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Ganoderma curtisii, Firstly Reported from Districts Lahore and Gujranwala of Punjab Province, Pakistan

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ABSTRACT: *The current study presents a Ganoderma sp., as a new record from three different localities of districts Lahore and Gujranwala of Punjab province, Pakistan. Based on morpho-anatomical characteristics, collected specimens were identified as Ganoderma curtisii. The macroscopic and microscopic features of G. curtisii include; semicircular to kidney shaped laccate pileus that is beautifully lacquered, duplex context, resinous bands, no concentric growth zones, pore surface white to cream brown and sub circular to circular pores, stipe lateral making an angle with the pileus (45-90 degrees), basidiospores 11.4 × 5.7 µm, ellipsoidal with the hyaline vesicular appendix double walled, trimitic hyphal system and club shaped cutis. The detailed study of different Ganoderma species from the published literature and comparisons with those species confirmed the identity of our specimen as G. curtisii. In this article, taxonomic descriptions, micrographs and illustrations elaborate the morphological and anatomical characters of Ganoderma curtisii, a distribution map of this species across Pakistan and a comparison table of morphoanatomical characteristics of Ganoderma curtisii reported from neighbouring countries is given. Conduction of molecular studies, investigation of ecological roles, development of conservational strategies, and exploration of biotechnological exploration are future perspectives for this taxon.*

Keywords: Canal-bank Road Lahore, *Ganoderma curtisii*, Macrofungi, Polyporaceae

INTRODUCTION

Ganoderma genus was founded by Karsten (1881) as a member of laccate pileated group of species, with *G. lucidum* as a type specimen. Genus *Ganoderma* has following subgenera, *Ganoderma* (which is classified in further sections *Ganoderma* and *Phaenema*), *Elfvingia*, and *Trachyderma* (Thawthong et al., 2017; Zhao and Zhang, 2000; Galappaththi et al., 2024). There are about 219 species assigned to genus *Ganoderma* (Moncalvo, 2000; Wachtel-Galor et al., 2012). This genus has distinguishing characters of laccate (shiny) surface with thick-walled pilocystidia that are present in an extracellular melanin matrix (Moncalvo, 2000), sessile to stipitate basidiomata and bilayed basidiospores with inter-wall pillars (Karsten, 1881; Moncalvo and Ryvarden, 1997; Luangharn et al., 2021). Due to extreme phenotypic plasticity, the identification of *Ganoderma* species is difficult (Ryvarden, 1994; Zhao and Zhang, 1994; Wachtel-Galor et al., 2012; Chen et al., 2024). More reliable criteria to identify and distinguish *Ganoderma* species includes context color and consistency, shape and size of spore and micro-anatomy of the pileal crust. *Ganoderma* is a cosmopolitan genus with global distribution in tropical and sub-tropical forests. Specimens flourish in hot and humid conditions (Pilotti et al., 2004; Singh et al., 2014; Thawthong et al., 2017).

Basidiomes are commonly found in bracket form (Pilotti et al., 2004), with most *Ganoderma* species are pathogenic and grow as facultative parasites of trees and cause various diseases in plants such as stem rot, wood decay and white rot (Ryvarden, 2004; Pilotti, 2005; Dai et al., 2007; Cao and Yuan, 2013; Coetzee et al., 2015). Some *Ganoderma* species are saprobes on rotting stumps and roots (Turner, 1981; Pilotti, 2005). This genus has a great pharmaceutical importance due to the presence of natural bioactive compounds, e.g., high and low molecular weight sterols, triterpenoids polysaccharides, and proteins (Ahmadi and Riazipour, 2007; Chan et al., 2007; Chen and Seleen, 2007; Luangharn et al., 2021). The bioactive constituents present in the genus *Ganoderma* are known to have broad therapeutic properties, such as antiviral, anticancer, anti-tumor, anti-inflammatory, anti-oxidant, anti-hypotensive, immunomodulatory, anti-diabetic, anti-viral, anti-bacterial, anti-fungal potentials (Liu et al., 2002; Paterson, 2006; Teng et al., 2011; De Silva et al., 2012a, b; Kao et al., 2013; Singh et al., 2014; Richter et al., 2015; Hyde et al., 2019; Luangharn et al., 2021).

Fruiting bodies of some *Ganoderma* species have been used as traditional medicine for more than 2,000 years in some countries for promoting longevity and health, boosting the immune system, lowering the risk of cancer, treatment of diabetes, insomnia, debility and weakness etc (Galor et al., 2004; Singh et al., 2014). The cultivated yield for *Ganoderma* has exceeded 10,000 tons per annum due to its unique pharmacological activity (El Sheikha, 2022; Khadbaatar et al., 2024), this is due to the presences of highly active compounds including polyphenols, polysaccharides, quinones, sterols, triterpenes (Seweryn et al., 2021; Fang et al., 2023; Khadbaatar et al., 2024).

In Pakistan, previously, about 18 species of this genus have been reported so far and these are *Ganoderma applanatum* (Pers.) Pat., *Ganoderma australe* (Fr.) Pat., *Ganoderma ahmadii* Steyaert, *Ganoderma boninense* Pat., *Ganoderma curtisii* (Berk.) Murrill, *Ganoderma colossus* (Fr.) C.F. Baker, *Ganoderma chalceum* (Cooke) Steyaert, *Ganoderma flexipes* Pat., *Ganoderma. gibbosum* (Blume & T. Nees) Pat., *Ganoderma lucidum* (Curtis) P. Karst., *Ganoderma leucocontextum* T.H. Li, W.Q. Deng, Sheng H. Wu, Dong M. Wang & H.P. Hu, *Ganoderma multipileum* Ding Hou, *Ganoderma multistipitatum* S. Ahmed, M. Awais, M.M. Sadiq, A. Umar, L. Dufosse, M.T. Khan, J. Alkahtani& R.M. Mahmoud, *Ganoderma multicornum* Ryvarden, *Ganoderma multiplicatum* (Mont.) Pat., *Ganoderma pakistanicum* Umar, A., Ahmed, S., & Gafforov, Y., *Ganoderma resinaceum* Boud., and *Ganoderma tornatum* (Pers.) Bres.

