

A new species of *Parasola* section *Conopileae* (Psathyrellaceae) from Pakistan

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Abstract: The genus *Parasola* is sparsely documented in Pakistan with almost all of its reports from lowlands or northern areas of the country. In this study, we describe a new species, *Parasola cinnamomescens*, from the Thal Desert, a subtropical region located in Punjab Province, Pakistan. Evidence from morphology and DNA sequence data encompassing the internal transcribed spacer (ITS1-5.8S-ITS2 = ITS) and D1/D2 domain of the large subunit of nuclear ribosomal DNA (28S) reveals that this species is divergent from all previously known species and confirms its placement in *Parasola* sect. *Conopileae*. It is recognized by convex to hemispherical or broadly conical dull orange or yellow to light gray pileus; light reddish gray lamellae; light reddish gray or shiny white stipe; basidiospores ellipsoid to broadly ellipsoid in side view, ovoid to broadly ellipsoid in frontal view; golden to dark brown sclerocystidia; and polymorphic cheilo-, pleuro-, pileo-, and caulocystidia. This discovery demonstrates the diversity of *Parasola* species in the Thal Desert of Punjab, Pakistan, and underlines the need for thorough attention to the fungal flora of this region.

Key words: Cystidia, Khushab, macrofungi, phylogenetic analyses, taxonomy, Thal Desert

1. Introduction

Parasola Redhead, Vilgalys & Hoppole is a small-sized mushroom genus in the family Psathyrellaceae Vilgalys, Moncalvo & Redhead, with *Parasola plicatilis* (Curtis) Redhead, Vilgalys & Hoppole as the type species (Redhead et al., 2001). The genus is widely distributed throughout Europe, North America, Africa, and the Lesser Antilles; however, it is particularly diverse in Asia and Australia (Pegler, 1966, 1983, 1986; Dennis, 1970; Orton and Watling, 1979; Ahmad, 1980; Hongo, 1987; Uljé and Bas, 1988, 1997; Grgurinovic, 1997; Nagy et al., 2009; Schafer, 2014; Hussain et al., 2016, 2017, 2018; Ganga and Manimohan, 2018, 2019; Schafer et al., 2022). The species grow saprobically on leaf litter, bare soil, herbivore dung, and woody debris in grasslands, shrubs, and forests (Schafer, 2014; Hussain et al., 2017; Szarkándi et al., 2017; Ganga and Manimohan, 2018, 2019). The taxa are recognized by short-lived basidiocarps, deeply plicate pileus (except *Parasola conopileae* (Fr.) Örstadius & E. Larss.), and absence of a veil (Orton and Watling, 1979; Uljé and Bas, 1988; Nagy et al., 2009; Schafer, 2010; Hussain et al., 2017; Ganga and Manimohan, 2018).

Recently, the taxa within the genus *Parasola* were divided into the two sections of *Parasola* and *Conopileae* Wächter & A. Melzer (Wächter and Melzer, 2020). According to Index Fungorum, about 50 species of the genus *Parasola* are known worldwide as of this time.¹ Only seven species

have previously been described from Pakistan: *Parasola auricoma* (Pat.) Redhead, Vilgalys & Hoppole; *P. glabra* S. Hussain, Afshan, H. Ahmad & Khalid; *P. lilatinctoides* P. Voto; *P. malakandensis* S. Hussain, N. Afshan & H. Ahmad; *P. plicatilis* (Curtis) Redhead, Vilgalys & Hoppole; *P. pseudolactea* Sadiqullah, S. Hussain & Khalid; and *P. setulosa* (Berk. & Broome) Redhead, Vilgalys & Hoppole (Ahmad, 1980; Hussain et al., 2016, 2017, 2018). Section *Conopileae* comprises only two species: *Parasola conopileae* (Fr.) Örstadius & E. Larss. and *Parasola psathyrelloides* K.G.G. Ganga & Manim. The former is the type species of the section (Wächter and Melzer, 2020).

In this study, we identify and describe a new species, *Parasola cinnamomescens*, belonging to section *Conopileae*. With the discovery of this new taxon, the number of species of the genus *Parasola* described from Pakistan is increased to eight. Additionally, this is the first species of sect. *Conopileae* to be identified from Pakistan. The distribution of the genus *Parasola* has been expanded to plains and subtropical areas of Pakistan.

2. Materials and methods

2.1. Description of sampling site

Peelowains is a well-known village in Tehsil Noorpur Thal, District Khushab. It is part of the Thal Desert, a

¹Index Fungorum (2023). Index Fungorum [online]. Website www.indexfungorum.org [accessed 25 March 2023].

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subtropical sandy desert in Punjab, Pakistan. Noorpur Thal is located at 31°53'18"N, 71°53'58"E at an altitude of 185 m above sea level with average annual rainfall between 185 and 300 mm. The winter season is very cold with average temperature ranging between 3 and 8 °C, while the summer season is very hot with an average temperature of 32 to 40 °C. The major tree flora of the locality includes *Dalbergia sissoo* Roxb., *Eucalyptus camaldulensis* Dehnh., *Tamarix aphylla* (L.) Karst., and *Ziziphus nummularia* (Burm.f.) Wight & Arn., among others. *Cicer arietinum* L., *Cyamopsis tetragonoloba* (L.) Taub., and *Triticum aestivum* L. are the major cultivated crops of this region (Shaheen et al., 2017; Yousaf, 2018; Khan et al., 2023).

Kanhatti Garden is located in Soon Valley Tehsil Naushehra, District Khushab. Soon Valley, with its natural charms and ancient mysteries, is situated in the Salt Range at 32°33'2.52"N, 71°55'0.95"E. The valley possesses a dry climate with chilly winters (lowest temperature of 1 °C) and hot summers (highest temperature of 36 °C) with annual rainfall of 510 mm. Soon Valley is rich in valuable medicinal flora including *Ajuga bracteosa* Wall. ex Benth., *Buxus papillosa* C.K. Schneid., *Nannorrhops ritchiana* (Griff.) Aitch., *Rhazya stricta* Decne., *Silybum marianum* (L.) Gaertn., and *Verbascum thapsus* L. (Shah and Rahim, 2017).

2.2. Sampling method and morphological investigation

Specimens were collected during the rainy season in the months of July and August 2022. All specimens were photographed in the field. The colors of basidiomata were determined using the Munsell color chart (Munsell, 1994). Specimens were dried in front of an electric fan heater at 50 °C. The dried specimens were then subjected to determination of micromorphological characters using a trinocular Olympus CH30 microscope in the Fungal Biology and Systematics Research Laboratory of the Institute of Botany, University of the Punjab, Lahore. The size and shape of basidiospores, basidia, cystidia, pileipellis, and stipitipellis and the presence or absence of clamp connections were investigated in hand-cut sections mounted in 5% KOH and stained with Congo Red. Color reactions were observed using Melzer's reagent. The shape of microscopic structures was determined following Vellinga (2001). About 50 measurements were taken for each microscopic character using ScopeImage 9.0 software. The values of measurements were less strictly rounded off. Abbreviations [n/m/p] represent the number of basidiospores (n) measured from basidiomata (m) of the collection (p). The specimens were finally deposited in the Lahore Herbarium (LAH), Institute of Botany, University of the Punjab, Lahore, Pakistan.

