New species and new records of lichenized Ascomycota from tropical deciduous forests of the Western Ghats biodiversity hotspot, India

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Abstract: *Stirtonia* ghattensis Sumesh N. Dudani, Nayaka, Komal K. Ingle & S. Joseph sp. nov. having UV+ white thallus, 4–6-spored asci, and 5(–7)-septate ascospores and lacking lichen substances is described as new to science. *Pertusaria mesotropa* Müll. Arg. is reported for the first time from India. *Bacidia subannexa* (Nyl.) Zahlbr., *Graphis caesiella* Vain., *G. handelii* Zahlbr., *Hemithecium scariosum* Makhija & Adaw., and *Pertusaria coccodes* (Ach.) Nyl. are new records for Western Ghats. *Arthothelium aphanocarpum* (Nyl.) Zahlbr., which had a restricted distribution in the Andaman Islands, is collected from the mainland of India for the first time. An updated world key for 28 *Stirtonia* taxa known to date is provided.

Key words: Arthoniomycetes, Lecanoromycetes, *Stirtonia*, biodiversity, taxonomy, Karnataka state

1. Introduction
Among the various biogeographic regions in India, the Western Ghats is an important habitat for numerous endemic, rare, and endangered taxa of flora and fauna. The Western Ghats has rich diversity of lichens represented by 1138 species, of which 266 are endemic. The region has a maximum number of crustose lichens with 728 species (Nayaka and Asthana, 2014). Novel taxa are constantly being reported from the Western Ghats (e.g., Subramanya and Krishnamurthy, 2015; Joshi and Upreti, 2016; Kumar and Krishnamurthy, 2016), which indicates that the lichen exploration in the region is far from completion and several ecologically interesting habitats are yet to be investigated. In such an attempt we are exploring the lichen diversity in the central Western Ghats, mostly belonging to state of Karnataka, and we have collected several interesting specimens. Among them, one species of *Stirtonia* A.L. Sm. is described as new species, one species of *Pertusaria* DC. is reported as a new record to India, and six other corticolous lichen species are reported as new to the Western Ghats.

The lichen genus *Stirtonia* A.L. Sm. is among the inconspicuous and understudied lichen elements in tropical forests across the world. This genus is typically characterized by the absence of a true hamathecium, ascigerous areas usually containing crystals and sometimes algal cells; asci generally round to ovoid containing mostly 8 ascospores; ascospores thick walled, trans-septate (Aptroot, 2009). Makhija and Patwardhan (1998) lectotypified the genus with *S. obvallata* (Stirt.) A.L. Sm. and provided a detailed morphotaxonomic account of 12 accepted species. Since then the genus was updated several times with discoveries of many new species (Aptroot, 2009; Wolseley and Aptroot, 2009; Lücking et al., 2011; Alves et al., 2014; Aptroot et al., 2014; Cáceres et al., 2014; Xavier-Leite et al., 2014; Seavey and Seavey, 2015; Weerakoon et al., 2016; Diederich et al., 2017; Seavey et al., 2017). At present the genus is represented by 28 species in the world. In India, eight species of *Stirtonia* have been recorded (Singh and Sinha, 2010; Gupta, 2015), of which five are endemic to India, found in the Andaman and Nicobar Islands, West Bengal, and Tamil Nadu. *S. santessonii* Makhija & Patw., which was considered to be restricted to the Andaman Islands, is also recorded in Karnataka (Rashmi and Rajkumar, 2015).