In this study, we are dealing with three specimens of *G. curtisii* species collected from three different localities of Lahore and Gujranwala districts. Previously this taxon has already been reported only from Murree Hills of Pakistan. The morphological and anatomical descriptions, macrographs of fruiting bodies, micrographs of anatomical features, comparison morpho-anatomical features of *Ganoderma curtisii* described from neighboring countries of Pakistan along with a map showing geographical locations of *G. curtisii* from Pakistan are given in this article.

MATERIALS AND METHODS

Three of *G. curtisii* specimens were collected during the during rainy seasons of 2021 from Canal-bank Road (Lahore) Wazirabad tehsil and Uggo Chak, along Hafizabad road (Gujranwala). Each specimen was photographed, tagged with a specific code and documented with location, date

and host tree details. In laboratory, the specimens were dried using a fan heater and preserved in zip locked bags with their tags.

Macroscopic Analysis

Macroscopic characteristics of fruiting body were analyzed including length and width, color and size of pileus, resinous bands, laccate surfaces, texture, margins of stipe and pileus, presence or absence of stipe, hymenial surface, discoloration, taste and odor.

Slide Preparation and Micrometry

For the slide preparations, small pieces of the dried specimens were soaked in alcohol for 5 minutes then thin sections were placed on glass slides. Two drops of 5% KOH were used as mounting medium and 1% aqueous Congo red solution (w/v) was applied for hyaline structures. The fine sections of fruiting bodies were sharply cut and covered with cover slip for observation. Microscopic characteristics were measured and recorded under a light microscope at 40X magnification.

For anatomical analysis, at least 20 readings were taken, focusing on the length and width, shape, and quotient value and range of basidiospores, basidiole, cutis elements. The width range of generative hyphae, skeletal hyphae, binding hyphae and stipe hyphae were also measured. Additionally, extreme spore length and width values were also noted. Total number of spores determined for each collection was n and Qavg was the average of the Q coefficient (length/width ratio). Manual illustrations were created observing hymenial section. Identification of the species was conducted based on morpho-anatomical features.

RESULTS

The morpho-anatomical explanation species *Ganoderma curtisii* (Berk.) Murrill, with voucher codes (KM-09; GM-95; GM-15) is given in the form of description, micrographs, and illustrations. This species was collected at young and mature stages and reported here as two new locality records from districts Lahore and Gujranwala of Punjab province, Pakistan.

Taxonomy

Ganoderma curtisii (Berk.) Murrill, N. Amer. Fl. (New York) 9(2): 120 (1908)

(Fig. 1-4)

Macroscopic Analysis

Basidiocarp 4-10 cm, annual, stalked or finger-like structure, aplanate, coriaceous to woody hard. **Pileus** 1.3-1.5 × 1-1.2 cm (when young), 3.5-12 × 9-10 cm, 2-6 cm deep (when mature) medium sized to large, upper surface smooth, flabellate to subflabellate, glabrous, semicircular to kidney shaped when mature, laccate, creamy

white to light brown when young and brownish red to reddish brown when mature with purple hues, reddish brown to orange-yellow and ultimately white from center to margins, uneven and bald surface, lacquered. Texture tough and hard but not woody. **Margins** slippery when wet, thin and sharp, unlike to the center softer and thinner, varies in color from orange red to brown from young to mature, have active developing hyphae, clearly laccate, thinner than center. **Hymenial surface** of the basidiocarp is fertile and porous, light brown and not even. Duplex context 0.35 cm thick, resinous bands (melanoid zone) present, no concentric growth zones as present in G. sessile, corky-woody, has club-shaped cuticle cells, thick at the base, clamped, and subsolid hyphae. **Pore surface** whitish to light brown color when young stage and medium dark brown when maturity, sub circular to circular in shape and 4-6 per mm, thin dissepiments. Tubes 0.5-2 cm deep, unstratified, have variations in thickness, scretched when dried, light brown, with a typical melanoid zone. **Stipe** (usually present) 6.8- 7.8 × 1.5- 2.2 cm, bald, reddish-brown color, glabrous lacquered, rough and solid texture, lateral making an angle with the pileus (45-90 degrees). **Taste and odor** not distinctive. **Habit and habitat** grow in solitary or group, present at the base of *Eucalyptus camaldulensis* Dehnh in terrestrial area.

