

INOCYBE SINEOFIBULAE SP. NOV. (SECT. *MARGINATAE*), A NEW CLAMP-LESS ECTOMYCORRHIZAL SPECIES FROM KUMRAT VALLEY, KP, PAKISTAN

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Abstract

A new clamp-less ectomycorrhizal species, *Inocybe sineofibulae* sp. nov., collected from the Lamleek Forest of Kumrat Valley, KP, Pakistan. Morpho-anatomical and molecular characterization classified it in *Inocybe* sect. *Marginatae*. This newly described species is characterized by small sized basidiomata (pileus 1.8–2.3 cm) having pale brown fibrillose pileus with cracked margins, orange adnexed lamellae and a longitudinally striate stipe (3.1–5.6 × 0.4 cm). Large amyloid basidiospores (11.2–11.5 × 7.2–7.6 μm), exceptionally large metuloid cystidia and absence of clamp connections. It resembles *I. cryptica* in its small basidiomata and smooth, ellipsoidal spores but differs by having larger amyloid spores, significantly larger cystidia and the absence of clamp connections, which are abundant in *I. cryptica*. Phylogenetic analysis (ITS) declares its genetic distinctness, showing ~90% ITS similarity to *I. cryptica*. This finding highlights the unexplored fungal diversity of the Hindukush regions of Pakistan and emphasizes the value of integrative taxonomy in resolving cryptic lineages.

Key words: Amyloid spores; Ectomycorrhizal; *Inocybe*, Kumrat; *Marginatae*; Pakistan; Phylogeny

Introduction

The family *Inocybaceae* Jülich includes ectomycorrhizal fungi grouped within the order Agaricales and establish a monophyletic, cosmopolitan lineage. Its members develop symbiotic mycorrhizal associations to an extensive range of angiosperms and gymnosperms crossway temperate to tropical ecosystems, having sturdy preference with up to 23 families such as Fagaceae, Pinaceae and Salicaceae (Ahmed *et al.*, 2025).

Phylogenetic studies have categorized the family into several well-distinct genera. *Inocybe* is amongst the most important and diverse genus in Agaricales, with more than 1,050 species presently documented worldwide (Kirk *et al.*, 2008; Matheny *et al.*, 2019; Bandini *et al.*, 2022; Ahmed *et al.*, 2025). Members are generally distinguished by a non-glutinous pileus, having brownish lamellae at maturity with pigmented large amyloid basidiospores without germ-pore and the occurrence of pleurocystidia and cheilocystidia (Khan *et al.*, 2022; Ashraf *et al.*, 2025).

Extensive studies have revealed significant *Inocybe* diversities world-widely across Europe, North America, Africa, Asia, China, and Japan (Fan & Bau, 2013, 2014; Latha & Manimohan, 2015; Buyck *et al.*, 2022; Aïgnon *et al.*, 2022). On the other hand, the global biodiversity hotspots of Hindukush moist temperate forests of Pakistan remain comparatively under-explored (Myers *et al.*, 2000). To date, approximately 40 species from genus *Inocybe* have been reported from the different regions of Pakistan (Ahmed *et al.*, 2025; Ashraf *et al.*, 2025).

In the course of fungal surveys in the coniferous Lamleek forest of Kumrat Valley, Khyber Pakhtunkhwa, Pakistan, an undescribed *Inocybe* species was collected. Here describes it as *Inocybe sineofibulae* sp. nov., based on integrated morphoanatomical and molecular confirmation, and assign it to sect. *Marginatae*. Exceptionally large amyloid spores, unusually long metuloid cystidia, and absence of clamp connections in hyphal system are distinctive characters which clearly distinguish it from morpho-anatomically related species, such as *I. cryptica*, *I. muricellata*, and *I. flocculosa*. This is the leading explosion of a clampless member of sect. *Marginatae* from Pakistan, escalating the known diversity of *Inocybe* in the region. This discovery accentuates the ecological significance of ectomycorrhizal fungi in Hindukush coniferous forests and emphasizes the need for continued integrative taxonomic exploration in this underexplored biodiversity hotspot. This research directly supports SDG 15 (Life on Land) by documenting and protecting terrestrial myco-diversity, a critical but often overlooked component of sustainable ecosystems.