*Arthothelium* A. Massal. and *Pertusaria* DC. are common lichen genera in the tropical region represented by about 120 and 500 species respectively in the world (Kirk et al., 2008; Lücking et al., 2016). Singh and Sinha (2010) listed a total of 42 *Arthothelium* species from India and later on three more species were added to the genus by Jagadeesh Ram et al. (2012), Makhija et al. (2014), and Singh et al. (2015). Similarly, Singh and Sinha (2010) listed 52 species of *Pertusaria* from India and a total of 20 more...
species were added to the genus by various researchers (Jagadeesh Ram and Sinha, 2010; Bajpai and Upreti, 2011; Shukla and Singh, 2011; Jagadeesh et al., 2012; Singh and Gupta, 2012; Gupta and Singh, 2013; Rai et al., 2014; Mishra and Upreti, 2015; Sinha et al., 2015).

2. Materials and methods
The specimens examined were collected from different forest patches in the Uttara Kannada district of Karnataka (Central Western Ghats, Figure 1) and deposited in the CSIR-National Botanical Research Institute herbarium (LWG), Lucknow. This is the northernmost coastal district of Karnataka state with the distinction of having the highest forest cover, accounting for about 76% of its total area (Ramachandra et al., 2015). It is dotted with numerous sacred groves. Morphological details were examined using a Leica S8APO stereo-zoom microscope. Anatomical details were studied using a Leica DM500 compound microscope. Hand-cut sections of thalli and ascomata mounted in distilled water, KOH solution (K), and lactophenol cotton blue (LPCB) were studied. The amyloid reactions were tested in Lugol's iodine solution without (I) or with pretreatment with KOH (KI). All measurements were made on material mounted in distilled water. The length, breadth, and length/breadth ratio (l/b) of ascospores are given as \((\text{min}–)\overline{X}–\text{SD}–(\text{max})\), where min and max are the extreme values, \(\overline{X}\) the arithmetic mean, and SD the corresponding standard deviation followed by the number of measurements (n).

The chemistry was studied by spot tests and thin-layer chromatography (TLC) following Orange et al. (2001).

3. Results and discussion
3.1. The new species

**Stirtonia ghattensis** Sumesh N. Dudani, Nayaka, Komal K. Ingle & S. Joseph sp. nov. (Figure 2)

*MycoBank No. MB823293*

**Type.** India. Karnataka, Uttara Kannada district, Dandeli road, 15°18′6.20″N, 74°38′5.14″E, elev. 400 m, on bark of tree, 9 January 2012, Sumesh Dudani 12-016857 (holotype-LWG).

**Diagnosis.** Similar to *Stirtonia alba*, but differs by UV+ white thallus, asci 4–6-spored, 5(–7) septate ascospores, and lacking lichen substances.

**Description.** Thallus corticolous, crustose, thin, smooth to uneven, continuous, 5–7 cm across, whitish, ca. 50 µm thick with calcium oxalate crystals; ecorticate; photobiont *Trentepohlia*, 8–13 × 5–8 µm. Prothallus dark brown to black.

Ascigerous zone punctiform to lirelliform, mostly in radiating lines, up to 1.5 mm long, ca. 0.1–0.2 mm wide; pale brown with crystals, without algal cells, ascigerous

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**Figure 1.** Map showing the lichen collection localities in Uttara Kannada district: A- *Stirtonia ghattensis*; B- *Pertusaria mesotropa*; C- *Arthothelium aphanocarpum*; D- *Bacidia subannexa*; E- *Graphis caesiella*; F- *Graphis handelii*; G- *Hemithecium scariosum*; H- *Pertusaria coccodes*. WG: Western Ghats.
zone separated from the thallus by crack; interascal tissue not inspersed, amyloid, IKI+ blue. Asci not abundant, globose to ovoid, not visible through surface, 4–6-spored, 67.37–112.29 × 51.23–70.75 µm; ascospores hyaline, oblong-ellipsoidal, upper cell distinctly enlarged, (53.09–58–63.6(–65.16) × (17.25–22.1–26.7(–27.02) µm (n = 25), mostly 5-septate, rarely up to 7-septate; septa 1.02–3.29 µm thick; wall 2.17–3.66 µm thick. Pycnidia not seen.

Chemistry. Thallus K–, C–, KC–, Pd–, UV+ white; no lichen substances detected in TLC.