2.3. DNA extraction, PCR, and sequencing

Some pieces of gills were taken from dried specimens and ground with a plastic micropestle (Chongqing New World Trading Company, Chongqing, China). DNA was

extracted with CTAB using the protocol of Bruns (1995). The primer combinations were ITS1F/ITS4 and LR0R/LR5 for the amplification of the internal transcribed spacer (ITS1-5.8S-ITS2 = ITS) and a fragment of the large subunit (28S) of nuclear ribosomal DNA, respectively (White et al., 1990; Gardes and Bruns, 1993). For PCR amplification, the protocols of Gardes and Bruns (1993) were followed. The PCR procedure for the ITS region entailed initial denaturation at 94 °C for 4 min, and then 40 cycles of 94 °C for 1 min, 55 °C for 1 min, and 72 °C for 1 min with final extension at 72 °C for 10 min. For the 28S region, PCR reactions were performed with initial denaturation at 94 °C for 2 min, and then 35 cycles at 94 °C for 1 min, 52 °C for 1 min, and 72 °C for 1 min with final extension at 72 °C for 7 min. The sequencing of both regions was done commercially by TsingKe (Qingdao, China) using the same pair of primers. The obtained sequences were deposited in the NCBI GenBank.

2.4. Molecular phylogenetic investigation

Consensus sequences were generated from the forward and reverse regions of both the ITS and 28S regions using BioEdit v. 7.0.9.0 (Hall, 1999). The consensus sequences were run in the BLAST search tool of the NCBI GenBank to check sequence similarity. Sequences from GenBank were retrieved that were recently published for the phylogeny of *Parasola* (Nagy et al., 2009; Hussain et al., 2016, 2017, 2018; Szarkándi et al., 2017; Ganga and Manimohan, 2019; Malysheva et al., 2019; Wächter and Melzer, 2020; Schafer et al., 2022). *Coprinopsis pseudonivea* was chosen as the outgroup taxon (Nagy et al., 2011). Both the ITS and combined ITS-28S datasets were aligned using MUSCLE v. 3.7. (Edgar, 2004). The maximum likelihood (ML) method was used to check the phylogenetic relationships among the sequences. ML analyses were performed using RAXML-HPC2 v. 8.1.11 on the CIPRES portal v. 3.1 (www.phylo.org; Miller et al., 2010). The final phylogram was visualized in FigTree v. 1.4.3 and manually edited with Adobe Illustrator software CC v. 26.0.

3. Results

3.1. Phylogenetic analysis

The final ITS dataset with 64 sequences consisted of a total of 676 characters. The dataset included 48 specimens representing 24 species of *Parasola* sect. *Parasola* and 15 specimens representing three species of sect. *Conopileae* while *Coprinopsis pseudonivea* (FM163181) was the outgroup taxon (Nagy et al., 2011) (Table 1). In the ITS phylogeny (Figure 1), both sections were well resolved with good statistical support. Section *Conopileae* consisted of two subclades, one subclade comprising sequences of *Parasola conopilea* and the other subclade formed by new species *Parasola cinnamomescens* and *Parasola psathyrelloides* K.G.G. Ganga & Manim.

The combined ITS-28S dataset consisted of 1630 characters. There were 68 specimens of *Parasola* sect. *Parasola* and 16 of *P.* sect. *Conopileae*, with *Coprinopsis pseudonivea* (FM160728) as the outgroup taxon (Nagy et al., 2011) (Table 1). In the combined ITS-28S phylogeny (Figure 2), both sections of *Parasola* were well resolved. Our new species was located in the clade comprising specimens of the other two taxa of section *Conopileae*, namely *P. conopilea* and *P. psathyrelloides*. However, it was on a separate branch from its sister species, which provides evidence of its novelty.

3.2. Taxonomy

Parasola cinnamomescens Z. Khan, M.A. Arshad, Niazi & Khalid, **sp. nov.** (Figures 3, 4a, and 4b)

Mycobank No. 848288

Etymology: The specific epithet *cinnamomescens* (in Latin) refers to the cinnamon-like coloration of the pileus.

Diagnosis: The new species can be distinguished by its dull orange to yellowish pileus with shallow plicate surface,

pale yellowish lamellae, and broadly ellipsoid to ellipsoid or ovoid basidiospores with central germ pore.

Holotype: Pakistan, Punjab Province, District Khushab, Noorpur Thal, Peelowains, on forest soil with decaying twigs and leaf litter under *Dalbergia sisso* (32°1'22.31"N, 71°59'28.5"E, 191 meter a.s.l.), 29 July 2022, *Zaman Khan*, P-136 (Holotype LAH37773), GenBank accession ITS: OQ779055, 28S: OQ779058.

Description: Basidiomata small-sized. Pileus 5–16 mm diam., convex to hemispherical or broadly conical to obtusely conical, initially striated then tuberculate-punctate, with inflexed margins, dull orange (5YR 7/4) at the center and becoming yellow (7.5YR 8/4) to light gray (10YR 8/2) towards margins. Lamellae narrowly adnate, subdistant, ventricose, regular, reddish gray (2.5YR 7/2) or light reddish gray (5RP 7/1) or light brownish (5YR 7/1), lamellulae present in 2 tiers. Stipe 14–47 × 1.2–2 mm, central, equal, hollow, glabrous, smooth, light reddish gray

Table 1. List of species, their geographical origins, vouchers/strains/isolates, and GenBank accession numbers used for the phylogenetic evolutionary analyses. Sequences generated in the current study are shown in bold.

