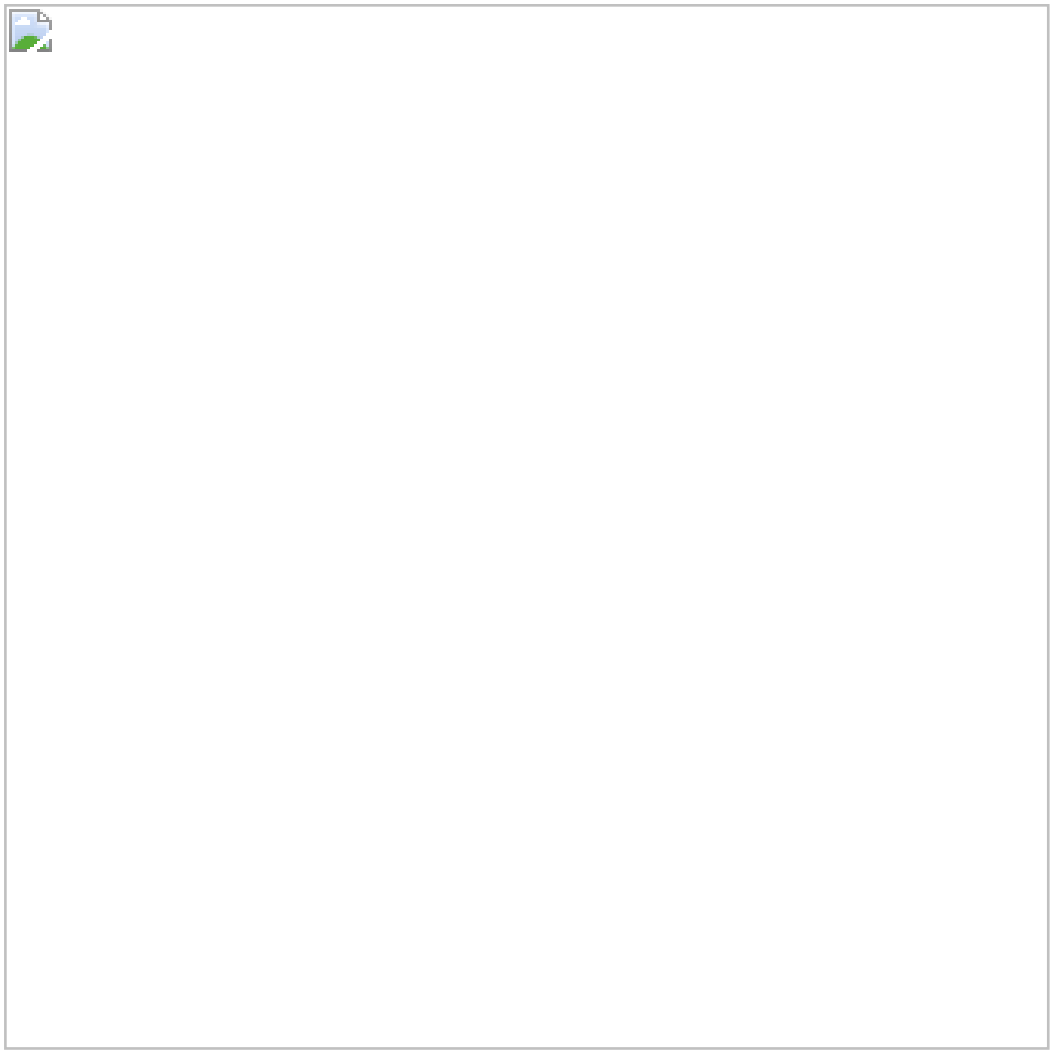

Lichenicolous species of the genus Arthonia (Ascomycetous fungi) from India

Authors: Joshi, Yogesh, Bansal, Pooja, Bisht, Sunita, Pargaien, Nirmala, and Halda, Josef P.

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Research

Lichenicolous species of the genus *Arthonia* (Ascomycetous fungi) from India

Yogesh Joshi[1], Pooja Bansal[1], Sunita Bisht[1,2], Nirmala Pargaien[2] and Josef P. Halda[3]

[1]Department of Botany, University of Rajasthan, Jaipur, Rajasthan, India
[2]Department of Botany, M. B. Govt. Post Graduate College, Haldwani, Nainital, Uttarakhand
[3]Faculty of Science, University of Hradec Králové, Hradec Králové, Czech Republic

Correspondence: Yogesh Joshi (dryogeshcalo@gmail.com)

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In the present paper four new records of lichenicolous species of *Arthonia* Ach. are reported from India. *Arthonia aspiciliae* is growing on the thallus and ascomata of *Aspicilia* sp., *Arthonia destruens* on the thallus of *Physcia stellaris*, *Arthonia hawksworthii* on the thallus of *Dimelaena* sp. and *Arthonia protoparmeliopseos* on the thallus and apothecial discs of *Protoparmeliopsis muralis*. Brief descriptions, illustrations, distributions, hosts and an artificial key to all known lichenicolous species of *Arthonia* from India is also provided.