Microscopic Analysis

Basidiospores 11.4 × 5.7 µm, with hyaline vesicular appendum; avgL 11.4 µm, avgW 5.7 µm, avgQ 2 µm, broadly ellipsoid with truncate apex, brown in KOH double walled, inamyloid, contains oil droplet, sharply spotted, utriculate, brown color overlaid by hyaline apex and the wall have a range of "pillars" that are intermediately thick (0.3-0.7 µm). **Hyphal system** trimitic; consist of generative hyphae that were difficult to observe, hyaline to yellowish, branched, clamped. Skeletal hyphae W_{range} 2.85-5.7 µm, avgW 4.27 µm, from pileus width ranges from 2.85-8.55 µm, avgW 5.13 µm, grouped, thick walled, apically branched, aseptate, golden brown, broader in the context and thinner crustohymeniderm, Binding hyphae hyaline to yellow in color and narrower than skeletal hyphae. **Basidia** 28-40 × 7-8.5 µm, double walled, light yellowish in color, bisporic, clavate to cylindrical, clamped at base, thin, without oil droplets. Cutis element 22.8-28.5 × 5.7-8.55 µm, avgL 25.65 µm, avgW 7.125 µm, Qrange 2.66-5 µm, avgQ 3.83 µm, clavate to sub-clavate shape, clustered, apedicellate, smooth, and golden brown-yellow, thin or thick laccate lines of melanoid

substance present that start off from the stipe and run to the upper surface correspondingly. **Stipe hyphae**; 3-7 µm, branched, aseptate, thin walled, light golden yellowish color, narrow.

Collection Sites

PAKISTAN: Punjab, Lahore, Canal Bank Road, Green belt near H-3 block, 217 m above sea level, growing singly or groups, on the bottom of *Eucalyptus camaldulensis* Dehnh trunk, Khadija Malhi, KM-09, 14th October 2021; District Gujranwala, Wazirabad Tehsil, Neevan Ojla, Wazirabad, attached with wood, solitary, 226 meters (744 ft.) above sea level, S.

Rukhsar (GM-15) 30th August 2021; Gujranwala Tehsil, Uggo Chak, Hafizabad Road, attached with base of tree trunk, solitary, 226 meters (744 ft.) above sea level, S. Rukhsar (GM-95) 25th September 2021.

Literature Reviewed for Species Identification:

The description of morphological and anatomical characters of the reported species was confirmed from published literature of Steyaert (1980), Torres-Torres and Guzman-Davalos (2012), Torres-Torres et al. (2015), Loyd et al. (2018), Mardones et al. (2023), and Chouhan & Kaur (2023).

Fig. 1: Morphology of *Ganoderma curtisii* **(**KM-09**). A & B.** Basidiocarp in its natural habitat. **C & D.** Basidiocarp showing both white cap and stipe. **Scale bars: A.** 0.8 cm. **B.** 0.5 cm. **C.** 1.95 cm. **D.** 1.5 cm.

Fig. 2: Morphology of basidiomata of *Ganoderma curtisii* (GM-15; GM-95). **A–C.** Basidioma. **D–F.** Pore surface. **Scale bars: A, D & E.** 2 cm, **B & C.** 1.5 cm, **F.** 1 cm.

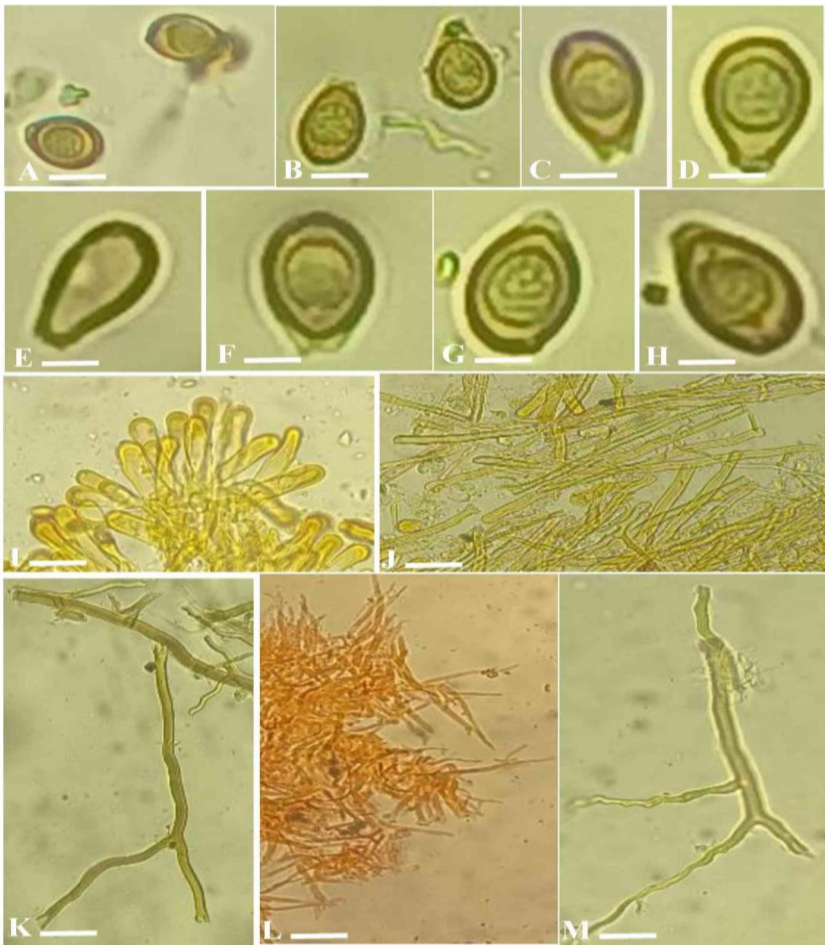

Fig. 3: Light micrographs of microscopic features of *Ganoderma curtisii* (GM-95)**. A–H.** Basidiospores. **I.** Cutis elements. **J & K.** Generative hyphae. **L.** Skeletal hyphae. **M.** Stipe hyphae. **Scale bars: A.** 8 µm, **B.** 7 µm, **C.** 4.5 µm, **D–F.** 4 µm, **G & H.** 3.5 µm, **I.** 17 µm, **J & K.** 25 µm, **L.** 30 µm, **M.** 12.5 µm.

