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Research article

A new species of *Tricholomopsis* (Agaricales) from Darjeeling Hills, India

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Abstract
This study concerns a novel white–spored Agaricales collected from Darjeeling Hills (India) during the monsoon. The new species, *Tricholomopsis darjeelingensis*, is described based on its morphological and molecular data. It is characterized by its caespitose fruiting body, long and slender stipe, occasionally eccentric, pileus covered with dense violet fibrils, 2 – 4 spored basidia, thin–walled caespitose cheilocystidia and basidiospores globose to broadly ellipsoid, 2.9 – 4.72 – 5.9 × 2.9 – 3.93 – 4.4 µm.

Keywords
ITS, LSU, novel species, phylogeny, taxonomy

Introduction

Tricholomopsis Singer (Basidiomycota, Agaricales) is a genus that can be recognized by its bright, mostly yellow basidiomata, with adnate to sinuate yellow lamellae, a fibrillose to squamulose dry pileus with red or yellow tones, white spore print, central stipe without a ring, smooth inamyloid spores, presence of large cheilocystidia, a pileipellis as a trichoderm or cutis type, and the presence of clamp connections (Singer, 1986; Olariaga et al., 2015; Hosen et al., 2020). Most *Tricholomopsis* species are known to be living on wood (Smith, 1960) generally growing primarily on conifer, rarely on hardwood, but also a handful of species have been documented to be living on bamboo or on soil (Dennis, 1951; Hongo, 1960; Singer, 1986). The Index Fungorum as of the date (7/07/2023) shows records of 78 species of *Tricholomopsis*, among them 49 taxa have been validated (www.indexfungorum.org). The taxonomy of this genus is still to be resolved, and the distribution of almost all of the species is not fully known except for *Tricholomopsis rutilans* (Schaeff. ex Fr.) Singer (Holec et al., 2019). But for *T. rutilans* the situation is trickier for its species complex (Olariaga et al., 2015). So far, three species of *Tricholomopsis* have been recognized in India, *viz., T. rutilans* from Darjeeling (Sarwal, 1984), *T. crocobapha* (Berk. & Br.) Pegler from Himachal Pradesh (Rai et al., 2007) and *T. sulphureoides* (Peck) Singer from North-Western Himalaya (Lakhanpal, 2014).

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Here we provide complete information on a novel species of *Tricholomopsis* collected from the Darjeeling District of West Bengal which has been done based on morphological features and phylogenetic analyses based on nuclear ribosomal internal transcribed spacer (nrITS) and nuclear ribosomal large subunit (nrLSU) sequences.

Materials and methods

Specimen collection

The study material was collected in Darjeeling Hills during the rainy season in the year 2022. Photographs, chemical reactions, and other essential field characters were well documented on the spot. The specimen was carefully dried and preserved referring to Pradhan et al. (2015) and was deposited to Calcutta University Herbarium (holotype, CUH AM791; isotype, CUH AM872 and CUH AM911).

DNA extraction, PCR amplification, DNA sequencing

E.Z.N.A.® Fungal DNA Kit (Norcross, Georgia) was used for genomic DNA extraction from the dried specimen. The protocol provided by the manufacturer of the fungal DNA kit was preferred. Two rDNA regions *viz.,* nrITS and nrLSU, were amplified with the primer pairs ITS1/ITS4 (White et al., 1990) and LROR/LR3 (Vilgalys and Hester, 1990) respectively. PCR protocol followed was: 94°C for 4min, followed by 30 cycles of 94°C for 30 s, 55°C for 30 s, 72°C for 1 min, and a final extension of 72°C for 5 min. PCR products were purified using the QIAquick® Gel Extraction Kit (QIAGEN, Germany). Sequencing was performed on ABI3730xl DNA Analyzer (Applied Biosystems, USA). For manual editing of the newly generated sequences of *Tricholomopsis darjeelingensis*, BioEdit v.7.0.5 (Hall 1999) software was used and the sequences were subjected to BLAST search (https://blast.ncbi.nlm.nih.gov). Newly generated sequences of *T. darjeelingensis* were deposited in GenBank (ITS, OQ913610; LSU, OQ861109).