Keywords: Arthoniaceae, Himalaya, new additions

Introduction

The genus *Arthonia* Ach. s.l. belonging to the order Arthoniales Henssen ex D.Hawksw. & O. E. Erikss. and the family Arthoniaceae Rchb. is highly heterogenous and polyphyletic (Sundin and Tehler 1998, Frisch et al. 2014, 2015, Ertz et al. 2018, Van den Broeck et al. 2018). The genus in its broad sense includes various segregates (*Bryostigma* Poelt & Döbbeler, *Coniangium* Fr., *Coniocarpon* DC., *Diarthonis* Clem., *Felipes* Frisch & G.Thor, *Naevia* Fr., *Pachnolepia* A.Massal. and *Synarthonia* Müll. Arg.) (Coppins and Aptroot 2009, Thiyagaraja et al. 2020) and comprises about 500 species (Diederich et al. 2018) belonging to different life forms: lichens, non-lichenized fungi, and parasymbionts. Of these 500 species of *Arthonia* s.l., the majority are lichenized, while ca one-fourth (152 species excluding five invalid names given by Alstrup et al. 2018) are lichenicolous taxa (Diederich et al. 2018, 2019, Kondratyuk et al. 2019, Zhurbenko et al. 2021, Hafellner and Grube 2023, Kantvilas and Motiejūnaitė 2023, Hollinger et al. 2024), and some non-lichenized and saprotrophic on bark (Sundin 1999, Grube 2007, Coppins and Aptroot 2009).

Table 1. Lichenicolous species of genus *Arthonia* in India (species in bold are new to India).

S. no.	Lichenicolous fungi	Host(s)	Reference(s)
1	*Arthonia apotheciorum* (A.Massal.) Almq.	Polyozosia dispersa (Pers.) S.Y. Kondr., Lőkös & Farkas	Falswal and Bhandari 2020
2	***A. aspiciliae* Alstrup & E.S.Hansen**	*Aspicilia* A. Massal. sp.	This paper
3	*A. ayseniae* Halıcı & Candan	*Acarospora* A. Massal. sp.	Joshi et al. 2020b
4	*A. clemens* (Tul.) Th. Fr. s.s.	*Protoparmeliopsis peltata* (Lam. & DC.) Arup, Zhao Xin & Lumbsch, *Rhizoplaca chrysoleuca* (Sm.) Zopf	Joshi et al. 2016
5	*A. cohabitans* Coppins	*Caloplaca cerina* (Hedw.) Th. Fr.	Falswal and Bhandari 2020
6	*A. coronata* Etayo	*Flavoparmelia caperata* Hale	Joshi et al. 2018
7	***A. destruens* Rehm**	*Physcia stellaris* (L.) Nyl.	This paper
8	*A. diorygmatis* S.Joshi & Upreti	*Diorygma junghuhnii* (Mont. & Bosch) Kalb, Staiger & Elix	Joshi et al. 2013
9	*A. epiphyscia* Nyl.	*Physcia stellaris* Nyl., *Physcia* (Schreb.) Michx. sp.	Joshi et al. 2016
10	***A. hawksworthii* Halıcı**	*Dimelaena* Norman sp.	This paper
11	*A. molendoi* (Frauenf.) R.Sant.	*Calogaya biatorina* (A.Massal.) Arup, Frödén & Søchting, *C. saxicola* (Hoffm.) Vondrák, *Caloplaca* Th. Fr. sp., *Rusavskia elegans* (Link) S.Y.Kondr. & Kärnefelt	Zhurbenko 2013
12	*A. pepei* Etayo & Pérez-Ort.	*Parmotrema reticulatum* (Taylor) M.Choisy	Sharma et al. 2023
13	*A. phaeophysciae* Grube & Matzer	*Phaeophyscia endococcina* (Körb.) Moberg, *Phaeophyscia* Moberg sp.	Joshi et al. 2016
14	***A. protoparmeliopseos* Etayo & Diederich**	*Protoparmeliopsis muralis* (Schreb.) M. Choisy	This paper
15	*A. punctella* Nyl.	*Diplotomma alboatrum* (Hoffm.) Flot.	Falswal et al. (2023)
16	*A. subconveniens* Nyl.	*Lobaria meridionalis* Vain.	Joshi et al. 2016

Recently Kondratyuk et al. (2020) based on mtSSU and RPB2 protein coding gene sequences transferred 12 species of *Arthonia* to the genus *Bryostigma* within the Arthoniaceae, including four lichenicolous species reported from India, viz. *Bryostigma apotheciorum* (A. Massal.) S.Y.Kondr. & J.-S.Hur, *B. epiphyscium* (Nyl.) S.Y.Kondr. & Hur, *B. molendoi* (Heufl. ex Frauenf) S.Y.Kondr. & Hur and *B. phaeophysciae* (Grube & Matzer) S.Y.Kondr. & Hur. However, Cannon et al. (2020) didn't accept the transfer made by Kondratyuk et al. (2020) and treated all these species as *Arthonia*.

