4-spored, ascospores not caudate and less heteropolar; on thallus and apothecial disc of *Xanthoria elegans*, *X. sorediata* (syn. *Rusavskia sorediata*) colonising rocks in temperate and alpine regions of Himachal Pradesh, Ladakh, Uttarakhand. Ref.: Zhurbenko & Triebel (2003); Zhurbenko (2013); Joshi *et al.* (2016) **Cercidospora xanthoriae**
15. Asci (4 – 6 –) 8-spored, ascospores caudate, strongly heteropolar with both cells very different in shape and size, with the lower cell curved and attenuated as a tail; on thallus and apothecial disc of *Caloplaca approximata* (syn. *Amundsenia approximata*), *C. biatorina*, *Xanthoria elegans* colonising rocks in temperate and alpine regions of Himachal Pradesh, Jammu & Kashmir, Ladakh, Uttarakhand. Ref.: Navarro-Rosinés *et al.* (2004); Joshi *et al.* (2016) **Cercidospora caudata**
16. Colonies delimited, erumpent through the upper cortex of the host or sometimes almost superficial, coral to bright pink. Sclerotia 80 – 250 μm diam., ±ellipsoidal; composed of subspherical to elongate, catenate cells, 5 – 12 × 3.5 – 7 μm in size; on thallus of *Xanthoria candelaria* (syn. *Polycauliona candelaria*) colonising bark in temperate regions of Jammu & Kashmir. Ref.: Diederich & Lawrey (2007); Zhurbenko (2013) **Marchandiomyces corallinus**
16. Fungus not coral to bright pink-coloured, sclerotia absent 17
17. Conidia produced from pycnidia or disc like open structures 18
17. Conidia produced on open or tufted hyphal structures or immersed in the host tissues 20
18. Conidia pale brown to dark brown 19
18. Conidia hyaline, (4.5 –) 5.5 – 6.5 (– 8) × 3.5 – 4 (– 4.5) μm; on apothecial disc of *Xanthoria elegans* colonising rocks in temperate regions of Jammu & Kashmir. Ref.: Zhurbenko (2013) **Phoma** sp.
19. Conidia septate, 4 – 7.5 × 2 – 3 μm, smooth walled; conidiomata 50 – 120 μm diam.; on thallus and apothecial disc of *Caloplaca cerina*, *Xanthoria candelaria*, *X. elegans* colonising rocks in tropical, temperate and alpine regions of Himachal Pradesh, Jammu & Kashmir, Karnataka, Madhya Pradesh, Sikkim, Uttarakhand. Ref.: Diederich (2004c); Zhurbenko (2013); Joshi *et al.* (2015, 2016) **Lichenodiplis lecanorae**
19. Conidia aseptate, (2.5 –) 3 – 4.5 (– 6) μm, minutely warted; conidiomata (80 –) 100 – 175 (– 200) μm; on

- thallus and apothecial disc of *Xanthoria elegans* colonising rocks in temperate and alpine regions of Jammu & Kashmir, Uttarakhand. Ref.: Hawksworth (1977); Diederich (2004b); Zhurbenko (2013); Joshi *et al.* (2016) **Lichenonium xanthoriae**
20. Conidiophores macronematous; conidia 0 – 1-septate, aseptate conidia 3.5 – 8 × 3 – 5 µm, septate conidia 7 – 13 × 5 – 7 µm; on thallus and soralia of *Xanthoria candelaria* colonising bark in temperate regions of Jammu & Kashmir. Ref.: Heuchert & Braun (2006); Zhurbenko (2013) **Cladsporium licheniphilum**
20. Conidiophores semi-macronematous; conidia 1 septate, 5 – 8 (– 9) × 4 – 6 (– 7) µm; on apothecial disc of *Caloplaca approximata*, *C. pachycheila* colonising rocks in temperate and alpine regions of Ladakh, Uttarakhand. Ref.: Diederich (2004a); Zhurbenko (2013); Joshi *et al.* (2016) **Intralichen christiansenii**

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