Taxon	Voucher/strain/isolate	GenBank Accession		Locality
		ITS	28S	
<i>Coprinopsis pseudonivea</i> (outgroup)	SZMC:NL:2340	FM163181	FM160728	Hungary
<i>Parasola</i> aff. <i>auricoma</i>	LAH-SH-P11	KX212107	-	Pakistan
<i>Parasola</i> aff. <i>auricoma</i>	LAH-SH-P6	KX212106	-	Pakistan
<i>Parasola</i> aff. <i>lilatincta</i>	SZMC:NL:0086	-	FM160705	Hungary
<i>Parasola</i> aff. <i>lilatincta</i>	SZMC:NL:0096	-	FM160704	Sweden
<i>Parasola aporos</i>	RC-F92.204	MK397585	MK397605	France
<i>Parasola aporos</i>	RC-F92.191, holotype	MK397584	MH196357	France
<i>Parasola aporos</i>	CL/F09.005	MH196355	MH196363	France
<i>Parasola aporos</i>	CL-F09.005	-	MK397606	France
<i>Parasola auricoma</i>	LAH-SHP-7	KY461721	KY461730	Pakistan
<i>Parasola auricoma</i>	SZMC:NL:0268	FM163186	FM160723	Hungary
<i>Parasola auricoma</i>	SZMC-NL-0087	JN943107	JQ045871	Hungary
<i>Parasola auricoma</i>	LAH-SHP-11	-	KY461728	Pakistan
<i>Parasola cinnamomescens</i>	LAH37774	OQ779056	OQ779059	Pakistan
<i>Parasola cinnamomescens</i>	LAH37775	OQ779057	OQ779060	Pakistan
<i>Parasola cinnamomescens</i> (Holotype)	LAH37773	OQ779055	OQ779058	Pakistan
<i>Parasola conopilea</i>	MushroomObserver.org/312390	MH125285	-	USA
<i>Parasola conopilea</i>	ZRL20151990	LT716064	KY418880	China
<i>Parasola conopilea</i>	CZ429	FJ755216	-	China
<i>Parasola conopilea</i>	CBS 325.39	FJ770396	MH867531	United Kingdom
<i>Parasola conopilea</i>	OSC50296	FJ899613	-	USA
<i>Parasola conopilea</i>	SZMC:NL:0465	FM163223	FM160686	Hungary
<i>Parasola conopilea</i>	SZMC:NL:0285	FM163225	FM160684	Hungary
<i>Parasola conopilea</i>	CBS 325.39	MH856033	-	Netherlands

Table 1. (Continued).

<i>Parasola conopilea</i>	LO186-02	DQ389725	-	Sweden
<i>Parasola conopilea</i>	TUB 011587	-	DQ071706	Germany
<i>Parasola crataegi</i>	G. Schmidt-Stohn SSt08-154	KY928605	-	Germany
<i>Parasola crataegi</i>	L. Nagy NL-4175	-	KY928631	Hungary
<i>Parasola galericuliformis</i>	SZMC:NL:6601	FM163187	FM160722	Hungary
<i>Parasola galericuliformis</i>	SZMC:NL:0095	FM163188	FM160721	Hungary
<i>Parasola glabra</i>	LAH-SHP-23	KY461718	KY621805	Pakistan
<i>Parasola glabra</i>	LAH-SHP-5	KY461717	KY621806	Pakistan
<i>Parasola hercules</i>	L:Ulje:1269	FM163190	FM160719	Netherlands
<i>Parasola hercules</i>	L146	HQ847027	HQ847112	Hungary
<i>Parasola hercules</i>	PERTH:8871574	-	MT537063	Australia
<i>Parasola hercules</i>	PERTH:8944229	-	MT537092	Australia
<i>Parasola kuehneri</i>	L:C.B. Ulje 31-V-1987	KY928608	KY928633	Netherlands
<i>Parasola kuehneri</i>	Ulje 1241	HQ847026	HQ847111	Hungary
<i>Parasola lactea</i>	L:C.B. Ulje 731	KY928614	-	Netherlands
<i>Parasola lactea</i>	L. Nagy NL-0678	KY928612	-	Hungary
<i>Parasola leiocephala</i>	KuP6.2.2.1	KP698198	-	Latvia
<i>Parasola leiocephala</i>	SZMC-NL-0283	-	JQ045887	Hungary
<i>Parasola leiocephala</i>	SZMC:NL:0466	-	FM160717	Hungary
<i>Parasola lilatincta</i>	SZMC:NL:0660	FM163195	FM160714	Hungary
<i>Parasola lilatincta</i>	SZMC:NL:0472	FM163199	FM160710	Hungary
<i>Parasola lilatincta</i>	L:Arnolds:6939	-	FM160707	Netherlands
<i>Parasola lilatincta</i>	Schafer:2382004	-	FM160708	England
<i>Parasola lilatinctoides</i>	LAH-SHP-8	KY461722	KY461725	Pakistan
<i>Parasola litoralis</i>	DJS20130125001	OL630107	-	Cyprus
<i>Parasola litoralis</i>	K(M):264814, ML81162CM	OL630108	-	Cyprus
<i>Parasola litoralis</i>	DJS20120213004	OL630106	-	Cyprus
<i>Parasola malakandensis</i>	LAH-SHP-17	KU599827	KU599830	Pakistan
<i>Parasola malakandensis</i>	LAH-SHP-13	KU599828	KU599829	Pakistan
<i>Parasola megasperma</i>	C:19683	FM163206	FM160703	Denmark
<i>Parasola megasperma</i>	E:Orton 4132	OL630101	-	England
<i>Parasola megasperma</i>	CH20041227001	OL630109	-	Cyprus
<i>Parasola megasperma</i>	AH:13089	-	FM160702	Spain
<i>Parasola megasperma</i>	SZMC:NL:1924	-	FM160701	Sweden
<i>Parasola misera</i>	L. Nagy NL-0462	KY928619	KY928638	Hungary
<i>Parasola misera</i>	SZMC:NL:0280	-	FM160699	Hungary
<i>Parasola misera</i>	SZMC:NL:0490	-	FM160700	Hungary
<i>Parasola nudiceps</i>	HB19870911A	MK063783	-	Germany
<i>Parasola nudiceps</i>	E:Orton 4133	OL630102	-	Scotland
<i>Parasola ochracea</i>	L.Nagy NL-3623	KY928626	KY928644	Sweden
<i>Parasola parvula</i>	CAL 1667	MH379796	MH393599	India
<i>Parasola hemerobia</i>	SZMC:NL:0284	FM163189	FM160720	Hungary

Table 1. (Continued).

<i>Parasola plicatilis</i>	SZMC:NL:0075	FM163214	FM160695	Hungary
<i>Parasola plicatilis</i>	SZMC:NL:0097	FM163215	FM160694	Hungary
<i>Parasola plicatilis</i>	HMJAU46405	-	OL376339	China
<i>Parasola plicatilis</i>	HMJAU46402	-	OL376340	China
<i>Parasola schroeterii</i>	SZMC:NL:0287	-	FM160691	Sweden
<i>Parasola plicatilis-similis</i>	L.Nagy NL-3980	KY928621	KY928639	Slovakia
<i>Parasola plicatilis-similis</i>	L. Nagy NL-2125	KY928620	-	Sweden
<i>Parasola psathyrelloides</i>	CAL 1753	MK682756	MK682754	India
<i>Parasola psathyrelloides</i>	AMH 10119	MK682752	-	India
<i>Parasola psathyrelloides</i>	AMH 10120	MK682758	MK682755	India
<i>Parasola pseudolactea</i>	HUP-SU-413	KY461720	KY621800	Pakistan
<i>Parasola pseudolactea</i>	HUP-SU-412	KY461719	KY621799	Pakistan
<i>Parasola schroeterii</i>	SZMC-NL-3167	-	JQ045865	Norway
<i>Parasola schroeterii</i>	SZMC-NL-3624	JN943135	JQ045874	Norway
<i>Parasola schroeterii</i>	L:Brier:1051999	FM163219	FM160690	Netherlands
<i>Parasola setulosa</i>	L32	HQ847030	HQ847115	Hungary
<i>Parasola setulosa</i>	SFC20150812-15	MF445222	-	South Korea
<i>Parasola setulosa</i>	MICH:232900	KR869775	-	USA
<i>Parasola setulosa</i>	HMJAU46367	-	OL376319	China
<i>Parasola schroeterii</i>	C:Klamer:061998	-	FM160692	Denmark

(5RP 7/1) or shiny white. Annulus and volva absent. Odor and taste not recorded.