To date, 12 lichenicolous species of *Arthonia* were reported from India (Table 1) of which only one – *Arthonia diorygmatis* has been originally described from India (Joshi et al. 2013). In the present study, we report four new records of lichenicolous *Arthonia* from India i.e. *Arthonia aspiciliae* colonizing thallus and ascomata of *Aspicilia* sp., *A. destruens* on the thallus of *Physcia stellaris A. hawksworthii* on the thallus of *Dimelaena* sp. and *A. protoparmeliopseos* on the thallus and apothecial discs of *Protoparmeliopsis muralis*, thereby raising the tally of lichenicolous *Arthonia* to 16 species from India.

Material and methods

The specimens were studied macroscopically with an Olympus SZ61 stereozoom dissecting microscope and microscopically with an Olympus BX 53 microscope equipped with Olympus differential interference contrast optics. Measurements were taken on thin hand-cut sections mounted in water. Ascospore measurements for the new records were given as (minimum–)(X – SD) – X – (X + SD) (– maximum), where X is the arithmetic mean and SD the corresponding standard deviation, and the length/breadth ratio (l/b) is presented in the same way, followed by the number of measurements in parentheses (n). For identification and staining, the standard reagents 10% KOH, Steiner's solution, Lactophenol Cotton Blue (LCB), Lugol's iodine solution were used. The specimens are deposited in the herbarium of the University of Rajasthan (RUBL) and CSIR-National Botanical Research Institute (LWG).

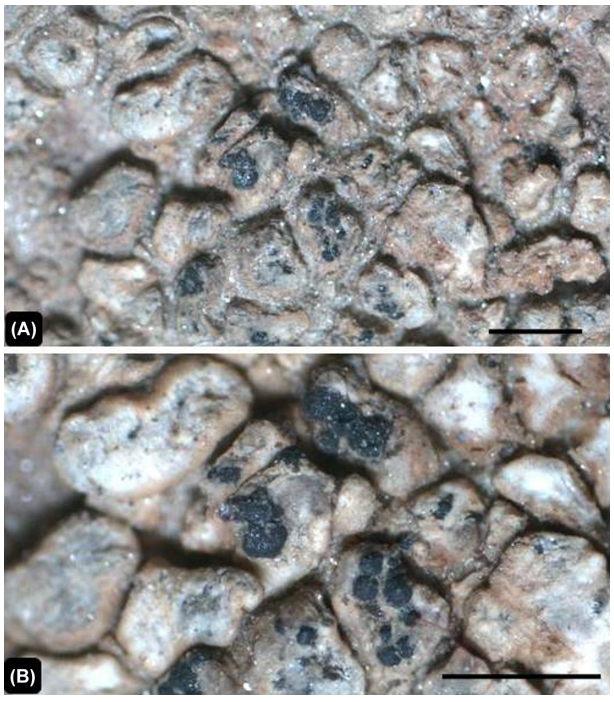

Figure 1. (A) Thallus and apothecial disc of *Aspicilia* sp. infected by *Arthonia aspiciliae* (scale bar = 1 mm), (B) magnified view of apothecia of *A. aspiciliae* (scale bar = 1 mm).

Results and discussion

Arthonia apotheciorum (A.Massal.) Almq., Kongl. Sve. Vetensk. Handl. 17(6): 58 (1880).

Host: Polyozosia dispersa (Pers.) S.Y. Kondr., Lőkös & Farkas (thallus).

Distribution in India: Uttarakhand (Falswal and Bhandari 2020).

Arthonia aspiciliae Alstrup & E.S.Hansen, Graphis Scripta 12(2): 42 (2001). (Fig. 1–2)

Diagnostic characters. Lichenicolous on the apothecial disc or sometimes the thallus of *Aspicilia* sp. Apothecia arthonioid, round to irregular, 0.1–0.3 mm diam., black, without a distinct margin (Fig. 1B). Epihymenium brown to brownish-black, K+ intense to olive green. Hymenium colourless or pale brown at maturity, I+ red, K/I-. Hypothecium blackish-brown with purple tinge, K+ intense to olive green, I+ red, K/I-. *Asci* without K/I+ blue ring structure, 8-spored. Ascospores hyaline, 1-septate, not or slightly constricted at the septa, smooth walled, ellipsoid to soleiform, I+ orange, KI-, perispore absent, (10.0–)11.0–15.0(–19.0) × (2.0–)2.5–4.5(–6.0) µm, l/b = (2.4–)3.7–3.9(–4.5) (n = 50). Conidiomata not observed.