Material and Methods

Sampling location: The fresh specimens of mushrooms were collected from Lamleek Forest, Kumrat Valley, Upper Dir, Khyber Pakhtunkhwa (35.3201°N, 72.4501°E; 2439–3048 m a.s.l.), during the monsoon month of July and August, 2023. Described as having granite, diorite, norite, and schist bedrocks; sandy loam soils with pH 6–6.5;

annual precipitation 600–1200 mm (Ahmad & Nizami, 2014); seasonal temperatures of 25–31°C and high humidity during rains. The valley hosts mixed deciduous and coniferous forests. These offer perfect substrates (decaying wood, leaf litter, dung) to support various mushroom communities (Hameed *et al.*, 2012).

Sampling and morphological-anatomical characterization: The basidiomata was photographed and tagged, together with field notes (e.g., morphological characters—, color, shape and texture), were done *in-situ*. Basidiomata colours were being noted using standard Munsell Color System (1975). Specimens were dried in a hot-air oven at 55°C. Anatomical characterization was made in 5% KOH solution by mounting thin section of the pileus, lamellae, and stipe and examining them under a compound microscope (OPTIKA Microscope, Optika SRL., Italia). Measurements of anatomical structures were taken using calibrated optikca vision pro plus; at least 20 basidiospores, basidia cystidia, pileipellis and stipitipellis elements measured. Line drawings were prepared using camera lucida. Voucher specimens were deposited to the Department of Botany in the Research Laboratory of Fungal Biology and Systematics, GC University Lahore, Pakistan.

Extraction of DNA, PCR and sequencing: Genomic DNA was extracted from the dried specimen with the 2% CTAB method (Bruns, 1995). The ITS region of nuclear rDNA was amplified with fungal-specific primer pairs: ITS1F & ITS4 for ITS (Grades & Bruns, 1993). The PCR product was observed by agarose gel electrophoresis with a gel documentation system (UVtec, Cambridge, UK). Purification of amplified products was done prior to the sequencing by Macrogen, Inc., Korea (Voytas, 2001).

Analysis of sequence data: Consensus sequence was obtained with software BioEdit-v.7.0.4.1 (Hall, 1999). It was subjected to BLAST search at NCBI and closely matched *Inocybe* sequences were downloaded from GenBank. All the sequences were aligned with MUSCLE. Maximum likelihood (ML) bootstrap analysis was conducted in MEGA11 with a General Time Reversible model (Tamura *et al.*, 2021).

Results

Taxonomy

Inocybe sineofibulae Amanat & Hanif, sp. nov.
(Figs. 1-4)

MycoBank: MB860483

Etymology: “sineofibulae” refers to the clampless character of this species.

Diagnosis: Differs from related species in sect. *Marginatae* by its small basidiomata (pileus 1.8–2.3 cm), pale brown fibrillose pileus with cracked margins, adnexed dull orange lamellae, longitudinally striate stipe, exceptionally large amyloid spores (11.2–11.5 × 7.2–7.6 μm), very large metuloid cystidia (up to 93 μm long), and absence of clamp connections.

Description

Basidiomata small. **Pileus** 1.8–2.3 cm diam., pale brown at disc, lighter toward margins (10YR 7/4); conical to subglobose when young, later convex; surface uneven, silky-sericeous, centrally bumpy, becoming furfuraceous and appressed fibrillose; margin often cracking. **Lamellae** dull orange (5YR 5/14), adnexed, close to crowded, 2–3 mm wide; edges even. **Stipe** 3.1–5.6 × 0.4 cm, cylindrical, terete, equal, with basal tomentum, longitudinally striate, slightly clavate at base; apex whitish (5.1GY 8.1/1.6), becoming pale brown (5.7Y 6.6/3) below; fibrillose; stuffed; annulus and volva absent. Odor not distinctive.

Microanatomical features

Basidiospores 11.2–11.5(11.3) × 7.2–7.6(7.4) μm; av. 11.3 × 7.4 μm; smooth, oval to amygdaliform; light brown in KOH; prominent apiculus; strongly amyloid. **Basidia** 42.9–45.8 × 9.9–11.3 μm; av. 44.3 × 10.9 μm; thin-walled clavate, hyaline in KOH; tetra-spored. **Cheilocystidia** 83.7–93.2 × 23.1–25.9 μm; av. 86.7 × 23.4 μm; polymorphic, thick-walled, metuloid, often crystalliferous at apex; utriform to fusiform, pedicellate or spheropedunculate. **Pleurocystidia** 81.3–92.2 × 19.7–21.4 μm; av. 85.2 × 20.4 μm; hyaline, thick-walled, crystalliferous at apex. **Pileipellis** hyaline, thin-walled, filamentous, septate, branched hyphae without clamps with 7.5–13.6 μm width. **Stipitipellis** hyaline, thin-walled, filamentous, septate, branched and clampless hyphae with 4.1–10.1 μm width.