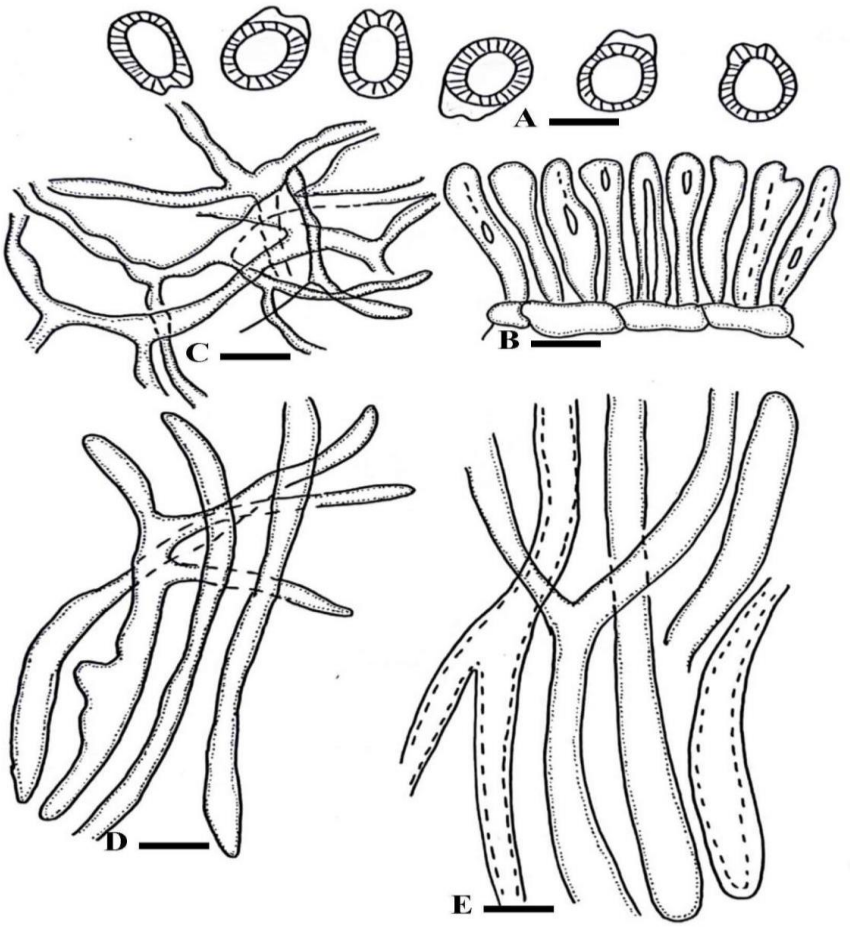

Fig. 4: Illustrations of microscopic features of *Ganoderma curtisii* (GM-95). **A.** Basidiospores. **B.** Cutis elements. **C.** Skeletal hyphae. **D.** Stipe hyphae. **E.** Generative hyphae. **Scale bars: A.** 6.5 µm, **B.** 14 µm, **C.** 8 µm, **D.** 8.5 µm, **E.** 10 µm.

Table 1: Comparison of Characteristic Features of *Ganoderma curtisii* reported from Neighbouring Countries of Pakistan

Species Name with country	Macroscopic characters							Microscopic Characterization							Source
	Pileus						Stipe Length (cm)	Basidiospores		Type of Hyphal system	Hyphal system			Basidia size (µm)	
	Size (cm)	Shape	Colour (at maturity)	Resinous Bands/ Non-Resinous Bands	Lactate/ Non Laccate	Concentric Zones (on the upper surface of the pileus)		Size (µm)	Shape		Generative Hyphae (Diameter in µm)	Skeletal Hyphae (Diameter in µm)	Binding Hyphae (Diameter in µm		
G. curtisii (Pakistan)	1.3-1.5 × 1-1.2	semicircular to kidney shaped	brownish red to reddish brown with purple hues	resinous bands	laccate	concentrically zonate	6.8-7.8	9.5-11.2 ×4.8-6.3	broadly Ellipsoidal	trimitic	2.4-4	2.85-5.7	2-3.1	12-27×5.6-11	Mukhtar, 2019
G. curtisii (India)	14× 2.5	circular	creamish white, r	resinous bands	laccate	concentrically zonate	8.0 × 3.0	14.0-16.5 × 9.0-10.5	ellipsoid	trimitic	5.9	4-5.5	3	21.8 × 3.12	Nagadesi & Arya, 2012; Chouhan & Kaur, 2023
G. curtisii (China)	10.5 ×4.4	reniform	yellowish-brown to reddish-brown with purple hues	resinous bands	laccate	concentrically zonate	9.0 × 4.0	(9-)11-17 × (7-)8-10	ellipsoid to oblong	trimitic	3.5	1.5-6	3-5	not observed	Cao et al., 2012; Zhou et al., 2015; He et al., 2021

DISCUSSION

Ganoderma was named due to its shiny or lustrous surfaces and *curtisii* represented the species name in the honor of Moses Ashley Curtis (1808-1872), an American Epicopal priest, botanist, mycologist and teacher. *Ganoderma curtisii* (Berk.) Murrill belongs to the laccate group of *Ganoderma* occurred in both temperate and sub-tropical forests. Initially, *Ganoderma curtisii*, was defined from North America (Moncalvo and Ryvarden, 1997; Thawthong et al., 2017). This species is saprobic and parasitic may be growing alone or in groups, found on the dead or decaying hardwood logs tree trunks or on the roots. From Pakistan this species was collected and reported from Murree Hills. In this study, *G. curtisii* was reported as new locality records from the base of *Eucalyptus camaldulensis*, and from base of an unknown tree trunk in terrestrial areas from Lahore and Gujranwala districts.

