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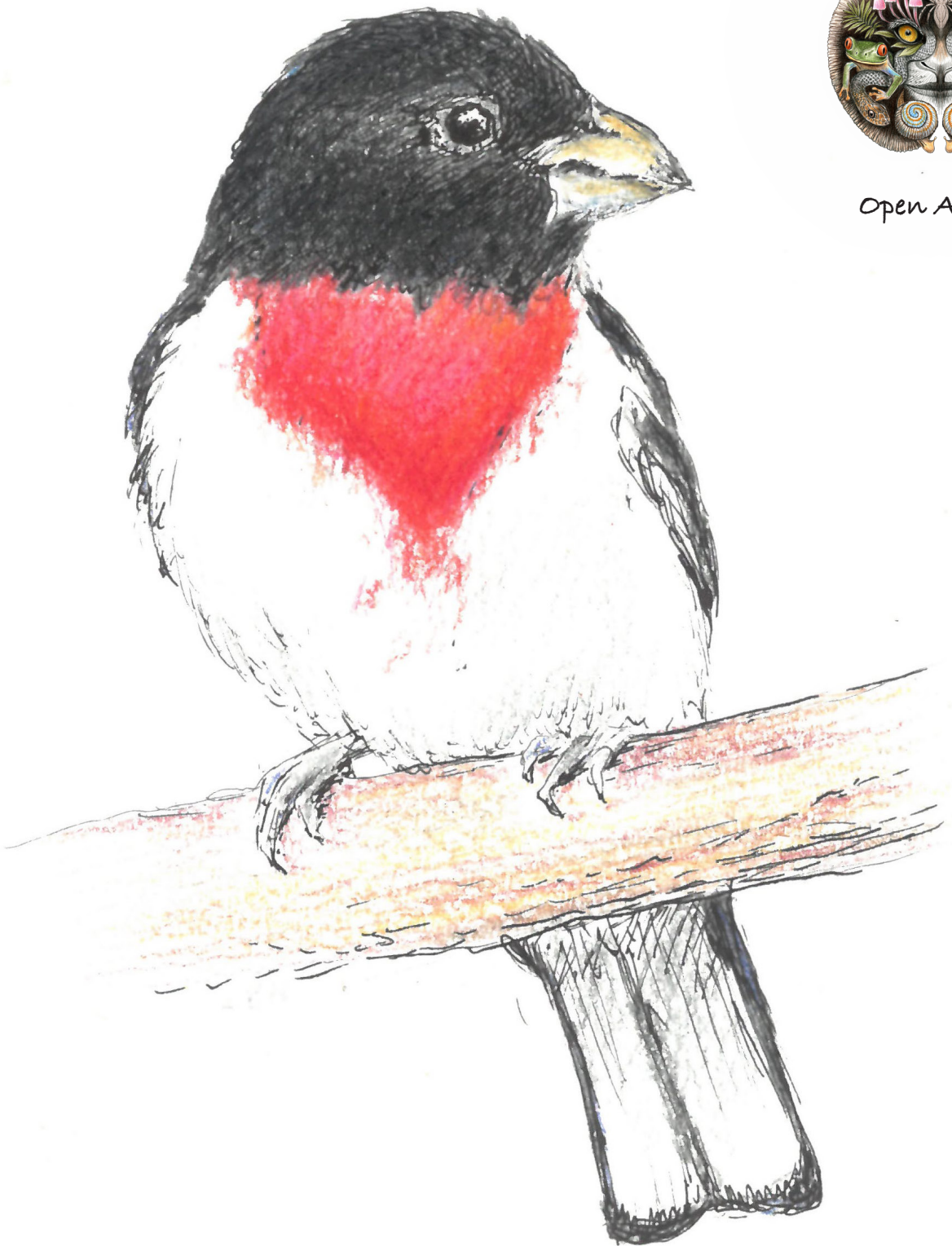
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Cover: Rose-breasted Grosbeak *Pheucticus ludovicianus*, pen & ink with colour pencil. © Lucille Betti-Nash.



Morphological characterization and distribution of four corticioid fungi species (Basidiomycota) in India

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Abstract: During the fungal forays conducted in Kullu district of Himachal Pradesh (India) several specimens of corticioid fungi were collected. Based on morphological characterization, these fungi have been identified as *Aphanobasidium pseudotsugae*, *Cyrtidiella albida*, *C. nitidula*, and *Phlebia viridesalebrosum*. These four species are new additions to the Indian mycobiota.