Sequence alignment and phylogenetic analyses

The final dataset of sequences including *T. darjeelingensis* and those acquired from GenBank (Table 1) were used for phylogenetic analyses. The sequences of *Pleurocybella porrigens* (Pers.) Singer, *Phyllotopsis* sp. and *Pluteus romelli* (Britzelm.) Lapl. were designated as outgroup taxa referring to Hosen et al. (2020). The datasets comprised 37 ITS and 29 LSU sequences of *Tricholomopsis* species. In the final dataset, ITS and LSU sequences were aligned individually in Mega v.7.0 (Kumar et al., 2016) and then concatenated for further analyses using MEGA X (Kumar et al., 2018). The best substitution model (GTR+I+G) was determined using jModelTest2 on XSEDE using the CIPRES web portal (www.phylo.org). Maximum likelihood (ML) and Bayesian Inference (BI) were executed using raxmlGUI 2.0 (Edler et al., 2020) and MrBayes v.3.2.7 (Ronquist et al., 2012) respectively to analyze the combined (ITS+LSU) dataset. Vishal et al. (2021) followed for Bayesian Metropolis–Coupled Markov chain Monte Carlo (MCMC) analyses. The values below 70% and 0.70 of Maximum Likelihood bootstrap (MLBS) and Bayesian posterior probabilities (pp) accordingly are not included in the phylogenetic tree (Fig. 1).

Morphological studies

Morphological details of the studied material are established based on the field notes and color photographs of the specimen. Methuen Handbook of color was referred to for shade codes (Kornerup and Wanscher, 1978). Free-hand sections were prepared from dried specimens and mounted in 5% KOH (potassium hydroxide), stained with Congo red, and observed under a compound microscope for the microscopical details. Melzer's reagent was used to check the amyloidity of the basidiospores. The abbreviation used for basidiospores are: 'Q' for the length/width ratio and 'Q_m' for the mean quotient of all spores.

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Table 1 - Lists of *Tricholomopsis* species used in phylogenetic analyses with locality, GenBank accession numbers, voucher numbers, and references.

Species	Country	Accession n. ITS	Accession n. LSU	Voucher no.	References
Tricholomopsis aff. rutilans	Germany	KP058981		TUB11582	Olariaga et al. 2015
T. aff. rutilans	Sweden	KP058984	KP058985	UPS–F–646220	Olariaga et al. 2015
T. aurea	Africa	MF100960	MF100993	SFSUDED8327	Desjardin et al. 2017
T. aurea	Africa	MF100961	MF100994	SFSUBAP618	Desjardin et al. 2017
T. badinensis	Slovakia	LS992163		PRM946195	Holec 2019
T. badinensis	Slovakia	LS992164		PRM899423	Holec 2019
T. darjeelingensis	**India**	**OQ913610**	**[OQ86110**9]	**CUHAM 119**	**This study**
T. decora	Slovakia	HE649942		PRM 899160	Holec et al. 2012
T. decora	Czech Republic	FN554891		PRM 898238	Holec et al. 2009
T. decora	Czech Republic	FN554890		PRM 882317	Holec et al. 2011
T. flammula	Spain	KP058973	KP058974	ARAN–Fungi 00322	Olariaga et al. 2015
T. flammula	Sweden	KP058975	KP058976	S–F156625	Olariaga et al. 2015
T. galeata	China	MW871732	MW871622	BJTC FM1107	Mao et al. 2021
T. galeata	China	MW871782	MW871630	BJTC FM1229	Mao et al. 2021
T. ornaticeps	New Zealand	KY010816	KY010825	PDD:57441	Cooper et al. 2017
T. ornaticeps	New Zealand	KY010817	KY010826	PDD:72909	Cooper et al. 2017
T. ornaticeps	New Zealand	KY010824	KY010828	PDD:102769	Cooper et al. 2017
T. ornaticeps	New Zealand	KY010820	KY010827	PDD:82501	Cooper et al. 2017
T. osiliensis	Poland	LT984726	LT978511	PRM:946096	Holec 2019
T. osiliensis	China	LT716068	KY418884	ZRL20151760	Zhao et al. 2017
T. pallidolutea	China	MW871614	MW871640	HSA398	Mao et al. 2021
T. pallidolutea	China	MW871749	MW871631	BJTC FM1184	Mao et al. 2021
T. pteridicola	Spain	KP058988	KP058989	ARAN–Fungi 00121	Olariaga et al. 2015
T. pteridicola	Spain	KP058986	KP058987	ARAN–Fungi 320	Olariaga et al. 2015
T. rubroaurantiaca	China	MN912496	MN912493	GDGM74616	Hosen et al. 2020
T. rubroaurantiaca	China	MN912494	MN912491	GDGM61454	Hosen et al. 2020
T. rutilans	Czech Republic	HE649946		PRM:899460	Holec et al. 2012
T. rutilans	Sweden	KP058977	KP058978	UPS–F–646219	Olariaga et al. 2015
T. scabra	New Zealand	KY010821	KY010831	PDD:102100	Cooper et al. 2017
T. scabra	New Zealand	KY010819	KY010830	PDD:81264	Cooper et al. 2017
T. scabra	New Zealand	KY010818	KY010829	PDD:78235	Cooper et al. 2017
T. scabra	New Zealand	KY010823	KY010832	PDD:102579	Cooper et al. 2017
T. sulphureoides	China	MW871623	MW867238	HSA 277	Mao et al. 2021
T. yunnanensis	China	MZ470249		HKAS28976	Liu et al. 2022
T. yunnanensis	China	MZ470247	OL614950	KUN–HKAS48887	Liu et al. 2021
T. yunnanensis	China	OK393697	OL614949	KUN–HKAS80034	Liu et al. 2021
T. yunnanensis	China	MZ470248	OL614951	HKAS93555	Liu et al. 2021
Pleurocybella porrigens	Canada	KC581309		UBCF23773	Direct submission
Phyllotopsis sp.		DQ404382	AY684161	AFTOLID773	Direct submission
Pluteus romelli	USA	AY854065	AY634279	AFTOLID625	Direct submission

