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E-ISSN : 2456-1045

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RESEARCH JOURNAL

VOLUME - 53 | ISSUE - 1

ADVANCE RESEARCH JOURNAL OF MULTIDISCIPLINARY DISCOVERIES

SEPTEMBER 2020

INTERNATIONAL JOURNAL FOUNDATION
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Phenotypical studies of Ganodermataceae members from Eco-regions of Gujarat, India

ORIGINAL RESEARCH ARTICLE

ISSN : 2456-1045 (Online)
ICV Impact Value: 72.30
GIF- Impact Factor: 5.188
IPI Impact Factor: 3.54
Publishing Copyright @ International Journal Foundation
Article Code: BGS-V53-I1-C3-SEP-2020
Category : BIOLOGICAL SCIENCE
Volume : 53.0 (SEPTEMBER-2020 EDITION)
Issue: 1(One)
Chapter : 3(Three)
Page : 17-26
Journal URL: www.journalresearchijf.com
Paper Received: 04.12.2020
Paper Accepted: 19.12.2020
Date of Publication: 10-01-2021
Doi No.:10.5281/zenodo. 4430457

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ABSTRACT

Ganoderma genus has different species with cultural, economic, and pathogenic importance. In present study, fungal bodies were collected from living or partially dead trees, fallen wooden logs and leaf litter of forest in ecological regions of Gujarat, India. Detailed description of the collected samples revealed the occurrence of Ganodermataceae members like Ganoderma applanatum (Per.) Pat., G. colossum (Fr.) Bers. G. curtisii (Berk.) Murill G. lucidum (Fr.) Karsten. G. zonatum Murrill. G. resinaceum Boud. G. carnosum Pat., G. tsugae Murrill G. sessile Murrill, G. megaloma (Lév.) Bres. G. sichuanense J.D. Zhao & X.Q. Zhang, G. multipileum Ding Hou. Some wood rot fungi belong to Ganodermatace were new records and host records to Gujarat, India. Ganoderma megaloma (Lév.) Bres Ganoderma sessile Murrill, Ganoderma sichuanense J.D. Zhao & X.Q. Zhang, were reported for first time from India.

KEYWORDS: New records, Ecological regions, Fungal Diversity, Ganoderma, Gujarat, India

CITATION OF THE ARTICLE

Nagadesi PK., Arya A. (2020) Phenotypical studies of Ganodermataceae members from Eco-regions of Gujarat, India; *Advance Research Journal of Multidisciplinary Discoveries;* 53(3) pp. 17-26

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I. INTRODUCTION

Taxon of Ganodermataceae members was using as traditional medicines for millions of years in Asia (Zhou et al. 2015). The species are widely researched for their highly potential medicinal values, because they contain many mycochemical constituents with potential nutritional and therapeutic values (Hapuarachchi et al. 2017). it is a large, cosmopolitan family of polypores with five accepted genera: *Amauroderma* Murril, *Ganoderma* P. Karst, *Haddowia* Steyaert, *Humphreya* Steyaert and *Polyporopsis* Audet (Richter et al. 2015). It is distinct from other families of polypores, in having a peculiar type of double-walled basidiospores (Adaskaveg & Gilbertson 1988). The inner walls of *Ganoderma* spores are quite often colored, and usually the surface is ornamented (Donk 1964). At present 596 (epithets) species of Ganodermataceae members are present, in which most of known genus was *Ganoderma* (www.indexfungorum.org, accessed 22 March 2019). *Ganoderma* is largest genus in order aphyllophorales with more than 300 species in India (Bhosle et al 2010). Bakshi (1971) contributed to the study of this genus, describing five species. Bilgrami et al. (1991) recorded seven species of *Ganoderma* in list, 'Fungi of India.' Nagadesi and Arya (2014) reported two species of *Ganoderma* from Gujarat. The state of Gujarat was known for different eco-regions like moist deciduous forests and deserts. The documentation of fungi of Gujarat state was least reported; In spite of this geographic, climatic and vegetation diversity, information on the fungal diversity of the state is scanty and our study is focused on exploration and documentation of fungal diversity of *Ganoderma* species of the state. The taxonomy of *Ganoderma*, group of mushrooms remains largely unresolved.

II. MATERIALS AND METHODS

Study area

Gujarat is bounded by the Arabian Sea at the southwest side. The geographical location of Gujarat was between 20° 6' N t° 24° 42' N and 68° 10'E to 74° 28' E. The total geographical area of the state comprises of land mass of 75,755 sq miles from which a less than 20 lakh hector of land was forest area which was unevenly distributed with hills and plains. the major concentration of different plant species and green patches of forest was found on the eastern hilly areas of Saurashtra region. The temperature ranges from 4° C to 46° C. The high variation in geophysical areas and climatic conditions in it resulted in the formation of different forest types. The rainfall received in the state varies from different region to region and the northern part of the state is a desert area. Great diversity of natural ecosystems ranging from moist deciduous forests to pure desert conditions was observed in the Gujarat state (Tadvi 2013).