Keywords: Agaricomycetes, Agaricales, Basidiomycota, coniferous trees, Himachal Pradesh, mycelium, northwestern Himalaya, Polyporales, white rot, wood rotting fungi.

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Competing interests: The authors declare no competing interests.

Author details: Ms. TANYA JOSHI is currently working as CSIR-UGC JRF in the Department of Botany, Punjabi University, Patiala. She has worked on the topic “Taxonomic studies on some corticioid fungi from Kullu district (Himachal Pradesh)” during her M.Sc. (Hons. in Botany) dissertation work. She has described 15 species of the corticioid fungi including four new records for India. DR. ELLU RAM is presently working as assistant professor in Department of Botany, Government College, Seraj, Lambathach, Mandi (Himachal Pradesh). He has worked on the topic “Mycofloristic studies on corticioid and poroid fungi of district Kullu (Himachal Pradesh) for his Ph.D. research work. He has thoroughly surveyed district Kullu for the collections of these fungi described 136 taxa of corticioid and poroid fungi from the study area including 36 new records for India. Ms. AVNEET KAUR has recently completed her Ph.D. research work on the systematic studies on polyporoid fungi from Punjab and evaluation of selected species for anticancer activity. She has worked on the diversity of polyporoid fungi and has special interest in antioxidant and anticancer activity of medicinally important polyporoid fungi. She has described more than 50 taxa of polyporoid fungi from different parts of India. DR. AVNEET PAL SINGH is working as assistant professor in the Department of Botany, Punjabi University, Patiala. His area of specialization is taxonomy, histo-pathology and evaluation of wood rotting corticioid and poroid fungi (Agaricomycetes, Basidiomycota). He actively engaged in the research work for more than two decades and has described more than 300 taxa of these fungi based on morphological and DNA sequence based molecular phylogenetic studies. He has described two new genera and 22 new species of corticioid and poroid fungi.

Author contributions: TJ—has worked out macro and micro-morphological details of the corticioid specimens collected from different parts of Kullu district of Himachal Pradesh. She has compiled the technical description and line diagrams of the new records described presently. ER—has thoroughly surveyed the area of investigation and collected the basidiocarp specimens of the species being described in the present manuscript. He has significantly contributed in working out the macro and micro-morphological details and preparation of taxonomic description and plates for identification. AK—has critically analyzed the morphological details of the specimens and contributed to the comparison and identification of these four new records of corticioid fungi. She has also contributed in drafting the manuscript. APS—has explored the taxonomic literature for identity of the worked out specimens. He has also contributed to the draft of manuscript and photography of the specimens described presently.

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INTRODUCTION

Corticioid fungi are a heterogenous conglomeration featuring customarily resupinate basidiocarps that are generally adnate or have reflexed-effused margins. These basidiocarps range from soft to hard, crystalline to amorphous and may occur either on gymnospermous or angiospermous wood. The configuration of the hymenophore is diversified in exhibiting smooth, tuberculate, ceraceous, grandinoid, odontoid, corneous, strigose, and sometimes velutinous surface. Microscopically, the basidiocarps are mainly composed of generative or sclerified hyphae.

As per the traditional morphotaxonomic studies, majority of the corticioid fungi were placed in the family Thelephoraceae of the order Aphyllophorales (Rea 1922). However, the modern molecular phylogenetic studies proved this group as a polyphyletic artificial assemblage. Based on these molecular studies, the corticioids are presently assigned to the class Agaricomycetes, belonging to sub-phylum Agaricomycotina of phylum Basidiomycota. Further, these are classified under the orders Agaricales, Atheliales, and Boletales of subclass Agaricomycetidae; and the orders Auriculariales, Cantharellales, Corticiales, Gloeophyllales, Hymenochaetales, Polyporales, Russulales, Sebaciniales, Thelophorales, and Treshisporales clustered under Agaricomycetes incertae sedis (Wijayawardene et al. 2020; Mycobank 2023).

Contributing vitally towards the ecological services, these fungi are known for their wood degrading nature and bioremediation of soil, thus nurturing forest ecosystem through mineral recycling (Pointing 2001). Among the wood rotting fungi, the white rot fungi decay lignin and are considered as good soil litter fungi (Yurchenko 2006).