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Results

Phylogenetic analyses

The combined ITS and LSU dataset contained 40 taxa and 3880 nucleotides including the gaps. Since the phylogenetic trees generated from ML and BI analyses show the same topology, only the tree resulting from ML analysis is shown. Our collected specimen *Tricholomopsis darjeelingensis* (voucher number: CUH AM791) formed an independent lineage with MLBS of 73% and PP of 0.74 rather than clustering with other species of the genus (Fig. 1). However, *T. darjeelingensis* shows neighbour homologues with *T.* aff. *rutilans* (Germany) and *T. pteridicola* Olariaga, Laskibar & Holec (Spain), but *T.* aff. *rutilans* is found to be undescribed, *T. pteridicola* has distinctive morphological characters, and both taxa are easily separated from our specimen.

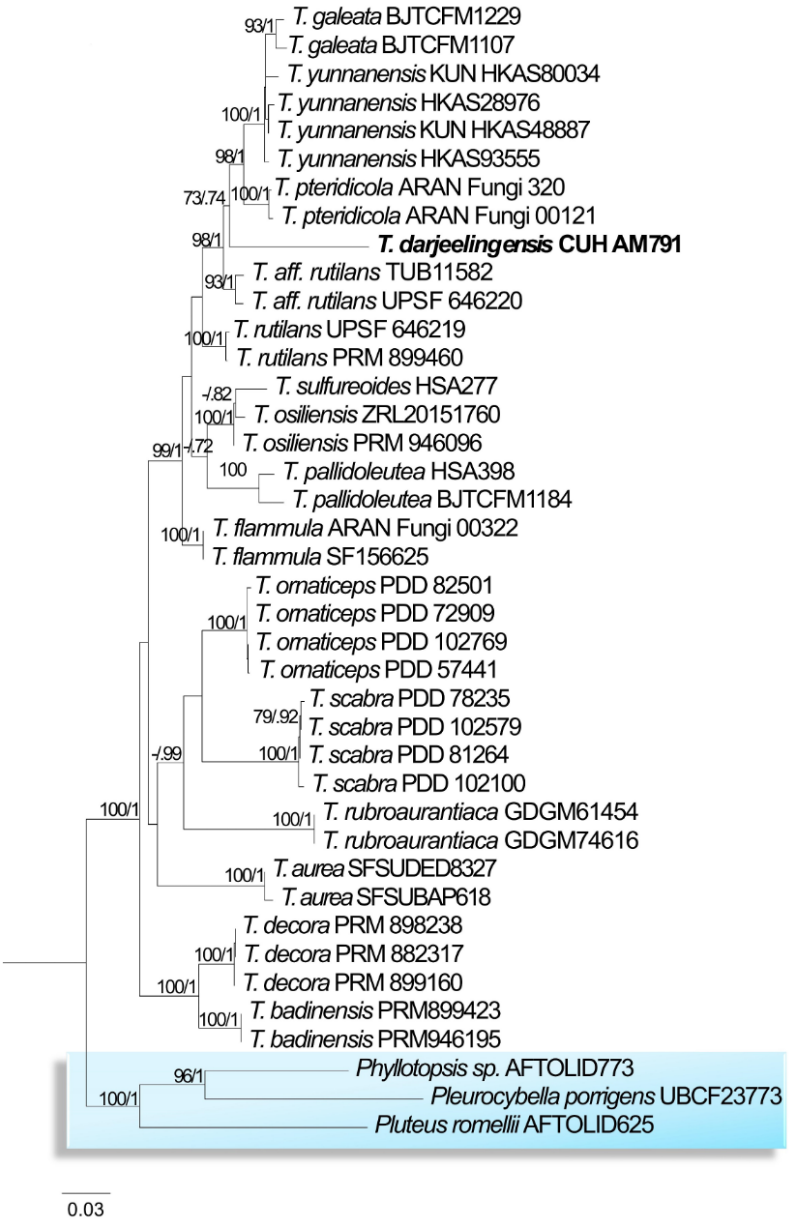

Fig. 1 Phylogenetic tree generated from Maximum Likelihood (ML) analyses based on concatenated ITS and LSU sequence datasets. Maximum likelihood bootstrap and Bayesian posterior probabilities support values greater than 70% and 0.70, respectively are indicated on the nodes. The highlighted region in the tree refers to the species selected as an outgroup.

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Taxonomy

Tricholomopsis darjeelingensis A. Thapa & K. Acharya, sp. nov **Figs 2, 3**

MycoBank no.: MB 848465

Diagnosis: Tricholomopsis darjeelingensis is characterized by its caespitose fruit body, long and slender stipe, sometimes eccentric, pileus covered with dense fibrils which are violet in color, 2 – 4 spored basidia, thin–walled caespitose cheilocystidia, and its terrestrial nature. Basidiospores globose to broadly ellipsoid, 2.9 – 4.72 – 5.9 × 2.9 – 3.93 – 4.4 µm.