Ecology and distribution. Stirtonia ghattensis was found growing on a tree trunk in a moist deciduous forest of Lagerstroemia sp. at an altitude of 400 m on the Dandeli road that heads toward Castle Rock in the Uttara Kannada district of Karnataka.

Etymology. The species epithet ghattensis refers to its type locality of Western Ghats.

Remarks. The new species S. ghattensis is characterized by white, smooth thallus, lirellate to radiating ascomata, 4–6-spored ascus, 5-septate ascospores with enlarged upper cell. Though the thallus is UV+ white, no chemicals were detected in TLC. Morphologically, it closely resembles S. alba Makhija & Patw. However, the latter species differs by having UV– thallus, 8-spored asci, slightly smaller ascospores (38–60 × 14–22 µm), and presence of perlatic acid as lichen substance. Among the Indian species, S. santessonii Makhija & Patw. differs in having pale brownish thallus, 8-spored asci and smaller oblong ascospores (35–50 × 13–18 µm). Another species, S. indica Makhija & Patw., was recorded from the Eastern Ghats in Tamil Nadu state. This species differs from S. ghattensis in having 8-spored asci, ascospores lacking enlarged end cell, presence of psoromic and conpsoromic acids as lichen substances. A world key for all known species of Stirtonia is provided, which is modified from Aptroot et al. (2014).
3.2. New record for India

*Pertusaria mesotropa* Müll. Arg. (Figure 3)

The species can be characterized by its verrucae with 1–3 apothecia, each usually with a distinct ostiole, 8-spored asci and 85–105 × 32–40 µm ascospores, and UV+ yellow thallus. It was found growing on the bark of a tree in a moist deciduous forest. Earlier it was reported from Sri Lanka, Northwest Mexico (Lumbsch et al., 1999), and Kenya (Archer et al., 2009).

**Specimen examined.** Karnataka, Uttara Kannada district, Sirsi-Yellapur road, 14°53′28.02″N, 74°46′33.43″E, elev. 520 m, on bark of a *Lagerstroemia* sp., 16 March 2012, Sumesh Dudani 12-016891 (LWG).

3.3. New to Western Ghats biodiversity hotspot

*Arthothelium aphanocarpum* (Nyl.) Zahlbr. (Figure 4A)

This species can easily be distinguished from other species by having branched, lirellate, reddish brown ascomata containing 8-spored asci, muriform ascospores of 44–65 × 15–26 µm with enlarged terminal cell, and thallus lacking lichen substances.

**Specimen examined.** Karnataka, Uttara Kannada district, Heravali Kan, 14°16′53.09″N, 74°32′18.66″E, elev. 80 m, on bark of *Hopea* sp., 5 May 2014, Sumesh Dudani 14-024699 (LWG).

*Bacidia subannexa* (Nyl.) Zahlbr. (Figure 4B)

This species is characterized by having a smooth thallus, brown apothecium, and transversely 5-septate, oblong to rod-shaped ascospores of 20–26 × 4–5 µm. The species is close to *B. submedialis* (Nyl.) Zahlbr. but the latter has 7-septate, fusiform to acicular and longer (34–50 × 3–4 µm) spores.

**Specimen examined.** Karnataka, Uttara Kannada district, Kathalekan relic forests, 14°16′17.84″N, 74°44′51.00″E, elev. 590 m, on bark of a *Mextesia* sp., 29 March 2012, Sumesh Dudani 12-018649 (LWG).

*Graphis caesiella* Vain. (Figure 4C)

This species is characterized by having elongate, irregularly branched lirellae, concealed disc, entire labia, white pruinose, laterally carbonized exciple, clear hymenium, 8-spored ascus with transversely 5–9-septate ascospores of 24–35 × 6–8 µm and containing norstictic acid. Similar *G. pyrrhocheiloides* Zahlbr. differs by exposed disc and ascospores of 11–30 × 6–8 µm.