Remarks

It is new to India and was previously reported from Greenland (Alstrup and Hansen 2001). The species is growing along with *Endococcus propinquus* (Körb.) Trevis. and *Muellerella erratica* (A.Massal.) Hafellner & Volk. John.

Specimens examined

India, Himachal Pradesh, Lahaul Spiti district, Keylong, Malong, elev. 3400 m, on *Aspicilia* sp. colonizing rocks, 15 Sept. 2001, D.K. Upreti 01-26548/A (LWG 15225); ibid,

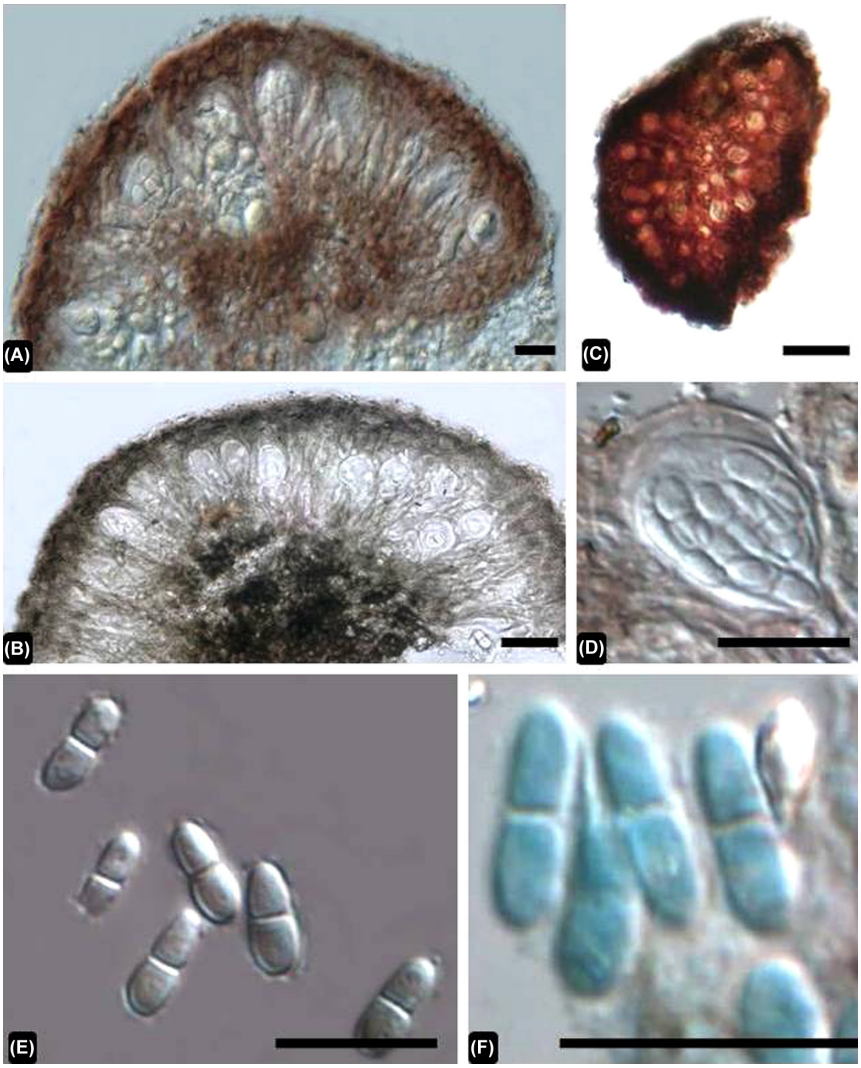

Figure 2. (A) Cross-section through the apothecium of *A. aspiciliae* in water (scale bar = 20 µm), (B) section through apothecium with K treatment showing K+ intense to olive green epihymenium (scale bar = 20 µm), (C) section of apothecium with I treatment showing I+ red hymenium and hypothecium (scale bar = 50 µm), (D) ascus with ascospores (scale bar = 20 µm), (E–F) ascospores in water and LCB, respectively (scale bar = 20 µm).

26548/B (LWG 15025). Uttarakhand, Pithoragarh district, Beilju, in route to Milam Glacier, elev. 3420 m, on *Aspicilia* sp. colonizing rocks, 19 Oct. 2014, K. Bisht s.n. (RUBL 21409).

Arthonia ayseniae Halıcı & Candan, Nova Hedwigia 88: 484 (2009).

Host: *Lecanora oxytona* (thallus).

Distribution in India: Uttarakhand (Joshi et al. 2020b).

Arthonia clemens (Tul.) Th. Fr., K. Sve. Vetensk. Akad. Handl. ser. 2, 7(2): 46 (1867).

Host(s): *Protoparmeliopsis peltata*, *Rhizoplaca chrysoleuca* (thallus and apothecia).

Distribution in India: Himachal Pradesh, Jammu & Kashmir, Uttarakhand (Joshi et al. 2016, 2020bc).