Kullu district of Himachal Pradesh is bestowed with the forests of deodar, towering above the trees of pine and sprawling orchards. The valley of Kullu is sandwiched between the Pir Panjal, lower Himalaya, and the Great Himalayan ranges. The different localities situated in Banjar subdivision of the study area were surveyed during the rainy season of years 2015–2017 for the collection of corticioid fungi specimens. These specimens were studied for their macro- and micro-morphological features and were identified as *Aphanobasidium pseudotsugae* (Burt) Boidin & Gilles (Agaricales, Radulomycetaceae), *Cyrtidiella albida* (Berk. & M.A.Curtis) Zmitr. (Polyporales, Meruliaceae), *C. nitidula* (P.Karst.) Ryvarden (Polyporales, Meruliaceae), and *Phlebia viridesalebrosus* J.Erikss. & Hjortstam

(Polyporales, Meruliaceae). These four species of the corticioid fungi are new additions to the Indian mycobiota.

MATERIAL AND METHODS

The fungal material was carefully removed from the substrate (surface of logs, stumps, branches, and twigs) with the help of a chisel and hammer or a sharp knife. The features like the nature of the basidiocarp, colour, and type of hymenial surface, and colour and type of margins were noted down carefully in the field. The data with reference to the name of the substrate, locality, type of forest, and date of the collection were also recorded. The fresh specimens were then photographed to compare the change upon drying, if any. Details of various microscopic features such as hyphal system, cystidia, basidia, and basidiospores and their reactions in reagents such as Melzer's reagent, cotton blue, and sulphovanillin were also checked and noted by making crush mounts from the fresh specimens.

The microscopic studies were made by preparing crush mounts and free hand section cut sections in 3%/5%/10% KOH solution, 1% Congo red in distilled water and 1% Phloxine in distilled water. These preparations were used to study the details of hyphae, cystidia, basidia, and basidiospores at different magnifications of a light microscope. The cyanophilous and amyloid reactions were checked in 1% cotton blue in lactophenol, and Melzer's reagent (0.5 g iodine, 1.5 g potassium iodide, 20 g chloral hydrate, and 20 ml distilled water). The outline of microscopic structures was drawn using the camera lucida at the magnifications mentioned above. The standard features were subjected to the taxonomic keys published in the monographs and other publications (Eriksson et al. 1981; Dhingra 2005; Bernicchia & Gorjón 2010; Chen et al. 2021) for identifying the collected specimens.

All the identified specimens were deposited at the herbarium of the Department of Botany, Punjabi University, Patiala which is internationally recognized with the standard abbreviation PUN. The colour standards used were as per Methuen's Handbook of Colours by Kornerup & Wanscher (1978).

RESULTS

Aphanobasidium pseudotsugae (Burt) Boidin & Gilles Cryptogamic Botany 1(1): 75 (1989).

- *Corticium pseudotsugae* Burt, Annals of the Missouri Botanical Garden 13(3): 246 (1926). (Image 1).

Description: Basidiocarp resupinate, adnate, effused, somewhat ceraceous, up to 120 μm thick in section; hymenial surface smooth to slightly tuberculate; orange white (6A2) when fresh, darkened on drying; margins concolourous to indeterminate.

Hyphal system monomitic; generative hyphae up to 4 μm wide, septate, clamped, ampullate, branched, thin- to thick-walled; horizontal, loosely arranged, less branched, thick-walled in subicular zone; vertical, compact, richly branched, thin-walled in the subhymenial zone. Cystidia absent. Basidia cylindrical, plural, 19.5–33.5 \times 5.5–8 μm , tetrasterigmate, basally clamped; sterigmata up to 5.2 μm long. Basidiospores subfusiform to subamygdaliform, 8–9.5 \times 3.5–4.5 μm , smooth, thin-walled, inamyloid, acyanophilous.