G. curtisii is a white root decay fungus, that causes the greater mass loss from the substrate where they are present, and this activity is comparable to the *F. ambrosius* as reported by (Kasson et al., 2016; Skelton et al., 2020).

G. curtisii, the mushroom of immortality or Ling-Chi, was characterized by semicircular to kidney shaped pileus beautifully lacquered with brilliant yellow new growth and white tips, duplex context, resinous bands, no concentric growth zones (Cao et al., 2012) as present in *G. sessile*, corky- woody, club-shaped cuticle cells present (Haddow and Haddow, 1931; Steyaert, 1980; Ojeda-Lopez et al., 1986; Torres-Torres et al., 2015), Pore surface white to crème brown and sub circular to circular pores (Steyaert, 1980), stipe lateral at the angle of (45-90 degrees) with the pileus, basidiospores 11.4 × 5.7 µm, ellipsoidal (Steyaert, 1980; Torres-Torres and Guzman-Davalos, 2012) with the hyaline vesicular appendix double walled, trimitic hyphal system and club shaped cutis (Torres-Torres et al., 2015; Gurpreet et al., 2017).

G. curtisii by some adjustments has been used to determine antioxidant activity and in the food industries other nutritional manufacturing because of its effective natural antioxidants (Huang et al., 2002; Ivone et al., 2016; Rosales-Lopez et al., 2022).

G. curtisii has been used to make composites due to its ability to form resistant mycelial matrix (Cesar et al., 2023). By this species about 29 lanostane triterpenoids have been obtained, that are the lipopolysaccharides, inhabit the nitric oxide (NO) production in the activated BV-2 microglia cells (Jiao et al., 2016).

G. curtisii exhibits antibacterial activity, in addition to ganoderic acids, phenolic compounds are also involved in this activity (Li et al., 2012; Rempe et al., 2017). The compounds extracted from this species responsible for this antibacterial activity are phenols, terpenes, and fatty acids. (Desbois and Smith, 2010; Rempe et al., 2017). This inedible fungus can be used to lower the blood pressure and to reduce the blood clot. It can also be used in cancer treatments.

G. curtisii was morphologically related to the *G. sessile* as both were annual, perennial (*G. curtisii* is sub-stipitate to stipitate or sessile while *G. sessile* is sessile), pileus surface laccate, flabelliform, dimidiate, lacquered (Steyaert, 1980; Torres-Torres et al., 2015; Nagadesi and Arya, 2016). The duplex context (Torres-Torres and Guzman-Davalos, 2012) have resinous bands (melanoid zone). There were no concentric growth zones in *G. curtisii* (Cao et al., 2012; Luangharn et al., 2021) but were present in *G. sessile*. Basidiospores ellipsoidal (Steyaert, 1980; Torres-Torres and Guzman-Davalos, 2012), the size of basidiospres in *G. sessile* were slightly larger as compared to *G. curtisii* (Luangharn et al., 2021), hyphal system is trimitic (Steyaert, 1980).

G. curtisii closely resembled *G. lingzhi* (*G. lucidum*) in phylogeny. The basidiomata of both resembles each other in juvenile stage, pileal surface is yellow with white pore surface. When mature, *G. lucidum* has pilleus reddish brown in color with a hard crust, however, *G. curtisii* still has yellowish brown to brick red pileus with a thin and soft crust. In *G. curtisii* the pore surface was white with thin dissepiments when mature, while in *G. lucidum* pore surface is yellow when mature with dissepiments thick. The cuticle cells in the *G. lucidum* are, closely packed, slender with narrower apical parts as compared to loosely arranged cutis cells inflated with wider apical parts in *G. curtisii* (Steyaert, 1980; Cao et al., 2012; Torres-Torres et al., 2015).

According to (Torres-Torres et al., 2015) *G. meredithiae* and *G. ravenelii* had identical morphology as that of *G. curtisii* in the basidiomata, pileus shape, color and texture, margins, context features, pore arrangments, stipe color and texture, and in microscopic characterizations. *G. meredithiae* (Adaskaveg and Gilbertson, 1988) had more diverticulated and differentiated cuticle cells. But in case of *G. ravenelii* there was a difference in terms of shape and size of basidiospores, as compared to *G. curtisii* they were more oblong to cylindrical (Steyaert, 1980) and in the context there were no resinous bands.