Basidiospores [50/4/3] 9.5–13 × 6–8 µm, avl × avw = 11 × 7 µm, Q = 1.52–1.62 µm, Qav = 1.57; ellipsoid to broadly ellipsoid in side view, ovoid to broadly ellipsoid in frontal view, brown to dark brown or black, apiculate, thick-walled, with central germ pore. Basidia 29–43 × 10–14 µm, clavate, 2- to 4-spored, hyaline, sterigmata up to 4.6 µm long. Cheilocystidia 21–85 × 14–29 µm, polymorphic, mostly utriform to narrowly utriform, subglobose, spheropedunculate, obpyriform, pyriform; sometimes intraparietal pale yellow pigment present. Pleurocystidia 32–84 × 17–41 µm, spheropedunculate, oblong, narrowly lageniform, narrowly utriform to utriform, some flexuose. Sclerocystidia 140–395 × 2–6 µm, narrow, mainly bulbous at base and tapering towards apex, golden to dark brown in color, thick-walled. Pileipellis hymeniform. Pileocystidia 25–79 × 12–29 µm, clavate to spheropedunculate, utriform to lageniform, rostrate, few with a ventricose or lecythiform basal body, subcapitate apex (2–5 µm) with two capitula. Stipitipellis a cutis, hyphae 3–12 µm in diam., cylindrical or elongated and septate. Caulocystidia 32–60 × 12–17 µm, lageniform or clavate with mucronate apex, fusiform, fusoid-ventricose with irregular outline, sometimes intraparietal yellow pigment present. Clamp connections rarely observed.

Habit, habitat, and distribution: Fruiting bodies of the species growing in close groups on forest soil with decaying twigs and leaf litter under *Dalbergia sisso* or scattered on loamy soil or on humus. Currently, the new species is only known from District Khushab, Punjab, Pakistan.

Additional specimens examined: Pakistan, Punjab Province, District Khushab, Noorpur Thal, Peelowains, on loamy soil, (31°59'17.36"N, 71°59'25.86"E), 2 August 2022, *Zaman Khan & Junaid Khan*, PW-05 (LAH37774), GenBank accession no. ITS: OQ779056, 28S: OQ779059; Ibidem, 4 August 2022, *PW-04* (LAH37775), GenBank accession no. ITS: OQ779057, 28S: OQ779060; District Khushab, Naushehra, Soon Valley, Kanhatti Garden, on soil rich with humus, 32°40'38.68"N, 72°14'50.93"E, 13 July 2022, *M. Awais Arshad & Hamza Ahmad*, KB-13 (LAH37788), GenBank accession no. ITS: OQ780325.

4. Discussion

The genus *Parasola* was first proposed on the basis of the parasol-like appearance of its fruiting bodies when the genus *Coprinus* was subdivided and the foundation of the family Psathyrellaceae was laid down (Redhead et al., 2001). Extensive studies of the genus were conducted, which proved the monophyly of the genus, but the taxonomic positioning of the taxa remained unresolved (Moncalvo et al., 2002; Ujle, 2005; Walther et al., 2005; Padamsee