Holotype

Pakistan Province Khyber Pakhtunkhwa (KP): District Upper Dir, Kumrat Valley, Lamleek Forest, under *Cedrus deodara* (Roxb. ex D. Don) G. Don woods, humus-rich soil, 28 July 2023, coll. R. Amanat, A. U. M. Zain & M. Hanif (Holotype: **MH-PFK 102**, Department of Botany, GC University Lahore, Pakistan). GenBank: ITS = PX113226.

MycoBank: MB860483

Phylogenetic analysis: A total of 54 ITS rDNA sequences were evaluated, including 53 from NCBI GenBank (Tables 1 and 2). The data matrix consisted of 1141 unambiguously aligned nucleotide positions (301 conserved, 667 variable, 552 parsimony-informative, 111 singletons). A BLAST search of the proposed *Inocybe sineofibulae* sequences showed 89.93% similarity with *Inocybe cryptica* (PQ279576). The specimen analyzed formed a distinct branch in the phylogenetic tree.



Fig. 1. A-D: Basidiomata of *Inocybe sineofibulae* sp. nov.; A. Basidiomatas, B. Pileus Surface C. gills, D. Stipe.

Table 1. Morpho-anatomical comparison of *Inocybe sineofibulae* sp. nov. with closely related species (*I. cryptica*, *I. muricellata*, *I. flocculosa*, and *I. rufuloides*).

Taxon	Habitat	Morphological characters	Anatomical characters	References
<i>Inocybe sineofibulae</i> sp. nov.	Kumrat valley, KPK, in leaf litter under Deodar forest	Pileus: 1.8–2.3 cm, pale brown, fibrillose. Lamellae: Dull orange, regular, crowded (2–3 mm wide), edges even. Stipe: 3.14–5.6 cm × 0.4 cm, terete, equal, striate, fibrillose, slightly clavate at basal tomentum.	Basidiospores: 11.2–11.5(11.3) × 7.2–7.6(7.4) μm, avL × avW = 11.3 × 7.4 μm; elliptical to amygdaliform. Basidia: 42.9–45.8(44.3) × 9.9–11.3(10.9) μm, 44.3 × 10.9 μm; hyaline; thin-walled; clavate; tetraspored. Cheilocystidia: 83.7–93.2(86.7) × 23.1–25.9(23.4) μm, avL × avW = 86.7 × 23.4 μm; hyaline; metuloid with crystalliferous apex; utriform; thick-walled. Pleurocystidia: 81.3–92.2(85.2) × 19.7–21.4(20.4) μm, avL × avW = 85.2 × 20.4 μm; polymorphic; crystalliferous apex.	In Present study
<i>I. cryptica</i>	Spain, sandy soil, under Quercus ilex	Pileus: 13–30 mm, conical, brown to greyish brown, fibrillose-lanose surface. Lamellae: Moderately crowded, narrowly adnate, brownish; edges irregular, fimbriate, concolorous. Stipe: (20–40 × 2–7 mm), cylindrically curved, base with whitish tomentum, no darkening on drying. Pileipellis: Parallel hyphae (4–7 μm wide). Clamp connections: Abundant.	Basidiospores: 7.7–11.3 × 4.5–6.4 μm; smooth; (sub) amygdaloid to ellipsoid. Basidia: (27–36 × 7–11 μm); predominantly tetraspored. Pleurocystidia: 58–86 × 9–18 μm; narrow (sub) fusiform.	Bandimi <i>et al.</i> , 2022
<i>I. muricellata</i>	Burnham Beeches, Bucks, UK Under broadleaved trees, calcareous soil.	Pileus: 10–20(30) mm, applanate; disc smooth then roughened; orange-ochre brown. Gills: Ventricose at maturity, pale ochre with orange tint. Stipe: 30 × 3–4 mm, cylindrical; swollen; fine white pruina throughout.	Basidiospores: 10–12 × 5–6 μm; smooth; amygdaliform with small apiculus. Basidia: Predominantly 4-spored. Hymenial cystidia: 60–68 × 12.5 μm; clavate; thin-walled.	Cullington, 2010
<i>I. flocculosa</i>	Chuwarta, District Suliamanyia North Iraq Gregariously growing among leaf litter in mixed forest of Quercus spp.	Pileus: 20–25 mm, small, fibrous; slightly umbonate; pale brown. Gills: Adnexed, pale brown, crowded. Stipe: 40–60 × 3.0–3.8 mm, cylindrical; pruinose; bent at bulbous base.	Basidiospores: 8.0–11.25 × 5.5–6.5 μm; amygdaliform, smooth, light brown. Basidia: 20–25 × 6.25–7.5 μm; 4-spored. Cheilocystidia & Pleurocystidia: Similar, (90.6–112.0 × 20–25 μm); hyaline, fusiform, apical crystals.	Sara <i>et al.</i> , 2017
<i>I. rufuloides</i>	Western Australia, Jandakot Regional Park, Thomas Rd, Oakford, roadside edge near Pinus spp.	Pileus: 5–35 mm, convex to conico-campanulate; margin plane with whitish appendiculate remnants; dry, fibrillose. Gills: Broadly adnexed, crowded. Stipe: 50 × 8 mm, cylindrical; longitudinally silky-fibrillose.	Basidiospores: 11–12.5(13) × 5.5–6.5 μm; ellipsoid to subamygdaliform; thick-walled. Basidia: 25–37 × 8.5–11.5 μm; quadrisporic; clavate. Pleurocystidia: 53–75 × 14–17 μm; lageniform, crystalliferous; thick-walled. Cheilocystidia: 20–56 × 11–15.5 μm; thin-walled. Clamp connections: Present.	Bougher and Matheny 2011