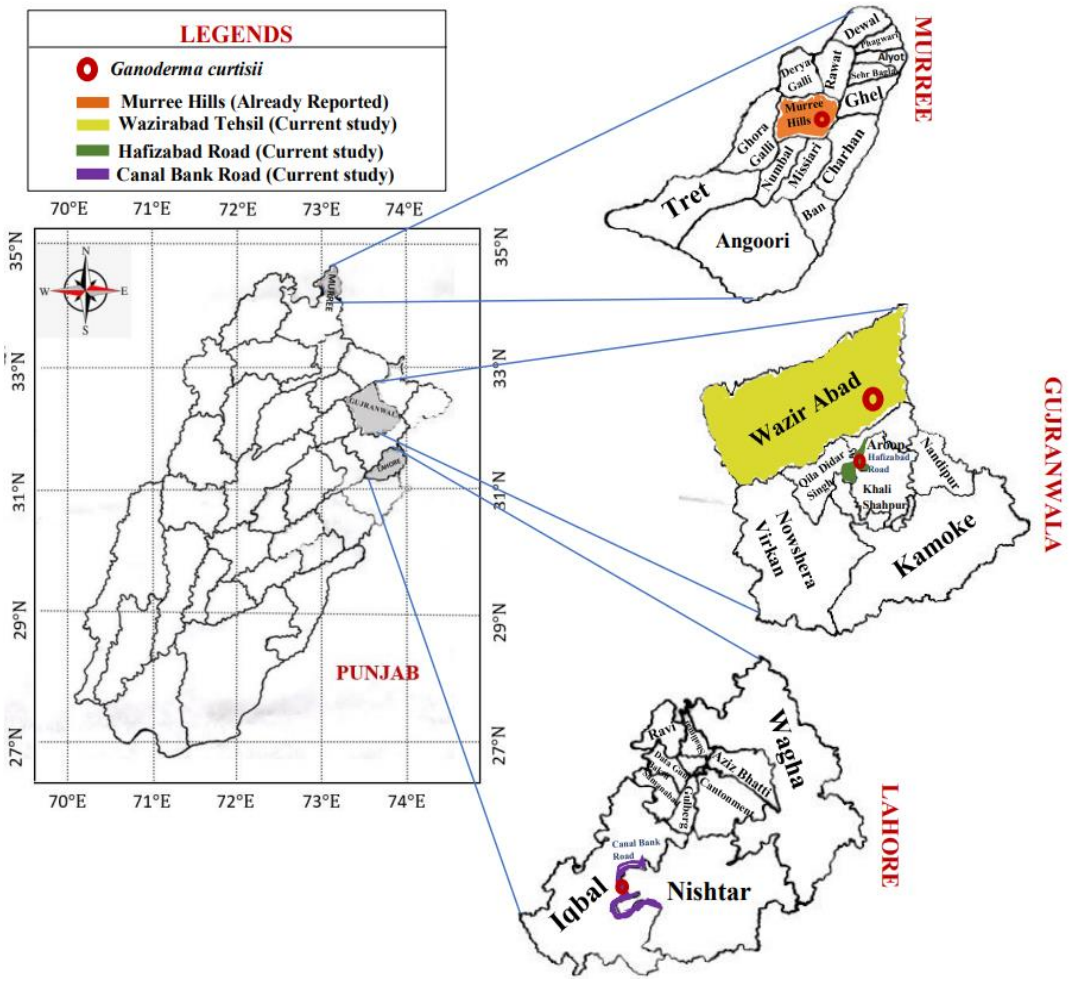

Figure 5: Distribution of *Ganoderma curtisii* in Pakistan

CONCLUSION

In conclusion, new locality reports of *Ganoderma curtisii* from three different sites (one from District Lahore and two from District Gujranwala) signified the notable expansion of its geographical range. This finding suggested that Punjab supports the growth of these macro-mycetes and there are many more that need to be explored. The morphological and anatomical features of *Ganoderma curtisii* was described by the illustrations, micro-plates and colored photographs of micro-plates, a distribution map of this speciesxat Murree (already reported), Lahore and Gujranwala (current study) reported from

Punjab, and a comparison table of characteristic attributes of *Ganoderma curtisii* recorded from neighboring countries of Pakistan were presented in this article.

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N/A

CONFLICT OF INTERESTS

The authors declare no conflict of interest.

REFERENCES

1. Adaskaveg JE, Gilbertson RL (1988). Basidiospores, pilocystidia, and other basidiocarp characters in several species of the Ganoderma lucidum complex. Mycologia 80(4): 493-507.
2. Ahmadi K, Riazipour M (2007). Effect of Ganoderma lucidum on cytokine release by peritoneal macrophages. Iran. J. Immunol. 4: 220-226.
3. Cao Y, Wu SH, Dai YC (2012). Species clarification of the prize medicinal Ganoderma mushroom “Lingzhi.” Fungal Divers. 56: 49-62.
4. Cao Y, Yuan HS (2013). Ganoderma mutabile sp. nov. from southwestern China based on morphological and molecular data. Mycol. Prog. 12: 121-126.
5. Cesar E, Castillo-Campohermoso MA, Ledezma-Perez AS, Villarreal-Cardenas LA, Montoya L, Bandala VM, Rodriguez-Hernandez AM (2023). Guayule bagasse to make mycelium composites: An alternative to enhance the profitability of a sustainable guayule crop. Biocatal. Agric. Biotechnol. 47: 102602.
6. Chan WK, Law HK, Lin ZB, Lau YL, Chan GC (2007). Response of human dendritic cells to different immunomodulatory polysaccharides derived from mushroom and barley. Int. Immuno pharmacol. 19: 891-899.
7. Chen AW, Seleen J (2007). Potential benefits of Ling-Zhi or Reishi mushroom Ganoderma lucidum (W. curt. Fr.) P. Karst. (Aphyllophoromycetideae) to breast cancer patients. Int. J. Med. Mushrooms 9: 29-38.
8. Chen TQ, Xu XL, Yang C, Yang L, Ying ZH, Shi XK, Ding MG (2024). Comparative genomics reveals ample evidence to Ganoderma sinense cultivars for molecular identification and new FIP exploration. Genomics 116: 110924.
9. Chouhan R, & Kaur S (2023). Diversity of the