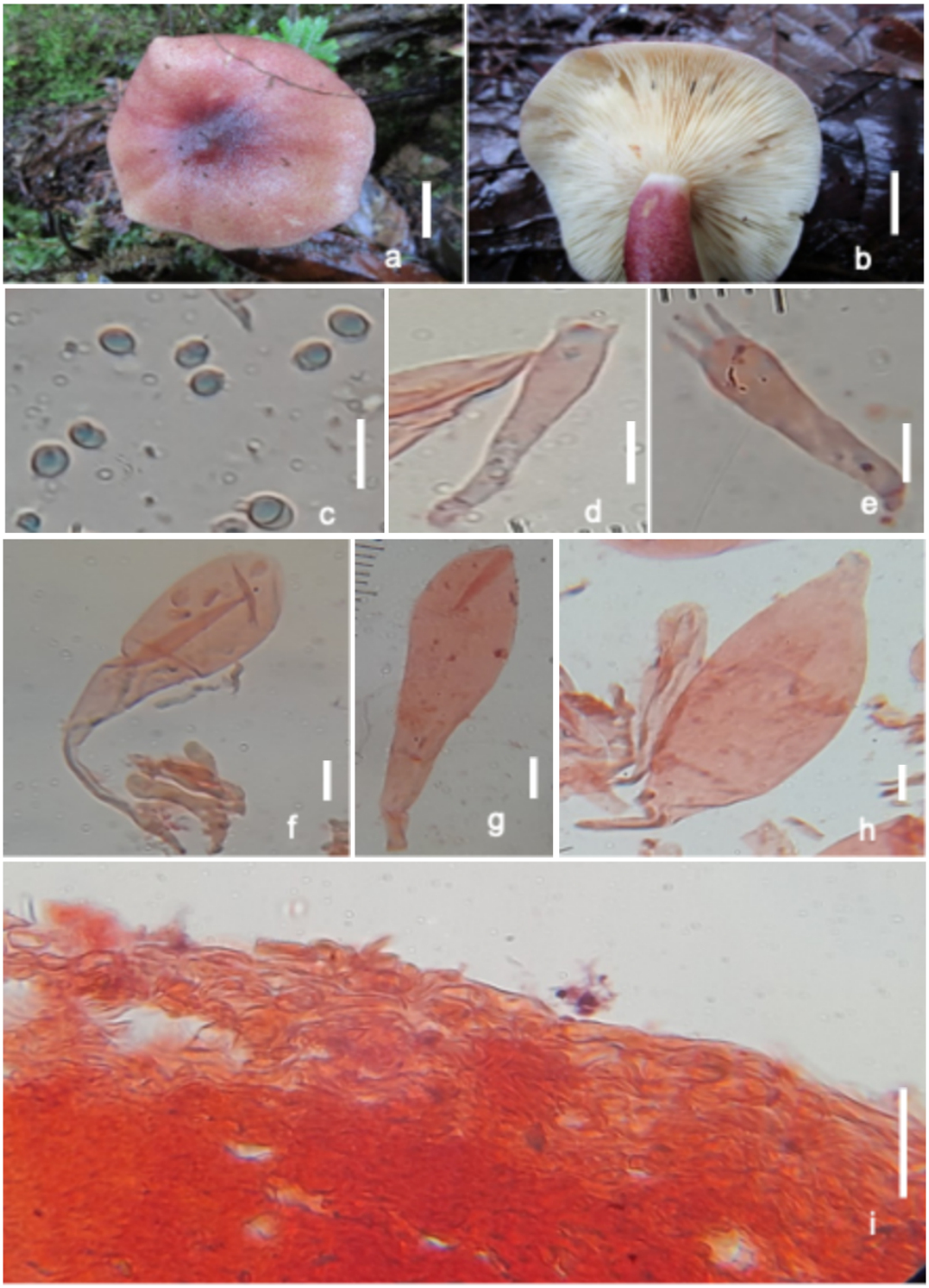

Fig. 2 (a-b) Fresh basidiomes of *Tricholomopsis darjeelingensis* (c) basidiospores (d-e) basidia (f-h) cheilocystidia (i) pileipellis. Scale bars a-b = 10 mm; c-i = 10 µm.

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Type: INDIA. West Bengal, Darjeeling, Old Military Road, 27°00'04.9"N 88°15'42.4"E, 17 Jul 2022, col. A. Thapa, J. Tamang (CUH AM791, holotype; CUH AM872, CUH AM911, isotype).

Etymology: referring to the place of collection of the specimen.

Basidiomata are small to large-sized. Pileus 18 – 75 mm in diameter, broadly convex, margin straight, moist, slightly depressed at the center, light lilac (15A5) to greyish violet (15D6) towards the center, surface pubescent, margin non–striate, incurved, context up to 3 mm wide, white (2A1), unchanging with bruising. Lamellae up to 3 mm broad, adnate to sinuate, yellowish white (4A2), crowded, edge serrate, lamellulae with 6 – 7 tiers. Stipe 59 – 72 × 7.6 – 9 mm, central to slightly eccentric, surface similar to pileus, with dense hairs, cylindrical, slightly curved, compressed, hollow, fleshy, concolorous to pileus. Odor and taste are not distinctive. Spore-print white.