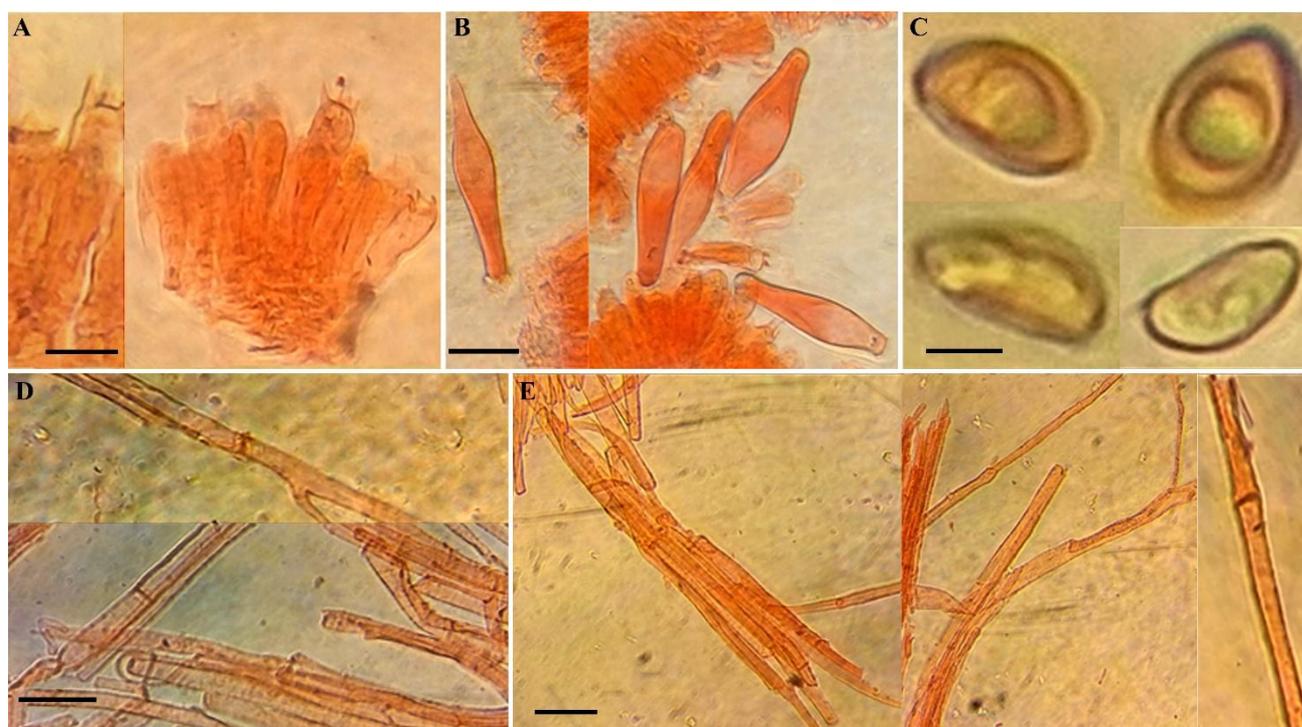


Fig. 2. Micrographs of *Inocybe sineofibulae* sp. nov. Anatomic features. A. Basidia, B. Cystidia, C. Basidiospores, D. Pileipellis, E. Stiptipellis.