Arthonia cohabitans Coppins, Lichenologist 21(3): 211 (1989).

Host: *Caloplaca cerina* (thallus).

Distribution in India: Uttarakhand (Falswal and Bhandari 2020).

Arthonia coronata Etayo, Bull. Soc. Linn. Provence 47: 95 (1996).

Host: *Flavoparmelia caperata* (soredia and thallus).

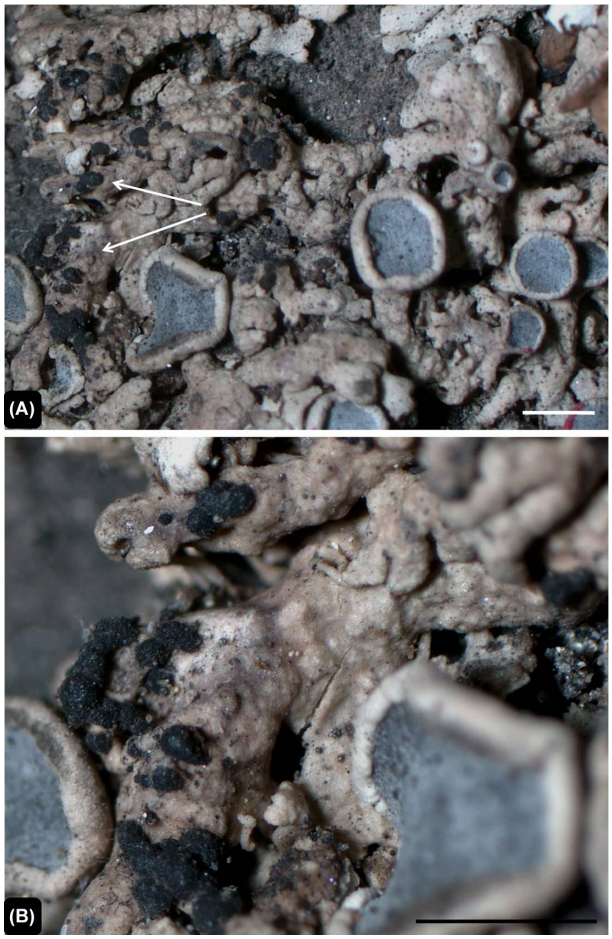

Figure 3. (A) Thallus of *Physcia* infected by *Arthonia destruens* Rehm (arrows indicating apothecia) (scale bar = 1 mm), (B) magnified view of *A. destruens* (scale bar = 1 mm).

Distribution in India: Arunachal Pradesh, Himachal Pradesh, Uttarakhand (Joshi 2018, Joshi et al. 2020b).

Arthonia destruens Rehm in Rabenh., Lich. Eur.: 816 (1868). (Fig. 3–4)

Diagnostic characters: Lichenicolous on thallus of *P. stellaris*. Apothecia arthonioid, round to irregular, 0.1–0.3 mm diam., black, without a distinct margin. Epihymenium brown with a yellowish tinge, I+ dark and sordid blue. Hymenium yellowish, K+ turning purplish violet. Hypothecium brown with a yellowish tinge, K+ turning purplish violet. Asci 4–8-spored, clavate. Ascospores 1-septate, oblong-ovoid, hyaline, becoming brown and verrucose at maturity, 11–16 × 5–6 µm (n = 25).

Remarks

It is new to India and was previously reported from Austria, Bolivia, Germany, Greenland, Great Britain, Ireland, Italy, Russia, Wales (Alstrup and Hawksworth 1990, Brackel 2008, 2014, Feuerer and Sipman 2005, Grube et al. 1995, Hawksworth et al. 2010, Rehm 1891, Zhurbenko 2017).

Specimen examined

India, Himachal Pradesh, Kinnaur district, Chitkul Forest area, elev. 3900-4000 m, on thallus of *P. stellaris* colonizing