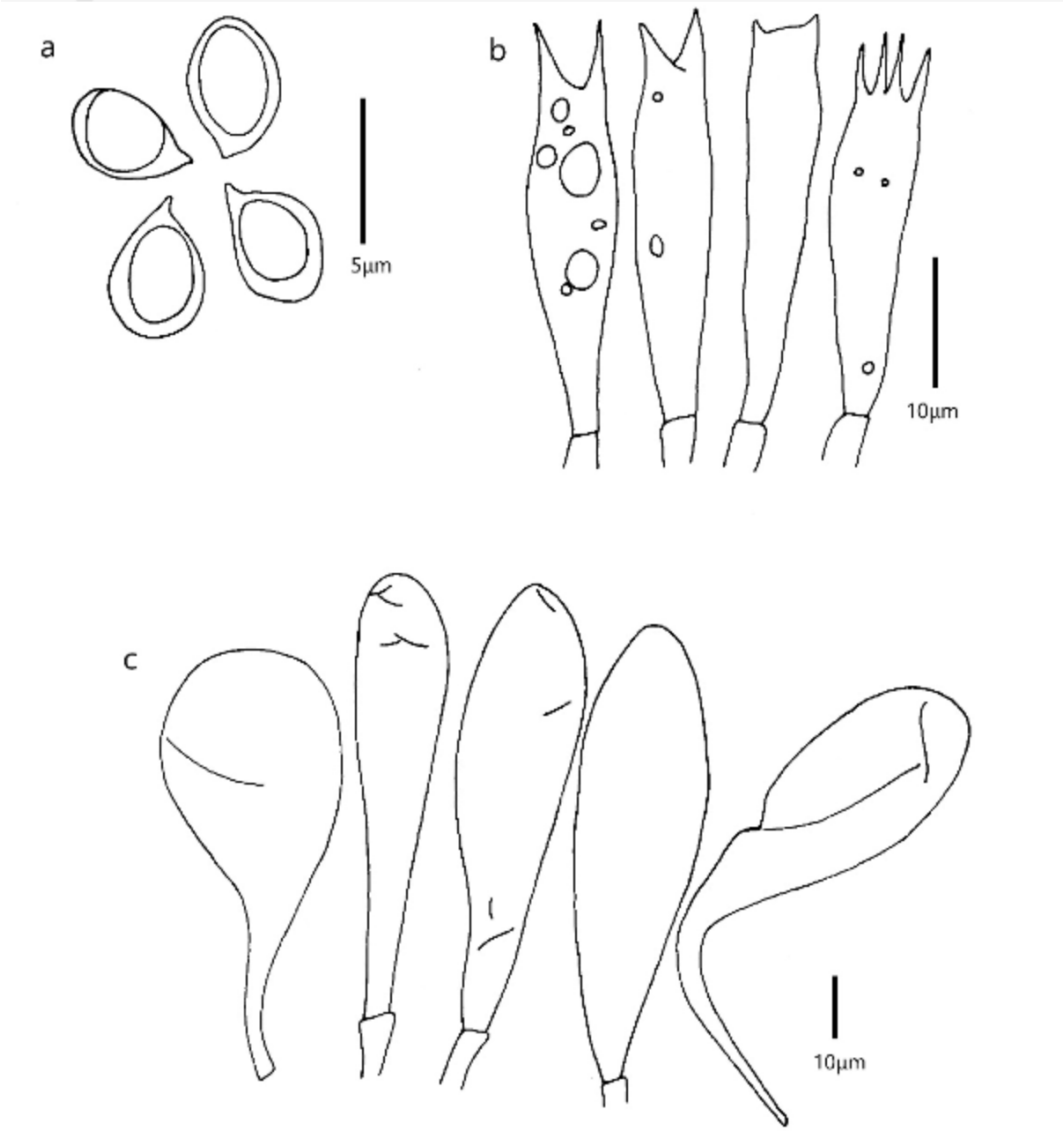

Fig. 3 *Tricholomopsis darjeelingensis* A. Thapa & K. Acharya, sp. Nov (a) basidiospores (b) basidia (c) cheilocystidia.

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Basidiospores 2.9 – 4.72 – 5.9 × 2.9 – 3.93 – 4.4 µm, Q = 1 – 1.67, Q_m = 1.2, globose to broadly ellipsoid, rarely oblong, slightly thick-walled, smooth, hyaline, inamyloid, guttate, with an apicule up to 0.3 µm long. *Basidia* 23.5 – 35.3 × 5.6 – 5.9 µm, 2- to 4-spored, clavate, sterigmata up to 8.2 µm long, smooth, hyaline, thin–walled, with basal clamp, guttate. *Pleurocystidia* absent. *Lamellae edge* sterile. *Cheilocystidia* 41.2–117.6 × 13.5–35.3 µm, abundant, caespitose, clavate to ovoid, and sometimes fusoid, hyaline, smooth, thin-walled, with a basal clamp. *Hymenophoral trama* regular, composed of long, cylindrical hyphae, up to 26.5 µm wide, thin-walled. *Pileipellis* is a cutis layer, composed of inflated hyphae up to 12.35 µm broad. *Stipitipellis* a cutis, composed of parallel, cylindrical hyphae, 2.9 – 14.1 µm broad. *Caulocystidia* absent. *Clamp connections* up to 3 µm wide present in all tissues.

Habit and habitat: Caespitose, terrestrial in a forest dominated by *Pinus* sp., *Quercus* sp., and *Betula* sp.

Discussion

Tricholomopsis darjeelingensis is characterized by its small to large basidiomes, covered with dense violet hairs, stipe concolorous to the pileus, globose-broadly ellipsoid basidiospores, 2 – 4 spored basidia, and abundant cheilocystidia. In the field, our specimen