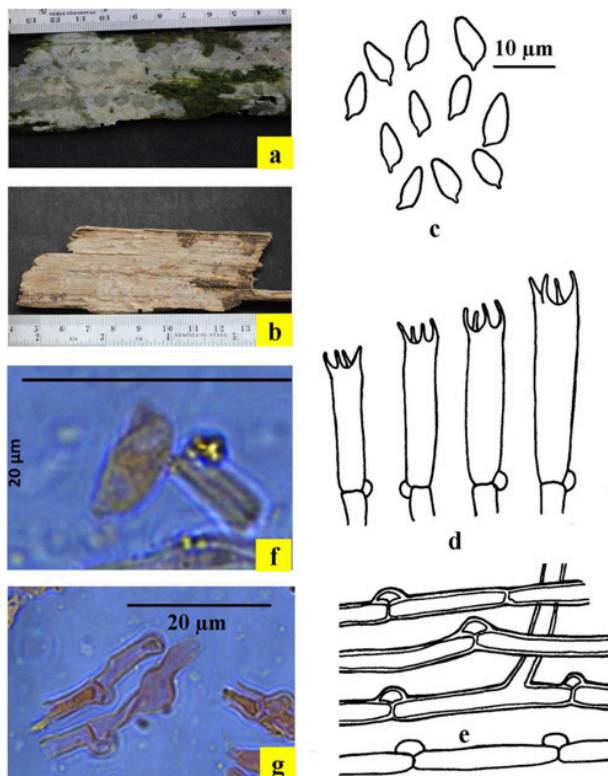


Image 1. *Aphanobasidium pseudotsugae*: a—Basidiocarp showing hymenial surface (fresh) | b— Basidiocarp showing hymenial surface (dry) | c–e— Line diagrams showing the outline of basidiospores (c), basidia (d) and generative hyphae (e) | f–g— Photomicrographs showing basidiospore (f) and generative hyphae (g). © a—Ellu Ram, b–g—Tanya Joshi.

Collection examined: India, Himachal Pradesh, Kullu, Banjar, 1 Km from Jalori Pass towards Shoja, on the log of *Abies spectabilis*, Ellu 11372 (PUN), 3 September 2016.

Remarks: *Aphanobasidium pseudotsugae* is marked by ceraceous basidiocarps, clamped, ampullate generative hyphae and distinctive subfusiform to subamygdaliform basidiospores. The only other species of genus *Aphanobasidium*, i.e., *A. subnitens*, differs in having basidia with bifurcated base and obovate to broadly oblong-ellipsoidal basidiospores (Mycobank 2023). It is a new report to India and has been earlier recorded from Germany, Estonia, Czech Republic, Belarus, Belgium, United Kingdom, Sweden, Denmark, Norway, Switzerland, Finland, Italy, Spain and Netherlands by Bernicchia and Gorjón (2010) and Mycobank (2023).

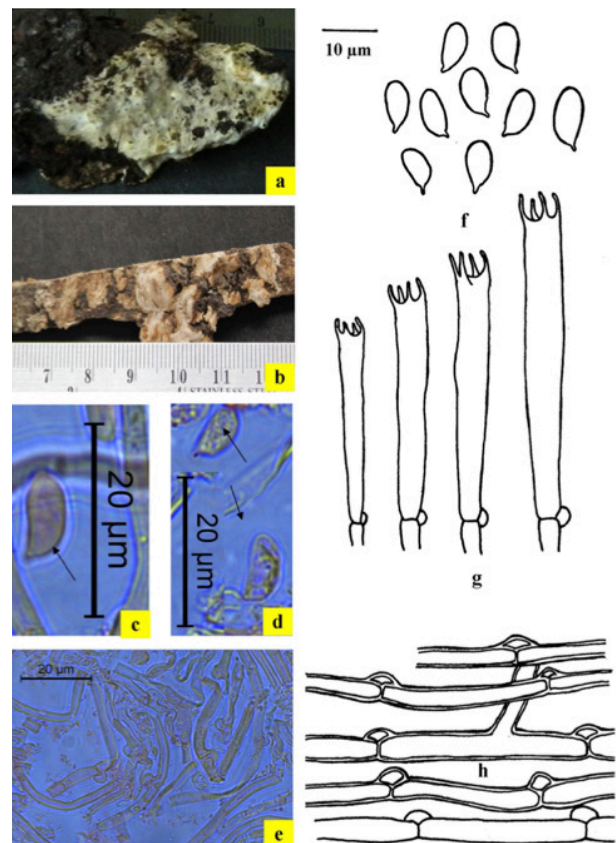


Image 2. *Cytidiella albida*: a—Basidiocarp showing hymenial surface (fresh) | b— Basidiocarp showing hymenial surface (dry) | c–e— Photomicrographs showing basidiospores (c–d) and generative hyphae (e) | f–h— Line diagrams showing the outline of basidiospores (f), basidia (g), and generative hyphae (h). © a—Avneet Pal Singh | b–h—Tanya Joshi.