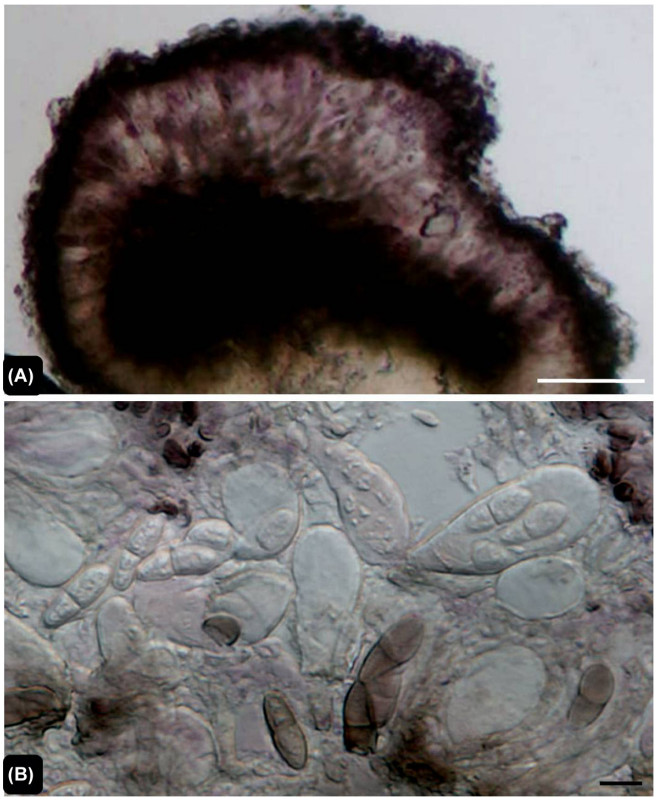

Figure 4. (A) Cross-section through the apothecium of *A. destruens* turning K+ purplish violet (scale bar = 55 µm), (B) ascus and hyaline to brown ascospores (scale bar = 20 µm).

twigs, 4 Nov. 2003, Upreti, Srivastava and Prakash 03-002729 (LWG 20705).

Arthonia diorygmatis S.Joshi & Upreti, Lichenologist 45: 323 (2013).

Host: *Diorygma junghuhnii* (thallus).

Distribution in India: Tamil Nadu (Joshi et al. 2013).

Arthonia epiphyscia Nyl., Flora (Regensburg) 58: 361 (1875).

Host(s): *Physcia* sp., *P. stellaris* (thallus).

Distribution in India: Himachal Pradesh, Ladakh, Uttarakhand (Joshi et al. 2016, 2020b, c).

Arthonia hawksworthii Halıcı, Mycotaxon 105: 90 (2008). (Fig. 5)

Diagnostic characters: Lichenicolous on thallus of *Dimelaena* sp. Apothecia arthonioid, round to irregular, 0.1–0.3 mm diam., black, without a distinct margin. Epihymenium olivaceous brown. Hymenium hyaline, K/I+ slightly blue, I+ orange red. Hypothecium pale brown. Asci 8-spored, broadly clavate. Ascospores 1-septate, ellipsoid, hyaline, 11–13 × 4–5 µm (n = 25).

Remarks

It is new to India and was previously reported from Turkey (Halıcı 2008).

Specimen examined

India, Uttarakhand, Chamoli district, Malari village, old route from Malari to Bampa village, alongside Dhauli Ganga River, alt. 3078 m, 30°42′14″N, 79°52′11″E, on thallus of *Dimelaena* colonising rocks, 23 May 2023, Sunita Bisht (RUBL 21399).

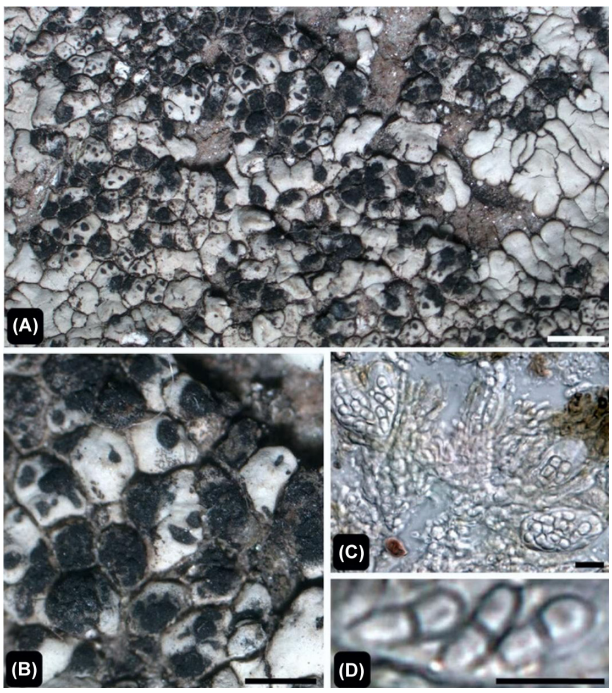

Figure 5. (A) Thallus of *Dimelaena* infected by *Arthonia hawksworthii* Halıcı (scale bar = 1 mm), (B) magnified view of *A. hawksworthii* (scale bar = 1 mm), (C) ascus with ascospores (scale bar = 10 µm), (D) ascospores in water (scale bar = 10 µm).

Arthonia molendoi (Heufl. ex Frauenf.) R.Sant., Thunbergia 3: 2 (1986).

Host(s): *Calogaya biatorina*, *C. saxicola*, *Caloplaca* sp., *Rusavskia elegans* (thallus and apothecia).

Distribution in India: Himachal Pradesh, Jammu & Kashmir, Ladakh, Uttarakhand (Joshi et al. 2016, 2020a, c, Zhurbenko 2013).

