Current Research in Environmental & Applied Mycology (Journal of Fungal Biology)
15(1): 287–299 (2025) ISSN 2229-2225
www.creamjournal.org **Article**
Doi 10.5943/cream/15/1/19

Taxonomic delineation and phylogenetic characterization of four species of *Ganoderma* Karst. from India

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Kaur A, Kaur R, Joshi T, Singh AP, Arora S, Dhingra GS, Singh R 2025 – Taxonomic delineation and phylogenetic characterization of four species of *Ganoderma* Karst. from India. Current Research in Environmental & Applied Mycology (Journal of Fungal Biology) 15(1), 287–299, Doi 10.5943/cream/15/1/19

Abstract

Ganoderma Karst., is a cosmopolitan genus of the polyporoid wood rotting fungi. The genus has attracted the mycologists, biotechnologists and experts from other fields due to its unique combination of morphological characters and use in antioxidative, anti-inflammatory, anticancer and other nutraceutical purposes worldwide. During the fungal forays carried out in different localities of northwestern India, many specimens of the genus were collected. The current publication presents an illustrated account of four species of the genus *Ganoderma* based on taxonomic and ITS sequence-based phylogenetic analysis. These four Indian *Ganoderma* species; *Ganoderma casuarinicola* J.H. Xing, B.K. Cui & Y.C. Dai, *G. destructans* M.P.A. Coetzee, Marinc. & M.J. Wingf., *G. enigmaticum* M.P.A. Coetzee, Marinc., M.J. Wingf. and *G. multipileum* Ding Hou, have been described based on specimens gathered from various regions of Punjab and Himachal Pradesh (India). Among these species, *G. casuarinicola* and *G. destructans* are new records for India, while *G. enigmaticum* and *G. multipileum* are new reports for the state of Punjab. This study accentuates the taxonomic richness of *Ganoderma* in India, particularly Punjab state. The combination of morphological and molecular analyses further adds to the species identification. It affirms the vital role of integrative taxonomy in illuminating India's fungal heritage.

Keywords – *Basidiomycota* – macrofungi – medicinal mushroom – polypore – taxonomy

Introduction

Ganoderma is a widely distributed genus of polyporoid fungi placed in the family *Polyporaceae*, order *Poyporales*, class *Agaricomycetes* of phylum *Basidiomycota* (Wasser & Weis 1999). *Ganoderma* is widely distributed across tropical, subtropical and temperate regions of the world (Luangharn et al. 2021). Ecologically, the members of this genus play an important role in the decomposition of lignin, which forms a crucial step in the nutrient recycling. These fungi have also been reported with a significant amount of bioactive compounds which have been used for edible, medicinal, nutraceutical and bioremediation purposes (Mayirnao et al. 2025).

The genus is characterized by an exceptional amalgamation of macro and micro-morphological characters, such as annual to perennial, sessile to sub-stipitate to stipitate

Submitted 04 August 2024, Accepted 20 November 2025, Published 09 December 2025
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basidiocarps with laccate or non-laccate pilear surface. Several species are characterized (subgenus-*Ganoderma*) by having a pileus cuticle, formed of different types of elements. The basidiospores are ellipsoid to broadly ellipsoid to ovoid, truncate and double-walled. The outer wall is smooth and hyaline, whereas the inner wall is usually brown and ornamented, the latter distinguished by the presence of individual inner-wall pillars, marking a deliberate separation between them (Ryvarden 2004).

The taxonomy of the genus *Ganoderma* is quite challenging and has been a subject of debate for a long time. The classical approach included consideration of morphological characters and the type of host for species identification (Ryvarden & Melo 2014). However, the DNA sequence-based molecular phylogenetic analysis indicated the polyphyletic nature of species recognised based on morphology and host (Fryssouli et al. 2020, Sun et al. 2022, Mardones et al. 2023). The combination of critically studied morphological features and DNA sequence-based molecular phylogenetic analysis is instrumental in solving many of the issues related to the taxonomy of the genus. The correct identification and classification of the species of this genus are quite important, particularly from the angle of their use in the medicinal system. As far as India is concerned, only a limited number of species have been identified on the basis of a polyphasic approach. The phylogenetic analysis is also needed to trace the evolutionary relationships between species.

Comprising 194 valid legitimates according to Mycobank (2024) and 218 authentic legitimate names according to Species Fungorum (2024), this genus stands out as unique with its vast species diversity. In India, the genus holds 58 legitimate taxa, among them 12 species have been described from Punjab, India (Kaur et al. 2017). Considering the above mentioned points, the present studies on the diversity of the genus *Ganoderma* from the Punjab and Himachal Pradesh states of India were planned and executed. In this study, based upon the exhaustive fungal collecting sessions conducted in different parts of the area of investigation during the monsoon seasons of 2016–2022, four *Ganoderma* species, namely, *G. casuarinicola*, *G. destructans*, *G. enigmaticum* and *G. multipileum* are described and illustrated below. Further, their molecular phylogeny has also been discussed.

Materials & Methods

Preliminary & microscopic examination

The states of Punjab and Himachal Pradesh were selected as the study area because of the availability of subtropical to temperate conditions. Both the states, particularly the regions with mature forest/tree vegetation, were thoroughly surveyed for the collection of basidioma specimens. On being located, the specimens were photographed in the field with the help of a Digital Single-Lens Reflex camera. Both the pilear and hymenial surfaces were photographed to record their morphological characters in the field. Basidiomas were collected from the substrate with the help of a hammer and chisel. The collected specimens were removed of any extraneous matter and were packed in the brown paper envelopes with a collection number. The information regarding vegetation type, host, attachment pattern, and locality was recorded. The specimens were brought to the field laboratory and details about the nature, and arrangement of the pilei, colour and nature of the pilear and hymenial surface and margins, were observed carefully. The colour standards referred to are as per Kornerup & Wanscher (1978). The specimens were dried either in the sun or in an electric dryer. The dried specimens were again packed in brown paper envelopes and brought to the permanent laboratory situated within the Department of Botany at Punjabi University, Patiala, that served as the primary hub for conducting microscopic examinations. The focus of these investigations centered on microscopic preparations, involving both crush mounts and free-hand cut sections of the basidioma portion. These specimens were scrutinized using a range of chemical reagents, including 3% KOH, 5% KOH, 10% KOH, 1% congo red in water, 1% phloxine in water, 1% cotton blue in lactophenol, and Melzer's reagent (0.5gm Iodine, 1.5gm KI, 20gm Chloral hydrate, and 20ml distilled water). Utilizing a compound microscope, detailed observations were made concerning the characteristics of hyphae, basidia, basidiospores, and sterile structures.