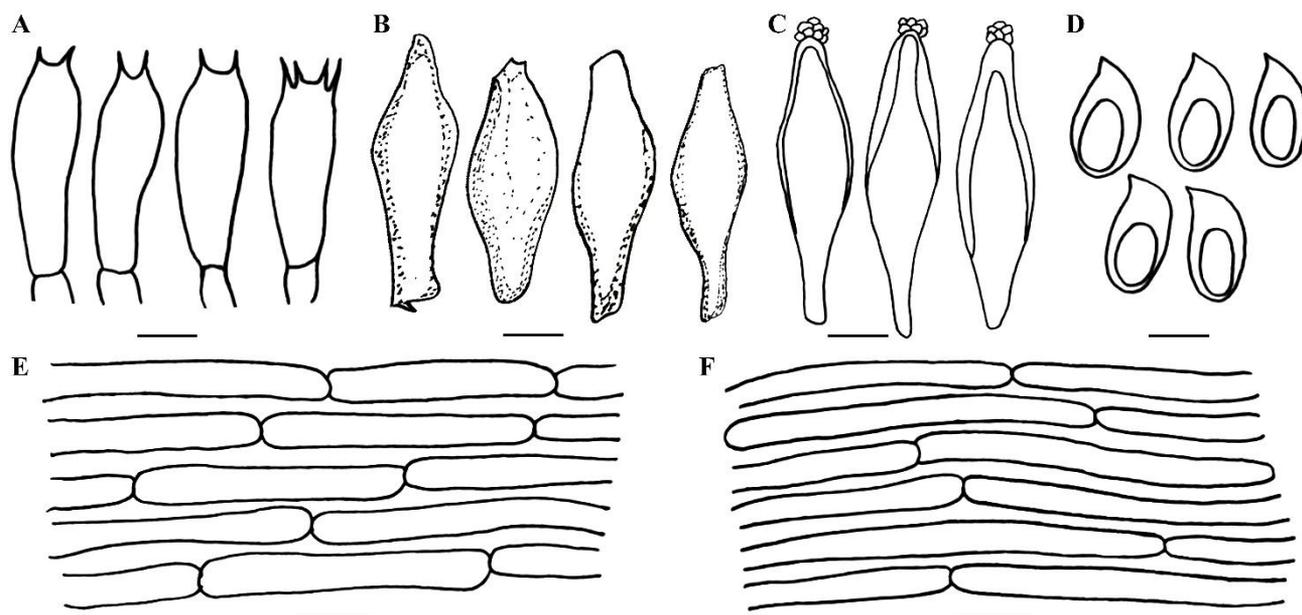


Fig. 3. Line Drawings of Microscopic features of *Inocybe sineofibulae* sp. nov. A. Basidia, B. Cheilocystidia, C. Pleurocystidia, D. Basidiospores, E. Pileipellis, F. Stiptipellis
Scale Bars: A=1.15cm, B=2.54 μ m, C=7.32 μ m, D=5.58 μ m, E=2.0 μ m, F=2.04 μ m,

Discussion

Inocybe sineofibulae is morphologically comparable to several species in sect. *Marginatae*, particularly *I. cryptica*, *I. muricellata*, *I. flocculosa*, and *I. rufuloides*. It resembles *I. cryptica* in its small basidiomata and smooth, ellipsoidal spores (Bandini *et al.*, 2022), but differs by having larger amyloid spores (11.2–11.5 \times 7.2–7.6 μ m vs. 7.7–11.3 \times 4.5–6.4 μ m), significantly larger cystidia (up to 93 μ m vs. 68 μ m), and the absence of clamp connections, which are abundant in *I. cryptica*. Compared with *I. muricellata*, the new species has larger spores (up to 11.5 μ m vs. 10–12 \times

5–6 μ m) and much larger cystidia (83–93 \times 23–26 μ m vs. 60–68 \times 12.5 μ m). From *I. flocculosa*, which has smaller spores (8.0–11.25 \times 5.5–6.5 μ m) and a bent bulbous stipe base (Sara *et al.*, 2017), *I. sineofibulae* is readily separated by its straight striate stipe and strongly amyloid, larger spores. Finally, *I. rufuloides* possesses smaller cystidia (53–75 \times 14–17 μ m) and clamp connections (Bougher and Matheny 2011), both absent in *I. sineofibulae*. This unique combination of larger amyloid spores, exceptionally large metuloid cystidia, and lack of clamp connections provides strong evidence for the recognition of *I. sineofibulae* as a distinct species.