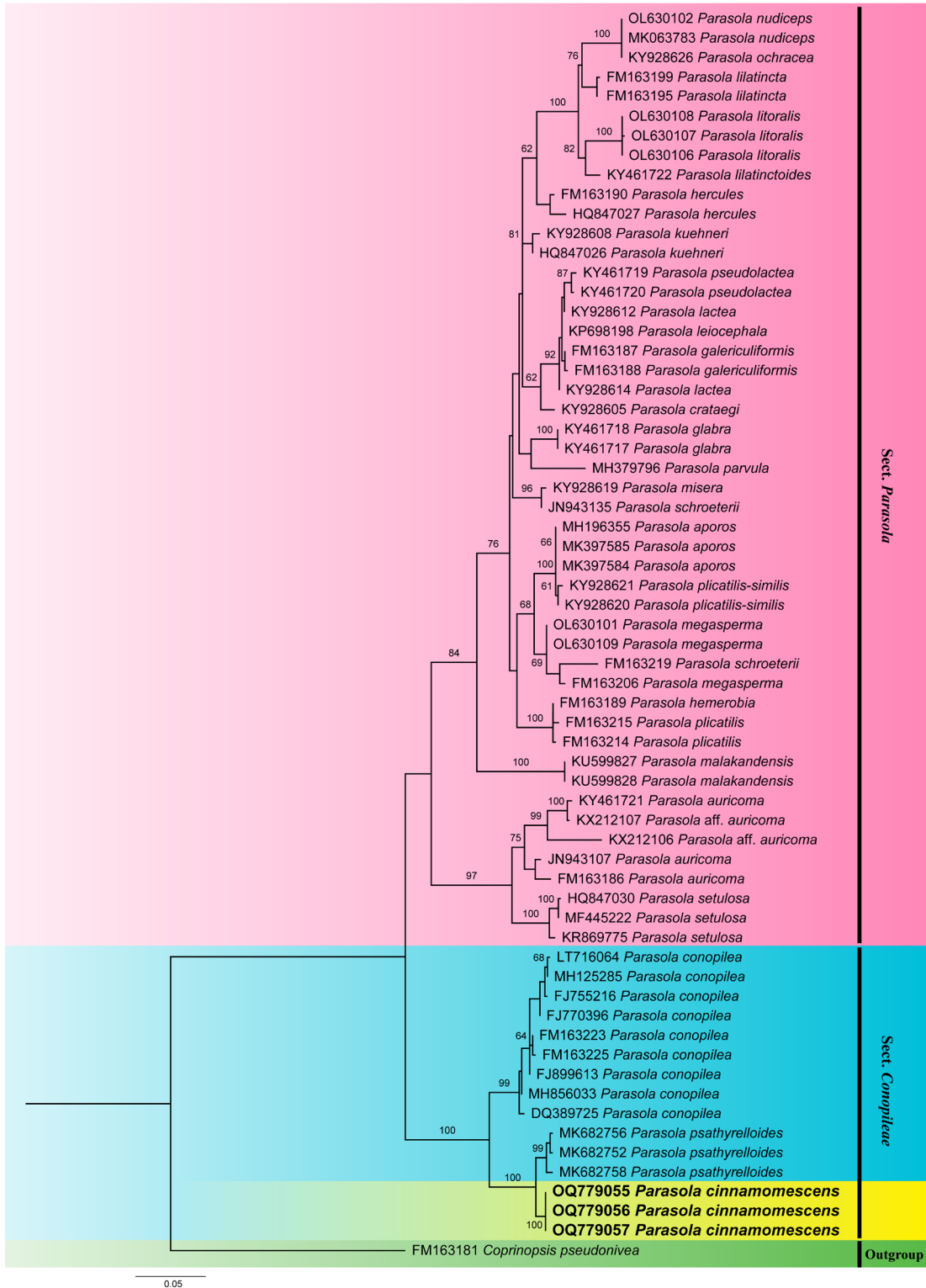


Figure 1. Maximum likelihood (ML) phylogram of *Parasola* based on 64 sequences of ITS region with *Coprinopsis pseudonivea* as the outgroup taxon. Species of the genus are considered in two sections, *P. sect. Parasola* and *P. sect. Conopileae*, and the values above the nodes represent the ML bootstrap percentage where 60% or above is considered significant. The yellow highlighted clade represents the new species.

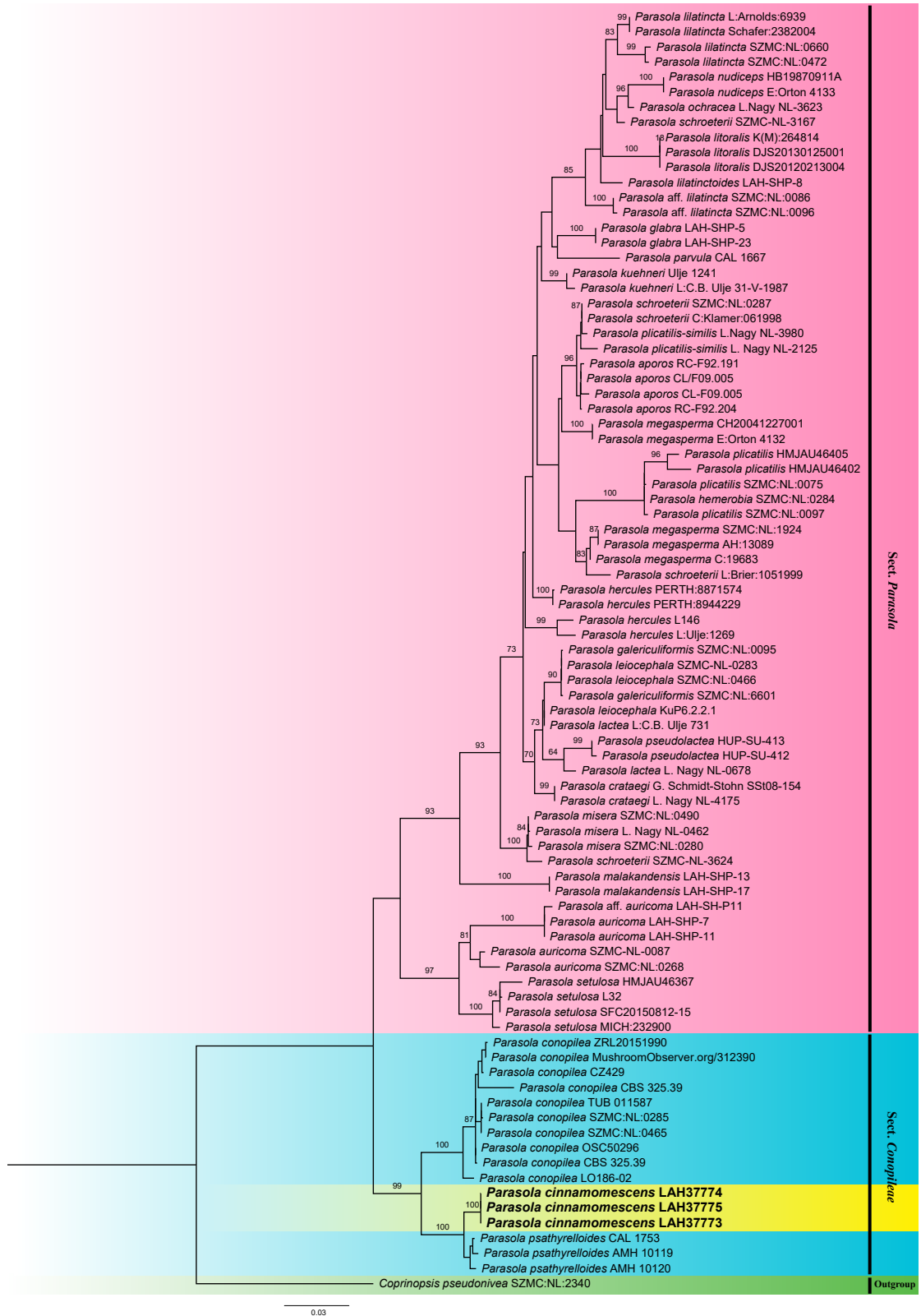


Figure 2. Maximum likelihood (ML) phylogram of *Parasola* drawn from the dataset of combined ITS-28S sequences belonging to genus *Parasola* and the outgroup taxon *Coprinopsis*. ML bootstrap support values above 60% are shown above the nodes. The newly amplified sequences of *P. cinnamomescens* are highlighted.