Various combinations of the eyepiece and objective magnifications (10x × 10x, 10x × 40x, and 10x × 100x) were employed for comprehensive analysis. The use of a camera lucida facilitated the precise measurements and drawing of the outline of the microscopic structures within the specimens.

DNA extraction and sequencing

Genomic DNA was extracted from the dried basidioma portion employing the CTAB method following the protocol outlined by Doyle & Doyle (1990). Subsequently, the quality of DNA was scrutinized via 1% Agarose gel electrophoresis. The genomic DNA was subjected to amplification using ITS1 (TCCGTAGGTGAACCTGCGG) and ITS4 (TCCTCCGCTTATTGATATGC) primers in a PCR setup. The PCR reactions were performed in a 50 µl reaction volume containing 34 µl PCR grade water (Sigma), 2.5 µl of the genomic DNA, 5.0 µl of 10X reaction buffers, 2.5 µl of 10mM dNTPs, 2.5 µl of each reverse and forward primers, 1 µl (5 U/µl) of Taq DNA polymerase (Sigma-Aldrich). The PCR cycling conditions were set with an initial denaturation at 95°C for 5 min and subjected to 35 cycles of the program as 94°C for 30 seconds, 55°C for 1 minute, 72°C for 2 minutes and final extension at 72°C for 10 minutes. The resulting amplified DNA fragments were sequenced by Biokart India Pvt. Ltd., Bengaluru (Karnataka, India). Further, the obtained sequences were subjected to comprehensive BLAST analysis via the official website of NCBI.

Results

Phylogenetic analysis

The ITS based phylogenetic analysis distinctly resolves the evolutionary tendencies among the four *Ganoderma* species studied, *G. casuarinicola*, *G. destructans*, *G. enigmaticum*, and *G. multipileum* with the well supported clades, each of them aligned with their closely related taxonomic identities, thus validating their evolutionary relationships as well as their genetic distinctness among the *Ganoderma* species. The topology encompasses the Bayesian inference employing over 120 representatives of the *Ganoderma* taxa, which provide the bootstrap and posterior probability values to confer the resolution in lineage divergence (Figure 1). In order to provide the directional evolution among the species of *Ganoderma*, *Amauroderma rude* and *A. rugosum* are considered as outgroups for the phylogeny to be rooted. The tree efficiently delineates the majority of the clades with *Ganoderma*, thus establishing the close affiliations among the related interspecific taxa for the phylogenetic placements of the species to be clarified. The specific nodal values further assure the genetic coherence within this cluster. The phylogeny explains that though *Ganoderma casuarinicola* (OQ119634), *G. destrctans* (OQ119636), *G. enigmaticum* (OQ119630), and *G. multipileum* (OQ119635) share a close evolutionary affinity, the related taxa demarcates the evolutionary distinct branches. Hence the phylogeny illustrates a distinct demarcation within *Ganodermataceae*, in order to affirm the monophyly of *Ganoderma* and its related genera. This comprehensive analysis not only reinforces the systematic placement of these taxa but also enriches the broader understanding of *Ganoderma* phylogeny, offering valuable insights into species boundary and evolutionary trajectory within this ecologically and medicinally important genus.

Ganoderma casuarinicola J.H. Xing, B.K. Cui & Y.C. Dai, MycoKeys 34: 100, 2018. Fig. 2

Index Fungorum 823321

Macroscopic description – Basidioma annual, pileate, pilei up to 14.5 × 12.7 × 0.8 cm, solitary, rosulate, stipitate; stipe up to 8.7 × 5.5 cm, eccentric; subcylindrical, flexuous, solid, laccate. Abhymenial surface laccate, glabrous, brown (6E8) to dark brown (6F7) when fresh, not changing much upon drying; margin obtuse, yellowish white (2A2) to light brown (6D8) to paler concolorous. Hymenial surface poroid, yellowish white (2A2) to greyish brown (6F3) when fresh, not changing much upon drying; margin yellowish white (2A2), sterile up to pore with 6 mm. Pores 4–6 per mm, suborbicular; dissepiments thin, entire; pore tubes greyish brown (6F3) to brown

(6E8), up to 3 mm in thickness. Context duplex, concentrically zonate; light brown (6D8) on abhymenial side, up to 3.5 mm in thickness; dark brown (6F7) on hymenial side, fibrous, up to 1.5 mm in thickness.