**Specimen examined.** Karnataka, Uttara Kannada district, Golehalli, 15°16′36.16″N, 74°48′20.74″E, elev. 520 m, on bark of a *Odina* sp., 3 December 2013, Sumesh Dudani 13-016864 (LWG).

*Graphis handelii* Zahlbr. (Figure 4D)

This species is characterized by having erumpent lirellae with lateral thaline margin, exposed epruinose disc, entire labia, laterally carbonized excipulum, inspersed hymenium, ascospores 7–11-septate, 20–40 × 6–10 µm, and contains norstictic acid. The species is similar to *G. crebra* Vain. but the latter has white pruinose disc and ascospores of 20–30 × 5–8 µm.

**Specimen examined.** Karnataka, Uttara Kannada district, Sambrani deciduous forest, on fallen twigs, 15°16′30.58″N, 74°44′35.30″E, elev. 530 m, 3 December 2013, Sumesh Dudani 13-023397 (LWG).

*Hemithecium scariosum* Makhija & Adaw. (Figure 4E)

This species can be easily distinguished from other species by its bright greenish stramineous, somewhat wrinkled thallus, immersed to slightly raised ascomata, noncarbonized and entire wooly brown colored exciple, transversely 15–22-septate, ellipsoid ascospores of 63–83 × 6–8 µm, and containing stictic, salazinic, and constictic acids.

**Figure 3. Pertusaria mesotropa:** A- habitus, B- asci, C–D- ascospores (scale bars: A = 1 mm; B–D = 50 µm).
Specimen examined. Karnataka, Uttara Kannada district, Chandawar, 14°24'55.55"N, 74°29'12.68"E, elev. 30 m, on fallen twigs, 16 April 2014, Sumesh Dudani 14-024459 (LWG).

**Pertusaria coccodes** (Ach.) Nyl. (Figure 4F)

This species is characterized by dense globose to cylindrical isidiate, UV– thallus, lacking apothecia, and the presence of norstictic acid complex. *P. coronata* is morphologically similar to this species but differs by UV+ orange thallus.

Specimen examined. Karnataka, Uttara Kannada district, Brahmur deciduous forest, 14°33'52.02"N, 74°29'14.27"E, elev. 170 m, on bark of a *Lannea* sp., 15 April 2014, Sumesh Dudani 14-024430 (LWG).

Among the new records of lichen, *B. subannexa*, which was reported earlier from the West Bengal plains in India, in the present study is being reported from Kathalekan swampy relic forests. *G. caesiella* and *H. scariosum* were earlier reported from single localities of India, i.e. the Lakshwadeep Islands and Andaman Islands, respectively.

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**Figure 4.** Habitus: A- *Arthothelium aphanocarpum*, B- *Bacidia subannexa*, C- *Graphis caesiella*, D- *Graphis handelii*, E- *Hemithecium scariosum*, F- *Pertusaria coccodes* (scale bars: A–F = 1 mm).
(Singh and Sinha, 2010). Another species, G. handelii, was earlier reported from Manipur, Meghalaya, and West Bengal (Singh and Sinha, 2010; Singh and Singh, 2015) and Andhra Pradesh (Mohabe et al., 2017). Arthothelium aphanocarpum was found growing on the bark of Hopea sp. in the moist deciduous forest of the Heravali sacred grove. This species was last reported in 1995 from North Andaman forests and since then there has been no collection or report of it from anywhere else in India. Hence, this record comes as the first record of this species from mainland India after a gap of 22 years from its last report.