Beyond morphology, the discovery of *I. sineofibulae* highlights the underexplored mycological richness of Hinduush moist temperate forests. These forests, dominated by conifers such as *Cedrus deodara* and *Pinus wallichiana* (A.B. Jacks.) provide ideal substrates for ectomycorrhizal fungi, which in turn play critical roles in nutrient cycling, forest regeneration, and ecosystem stability (Ali *et al.*, 2021). As *Inocybe* species are well-known ectomycorrhizal partners of Fagaceae, Pinaceae, and Salicaceae, the presence of *I. sineofibulae* in association with Himalayan conifers emphasizes its potential ecological importance in sustaining forest health under changing climatic conditions.

This documentation of novel ectomycorrhizal species highlights significant contributions to SDG 15, which aims to cessation of biodiversity destruction by protecting ecosystems and encouraging the conservation of endemic species. This finding also aligns with recent explorations of new *Inocybe* taxa from different regions of Pakistan, including *I. crenata* (Ashraf *et al.*, 2025) and *I. quercicola* (Khan *et al.*, 2022). Together, these studies indicate that the Himalayan and sub-Himalayan regions harbor a cryptic diversity of ectomycorrhizal fungi that remain poorly characterized. Integrative taxonomic approaches, combining morphology with multilocus phylogenetics, are therefore essential to unravel the true diversity and ecological significance of *Inocybe* in Pakistan.

Table 2. *Inocybe* sequences used for phylogenetic analyses; species name, geographical origin, voucher information & GenBank accession numbers (ITS region) are included.