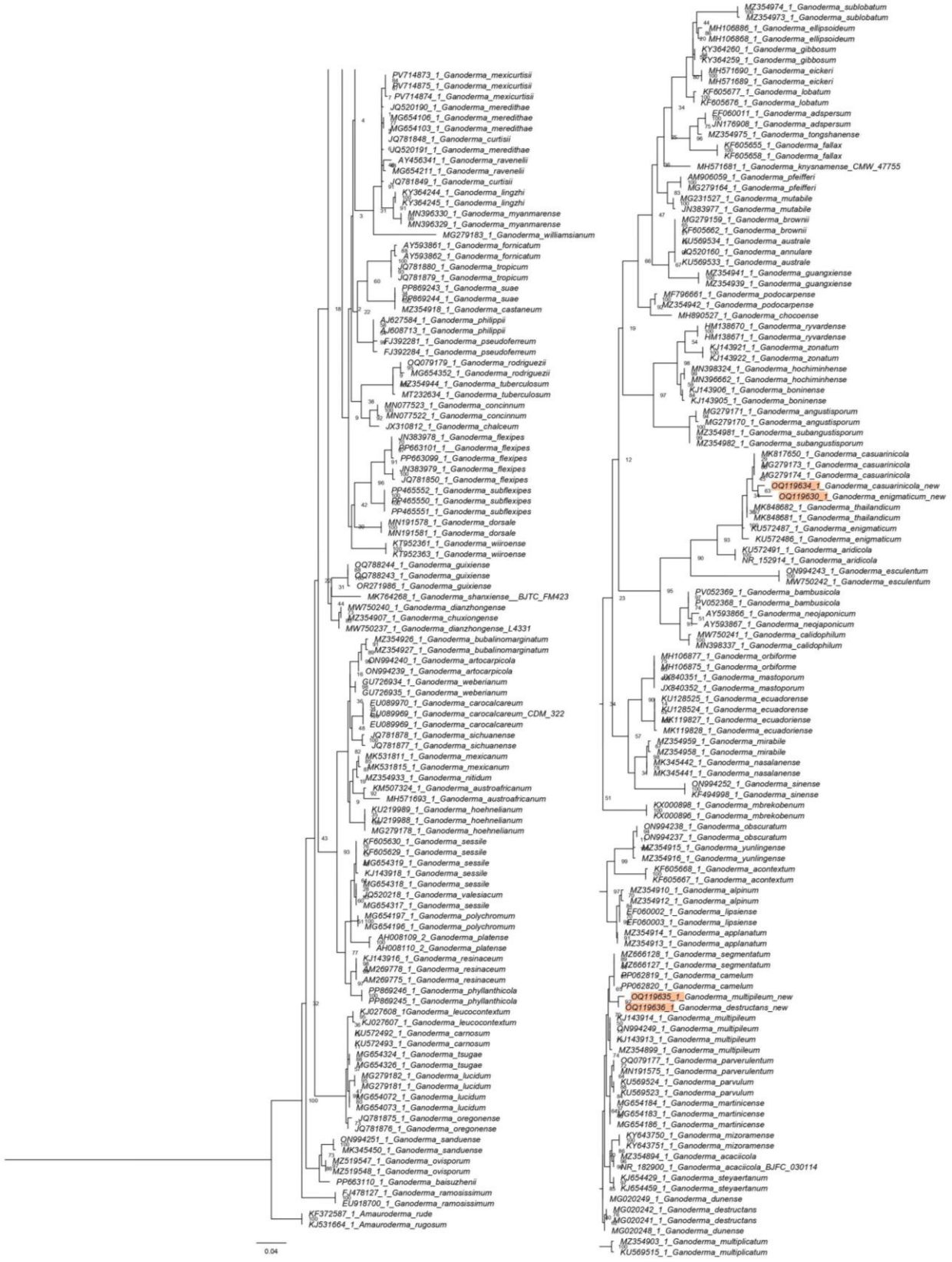

Fig. 1 – Phylogenetic relationships among *G. casuarinicola*, *G. destructans*, *G. enigmaticum* and *G. multipileum* from India using ITS rDNA sequence and *Amanita muscaria* was used as an outgroup taxon.

Microscopic description – Hyphal system trimitic; generative hyphae clamped, thin–walled, branched, subhyaline, smooth; skeletal hyphae pale yellowish to yellowish brown, thick–walled, lumen narrow, aseptate, rarely branched; binding hyphae subhyaline, thick–walled, lumen comparatively broader, profusely branched. Trama composed of generative, skeletal and binding hyphae; generative hyphae up to 2.5 µm thick; skeletal hyphae dominant, yellowish brown, up to 5.1 µm in thickness; binding hyphae up to 4.8 µm in thickness. Subhymenium generative hyphae up to 2 µm in thickness; skeletal hyphae up to 4.5 µm in thickness; binding hyphae up to 2.1 µm in thickness. Pilear crust hymenioderm; cuticular elements 19.3–30.1 × 7.5–9 µm, clavate, apex inflated, thick–walled, brown, wall shows no reaction in Melzer's reagent. Basidia not observed. Basidiospores 8.8–12 × 5.6–6.8 µm, ovoid to ellipsoid, truncate at apex, guttulate, thick–walled; exospore subhyaline, smooth; endospore thick, brown; two walls connected by inter-wall pillars; wall shows no reaction in Melzer's reagent but darkly stained in cotton blue.

Habitat – Roots of dried gymnospermous tree and trunk of *Dalbergia sissoo*.

Distribution – Beas town of Amritsar district of Punjab state and Batyuri village of Sirmaur district of Himachal Pradesh state (India).

Genbank number: OQ119634

Material examined – INDIA, Punjab, District Amritsar, Beas, on *Dalbergia sissoo* tree, 23 August 2021, *Avneet & Avneet* 12086 (PUN); Himachal Pradesh, District Sirmaur, Rajgarh, Batyuri, on the roots of a dried gymnospermous tree, 12 September 2016, *Ramandeep* 10782 (PUN).

Remarks – The peculiar features of this species are stipitate basidioma and cyanophilous basidiospores. Its identification is further supported by ITS sequence-based molecular phylogenetic analysis. This is the first report of the species from India. Earlier, it has only been described from China (Xing et al. 2018, Mycobank, 2024).

Ganoderma destructans M.P.A. Coetzee, Marinc. & M.J. Wingf., IMA Fungus 6 (1): 253, 2015 Fig. 3

Index Fungorum 812511

Macroscopic description – Basidioma annual, pileate; pilei up to 16 × 11.4 × 0.7 cm, solitary, applanate, dimidiate, stipitate; stipe up to 16.1 × 3.4 cm, eccentric to lateral, subcylindrical, flexuous, solid, laccate. Abhymenial surface strongly laccate, glabrous, brown (6E8) to violet brown (11F8) when fresh, not changing much upon drying; margin acute, yellowish white (2A2) to light brown (6D8) to paler concolorous. Hymenial surface poroid, yellowish white (2A2) to greyish brown (6F3) when fresh, not changing much upon drying; margin yellowish white (2A2) to light brown (6D8), sterile up to 2 mm. Pores 4–7 per mm, suborbicular; dissepiments thin, entire; pore tubes pale yellowish (2A3) to greyish brown (6F3), up to 1 mm in thickness. Context homogenous; concentrically zonate, light brown (6D8) to brown (6E8), fibrous, up to 6 mm in thickness.

Microscopic description – Hyphal system trimitic; generative hyphae clamped, thin–walled, branched, subhyaline, smooth; skeletal hyphae pale yellowish, thick–walled, lumen narrow, aseptate, rarely branched; binding hyphae subhyaline, thick–walled, lumen comparatively broader, profusely branched. Trama composed of generative, skeletal and binding hyphae; generative hyphae up to 3.1 µm in thickness; skeletal hyphae dominant, up to 6.5 µm in thickness; binding hyphae up to 4.2 µm in thickness. Subhymenium generative hyphae up to 2.2 µm in thickness; skeletal hyphae up to 4.8 µm in thickness; binding hyphae up to 3.1 µm in thickness. Pilear crust hymenioderm; cuticular elements 27.5–37 × 7.5–9 µm, subclavate, apex inflated, thick–walled, brown, wall shows no reaction in Melzer's reagent. Basidia not observed. Basidiospores 9.5–12.5 × 6–8 µm, ovoid to ellipsoid, truncate at apex, guttulate, thick–walled; exospore subhyaline, smooth; endospore thick, brown; two walls connected by inter-wall pillars; wall shows no reaction in Melzer's reagent and cotton blue.