might be confused with *T. rutilans, T. pteridicola*, *T. yunnanensis* (M. Zang) Li R. Liu, Yan C. Li & Zhu L. Yang, and *T. galeata* L. Fan & N. Mao, but all of those species differ from our specimen by having few distinguishable macro and microscopic characters such as size and color of the pileus, absence or presence of the cystidia, etc. as compared in Table 2.

Though three species of *Tricholomopsis* have been reported from different regions of India, none of them have shown the phylogenetic analyses in past works. Thus, this study shows the first phylogenetic approach from India on the genus *Tricholomopsis.* The morphological details indicated our specimen *T. darjeelingensis* to be a novel species, which is well supported by molecular evidence.

Dichotomous key to species of *Tricholomopsis* reported from India

1. Pileus covered with dense minute purple/violet fibrils……..……..2
1b. Pileus glabrous or with sparse yellow/buff fibrils..……...……...…….……...3
2. Caulocystidia present..…….……..*T. rutilans*
2b. Caulocystidia absent..……...……...…*T. darjeelingensis*
3. Pileipellis trichoderm–type, pleurocystidia abundant……..…..*T. sulphureoides*
3b. Pileipellis cutis–type, pleurocystidia absent…….……..*T. crocobapha*

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Table. 2 Comparative table of characters of look–alike species of *Tricholomopsis* with *T. darjeelingensis.* **References**: **(a)** Liu et al. 2022; **(b)** Olariaga et al. 2015; **(c)** Mao et al. 2021; **(d)** Cooper et al. 2016; **(e)** This study.