Ganoderma species from Rajasthan, India. J. Mycol. Pl. Pathol. 53: 3.
10. 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: 249-25.
11. Dai YC, Cui BK, Yuan HS, Li BD (2007). Pathogenic wood-decaying fungi in China. For. Pathol. 37: 105-120.
12. De Silva DD, Rapior S, Fons F, Bahkali AH, Hyde KD (2012b). Medicinal mushrooms in supportive cancer therapies: An approach to anti-cancer effects and putative mechanisms of action. Fungal Divers. 55: 1-35.
13. De Silva DD, Rapior S, Hyde KD, Bahkali AH (2012a). Medicinal mushrooms in prevention and control of diabetes mellitus. Fungal Divers. 56: 1-29.
14. Desbois AP, Smith VJ (2010). Antibacterial free fatty acids: activities, mechanisms of action and biotechnological potential.Appl. Microbiol. Biotechnol. 85: 1629-1642.
15. El Sheikha AF (2022). Nutritional profile and health benefits of Ganoderma lucidum "lingzhi, reishi, or mannentake" as functional foods: Current scenario and future perspectives. Foods 11: 1030.
16. Fang H, Li X, Lin D, Wang L, Yang T, Yang B (2023). Inhibition of intrarenal PRR-RAS pathway by Ganoderma lucidum polysaccharide peptides in proteinuric nephropathy. Int. J. Biol. Macromol. 253: 127336.
17. Galappaththi MCA, Priyashantha AKH, Patabendige NM, Stephenson SL, Hapuarachchi KK, Karunarathna SC (2024). Taxonomy, Phylogeny, and Beneficial Uses of Ganoderma (Ganodermataceae, Polyporales). CRC Press. In Ganoderma Pp. 1-18.
18. Galor SW, Tomlinson B, Benzie IFF (2004): Ganoderma lucidum ('Lingzhi'), a Chinese medicinal mushroom: biomarker responses in a controlled human supplementation study. Brit. J. Nutr. 91: 263-269.
19. Gurpreet K, Singh AP, Dhingra GS (2017). Diversity of the genus Ganoderma in Punjab (India). Mycobiota 7: 25-49.
20. Haddow WR, Haddow WH (1931). Studies in

Ganoderma. J. Arnold Arbor. 12(1): 25-46.
21. He J, Luo ZL, Tang SM, Li YJ, Li SH, Su HY (2021). Phylogenetic analyses and morphological characters reveal two new species of Ganoderma from Yunnan province, China. MycoKeys 84: 141.
22. Huang D, Ou B, Hampsch-Woodill M, Flanagan J, Prior R (2002). High-throughput Assay of Oxigen Radical Absorbance Capcity (ORAC), using a Multichannel Liquid Handling System Coupled with a Microplate Fluorescence Reader in 96-well format. J. Agric. Food Chem.50: 4437-4444.
23. Hyde KD, Xu J, Rapior S, Jeewon R, Lumyong S, Niego AGT, ..., Stadler M (2019). The amazing potential of fungi: 50 ways we can exploit fungi industrially. Fungal Divers. 97: 1-136.
24. Ivone HA, Jorge MT, Guadalupe GRM, Berenice YJ (2016). Total polyphenols and antioxidant activity of Ganoderma curtisii extracts. J. of Med. Plants Studies 4(4): 136-141.
25. Jiao Y, Xie T, Zou LH, Wei Q, Qiu L, Chen LX (2016). Lanostane triterpenoids from Ganoderma curtisiiand their NO production inhibitory activities of LPS-induced microglia. Bioorg. Med. Chem. Lett. 26(15): 3556-3561.
26. Kao C, Jesuthasan AC, Bishop KS, Glucina MP, Ferguson LR (2013). Anti-cancer activities of Ganoderma lucidum: active ingredients and pathways. Funct. Foods Health Dis. 3(2): 48-65.
27. Karsten P (1881). Enumeratio Boletinearumet Polyporearum Fennicarum, systemate novo dispositarum. Rev. Mycol. 3: 16-19.
28. Kasson MT, Wickert KL, Stauder CM, Macias AM, Berger MC, Simmons DR, ..., Hulcr J (2016). Mutualism with aggressive wood-degrading Flavodonambrosius (Polyporales) facilitates niche expansion and communal social structure in Ambrosiophilus ambrosia beetles. Fungal Ecol. 23: 86-96.
29. Khadbaatar S, Bao H, Gao X, Huo H (2024). Study on Differences of Metabolites among Different Ganoderma Species with Comprehensive Metabolomics. J. Fungi 10(8): 524.
30. Li WJ, Nie SP, Liu XZ, Zhang H, Yang Y, Yu Q, Xie MY (2012). Antimicrobial properties,

antioxidant activity and cytotoxicity of ethanol-soluble acidic components from Ganoderma atrum. Food Chem. Toxicol. 50: 689-694.
31. Liu X, Yuan JP, Chung CK, Chen XJ (2002). Antitumor activity of the sporoderm broken germinating spores of Ganoderma lucidum. Cancer Lett. 182: 155-161.
32. Loyd AL, Held BW, Barnes CW, Schink MJ, Smith ME, Smith JA, Blanchette RA (2018). Elucidating 'lucidum': Distinguishing the diverse laccate Ganoderma species of the United States. PLoS ONE 13(7): e0199738.
33. Luangharn T, Karunarathna SC, Dutta AK, Paloi S, Promputtha I, Hyde KD, ..., Mortimer PE (2021). Ganoderma (Ganodermataceae, basidiomycota) species from the greater mekongsubregion. J. Fungi 7(10): 819.
34. Mardones M, Carranza-Velazquez J, Mata-Hidalgo M, Amador-Fernandez X, Urbina H (2023). Taxonomy and phylogeny of the genus Ganoderma (Polyporales, Basidiomycota) in Costa Rica. MycoKeys 100: 5.
35. Moncalvo JM (2000). Systematics of Ganoderma. In: Ganoderma Diseases of Perennial Crops. CAB International, Wallingford, UK. Pp. 23-45.
36. Moncalvo JM, Ryvarden L (1997). A nomenclatural study of the Ganodermataceae Donk. Fungi flora 10: 1-114.
37. Mukhtar T (2019). Morphological characterization of Ganoderma species from Murree hills of Pakistan. Plant Prot. 3(2): 73-84.
38. Nagadesi PK, Arya A (2012). New records of lignicolous fungi deteriorating wood in India. Mycosphere 3(6): 997-1004.
39. Nagadesi PK, Arya A (2016). Lignicolous macro fungi from Gujarat, India. World Sci. News 2(45): 307-330.
40. Ojeda-Lopez S, Sandoval MDLL, Valenzuela R (1986). The polypores of Mexico I. descriptions of some species from the northeastern of the guanajuato state. Rev. Mex. Mic. 2: 367-436.
41. Paterson RR (2006). Ganoderma- A therapeutic fungal biofactory. Phytochemistry 67: 1985-2001.
42. Pilotti CA (2005). Stem rots of oil palm caused by Ganoderm aboninense: Pathogen biology and epidemiology.