Habitat – An angiospermous tree.

Distribution – Bassi Pathana town of Fatehgarh district of Punjab state (India)

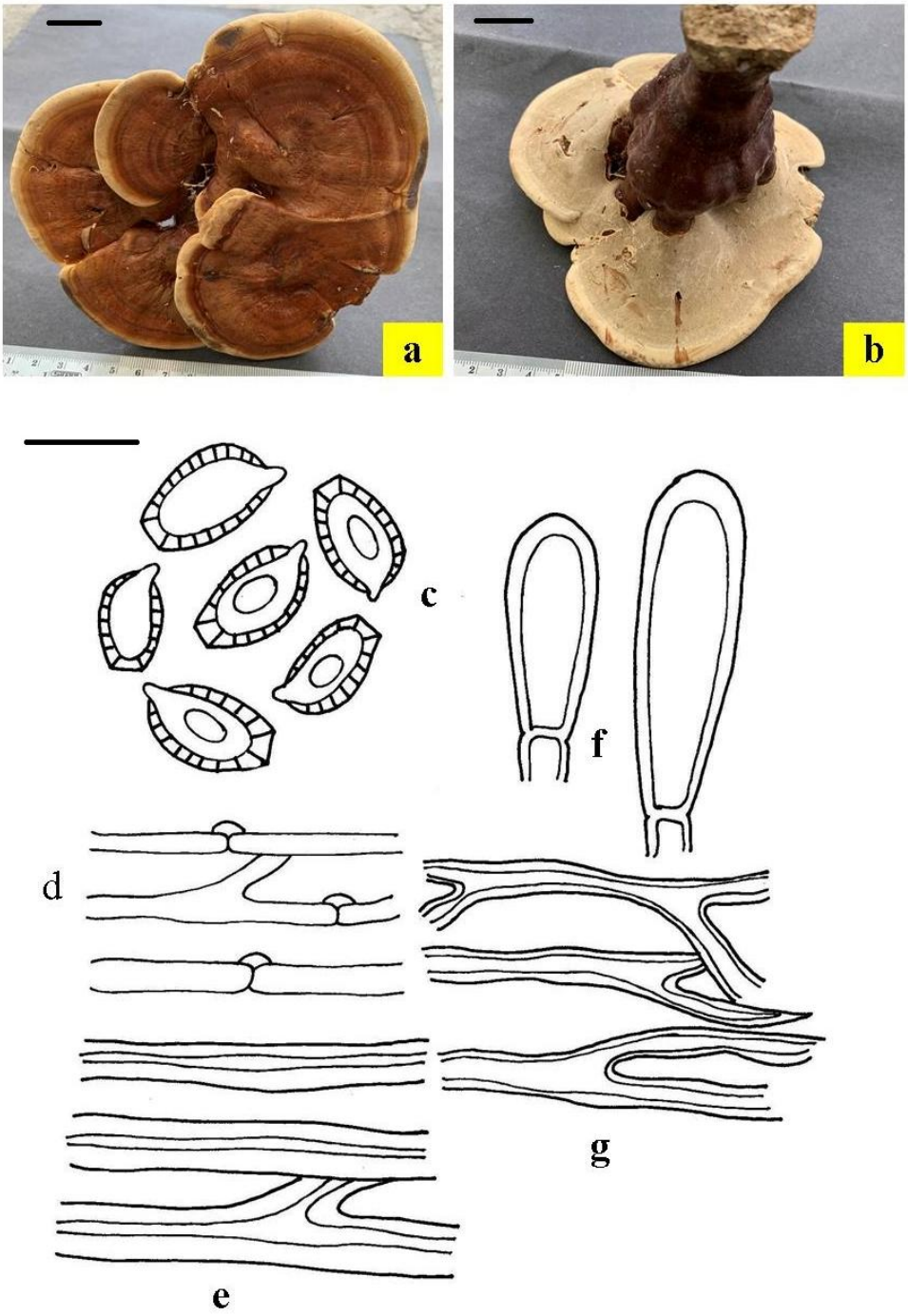

Fig. 2 – *Ganoderma casuarinicola* (12086 PUN) a Basidioma showing abhymenial surface. b Basidioma showing hymenial surface. c basidiospores. d generative hyphae. e skeletal hyphae. f cuticular elements. g binding hyphae. Scale bars: a, b = 2cm. c - g = 10 µm. del. Avneet Kaur (c-g). Photo Avneet Kaur (a-b).

Genbank number: OQ119636

Material examined – INDIA, Punjab, District Fatehgarh Sahib, Bassi Pathana town, on an angiospermous tree, 28 August 2019, Avneet & Avneet 12090 (PUN).

Remarks - This species is characteristic of having strongly laccate basidioma and long stipe. The identification of this species is further supported by ITS sequence-based phylogenetic analysis. It has earlier been described from South Africa (Coetzee et al. 2015, Mycobank 2024).