Characters	Pileus	Stipe	Lamellae	Basidiospores	Basidia	Pleurocystidia	Cheilocystidia	Caulocystidia	Pileipellis
T. darjeelingensis (e)	18–75 mm, covered with liliac to violet hairs	72×9 mm, central to eccentric, covered with violet hairs	Adnate to sinuate	2.94–5.9×2.9–4.4 µm, globose to broadly ellipsoid	23.52–35.28×5.58–5.88 µm, 2–4 spored	Absent	41.16–117.6×13.52–35.28 µm, caespitose, clavate to ovoid	Absent	Cutis–type
T. rutilans (d)	20–160 mm, covered with purplish–reddish hairs	25–85×3–25 mm, covered with purplish–reddish hairs	Adnate or sinuate	6.5 µm×4.9 µm broadly ellipsoid to ellipsoid	35–45×6.0–8.0 µm, 4–spored	Absent/sparse	40–120×12–25 µm, clavate, with brown, intracellular pigment	Present (20–80×4.0 µm)	Cutis with transitions to a trichoderm
T. galeata (c)	50–130 mm, covered with red to purple reddish hairs	35–120×12–20 mm, glabrous	–	5–7×4–5 µm, broadly ellipsoid to ellipsoid	30–40×6–8 µm, 2–4 spored	Absent	55–105×13–23 µm, mostly narrowly clavate to lageniform–fusiform	Absent	Cutis–type
T. pteridicola (b)	7–28(60) mm, covered with purple-red hairs	14–35(70) × 3–5(12) mm, covered with purple red hairs	Adnate–sub decurrent	5.5–7×4–5.5 µm, subglobose to broadly ellipsoid	25–35×5.5–8 µm, 2–4 spored	40–62×4–6.5 µm, cylindrical to narrowly clavate	53–98×10.5–18 µm, mostly clavate	Absent	Cutis–type
T. yunnanensis (a)	41–95 mm, covered with red-brown hairs	7–13×2.1–5 cm, pale lemon–yellow, covered with red–violet hairs	Adnexed	5–7.5×4–6 µm, subglobose to broadly ellipsoid	22–29×6–8 µm, 4–spored	30–50×5–7 µm, sub fusiform or cylindrical to narrowly clavate, often slightly flexuous	60–195×11–39 µm, fusiform	Absent	Palisadoderm

References

Cooper JA, Park D (2016) The fungal genus *Tricholomopsis* (Agaricales) in New Zealand, including *Tricholomopsis scabra sp. nov.* Phytotaxa 288:1–69. https://doi.org/10.11646/PHYTOTAXA.288.1.7

Dennis, RWG (1951) Some Agaricaceae of Trinidad and Venezuela. Leucosporae. Part. 1. Transactions of the British Mycological Society 34:411–482.

Desjardin D (2017) The gymnopoid fungi (Basidiomycota,Agaricales) from the Republic of São Tomé and Príncipe, West Africa. Mycosphere 8(9):1317–1391. https://doi.org/10.5943/mycosphere/8/9/5

Edler D, Klein J, Antonelli A, Silvestro D (2020) raxmlGUI 2.0: A graphical interface and toolkit for phylogenetic analyses using RAxML. Methods in Ecology and Evolution 12:373–377. https://doi.org/10.1111/2041–210X.13512

Hall TA (1999) – Bio Edit: a user–friendly biological sequence alignment editor and analysis program for Windows 95/98/NT. Nucleic Acids Symposium Series 41:95–98.

Holec J (2009) Valid publication of the name *Tricholomopsis flammula* (Fungi, Basidiomycota, Tricholomataceae), a species separated from *T. rutilans*. Journal of the National Museum (Prague), Natural History Series 178(3):7–13.

Holec J (2012) *Tricholomopsis osiliensis* (Basidiomycota, Agaricales), recently described from Estonia, found in Slovakia. Czech Mycology 64(1):93–100.

Holec J, Kolařík M (2011) *Tricholomopsis flammula* (Basidiomycota, Agaricales) molecular taxonomy, delimitation, variability, and ecology. Mycological Progress 10(1):93–99. https://doi.org/10.1007/s11557-010-0679-0

Holec J, Kunca V, Kolařík M (2019) *Tricholomopsis badinensis sp. nov*. and *T. sulphureoides*–two rare fungi of European old-growth forests. Mycological Progress 18(3):321–334. https://doi.org/10.1007/s11557-018-1449-7

Hongo T (1960) Notes on Japanese larger fungi (15). Journal of Japanese Botany 35:83–90.