Remarks

The species was previously reported from Himachal Pradesh, Jammu & Kashmir, Ladakh by earlier workers (Joshi et al. 2016, 2020a, c, Zhurbenko 2013), and for the first time is being reported from Uttarakhand, showing its range extension in India.

Arthonia pepei Etayo & Pérez-Ort., Herzogia 29: 317 (2016).

Host: *Parmotrema reticulatum* (thallus).

Distribution in India: Tamil Nadu (Sharma et al. 2023).

Arthonia phaeophysciae Grube & Matzer, Progr. Probl. Lichenol. Nineties. Proc. 3rd Symp. Int. Assoc. Lichenol., Biblthca Lichenol. 68: 10 (1997).

Host(s): *Phaeophyscia* sp., *P. endococcina* (thallus).

Distribution in India: Himachal Pradesh, Uttarakhand (Joshi et al. 2016, 2020b).

Arthonia protoparmeliopseos Etayo & Diederich, Bull. Soc. Nat. Luxemb. 110: 93 (2009). (Fig. 6)

Diagnostic characters: *Lichenicolous* on thallus and apothecial disc of *P. muralis*. Apothecia arthonioid, round to irregular, 0.1–0.5 mm diam., black, without a distinct margin. Epihymenium brown. Hymenium hyaline to pale brown, I+ red, K/I+ blue. Hypothecium hyaline, I+ blue, K/I+ blue. Asci 8-spored, broadly clavate to elongate ellipsoid. Ascospores 1-septate, ellipsoid, hyaline, 10–12 × 4–5 µm (n = 25).

Remarks

It is new to India and was previously reported from Spain and Luxembourg (Etayo and Diederich 2009).

Specimen examined

India, Uttarakhand, Chamoli district, Badrinath, Nar Mountain, uphill from forest Guest house, alt. 3187 m, 30°44′16″N, 79°29′52″E, on thallus and apothecial discs of *Protoparmeliopsis muralis*, 18 June 2023, Sunita Bisht (RUBL 21404).

Arthonia punctella Nyl., in Carroll, Nat. Hist. rev. Quart. J. Sci. 6: 533 (1859).

Host: *Diplotomma alboatrum* (thallus and apothecia).

Distribution in India: Uttarakhand (Falswal et al. 2023).

Arthonia subconveniens Nyl., Flora (Regensburg) 50: 440 (1867).

Host: *Lobaria meridionalis* (thallus).

Distribution in India: Himachal Pradesh (Joshi et al. 2016).

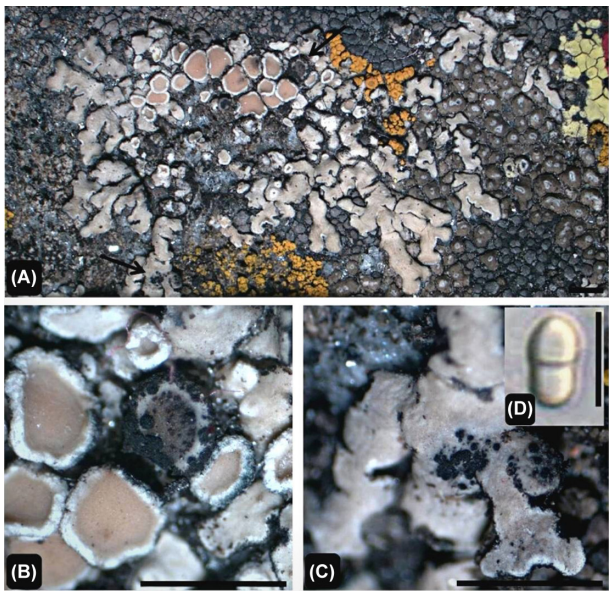

Figure 6. (A) Thallus of *Protoparmeliopsis muralis* infected by *Arthonia protoparmeliopseos* Etayo & Diederich (scale bar = 1 mm), (B) magnified view of *A. protoparmeliopseos* infecting apothecial disc (scale bar = 1 mm), (C) magnified view of *A. protoparmeliopseos* infecting thallus (scale bar = 1 mm), (D) Ascospore (scale bar = 15 µm).