Table 1. Diversity of the genus *Phlebia* in India.

	Current name of the taxon	Earlier described as	Localities	Records
1.	<i>Phlebia brevbasisidia</i>	<i>P. brevbasisidia</i>	Punjab	Kaur 2017
2.	<i>P. centrifuga</i>	<i>P. centrifuga</i>	Uttarakhand	Sharma 2012; Sanyal 2014; Manoharachary et al. 2022
			Himachal Pradesh	Ritu 2019
3.	<i>P. coccineofulva</i>	<i>P. coccineofulva</i>	Himachal Pradesh	Kaur 2018
4.	<i>P. crassisubiculata</i>	<i>P. crassisubiculata</i>	Himachal Pradesh	Dhingra et al. 2014
5.	<i>P. cremeoalutacea</i>	<i>P. cremeoalutacea</i>	Himachal Pradesh	Singh 2007; Priyanka 2012; Kaur 2018
			Jammu & Kashmir	Sharma 2017
6.	<i>P. cretacea</i>	<i>P. cretacea</i>	Uttarakhand	Sharma 2012
7.	<i>P. deflectens</i>	<i>Phanerochaete deflectens</i>	Himachal Pradesh	Dhingra et al. 2014; Kaur 2018; Kaur 2020
8.	<i>P. griseolivens</i>	<i>P. griseolivens</i>	Tamil Nadu	Natarajan & Kolandavelu 1998
9.	<i>P. himalaica</i>	<i>P. himalaica</i>	Himachal Pradesh	Thind & Rattan 1973
			Uttarakhand	Sharma 2012
10.	<i>P. kamengii</i>	<i>P. kamengii</i>	Eastern Himalaya	Dhingra 2005; Dhingra et al. 2011
			Himachal Pradesh	Poonam 2020
11.	<i>P. lilascens</i>	<i>P. lilascens</i>	Uttarakhand	Sanyal 2014
			Himachal Pradesh	Kaur 2018; Poonam 2020
12.	<i>P. livida</i>	<i>P. livida</i>	Himachal Pradesh	Thind & Rattan 1973; Rattan 1977; Dhingra et al. 2014; Ritu 2019; Poonam 2020; Manoharachary et al. 2022
			Eastern Himalaya	Dhingra 2005; Dhingra et al. 2011
			Uttarakhand	Sharma 2012; Sanyal 2014; Manoharachary et al. 2022
			Jammu & Kashmir	Sharma 2017
13.	<i>P. microspora</i>	<i>P. microspora</i>	Eastern Himalaya	Dhingra 2005; Dhingra et al. 2011
			West Bengal	Manoharachary et al. 2022
14.	<i>P. ochraceofulva</i>	<i>Mycoacia subochraceae</i>	Himachal Pradesh	Rattan 1977
		<i>P. subochracea</i>	Uttarakhand	Sharma 2012
			Himachal Pradesh	Sharma 2012
		<i>P. ochraceofulva</i>	Himachal Pradesh	Dhingra et al. 2014; Ritu 2019; Poonam 2020; Manoharachary et al. 2022
15.	<i>P. queletii</i>	<i>Metulodontia queletii</i>	Himachal Pradesh	Rattan 1977; Dhingra et al. 2006; Ritu 2019
		<i>P. queletii</i>	Himachal Pradesh	Dhingra et al. 2006; Dhingra et al. 2014; Lal Ji 2003; Kaur 2018; Poonam 2020; Kaur 2020; Manoharachary et al. 2022
			Uttarakhand	Sharma 2012; Sanyal 2014; Manoharachary et al. 2022
16.	<i>P. radiata</i>	<i>P. radiata</i>	Himachal Pradesh	Rattan 1977; Dhingra et al. 2014; Kaur 2018; Ritu 2019; Manoharachary et al. 2022
			Eastern Himalaya	Dhingra 2005; Dhingra et al. 2011
			Uttarakhand	Sharma 2012; Sanyal 2014; Manoharachary et al. 2022
17.	<i>P. rufa</i>	<i>P. rufa</i>	Eastern Himalaya	Dhingra 1983; Manoharachary et al. 2022
			Tamil Nadu	Natarajan & Kolandavelu 1998
			Himachal Pradesh	Manoharachary et al. 2022
18.	<i>P. segregata</i>	<i>P. segregata</i>	Himachal Pradesh	Dhingra et al. 2014; Kaur 2018; Poonam 2020; Manoharachary et al. 2022
			Uttarakhand	Sanyal 2014
19.	<i>P. serialis</i>	<i>P. serialis</i>	Himachal Pradesh	Sharma 2012; Manoharachary et al. 2022
			Uttarakhand	Manoharachary et al. 2022