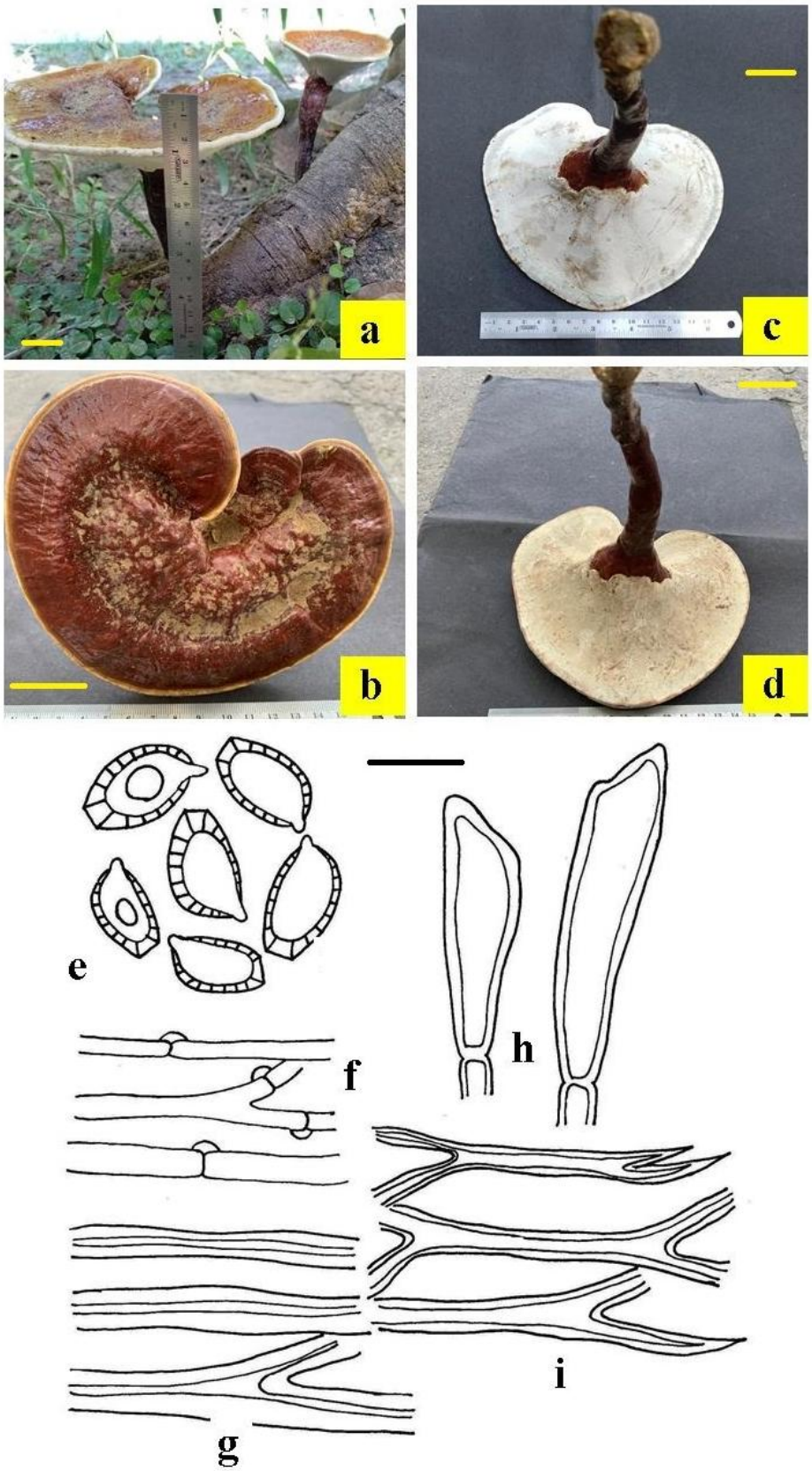

Fig. 3 – *Ganoderma destructans* (12090 PUN) a Basidioma showing abhymenial surface (fresh). b Basidioma showing abhymenial surface (dry). c Basidioma showing hymenial surface (fresh). d Basidioma showing hymenial surface (dry). e basidiospores. f generative hyphae. g skeletal hyphae. h cuticular elements. i binding hyphae. Scale bars: a = 2cm. b - d = 3cm. e - i = 10 µm. del. Avneet Kaur (e-i). Photo Avneet Pal Singh (a-d).

Ganoderma enigmaticum M.P.A. Coetzee, Marinc., M.J. Wingf., IMA Fungus 6 (1): 251, 2015 Fig. 4

Index Fungorum 812509

Macroscopic description – Basidioma perennial, pileate; pilei up to 8.7 × 6.9 × 1.6 cm, solitary, applanate, sessile. Abhymenial surface laccate, glabrous, yellowish white (2A2) to pale yellowish (2A3) when fresh, becoming yellowish brown (5E8) to dark brown (6F7) upon drying; margin obtuse, yellowish white (2A2) to paler concolorous. Hymenial surface poroid, yellowish white (2A2) when fresh, becoming greyish brown (6F3) to light brown (6D8) upon drying; margin yellowish white (2A2) to brown (6E8), sterile up to 4 mm. Pores 3–5 per mm, suborbicular; dissepiments thin, entire; pore tubes dark brown (6F7), up to 5 mm in thickness. Context homogenous; concentrically zonate, dark brown (6F7) to violet brown (11F8), corky, up to 1.1 cm in thickness.

Microscopic description – Hyphal system trimitic; generative hyphae clamped, thin–walled, branched, subhyaline, smooth; skeletal hyphae yellowish brown, thick–walled, lumen narrow, aseptate, rarely branched; binding hyphae subhyaline, thick–walled, lumen comparatively broader, profusely branched. Trama composed of generative, skeletal and binding hyphae; generative hyphae up to 2.8 µm in thickness; skeletal hyphae dominant, up to 4.5 µm in thickness; binding hyphae up to 4.2 µm in thickness. Subhymenium generative hyphae up to 2.5 µm in thickness; skeletal hyphae up to 4 µm in thickness; binding hyphae up to 3.4 µm in thickness. Pilear crust hymenioderm; cuticular elements 29.5–37 × 6.2–8 µm, subclavate, apex inflated, sometimes lobed, thick–walled, brown, wall shows no reaction in Melzer's reagent. Basidia not observed. Basidiospores 8.5–14.2 × 5.1–7.3 µm, ovoid to ellipsoid, truncate at apex, guttulate, thick–walled; exospore subhyaline, smooth; endospore thick, brown; two walls connected by inter-wall pillars; wall shows no reaction in Melzer's reagent and cotton blue.

Habitat – *Mangifera indica* tree.

Distribution – Dasuya Forest Division of Hoshiarpur district of Punjab state (India).

Genbank number: OQ119630

Material examined – INDIA, Punjab, District Hoshiarpur, Dasuya Forest Division, on *Mangifera indica*, 18 December 2018, *Avneet* 12091 (PUN).

Note – *Ganoderma enigmaticum* is characteristic in having perennial, laccate basidioma and ovoid to ellipsoid basidiospores. Vinjusha & Kumar (2022) described two specimens (ZGCVN73 & ZGCVN731) from Kerala as *G. enigmaticum*. However, the morphology of the basidioma does not match with the description of *G. enigmaticum* proposed by Coetzee et al. (2015). The authors seem to have misidentified the specimens only based on ITS sequence similarity. Further, the micro-morphological details shared by Vinjusha & Kumar (2022) are also not conclusive. The specimens submitted by Vinjusha & Kumar (2022) need serious scrutiny. The present description matches the description of *Ganoderma enigmaicum* proposed by Coetzee et al. (2015) except for some minor variations in dimensions. The identity of 12901 (PUN) is further supported by ITS sequence based molecular phylogenetic analysis. However, currently, it is being recorded as new to Punjab.