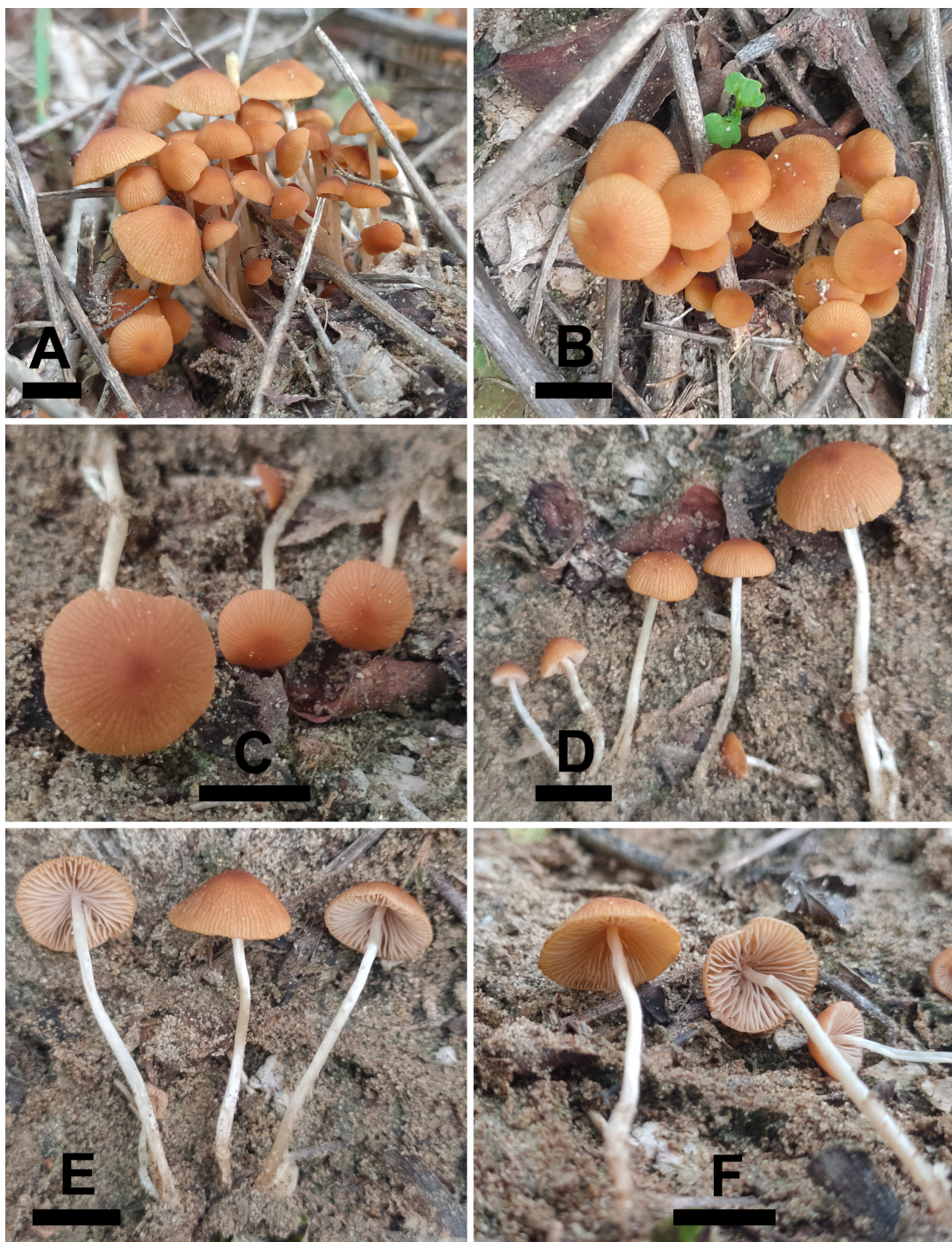


Figure 3. Basidiomata of *P. cinnamomescens*. Scale bars (A–F): 10 mm. Photographs by Zaman Khan.

et al., 2008; Vasutova et al., 2008; Nagy, 2009, 2010). Later *Psathyrella conopilea* was transferred to the genus *Parasola* as *Parasola conopilea* (Larsson and Örstadius, 2008). A key to the sections of *Parasola*, *Coprinellus*, *Coprinopsis*, and *Coprinus* was provided in which the subsections of *Coprinus* sensu, namely *Glabra* and *Auricomi*, were included as sections of *Parasola* (Schaffer et al., 2010). Many species

of *Parasola* were described based on morphological analysis and molecular techniques (Schaffer, 2014; Hussain et al., 2016, 2017, 2018; Ganga and Manimohan, 2018, 2019). Szarkándi et al. (2017) reconstructed the phylogeny of *Parasola* and identified some novel taxa. Recently, a new sectional division of the genus was proposed by Wachter and Melzer (2020). According to that study, *P. conopilea* does

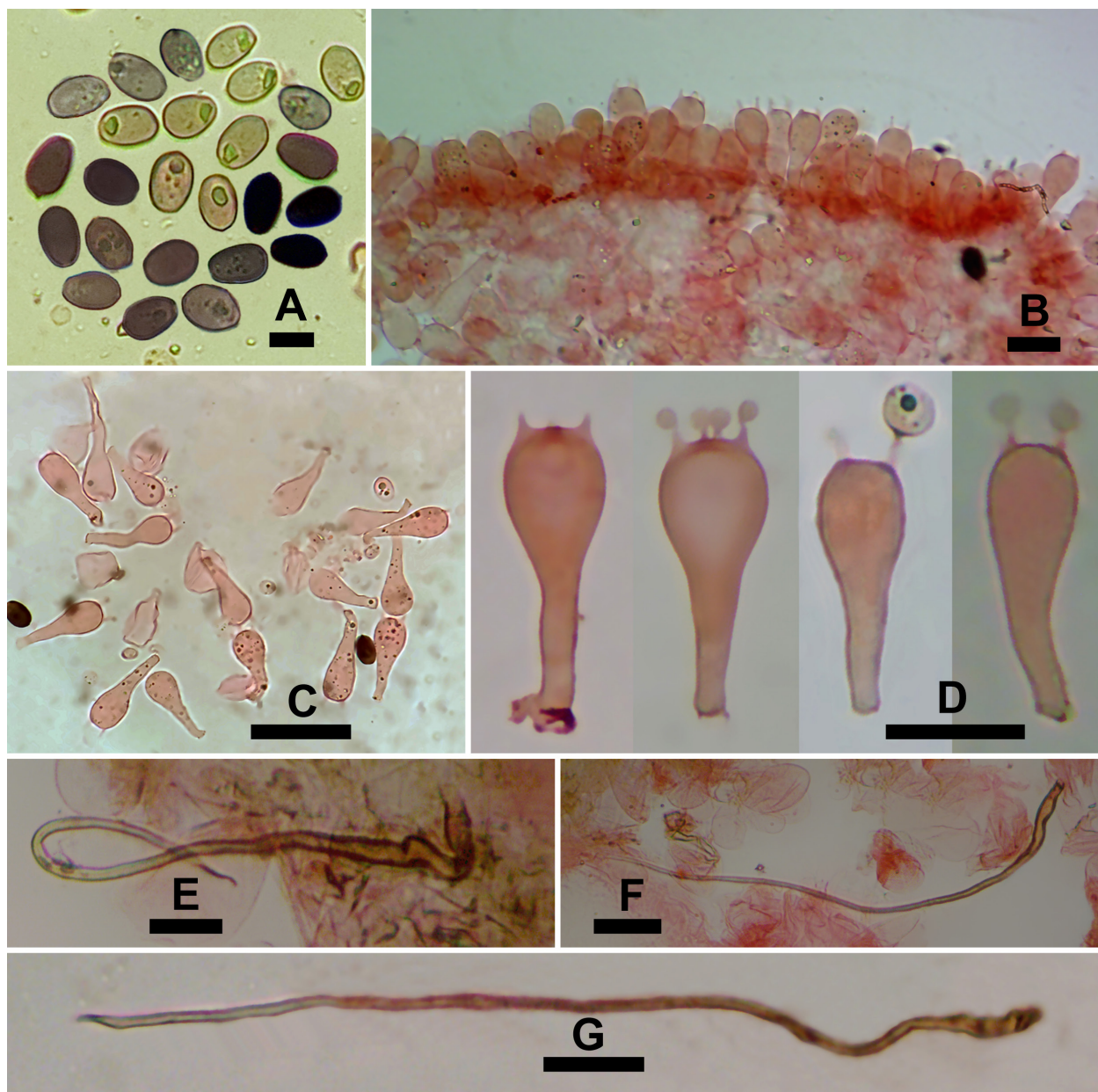


Figure 4a. *Parasola cinnamomescens*. Microscopic features (A), basidiospores (B), lamellae edge (C, D), basidia, sclerocystidia (E–G). Scale bars (A–G): 10 μ m. Photographs by Zaman Khan.