	Current name of the taxon	Earlier described as	Localities	Records
20.	<i>P. singularisa</i>	<i>P. singularisa</i>	Himachal Pradesh	Dhingra et al. 2014; Poonam 2020; Manoharachary et al. 2022
21.	<i>P. subalata</i>	<i>P. subalata</i>	Himachal Pradesh	Sharma 2012
			Uttarakhand	Sharma 2012
22.	<i>P. subceracea</i>	<i>P. subceracea</i>	Maharashtra	Ranadive et al. 2011; Manoharachary et al. 2022
23.	<i>P. subcretacea</i>	<i>P. subcretacea</i>	Himachal Pradesh	Rattan 1977; Sharma 2012; Dhingra et al. 2014; Manoharachary et al. 2022
			Tamil Nadu	Natarajan & Kolandavelu 1998
			Jammu & Kashmir	Sharma 2017
24.	<i>P. subserialis</i>	<i>P. subserialis</i>	Himachal Pradesh	Rattan 1977; Dhingra et al. 2014; Kaur 2018; Manoharachary et al. 2022
			Uttarakhand	Sharma 2012; Sanyal 2014; Manoharachary et al. 2022
			Jammu & Kashmir	Sharma 2017
25.	<i>P. thindii</i>	<i>P. thindii</i>	Eastern Himalaya	Dhingra 2005; Dhingra et al. 2011
			West Bengal	Manoharachary et al. 2022
26.	<i>P. unica</i>	<i>P. unica</i>	Himachal Pradesh	Dhingra et al. 2014; Ritu 2019; Manoharachary et al. 2022
			Uttarakhand	Sanyal 2014; Manoharachary et al. 2022

Cyrtidiella albida (H.Post) C.C.Chen & Sheng H.Wu Fungal Diversity 111: 400 (2021).

- *Phlebia albida* H. Post, Monographia Hymenomycetum Sueciae 2: 280 (1863). (Image 2)

Description: Basidiocarp resupinate, adnate, effused, up to 500 µm thick in section; hymenial surface smooth to tuberculate to somewhat strigose; yellowish white (4A2) when fresh, pale orange (5A3) to orange white (6A2) on drying; margins concolourous, finally fimbriate.

Hyphal system monomitic, generative hyphae up to 5.3 µm wide, septate, clamped, richly branched, thin-to thick-walled; loosely arranged, thick-walled, parallel to the substrate in the basal zone; compactly arranged, thin-walled, vertically arranged in the subhymenial zone. Cystidia absent. Basidia clavate, 36.5–58 × 5.2–8 µm, tetrasterigmate, with basal clamp; sterigmata up to 4.8 µm long. Basidiospores ellipsoid, 8–11.5 × 4–5 µm thin-walled, smooth, inamyloid, acyanophilous.

Collection examined: India, Himachal Pradesh, Kullu, Banjar, Paldi, on stump of *Cedrus deodara*, Ellu 11380 (PUN), 16 August 2017.

Remarks: *Cyrtidiella albida* is distinctive in having smooth to tuberculate to somewhat strigose hymenial surface, clamped generative hyphae, comparatively larger basidia and ellipsoid basidiospores. It was earlier described under the genus *Phlebia* from various parts of Europe and America (Eriksson et al. 1981; Nakasone 1996). However, Chen et al. (2021) shifted it to the genus

Cyrtidiella based on morphological and DNA sequence based molecular studies and recorded its distribution from Europe, North Africa, and temperate regions of Asia. It is a new addition to the corticioid fungi from India.

Cyrtidiella nitidula (P.Karst.) Zmitr. Folia Cryptogamica Petropolitana 6: 97 (2018).

- *Corticium nitidulum* P. Karst., Meddelanden af Societas pro Fauna et Flora Fennica 6: 11 (1881) (Image 3).