Ganoderma multipileum Ding Hou, Quarterly Journal of the Taiwan Museum 3: 101, 1950 Fig. 5

Index Fungorum 344109

Macroscopic description – Basidioma annual, pileate; pilei up to 12.5 × 8.9 × 0.9 cm, solitary, dimidiate, applanate, substipitate; stipe up to 2 × 5 cm, dorsolateral, flattened, solid, laccate. Abhymenial surface laccate, glabrous, concentrically zonate towards margin, yellowish white (2A2) to light brown (6D8) when fresh, becoming reddish brown (8E8) to brown (6E8) to pale yellowish (2A3) to yellowish white (2A2) upon drying; margin obtuse, yellowish white (2A2) to pale yellowish (2A3) to light brown (6D8) to paler concolorous. Hymenial surface poroid, yellowish white (2A2) to greyish brown (6F3) when fresh, becoming greyish brown (6F3) to light brown (6D8) upon drying; margin yellowish white (2A2) to light brown (6D8) to brown (6E8), sterile up to 4 mm. Pores 5–6 per mm, suborbicular; dissepiments thin, entire; pore tubes brown

(6E8) to greyish brown (6F3), up to 2 mm in thickness. Context homogenous; concentrically zonate, light brown (6D8) to dark brown (6F7), up to 7 mm in thickness

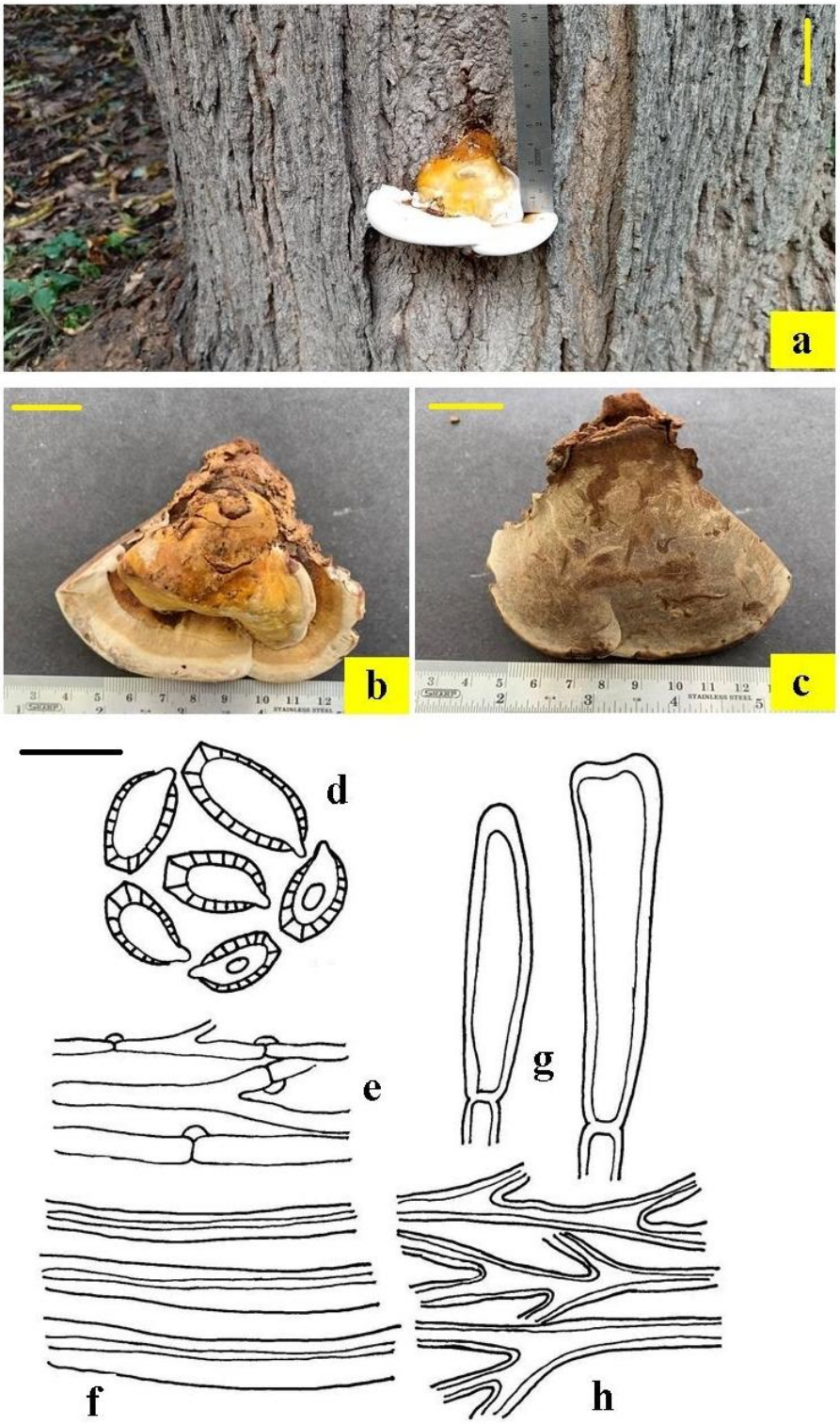

Fig. 4 – *Ganoderma enigmaticum* (12091 PUN) a Basidioma showing abhymenial surface (fresh). b Basidioma showing abhymenial surface (dry). c Basidioma showing hymenial surface (dry). d basidiospores. e generative hyphae. f skeletal hyphae g cuticular elements. h binding hyphae. Scale bars: a = 3cm. b – c = 2cm. d – h = 10 µm. del. Avneet Kaur (d-h). Photo Avneet Pal Singh (a-c).