An artificial key to the lichenicolous species of *Arthonia* from India

1. Fungus on crustose, placodioid or squamulose lichens 2
– Fungus on foliose lichens 9
2. On crustose and placodioid lichens 3
– On squamulose lichens, ascomata partly immersed, 0.2–1.0 mm diam. colonizing apothecial disc of *Lichen chrysoleucus* and *R. melanophthalma* ..... *Arthonia clemens*
3. On bark inhabiting lichens 4
– On rock inhabiting lichens 5
4. On members of Graphidaceae; ascomata slightly pruinose; spores hyaline to greyish in late maturity, (13–)14–15(–21) × 5–7 µm. On thallus of *Diorygma junghuhnii* ..... *Arthonia diorygmatis*
– Not on members of Graphidaceae; ascomata erpuinose 5
5. On thallus of *Polyozosia dispersa*; ascomata up to 0.4 mm diam., spores hyaline, smooth, 11–15 × 3–5 µm ..... *Arthonia apotheciorum*
– On thallus of *Diplotomma alboatrum*; ascomata up to 0.2 mm diam., spores hyaline to brown, verruculose, 12–17 × 5–6.5(–7.5) µm ..... *Arthonia punctella*
6. Fungus colonizing placodioid lichens 7
– Fungus colonizing crustose lichens 8
7. Fungus colonizing thallus of *Dimelaena* sp. Epihymenium olivaceous brown. Hymenium hyaline. Hypothecium pale brown ..... *Arthonia hawksworthii*
– Fungus colonizing thallus and apothecia disc of *Protoparmeliopsis muralis*. Epihymenium brown. Hymenium hyaline to pale brown. Hypothecium hyaline ..... *Arthonia protoparmeliopseos*
8. Fungus colonizing thallus as well as apothecial disc of the host. Ascomata up to 0.2 mm across, epruinose; spores hyaline, (10–)11–15(–19) × (2–)2.5–4.5(–6) µm. On *Aspicilia* sp ..... *Arthonia aspiciliae*
– Fungus colonizing only thallus of the host 10
9. Ascomata 0.06–0.16 mm diam.; spores hyaline to brownish in late maturity, 10.5–14 × 4–5 um. On *Caloplaca cerina* ..... *Arthonia cohabitans*
– Ascomata up to 0.2 mm diam.; spores hyaline, (9–)10–14 × (4–)5–6 µm. On *Lecanora oxytona* ..... *Arthonia ayseniae*
10. On phycolichens 11
– On cyanolichens. Asci (6–)8-spored, 22–30 × 14–17 µm; ascospores narrowly oblong to soleiform, 13–15 × 4 µm. On thallus of *Lobaria* ..... *Arthonia subconveniens*
11. On members of Physciaceae 12
– Not on members of Physciaceae 14
12. Hypothecium dark red to black-brown; on *Physcia stellaris* 13
– Hypothecium colourless to pale red; on *Phaeophyscia orbicularis*. Ascomata breaking through the cortex of the host thallus, 0.1–0.3 mm diam., sometimes grey-pruinose; ascospores hyaline, obovate, 12–14 × 4–6 µm ..... *Arthonia phaeophysciae*
13. Hymenium not yellowish; K-; ascomata arise superficially on the host thallus; disc convex; asci 80–95 × 25–30 µm, 8-spored; ascospores hyaline, clavate to clavate-cylindrical, 10–14 × (3–)3.5–5 µm ..... *Arthonia epiphyscia*
– Hymenium yellowish, K+ purple-lilac; ascomata erumpent from the host thallus and becoming sessile; disc flat; asci 29–43 × 11–15 um, 4(–8)-spored; ascospores hyaline and becoming brown and verrucose at maturity, ovoid-cylindrical, 10.5–17 × 5–7 µm ..... *Arthonia destruens*
14. On members of Parmeliaceae 15
– On members of Teloschistaceae. Ascomata without hairs, 0.1–0.2 mm diam.; ascospores 12–15 × 5–6 µm. On thallus and apothecial disc of *Rusavskia elegans* ..... *Arthonia molendoi*
15. Ascomata surface with protruding dark hairs, not arranged in concentric fashion; ascospores (10–)11–14 × 3.5–4.5(–5) µm. On thallus, especially amongst soralia of *Flavoparmelia caperata* ..... *Arthonia coronata*
– Ascomata without protruding dark hairs, arranged in concentric manner; ascospores (7.6–)8.5–9.9(–10.3) × (3.1–)3.5–4.3(–4.5) µm. On thallus of *Parmotrema reticulatum* ..... *Arthonia pepei*

Note

Arthonia cohabitans and *A. punctella* reported on *Caloplaca cerina* and *Diplotomma alboatrum*, respectively by Falswal and Bhandari (2020) and Falswal et al. (2023) seems to be doubtful. *Anthonia cohabitans* typically colonizes *Arthothelium macounii* (G.Merr.) W.J. Noble, rather than *Caloplaca cerina*. Given that *Arthonia molendoi* is more commonly found on members of Teloschistaceae, it is possible

that the specimen identified by Falswal and Bhandari (2020) as *A. cohabitans* is actually *A. molendoi*. Similarly, the habitat reported for *A. punctella* by Falswal et al. (2023) on *Diplotomma alboatrum* is questionable. *Diplotomma alboatrum* is typically saxicolous, but they have reported it as corticolous. This discrepancy raises doubts about the accuracy of the reported association. *Arthonia pantherina* Etayo previously reported by Joshi et al. (2017) is excluded from Indian mycobiota as it was misidentified by the authors; the correct identity of which was *Tremella pertusariae* Diederich, which itself is new to India.

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Data availability statement

There are no additional data for this paper.

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