not fit with other taxa of the genus in terms of morphological characterizations and molecular phylogenetic analysis. Therefore, *P. conopileae* was placed in a new section, *Conopileae*, and all other taxa were included in section *Parasola*.

The taxa within sect. *Parasola* are recognized by small to medium-sized, occasionally fimicolous and withering fruiting bodies; radially sulcate pileus often with brown hairs and absence of veil; withering lamellae; ovoid, rounded, hexagonal, subglobose, or subtriangular to subpentangular basidiospores in frontal view and

lentiform in side view; four-spored basidia; presence of clavate to spheropedunculate, utriform, sublageniform, or lageniform cheilocystidia; utriform or subcylindrical pleurocystidia; and occurrence of clamp connections. On the other hand, the species of sect. *Conopileae* are characterized by nonfimicolous and persevering fruiting bodies; nonradially sulcate pileus; absence of veil and long brownish hairs; nondeliquescent and nonwithering lamellae; ellipsoid and large basidiospores with eccentric or almost central germ pore; four-spored basidia; utriform,

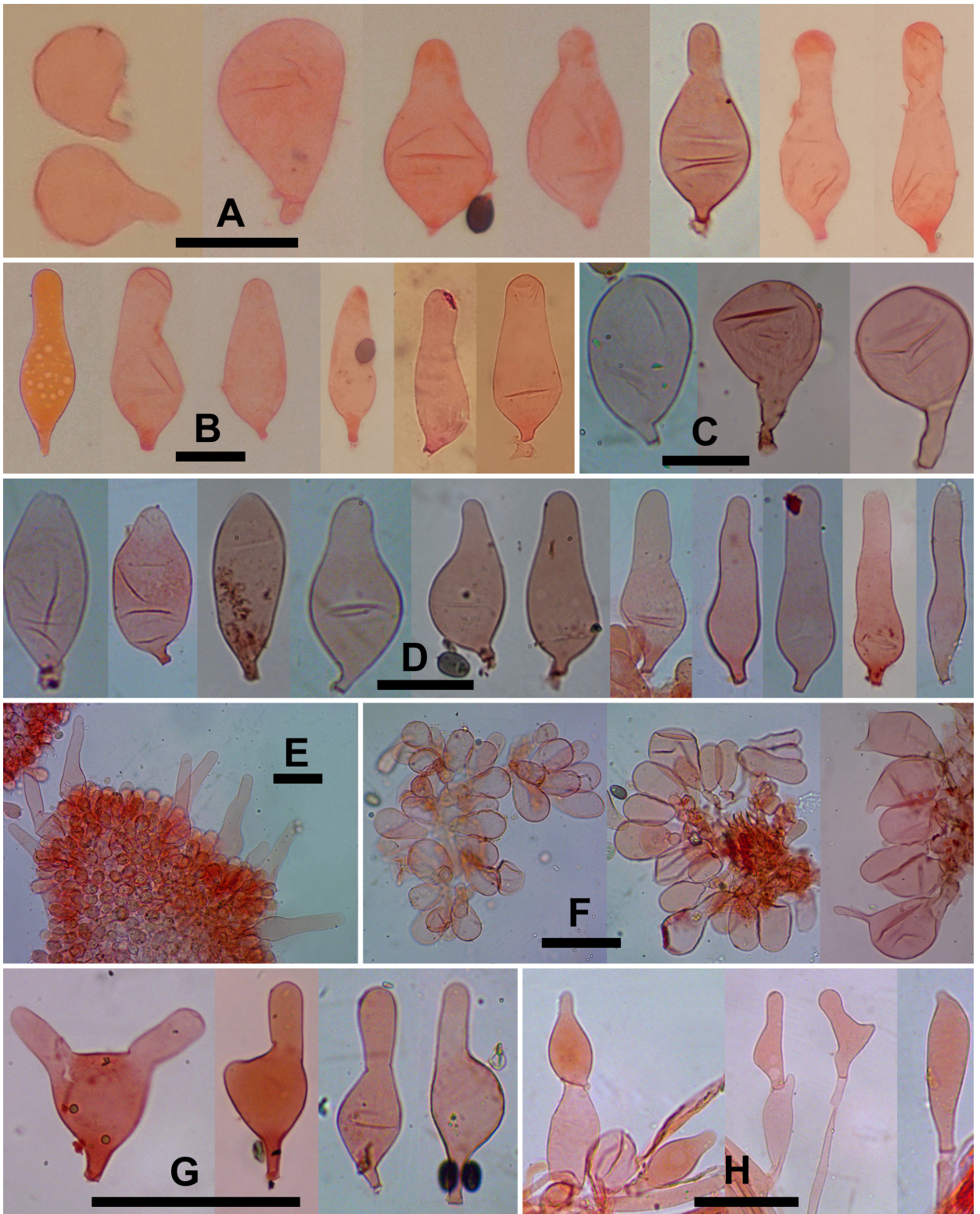


Figure 4b. *Parasola cinnamomescens*. Microscopic features (A, B), cheilocystidia (C-E), pleurocystidia (F, G), pileocystidia, caulocystidia (H). Scale bars (A-H): 10 μ m. Photographs by Zaman Khan.

Table 2. Comparative characters of *Parasola cinnamomescens* and related taxa (Keirle et al., 2004; Nagy et al., 2010; Schafer, 2014; Hussain et al., 2017; Ganga and Manimohan, 2019).