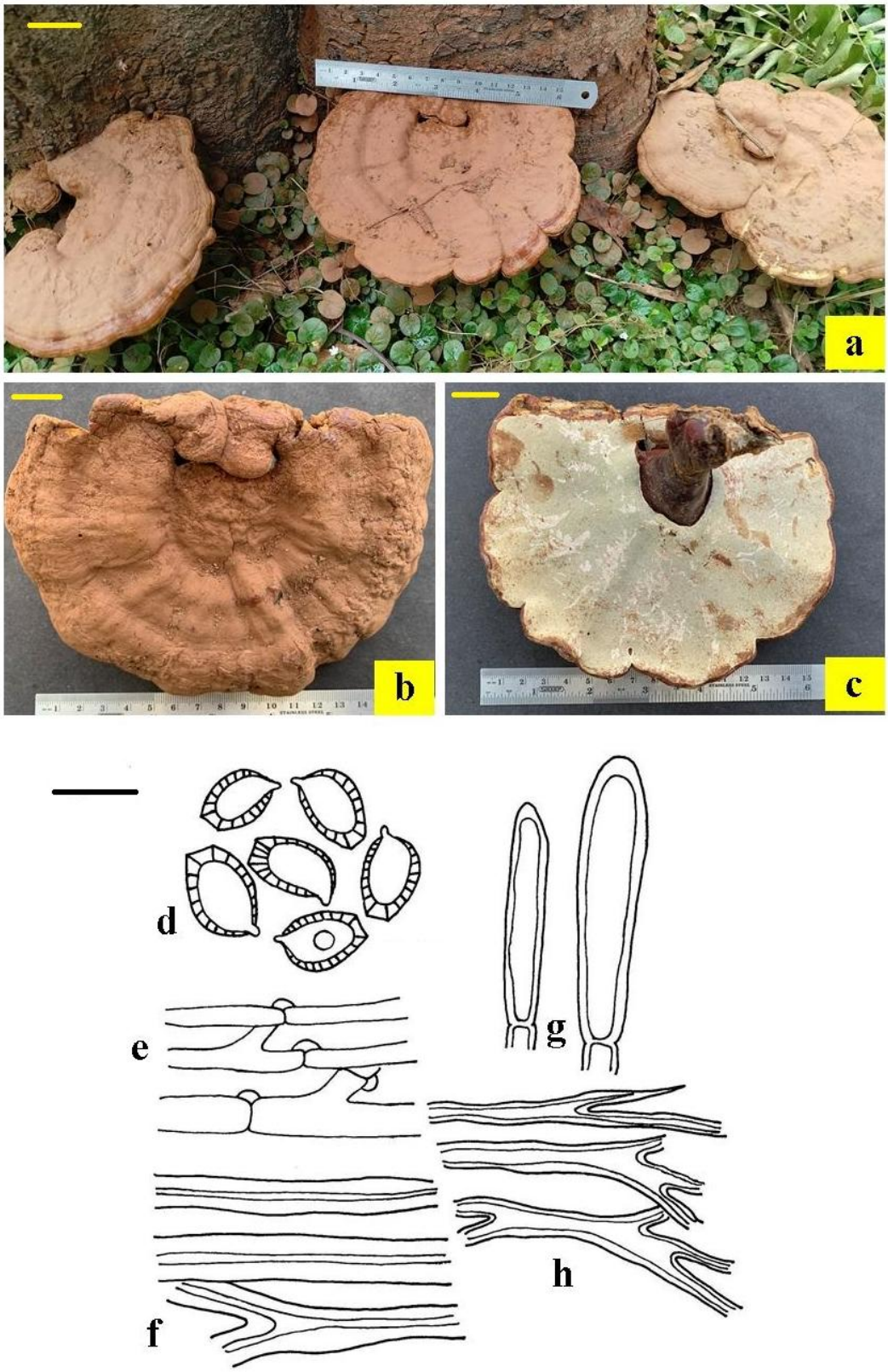

Fig. 5 – *Ganoderma multipileum* (12102 PUN) a Basidioma showing abhymenial surface (fresh). b Basidioma showing abhymenial surface (dry). c Basidioma showing hymenial surface (dry). d basidiospores. e generative hyphae. f skeletal hyphae. g cuticular elements. h binding hyphae. Scale bars: a = 3cm. b, c = 2cm. d – h =10 µm. del. Avneet Kaur (d-h). Photo Avneet Pal Singh (a-c).

Microscopic description – Hyphal system trimitic; generative hyphae clamped, thin–walled, branched, subhyaline, smooth; skeletal hyphae yellowish brown, thick–walled, lumen narrow, aseptate, rarely branched; binding hyphae subhyaline, thick–walled, lumen comparatively broader, profusely branched. Trama composed of generative, skeletal and binding hyphae; generative hyphae up to 2.8 µm in thickness; skeletal hyphae dominant, up to 5.2 µm in thickness; binding hyphae up to 4.5 µm in thickness. Subhymenium generative hyphae up to 2.2 µm in thickness; skeletal hyphae up to 3.6 µm in thickness; binding hyphae up to 3.1 µm in thickness. Pilear crust hymenioderm; cuticular elements 26.0–54.5 × 6.2–7.1 µm, subcylindrical, apex inflated, bi to trilobed, thick–walled, brown, wall shows no reaction in Melzer's reagent. Basidia not observed. Basidiospores 7.3–10.2 × 4.5–6.5 µm, broadly ovoid to ellipsoid, truncate at apex, thick–walled; exospore subhyaline, smooth; endospore thick, brown; two walls connected by inter-wall pillars; wall shows no reaction in Melzer's reagent and cotton blue.

Habitat – An angiospermous log.

Distribution – Kanjli wetland of Kapurthala district of Punjab state (India).

Genbank number: OQ119635

Material examined – INDIA, Punjab, District Kapurthala, Kanjli Wetland, on an angiospermous log, 26 September 2021, *Avneet & Avneet* 12102 (PUN).

Remarks – *Ganoderma multipileum* is distinguished by bi to tri-lobed cuticular elements and sessile basidiome and its identity has been confirmed by ITS sequence-based phyogeny. It is a new report for North West India as it has been reported only from Kerala by Vinjusha & Kumar (2022).

Key to the species of genus *Ganoderma*

1. Basidioma stipitate 2
1. Basidioma sessile ….....*G. enigmaticum*
2. Stripe branched .....*G. casuarinicola*
2. Stripe unbranched 3
3. Cuticular elements lobed .....*G. multipileum*
3. Not as above .....*G. destructans*

Discussion

Ganoderma is one of the largest genera of the family *Polyporaceae*. Previously, the genus was placed in the family *Ganodermataceae.* Based on the current morphological and phylogenetic analyses and comparison with the literature (Moncalvo & Ryvarden, 1997, Karunarathna et al. 2025), the identity of four *Ganoderma* species has been confirmed.

During current studies, taxonomic as well as genetic variations have been found amongst species of the genus *Ganoderma* collected from various localities of Punjab and Himachal Pradesh. The macro and micromorphological character based variations have been summarized in Table 1. The genetic variations have been analysed with the help of ITS markers. The sequences retrieved have been submitted to GenBank with GenBank numbers mentioned in the results section above. The phylogenetic tree has also been constructed using Maximum Likelihood method and Bayesian analysis to study the evolutionary relationships.