Description: Basidiocarp resupinate, adnate, effused, ceraceous to membranous, up to 280 µm thick in section; hymenial surface smooth to slightly tuberculate; orange white (6A2) when fresh, white (6A1) to light orange (6A5) upon drying; margins thinning, concolourous, fibrillose.

Hyphal system monomitic, generative hyphae up to 4.5 µm wide, septate, clamped, thin-walled; horizontal, loosely interwoven in the subiculum; dense and vertically arranged in the subhymenium. Cystidia absent. Basidia clavate, 24.5–32 × 5.5–7 µm, tetrasterigmate, basally clamped; sterigmata up to 4.6 µm long. Basidiospores subcylindrical, 7.4–9.5 × 3–4 µm, smooth, thin-walled, inamyloid, acyanophilous.

Collection examined: India, Himachal Pradesh, Kullu, Banjar, Manglore village, on angiospermous twig, Ellu 11381 (PUN), 28 August 2017.

Remarks: *Cyrtidiella nitidula* is distinguished from *C. albida* and *P. viridialebrosus* in having subcylindrical

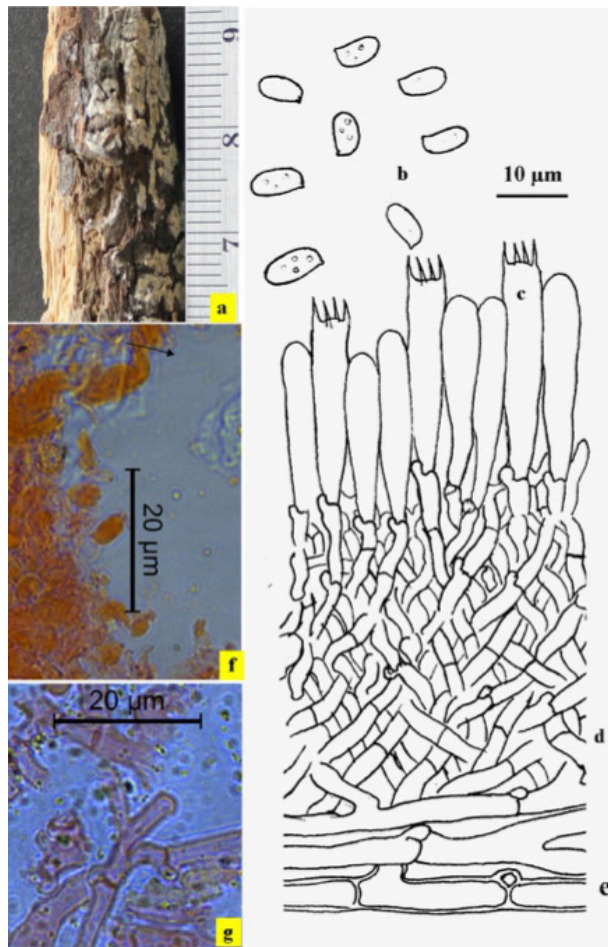


Image 3. *Cytdiella nitidula*: a—Basidiocarp showing hyemial surface | b–d—Section showing outline of basidiospores (b), basidia (c) Subhymenial generative hyphae (d), basal generative hyphae (e) | f–g— Photomicrographs showing basidiospores (f) and generative hyphae (g). © a—Ellu Ram, b–g—Tanya Joshi.

basidiospores. Previously, it was described as *Phlebia nitidula* but Zmitrovich (2018) proposed it as *Cytdiella nitidula* comb. nov. It is a new report to India. Earlier, the species has been listed from Germany, Croatia, Belgium, Russia, Finland, Iceland, Norway, Italy, Spain, Estonia and North America by Eriksson et al. (1981), Bernicchia & Gorjón (2010), and Mycobank (2023).

Phlebia viridesalebrosus J.Erikss. & Hjortstam

The *Corticiaceae* of North Europe 6: 1127 (1981). (Image 4).

Description: Basidiocarp resupinate, adnate, effused-reflexed, ceraceous when fresh, turns corneous upon drying, up to 265 μm thick in section; hymenial surface smooth to tuberculate; reddish grey (8B2) to greyish-red (8B5) when fresh, darkened on drying; margins somewhat thick, paler concolourous.