Hosen MI, Xu JY, Li T (2020) *Tricholomopsis rubroaurantiaca*, a new species of Tricholomataceae from southern China. Mycoscience 61:342–347. https://doi.org/10.1016/j.myc.2020.06.005

Kornerup A, Wanscher JH (1978) Methuen handbook of color, 3rd edition. Methuen, London.

Kumar S, Stecher G, Tamura K (2016) MEGA7: Molecular Evolutionary Genetics Analysis Version 7.0 for Bigger Datasets. Molecular Biology and Evolution 33:1870–1874. https://doi.org/10.1093/molbev/msw054

Kumar S, Stecher G, Li M, Knyaz C, Tamura K (2018) MEGA X: Molecular Evolutionary Genetics Analysis across Computing Platforms. Molecular Biology and Evolution 1:35(6):1547–1549. https://doi.org/10.1093/molbev/msy096

Lakhanpal TN (2014) Mushroom Biodiversity in India: prospects and potential. In: Proceedings of the 8th International Conference on Mushroom Biology and Mushroom Products (Singh M, Upadhyay RC, Sharma VP, Ahlawat OP, Kumar S, Kamal S, Arora B, Gupta M, ed), 19–22 November 2014. World Society of Mushroom Biology and Mushroom products, ICAR-Directorate of Mushroom Research, Mushroom Society of India, Solan, pp 7–16.

Liu LR, Wang GS, Jia LK (2022) Type studies on two *Paxillus* species (Paxillaceae, Boletales) described from China. Phytotaxa 530:177–188. https://doi.org/10.11646/phytotaxa.530.2.4

Mao N, Xu YY, Fan L (2021) Three new species of *Tricholomopsis* (incertae sedis) from North China based on morphological and molecular data. Phytotaxa 507:155–166. https://doi.org/10.11646/phytotaxa.507.2.3

Olariaga I, Laskibar X, Holec J (2015) Molecular data reveal cryptic speciation within *Tricholomopsis rutilans*: description of *T. pteridiicola* sp. nov. associated with *Pteridium aquilinum*. Mycological Progress 14:21. https://doi.org/10.1007/s11557–015–1040–4

https://doi.org/10.6092/issn.2531-7342/18381

Pradhan P, Dutta AK, Acharya K (2015) A low–cost long term preservation of macromycetes for fungarium. Protocol Exchange. https://doi.org/10.1038/protex.2015.026

Rai RD, Singh SK, Yadav MC, Tewari RP (2007) Mushroom Biology and Biotechnology. Mushroom Society of India, National Research Centre for Mushroom Chambaghat, Solan.

Ronquist F, Teslenko M, van der Mark P, Ayres DL, Darling A, Höhna S, Larget B, Liu L, Suchard MA, Huelsenbeck JP (2012) MrBayes 3.2: efficient Bayesian phylogenetic inference and model choice across a large model space. Systematic Biology 61:539–542. https://doi.org/10.1093/sysbio/sys029

Sarwal BM (1984) Taxonomic studies on Indian agarics – II. Indian Phytopathology 37:228–233.

Singer R (1986) The Agaricales in modern taxonomy. Koeltz Scientific Books, Koenigstein.

Smith AH (1960) *Tricholomopsis* (Agaricales) in the Western hemisphere. Brittonia 12:41–70. https://doi.org/10.2307/2805334

Vilgalys R, Hester M (1990) Rapid genetic identification and mapping of enzymatically amplified ribosomal DNA from several *Cryptococcus* species. Journal of Bacteriology 172:4238–4246. https://doi.org/10.1128/jb.172.8.4238-4246.1990

Vishal V, Munda SS, Singh G, Lal S (2021) Wild edible gasteroid fungus *Astraeus* (Diplocystidiaceae) from Jharkhand, India. Indian Journal of Applied & Pure Biology. 36:569–579.

White TJ, Bruns TD, Lee SB, Taylor JW (1990) Amplification and direct sequencing of fungal ribosomal RNA genes for phylogenetics. In: PCR protocols: a guide to methods and applications (Innis MA, Gelfand DH, Sninsky JJ, White TJ, eds). Academic Press, New York, pp 315–322. https://doi.org/10.1016/b978–0–12–372180–8.50042–1

Zhao RL, Li GJ, Sánchez–Ramírez S, Stata M, Yang ZL, Wu G, Dai YC, He SH, Cui BK, Zhou JL, Wu F, He MQ, Moncalvo JM, Hyde KD (2017) A six–gene phylogenetic overview of Basidiomycota and allied phyla with estimated divergence times of higher taxa and a phyloproteomics perspective. Fungal Diversity 84:43–74. https://doi.org/10.1007/s13225–017–0381–5