Among the four species described, *Ganoderma casuarinicola*, *G. destructans* and *G. multipileum* showed annual basidiomata while *G. enigmaticum* displayed perennial basidiomata. The basidioma was observed to vary from sessile (*G. enigmaticum*) to substipitate (*G. multipileum*) to stipitate (*G. casuarinicola* and *G. destructans*). Further, the pileus shape ranged from dimidiate (*G. destructans* and *G. multipileum*) to applanate (*G. enigmaticum*) to rosulate (*G. casuarinicola*). The nature of abhymenial surface is the key character used in *Ganoderma* taxonomy. Although all four species were placed in the laccate group, a weakly laccate abhymenial surface was observed is a case of *G. enigmaticum.*

The pore shape varied from round to angular to suborbicular to orbicular. *G. destructans* has been documented with the smallest pores (up to 7/mm) with minimum pore thickness (1mm). On the contrary, *G. enigmaticum* demonstrated comparatively larger pores (3-5/mm) with maximum pore thickness (5mm) when compared to the other species. Pilear crust in all four species is hymeniodermis. All four species lacked cystidial elements. The basidiospore morphology varied from ellipsoid to broadly ellipsoid to ovoid, with *G. destructans* having the largest spore size. The largest length of the pilei as well as stipe is observed in *G. destructans*, whereas *G. enigmaticum* possesses smallest pilei length and is sessile.

The genus has been represented by fifty eight legitimate taxa from different parts of India. As far as the state of Punjab is concerned the genus is represented by twelve species only. During the course of the present studies two new reports of the genus *Gaonderma* have been added at the national level and two new records have been added to the mycoflora of Punjab.

Table 1 Macro and micromorphological character comparison among the species of genus *Ganoderma*.

	G. casuarinicola	*G. destructans*	*G. enigmaticum*	*G. multipileum*
Basidiospore size length×breadth (µm)	8.8-12× 5.6-6.8	9.5-12.5× 6-8	8.5-14.2× 5.1-7.3	7.3-10.2× 4.5-6.5
No. of pores per mm	4-6	4-7	3-5	5-6
Pore thickness (mm)	3	1	5	2
Pilei size (cm)	14.5×12.7×0.8	16×11.4×0.7	8.7×6.9×1.6	12.5×8.9×0.9
Stipe size (cm)	8.7×5.5	16.1×3.4	sessile	2×5

Acknowledgements

The authors are thankful to Head, Department of Botany, Punjabi University, Patiala for providing necessary laboratory facilities and University Grants Commission and Department of Science and Technology, Government of India for financial assistance under SAP DSA-1 and DST FIST level-1 programme.

References

Coetzee MP, Marincowitz S, Muthelo VG, Wingfield MJ. 2015 – *Ganoderma* species, including new taxa associated with root rot of the iconic *Jacaranda mimosifolia* in Pretoria, South Africa. IMA Fungus 6(1), 249-256. Doi 10.5598/imafungus.2015.06.01.16

Doyle JJ, Doyle JL. 1990 – Isolation of plant DNA from fresh tissue. Focus 12, 13–15.

Fryssouli V, Zervakis GI, Polemis E, Typas MA. 2020 – A global meta-analysis of ITS rDNA sequences from material belonging to the genus *Ganoderma* (*Basidiomycota*, *Polyporales*) including new data from selected taxa. MycoKeys 75, 71–143. Doi 10.3897/mycokeys.75.59872

Karunarathna SC, Patabendige NM, Luangharn T, Hapuarachchi KK. 2025 – *Ganodermataceae*—current status, research, and development in Lower Mekong Basin. Frontiers in cellular and infection microbiology 15, 1545135.

Kaur G, Singh AP, Dhingra GS. 2017 – Diversity of the genus *Ganoderma* in Punjab (India). Mycobiota 7, 25-49. 10.12664/mycobiota.2017.07.05.

Kornerup A, Wanscher JH. 1978 – Metheun‘s Handbook of colours, IIIrd Ed.Metheun and Co. Ltd. London. 252pp.

Luangharn T, Karunarathna SC, Dutta AK, Paloi S et al. 2021 – *Ganoderma* (*Ganodermataceae*, *Basidiomycota*) Species from the Greater Mekong Subregion. J Fungi (Basel). 7(10), 819. Doi 10.3390/jof7100819

Mardones M, Carranza-Velázquez J, Mata-Hidalgo M, Amador-Fernández X et al. 2023 – Taxonomy and phylogeny of the genus *Ganoderma* (*Polyporales*, *Basidiomycota*) in Costa Rica. MycoKeys 100, 5-47. Doi 10.3897/mycokeys.100.106810

Mayirnao HS, Sharma K, Jangir P, Kaur S et al. 2025 – Mushroom-derived nutraceuticals in the 21st century: an appraisal and future perspectives. Journal of Future Foods 5(4), 342-360.

Moncalvo JM, Ryvarden L. 1997 – A nomenclatural study of Ganodermataceae Donk. Fungiflora, Oslo, Norway 114pp.

MycoBank. 2024 – Fungal databases. Nomenclature and Species Banks.https://mycobank.org. (accessed on 21/03/2024).

Ryvarden L. 2004 – Neotropicalpolypores: Part 1: Introduction, *Ganodermataceae* & *Hymenochaetaceae*. Fungiflora 227pp.

Ryvarden L, Melo I. 2014 – Poroid fungi of Europe. Synopsis Fungorum 31, 455pp.

Species Fungorum. 2024 – Fungal databases. Nomenclature and Species Banks. https://speciesfungorum.org. (accessed on 21/03/2024).

Sun YF, Xing JH, He XL, Wu DM et al. 2022 – Species diversity, systematic revision and molecular phylogeny of *Ganodermataceae* (*Polyporales*, *Basidiomycota*) with an emphasis on Chinese collections. Studies in Mycology 101(1), 287–415. Doi 10.3114/sim.2022.101.05

Vinjusha N, Kumar TKA. 2022 – The *Polyporales* of Kerala. SporePrint Books Calicut, Kerala, India. 1-229.

Wasser P, Weis L. 1999 – Medicinal Properties of Substances Occurring in Higher Basidiomycetes Mushrooms: Current Perspectives. International Journal of Medicinal Mushrooms. 1, 31-62.

Xing JH, Sun YF, Han YL, Cui BK et al. 2018 – Morphological and molecular identification of two new *Ganoderma* species on *Casuarina equisetifolia* from China. MycoKeys 34, 93-108. Doi 10.3897/mycokeys.34.22593