Hypal system monomitic, generative hyphae up to 4.5 μm wide, simple-septate, thick-walled; somewhat parallel to the substrate, loosely packed in the subicular zone; vertical and compactly arranged in the subhymenium. Cystidia absent. Basidia clavate, 30–37.5 \times 4.5–7 μm , tetrasterigmate, without basal clamp; sterigmata up to 4.6 μm long. Basidiospores ellipsoid, 5.5–7.5 \times 3–3.7 μm , thin-walled, smooth, inamyloid, acyanophilous.

Collection examined: India, Himachal Pradesh, Kullu, Sainj, Dhaugi, on the angiospermous log, Ellu 11378 (PUN), 4 August 2015.

Remarks: This species is different from *C. albida* in having corneus basidiocarp and simple-septate generative hyphae. The species contributes a new record from India. The earlier available account is from France, Austria, and Italy (Bernicchia & Gorjón 2010; Mycobank 2023).

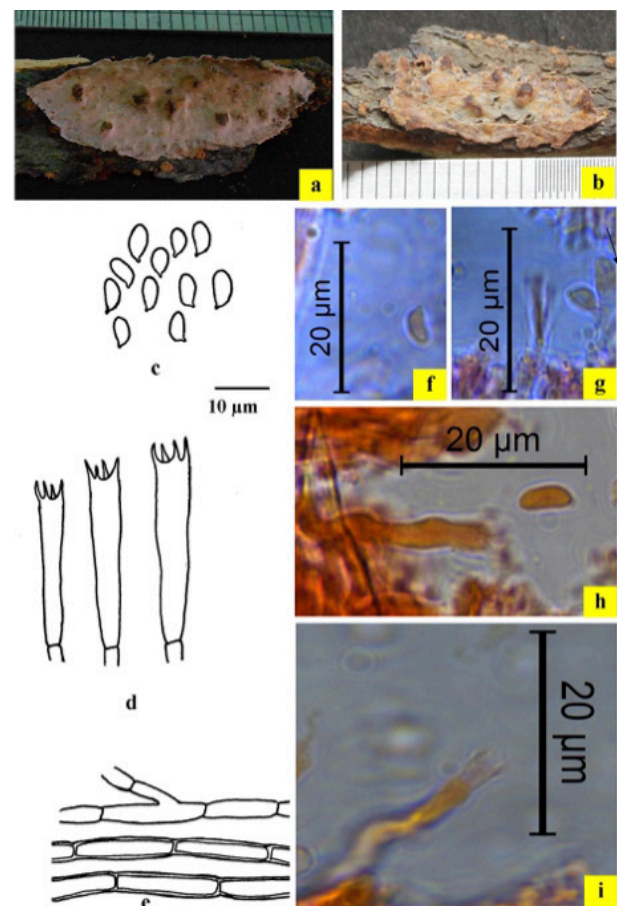


Image 4. *Phlebia viridesalebrosus*: a—Basidiocarp showing hyemial surface (fresh) | b. Basidiocarp showing hyemial surface (dry) | c–e. Line diagrams showing the outline of basidiospores (c), basidia (d) and generative hyphae (e) | f–i. Photomicrographs showing basidiospores (f–h) and basidium (i). © a—Ellu Ram, b—Avneet Pal Singh, c–i—Tanya Joshi.

DISCUSSION

The present compilation presents an account of four corticioid species belonging to three genera. Among these, the genus *Aphanobasidium* has been earlier described on the basis of a single species, i.e., *A. subnitens* from Shimla district of Himachal Pradesh (Prasher & Ashok 2013). Presently, *A. pseudotsugae* is being described as new to India as it is earlier known only from different parts of Europe (Bernicchia & Gorjón 2010; Mycobank 2023).

The genus *Cyrtidiella* is being recorded for the first time from India based on *C. albida* and *C. nitidula* that have been described presently. Earlier, *C. albida* has been reported from Europe, northern Africa, and temperate regions of Asia (Chen et al. 2021) to India whereas that of *C. nitidula* has been extended from northern Scandinavia and other parts of Europe to India. The genus *Phlebia* has been worked out from different parts of India on the basis of 26 species (Table 1). Of these, 21 species have been described from northwestern India (Himachal Pradesh, Jammu & Kashmir, Punjab, and Uttarakhand), seven species from southern India (Maharashtra and Tamil Nadu), and six species from eastern Himalaya. The present studies have also added *Phlebia viridesebrosum*, earlier known from France, Austria, and Italy (Mycobank 2023), as new to India.

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