Taxon	Geographical area	Voucher	Genbank Accession number of ITS	References
<i>Inocybe cryptica</i>	Europe	MA-Fungi 98674	ON010593	Bandini <i>et al.</i> , 2022
<i>I. flocculosa</i> var. <i>flocculosa</i>	Canada	UBC:F19292	HQ604516	Berbee <i>et al.</i> , 2010
<i>I. cryptica</i>	Europe	MA-Fungi 98672	ON010592	Bandini <i>et al.</i> , 2022
<i>I. muricellata</i>	Europe	DB16-10-11-2	MW856432	Bandini <i>et al.</i> , 2022
<i>I. muricellata</i>	Europe	STU:SMNS-STU-F-0900985	MW845931	Bandini <i>et al.</i> , 2022
<i>I. cf. microspora</i>	Europe & North America	TAA185187	AM882808	Ryberg <i>et al.</i> , 2008
<i>I. rufuloides</i>	Australia	PERTH7700598	JN035292	Bougher and matheny 2011
<i>I. rufuloides</i>	Australia	NLB00618	JN035291	Bougher and matheny 2011
<i>I. nitidiuscula</i>	Italy	voucher 80	JF908088	Osmundson <i>et al.</i> , 2013
<i>I. tarda</i>	France	EL23506	FN550920	Ryberg <i>et al.</i> , 2009
<i>I. pseudodistricta</i>	Italy	voucher 16041	JF908157	Osmundson <i>et al.</i> , 2013
<i>I. rufuloides</i>	Italy		DQ067579	Bougher and matheny 2011
<i>I. flocculosa</i> var. <i>flocculosa</i>	Canada	UBC:F19374	HQ604506	Berbee <i>et al.</i> , 2010
<i>I. oblectabilis</i>	Sweden	BJ920908	AM882831	Ryberg <i>et al.</i> , 2008
<i>I. flocculosa</i> var. <i>flocculosa</i>	Canada	UBC:F19087	HQ604464	Berbee <i>et al.</i> , 2010
<i>I. pseudodistricta</i>	Canada	UBC:F19094	HQ604460	Berbee <i>et al.</i> , 2010
<i>I. pseudodistricta</i>	Canada	UBC:F19009	HQ604530	Berbee <i>et al.</i> , 2010
<i>I. squamata</i>	Sweden	J85048	AM882778	Ryberg <i>et al.</i> , 2008
<i>I. squamata</i>	Sweden	TK96109	AM882780	Ryberg <i>et al.</i> , 2008
<i>I. squamata</i>	Italy	16576	JF908162	Osmundson <i>et al.</i> , 2013
<i>I. umbrinella</i>	North Europe	JV17954	FJ904166	Larsson <i>et al.</i> , 2009
<i>I. umbrinella</i>	Sweden	F14488	HM209796	Larsson <i>et al.</i> , 2009
<i>I. umbrinella</i>	North Europe	JV13699	FJ904165	Larsson <i>et al.</i> , 2009
<i>I. nitidiuscula</i>	japan	TAKK 08.8.18.22-2	AB594843	Kobayashi & Courtecuisse, 2000
<i>I. nitidiuscula</i>	Italy	3665	JF908112	Osmundson <i>et al.</i> , 2013
<i>I. oblectabilis</i>	Italy	8458	JF908129	Osmundson <i>et al.</i> , 2013
<i>I. muricellata</i>	Sweden	KG980725	AM882916	Ryberg <i>et al.</i> , 2008
<i>I. muricellata</i>	Sweden	BJKGN980720	AM882917	Ryberg <i>et al.</i> , 2008
<i>I. cf. hirtella</i>	USA	PBM 2655	EU523582	Hughes <i>et al.</i> , 2010
<i>I. cf. hirtella</i>	USA	PBM 2624	EU523572	Hughes <i>et al.</i> , 2010
<i>I. cf. hirtella</i>	USA	PBM 2655	EU523583	Hughes <i>et al.</i> , 2010
<i>I. hirtella</i>	USA	PBM 2650	EU523581	Hughes <i>et al.</i> , 2010
<i>I. hirtella</i>	Norway	KH53	GU234131	Geml <i>et al.</i> , 2011
<i>I. hirtella</i>	Norway	KH52	GU234122	Geml <i>et al.</i> , 2011
<i>I. cf. glabripes</i>	Sweden	EL10805	AM882794	Ryberg <i>et al.</i> , 2008
<i>I. margaritispora</i>	Italy	5050	JF908120	Osmundson <i>et al.</i> , 2013
<i>I. praetervisa</i>	France	PAM01043008	HQ586860	Geml <i>et al.</i> , 2011
<i>I. praetervisa</i>	Canada	UBC:F19231	HQ604598	Berbee <i>et al.</i> , 2010
<i>I. praetervisa</i>	Canada	UBC:F19317	HQ604596	Berbee <i>et al.</i> , 2010
<i>I. cryptocystis</i>	Sweden	BJ900914	AM882906	Ryberg <i>et al.</i> , 2008
<i>I. praetervisa</i>	Italy	5052	JF908121	Osmundson <i>et al.</i> , 2013
<i>I. glabripes</i>	Sweden	BJ940922	AM882807	Ryberg <i>et al.</i> , 2008
<i>I. cf. glabripes</i>	Denmark	MC01-510	AJ889952	Ryberg <i>et al.</i> , 2008
<i>I. glabripes</i>	Finland	TAA145067	AM882902	Ryberg <i>et al.</i> , 2008
<i>I. kohistanensis</i>	Pakistan	LAH35024	KT897911	Jabeen <i>et al.</i> , 2016
<i>I. kohistanensis</i>	Pakistan	LAH35002	KP316244	Jabeen <i>et al.</i> , 2016
<i>I. kohistanensis</i>	Pakistan	LAH35003	KP316245	Jabeen <i>et al.</i> , 2016
<i>I. kohistanensis</i>	Pakistan	LAH35001	KP316243	Jabeen <i>et al.</i> , 2016
<i>I. quercicola</i>	Pakistan	LAH	MW412768	Khan <i>et al.</i> , 2022
<i>I. quercicola</i>	Pakistan	HUP32966	MK368637	Khan <i>et al.</i> , 2022
<i>I. quercicola</i>	Pakistan	FA167	MN812171	Khan <i>et al.</i> , 2022