3.4. World key to Stirtonia species

1. Thallus folicolous, ascospores 9-septate, 75–85 × 30–36 µm, confluent acid present ....................... S. epiphylla Aptroot & Seaward
   - Thallus otherwise ........................................................................ 2
   - Thallus lacking isidia .................................................. 3
   - Ascospores with enlarged upper cell ........................................ 4
   - Ascospores without enlarged upper cell .................................. 8
4. Ascospores <30 µm long ...................................................... 5
   - Ascospores >30 µm long ....................................................... 6
5. Thallus byssoid, greenish gray, perlatolic acid present ........................................... S. byssoides F. Seavey & J. Seavey
   - Thallus crustose, pale greenish, lacking lichen substances ............... S. microspora Xavier-Leite et al.
6. Thallus with perlatolic acid, thallus whitish .......................................................... S. alba Makhija & Patw.
   - Thallus lacking lichen substances ............................................... 7
   - Thallus UV−, asci 8-spored, ascospores 35–50 µm long .................. S. santessonia Makhija & Patw.
8. Ascigerous zones linear, branched or anastomosing, raised above thallus level or not ........................................ 9
   - Ascigerous zones mostly rounded, often distinctly raised above thallus level ........................................... 20
9. Ascospores 15–30 µm long .................................................... 10
   - Ascospores 35–73 µm long ..................................................... 12
10. Ascigerous zones inconspicuous ..........S. dubia A. L. Sm.
   - Ascigerous zones conspicuous, white, contrasting in color with the green thallus ........................................ 11
   - Ascospores 17–19 µm long ........................................ S. lucida M. M. E. Alves et al.
   - Ascospores 7–12-septate, ascigerous zones different ........................................ 13
13. Thallus and ascigerous zones partly C+ red, gyrophoric acid present, sometimes also partly UV+ yellow with lichexanthone ........................................... S. neotropica Aptroot
   - Thallus and ascigerous zones C− and UV− ...................................... 14
14. Ascospores 35–55 µm long .................................................... 15
   - Ascospores 55–73 µm long ..................................................... 18
15. Thallus with perlatolic acid, ascospores usually curved ........................................... S. curvata Aptroot
   - Thallus lacking lichen substances .......................................... 16
16. Ascigerous zone strongly raised above the thallus surface, branched or unbranched ............... S. coei F. Seavey & J. Seavey
   - Ascigerous zone immersed, at level or slightly raise above the thallus .................................................. 17
17. Ascospores 52–55 µm long, mid cell distinctly enlarged....................... S. latispora F. Seavey & J. Seavey
   - Ascospores 35–47 µm long, mid cell not enlarged ......................... S. nivea Xavier-Leite et al.
18. Thallus with divaricatic acid, ascospores with enlarged midcell............... S. divaricatic F. Seavey & J. Seavey
   - Thallus lacking lichen substances ............................................. 19
19. Ascigerous zones conspicuous, linear and anastomosing, white, contrasting in color with the green thallus; ascospores hyaline, 55–58 µm long .... S. viridis Aptroot et al.
   - Ascigerous zones inconspicuous, linear or round or consisting of individual asci, of thallus color, ascospores brown, 61–73 µm long..... S. punctiformis Aptroot & Sipman
20. Thallus UV+ bright white or yellow, with 2’-O-methylsuperphyllinic acid or lichexanthone . 21
   - Thallus UV− ........................................................................ 22
   - Thallus UV+ yellow, with lichexanthone .......... S. nitida Xavier-Leite et al.
22. Thallus Pd+ yellow, with psoromic acid ........................................ 23
   - Thallus Pd−, without psoromic acid ....................................... 25
23. Ascospores 36–45 µm long.............. S. schummi Aptroot
   - Ascospores 50–87 µm long ..................................................... 24
   - Ascospores 75–87 µm long, ascigerous zones <1 mm wide ........... S. psoromica Aptroot & Wolseley
25. Thallus brownish ....................................................... 26
26. Thallus whitish .................................................................. 27
   - Ascigerous zones not raised, white ........... S. obvallata (Stirt.) A. L. Sm.
27. Thallus with confluent acid........ S. rhizophorae Kalb & Mongkolsuk
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