	Size, form, and color of pileus	Size, form, and color of basidiospores	Presence, size, and form of cheilocystidia	Presence, size, and form of pleurocystidia	Presence, size, and form of pileocystidia	Presence, size, and form of caulocystidia	Size and color of sclerocystidia
<i>P. auricoma</i>	13–60 mm, red brown to ochre brown	13–15 × 8–8.9 × 7.5 µm, broadly ellipsoid to lacrimiform in frontal view, amygdaliform or ellipsoid in side view, dark reddish brown	12–50 × 10–22 µm, vesicular to subglobose, ellipsoid to narrowly ellipsoid, or elongate utriform	40–70 × 8–14 µm, ellipsoid to subpedicellate	20–35 × 10–15 µm, clavate	Absent	100–350 or up to 1 mm in length, 2–5 µm in width
<i>P. cinnamomescens</i>	5–16 mm, convex to hemispherical or broadly conical to obtusely conical; dull orange to yellow to light gray	9.5–13 × 6–8 µm, ellipsoid to broadly ellipsoid in side view, ovoid to broadly ellipsoid in frontal view, brown to dark brown or black	21–85 × 14–29 µm, polymorphic, mostly utriform to narrowly utriform, subglobose, spheropedunculate, obpyriform or pyriform	32–84 × 17–41 µm, spheropedunculate, oblong, narrowly lageniform, narrowly utriform to utriform or flexuose	25–79 × 12–29 µm, clavate to spheropedunculate, utriform to lageniform, rostrate sometimes with ventricose or lecythiform basal body, subcapitate apex (2–5 µm) with two capitula	32–60 × 12–17 µm, lageniform or clavate with mucronate apex, fusiform, or fusoid-ventricose with irregular outline	140–395 × 2–6 µm, golden to dark brown
<i>P. conopilea</i>	25–55 mm, ellipsoid to conical, dark reddish brown	12.5–17.5 × 6.5–9 µm, ellipsoid or slightly lentiform, dark reddish brown	lageniform or subutriform or subfusiform	Absent	Absent	Absent	100–400 µm or up to 1 mm
<i>P. malakandensis</i>	15–30 mm, cylindrical to subglobose to convex, light reddish brown to light grayish reddish brown	13–18 × 12.5–16 × 10–13 µm, broadly oblong to subglobose in frontal view, ellipsoid to oblong in side view, dark brown to black	42–68 × 15–20 µm, subclavate to cylindrical	25–46 × 14–22 µm, lageniform, utriform, or subcylindrical	20–28 × 4–7 µm, clavate	Absent	70–165 × 5–10 µm, dark brown
<i>P. psathyrelloides</i>	2–20 mm, hemispherical to convex to conico-convex, light brown to brownish orange	8–12 × 7–9 × 6–8 µm, lenticular, ovoid to ovoid-ellipsoid in frontal view, oblong to ellipsoid in side view, dark brown to black	27–47 × 18–23 µm, globose to subglobose, utriform or lageniform, sometimes with a short pedicel	Absent	27–43 × 7–23 µm, clavate	300–700 µm long brown hairs present at base	103–250 × 5–7.5 µm, brown
<i>P. setulosa</i>	Up to 10 mm, cylindrical to bell-shaped to obtuse, pale brown	8.8–10.4 × 7.4–8.9 × 5.3–6.7 µm, subglobose to broadly ovoid in frontal view, ellipsoid to subamygdaliform in side view, dark reddish brown	Utriform	Subcylindrical or oblong	Absent	Absent	150–310 × 10–16 µm, brown

subtriform, lageniform, or clavate cheilocystidia; absence of pleurocystidia; and presence of clamp connections (Wächter and Melzer, 2020).

Parasola psathyrelloides, originally reported from India, is a sister taxon to the new species *P. cinnamomescens* based on phylogenetic evolutionary analysis of nrDNA sequence data. It differs morphologically from our new species by the occurrence of brown hairs on the pileus in its initial stage, moderately close to close lamellae with whitish coloration in the initial stage and grayish brown coloration in the final stage, and the presence of hairs on the stipe surface in the young stage. It is also distinct anatomically due to its oblong basidiospores, smaller cheilocystidia ($27\text{--}47 \times 18\text{--}23 \mu\text{m}$) without intraparietal pigmentation, absence of pleurocystidia, small-sized pileal elements ($27\text{--}43 \times 7\text{--}23 \mu\text{m}$) with limited variety and intraparietal yellow pigment at the base, smaller ($103\text{--}250$) sclerocystidia, presence of thick-walled brown hairs $300\text{--}700 \mu\text{m}$ long at the base of the stipe, and smaller diameter ($3\text{--}5 \mu\text{m}$) of stipe hyphae (Ganga and Manimohan, 2019).

Parasola malakandensis, described from District Malakand and District Lahore of Pakistan, can be distinguished by the pileus having light reddish brown to light grayish red or brown coloration; pileus with umbilicate glabrous center at maturity, deeply plicate towards margin; brownish-orange to blackish free lamellae; and longer stipe ($70\text{--}95 \text{ mm}$). It is also distinct due to its larger ($13\text{--}18 \times 12\text{--}16 \times 10\text{--}13 \mu\text{m}$) and oblong to subglobose basidiospores; smaller ($55 \times 17 \mu\text{m}$) subclavate to subcylindrical cheilocystidia; rarely present subcylindrical and small-sized ($40 \times 16 \mu\text{m}$) pleurocystidia; presence of only clavate cells ($20\text{--}28 \times 4\text{--}7 \mu\text{m}$) in pileus, which are light brown at the base; smaller ($70\text{--}165 \times 5\text{--}10 \mu\text{m}$) sclerocystidia; small diameter ($3\text{--}5 \mu\text{m}$) of stipe hyphae; and absence of caulocystidia (Hussain et al., 2017).

The European species *Parasola auricoma*, originally described from Hungary and also reported from Pakistan, is distinct owing to its paraboloid to ovoid or oblong, campanulate, umbonate, brown to dark brown or reddish brown pileus with diameter up to 60 mm ; crowded or close lamellae, which are blackish at full maturity with 0–4 tiers of lamellulae; longer stipe ($90\text{--}110 \text{ mm}$); shorter basidia ($18\text{--}24 \mu\text{m}$); narrowly ellipsoid to ellipsoid smaller cheilocystidia ($12\text{--}50 \times 10\text{--}22 \mu\text{m}$); sometimes ellipsoid or totally absent pleurocystidia; presence of only clavate cells ($25\text{--}35 \times 10\text{--}15 \mu\text{m}$) in pileipellis; and absence of caulocystidia (Keirle et al., 2014; Schaffer, 2014; Hussain et al., 2018).

The characters that discriminate *Parasola conopilea* from the new species include the ellipsoid, dark reddish brown pileus; crowded and pale brown or dark lamellae; predominantly longer stipe ($90\text{--}190 \text{ mm}$); larger basidiospores ($12.5\text{--}17.5 \times 6.5\text{--}9 \mu\text{m}$); and complete absence of pleurocystidia, pileocystidia, and caulocystidia (Schaffer, 2014).

Several characters distinguish *Parasola setulosa*, such as cylindrical and bell-shaped pileus; presence of subglobose, subamygdaliform, and sometimes subhexagonal or triangular basidiospores; rarely present cheilocystidia; subcylindrical pleurocystidia; and absence of caulocystidia (Nagy et al., 2010) (Table 2).

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