Mycopathologia 159: 129-137.
43. Pilotti CA, Sanderson FR, Aitken AB, Armstrong W (2004) Morphological variation and host range of two Ganoderma species from Papua New Guinea. Mycopathologia 158(2): 251-265.
44. Rempe CS, Burris KP, Lenaghan SC, Stewart Jr CN (2017). The potential of systems biology to discover antibacterial mechanisms of plant phenolics. Front. Microbial. 8: 422.
45. Richter C, Wittstein K, Kirk PM, Stadler M (2015). An assessment of the taxonomy and chemotaxonomy of Ganoderma. Fungal Divers. 71: 1-15.
46. Rosales-Lopez C, Arce-Torres F, Monge-Artavia M, Rojas-Chaves M (2022). Evaluation of the Use of Elicitors for the Production of Antioxidant Compounds in Liquid Cultures of Ganoderma curtisii from Costa Rica. Molecules 27(13): 4265.
47. Ryvarden L (1994). Can we trust morphology in Ganoderma? In: Buchanan PK, Hseu RS, Moncalvo JM (eds) Ganoderma: systematics, phytopathology and pharmacology. Proceedings of contributed symposium 59A, B, 5th International Mycological Congress, Vancouver 1994: Pp. 19-24.
48. Ryvarden L (2004). Neotropical Polypores Part 1. Fungi Flora, Oslo. Pp. 1-227.
49. Seweryn E, Ziała A, Gamian A (2021). Health-promoting of polysaccharides extracted from Ganoderma lucidum. Nutrients 13: 2725.
50. Singh R, Singh AP, Dhingra GS, Shri R (2014). Taxonomy, physicochemical evaluation and chemical investigation of Ganoderma applanatum and G. brownie. Int. J. Adv. Res. 2(5): 702-711.
51. Skelton J, Loyd A, Smith JA, Blanchette RA, Held BW, Hulcr J (2020). Fungal symbionts of bark and ambrosia beetles can suppress decomposition of pine sapwood by competing with wood-decay fungi. Fungal Ecol. 45: 100926.
52. Steyaert RL (1980). Study of some Ganoderma species. Bulletin du Jardin botanique national de Belgique/Bulletin van de Nationale Plantentuin van België, 50: 135-186.
53. Teng BS, Wang CD, Yang HJ, Wu JS, Zhang D, Zheng M, Fan ZH, Pan D, Zhou PA (2011). protein tyrosine

phosphatase 1B activity inhibitor from the fruiting bodies of Ganoderma lucidum (Fr.) Karst and its hypoglycemic potency on streptozotocininduced type 2 diabetic mice. J. Agric. Food Chem. 59: 6492-6500.

54. Thawthong A, Hapuarachchi KK, Wen TC, Raspe O, Thongklang N, Kang JC, Hyde KD (2017). Ganoderma sichuanense (Ganodermataceae, Polyporales) new to Thailand. MycoKeys 22: 27-43.
55. Torres-Torres MG, Guzman-Davalos L (2012). The morphology of Ganoderma species with a laccate surface. Mycotaxon 119(1): 201-216.
56. Torres-Torres MG, Ryvarde L, Guzman-Davalos L (2015). Ganoderma subgenus Ganoderma in Mexico. Rev. Mex. Mic. 41: 27-45.
57. Turner PD (1981). Oil Palm Diseases and Disorders. Oxford University Press, Oxford. Pp. 88-110.
58. Upton R (2000). American herbal pharmacopeia and therapeutic compendium: reishi mushroom, Ganoderma lucidum. Standards of Analysis, Quality Control, and Therapeutics. USA Canada: Santa Cruz. Pp. 405-407.
59. Wachtel-Galor S, Yuen J, Buswell JA, Benzie IF (2012). Ganoderma lucidum (Lingzhi or Reishi): a medicinal mushroom. CRC Press, Boca Raton, Florida, USA.
60. Woo YA, Kim HJ, Cho JH, Chung H (1999). Discrimination of herbal medicines according to geographical origin with near infrared reflectance spectroscopy and pattern recognition techniques. J. Pharm. Biomed. Anal. 21: 407-13.
61. Zhao JD, Zhang XQ (1994). Importance, distribution and taxonomy of Ganodermataceae in China. In Proceedings of Contributed Symposium, B 5th International Mycological Congress, Vancouver 1994: Pp. 14-21.
62. Zhao JD, Zhang XQ (2000). Ganodermataceae. Flora Fungorum Sinicorum Science Press, Beijing 18: 1-178.
63. Zhou LW, Cao Y, Wu SH, Vlasák J, Li DW, Li MJ, Dai YC (2015). Global diversity of the Ganoderma lucidum complex (Ganodermataceae, Polyporales) inferred from morphology and multilocus phylogeny. Phytochemistry 114: 7-15.