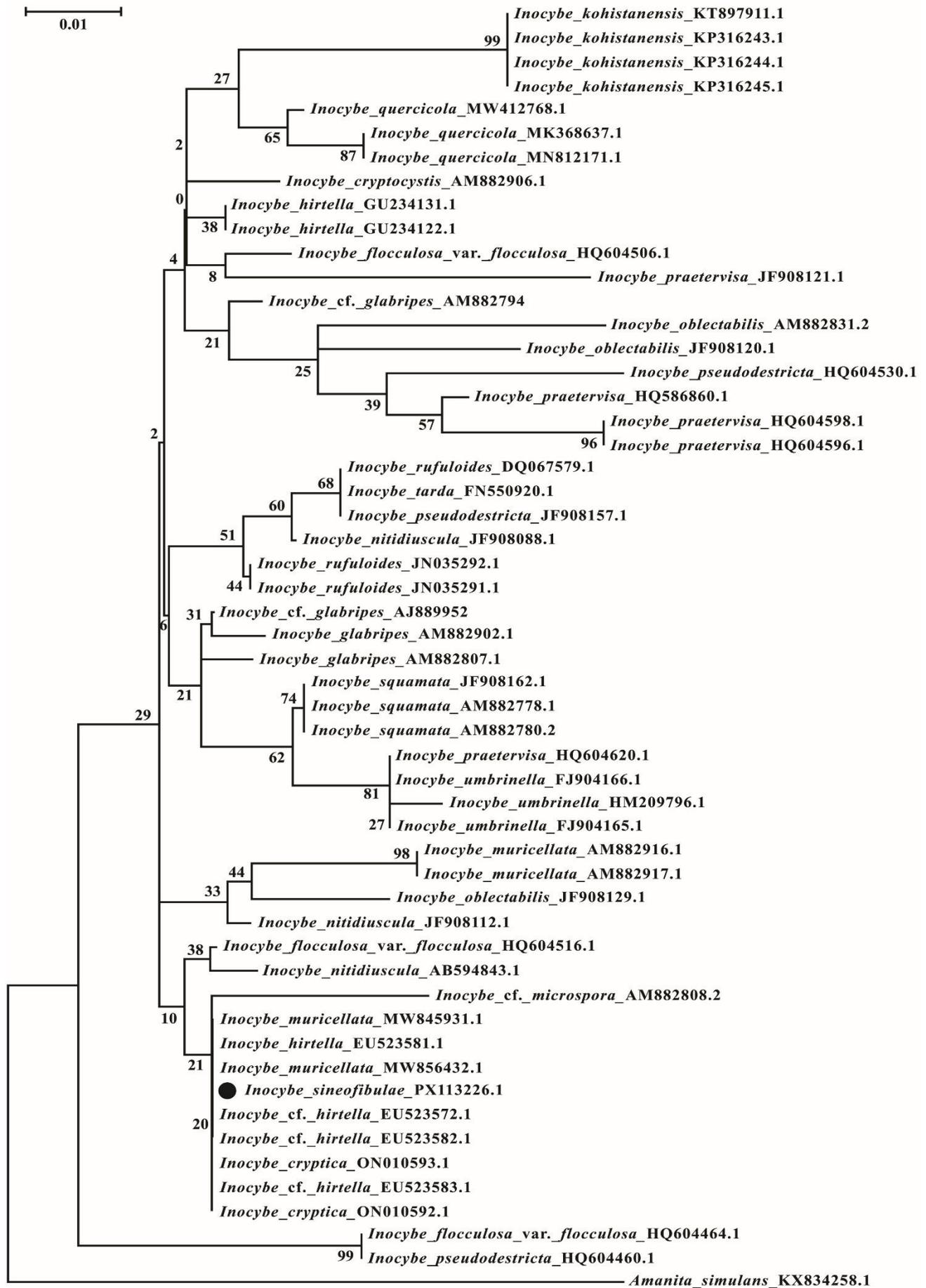


Fig. 4. Maximum Likelihood Phylogeny based on ITS sequences showing the placement of *Inocybe sineofibulae* sp. nov. within sect. *Marginatae*. Bootstrap support values ($\geq 70\%$) are indicated at nodes. *Amanita simulans* was used as the outgroup.

Conclusion

Inocybe sineofibulae sp. nov. is distinguished by its unique morphological features and phylogenetic distinctness within sect. *Marginatae*. Its discovery from Himalayan coniferous forests underscores the ecological importance of ectomycorrhizal fungi in these ecosystems and highlights Pakistan as a reservoir of cryptic fungal diversity. Continued integrative taxonomic work is essential for documenting and conserving this underexplored mycobiota. Ultimately, this research work supports the overarching mission of SDG 17 (Partnership for the Goals) by providing a foundational taxonomic resource that enables future international collaborative research on fungal conservation, ecology and biogeography. It is recommended that monitoring of Lamleek Forest ecosystem be implemented to conserve this taxon and its unique habitat.

Acknowledgements

The authors are grateful to the Office of Research, Innovation, and Commercialization (ORIC) at **GC University Lahore** and Higher Education Commission of Pakistan for their financial and administrative support under the NRP Grant No. 17613, which was instrumental in facilitating this research.

Conflict of Interest: The authors declare no conflict of interest.

Authors' Contribution: Rizwan Amanat planned field work, collected specimens, conducted morpho-anatomical analysis and drafted the majority of the manuscript. Served as the primary point of contact for journal communication. Dr. Muhammad Hanif overall supervised the lab work and secured funding for the research. Atta Ull Mustafa Zain remained a key participant in fieldwork. Zubaria Ashraf provided the detailed description of ecology and geography of the sampling site. Sammar Bashir did phylogenetic analysis. Dr. Nousheen Yousaf contributed to manuscript preparation. Dr. Samina Sarwar reviewed the data interpretation.

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