Sample collection and phenotypical identification

A survey was conducted during 2009 to 2019 in Gujarat forest, timber merchant shops, sawmills, for collection of samples and phenotypical identification of Ganodermataceae members. Fungal bodies were collected in clean polythene bags from different parts of Gujarat and brought to the lab for phenotypical identification. The fungal bodies were examined for morphological characters based on the method followed by Nagadesi et al. (2014) and Ryvarden (1991). The compound microscope was used to observe the microscopic characters. The various details of specimen were compared with Indian Polyporaceae (Bakshi 1971), Hymenochaetaceae of India (Sharma 1995), and CBS Aphyllophorales database, New Zealand Fungi database, and Species Fungorum, (Sep. 2005). All specimens were identified and sample specimens were kept in the fungal collection of Department of Botany, The Maharaja Sayajirao University of Baroda, Vadodara, India.

III. RESULT AND DISCUSSION

Out of 115 timbers degrading fungi collected, twelve were phenotypicaly identified as *Ganoderma applanatum* (Per.) Pat., *G. colossum* (Fr.) Bers. *G. curtisii* (Berk.) Murill *G. lucidum* (Fr.) Karsten. *G. zonatum* Murrill. *G. resinaceum* Boud. *G. carnosum* Pat., *G. tsugae* Murrill *G. sessile* Murrill, *G. megaloma* (Lév.) Bres. *G. sichuanense* J.D. Zhao & X.Q. Zhang, *G. multipileum* Ding Hou.from different Ecological regions of forests, timber merchant shops, sawmills of Gujarat, India. *G. megaloma* (Lév.) Bres *G. sessile* Murrill, *G. sichuanense* J.D. Zhao & X.Q. Zhang, were reported for first time from India. Some of the fungi were new records to Gujarat, India. The detailed description of Ganodermataceae members were given below.

***Ganoderma applanatum* (Per.) Pat. Bull. Soc. Mycol. France 5: 67, 1889.**

Sporophore perennial, sessile, applanate, single, corky soon becoming hard and woody in dry condition, 12 - 18 X 8 - 11 X 2 - 4 cm sometimes very large (Plate I Fig. B), upper surface brown, zoned, uneven, crusty; context light brown, interspersed with white lint material, fibrous, with silky shine, 2-3.5 cm thick (Plate I Fig. C),. Hymeneal surface white when fresh turning light brown on drying, pores round, 4-5 per mm, pore wall thick, pore tube distinct from context, generally with a distinct white region bordering pore surface stratified, Cuticle hard, less than 0,5 mm thick, context is 2 mm broad, hyphal system trimitic, Basidiospores brown, broadly ellipsoid, thickwalled with outer wall smooth, inner wall echinulate, truncate 6.25- 9.33 (10) X 5.1 – 7.8 (8) µm. Found on *Santalum album, Polyathia longifolia,* and *Pithacelobium dulce.*

Collection examined: Arboretum, Botany department, Biochemistry department, Faculty of Science gate,

Vadodara, Gujarat. Collected by N. Praveen Kumar, Accession no: MSU Bot. 94,127,128; 5-6-2005, 6-7-2007, 7-7-2008.

It is a wound parasite on a great variety of hardwoods species and attack both heartwood and sapwood. The attacked trees are liable to snap on the stem at the region of decay (Bakshi 1971).

***Ganoderma colossum* (Fr.) Bers. Fungi Malay. no 425, 1918,**

Sporphore annual, sessile, applanate, semicircular, corky, soft when fresh, light in weight 25 x 18 x 6 cm, upper surface glabrous, semiglossy, yellow, laccate, cuticle present, cracks up under drying and is often destroyed, margin of lighter colour than the basal part (Plate I Fig.D), hymenial surface white when fresh, pale brown when dry, pores round 2-3 per mm, tubes concolorous with pore surface, pale brown, up to 3 cm deep (Plate I Fig. E), context soft and punky when fresh, cream, corck, up to 6 cm, Hyphal system di-trimitic, Cystidiols present at hyphal end, ventricose, hyaline organs, up to 30.56 µm long. Basidia spherical, 4-sterigmate, 30.25 x 13.65 µm, Basidiospores echinulate, truncate, yellow 14.23 -18.9 x 8.67 -12.65 µm. It was found on angiosperms of many kinds. Pantropical, but not seen from East Africa (Ryvarden and Johansen 1980). It is found on dead trunk of *Polyalthia longifolia* growing in Faculty of Science, MSU campus, Vadodara

Collection examined: Biochemistry Department, Vadodara, Gujarat; collected by N. Praveen Kumar, Accession no: MSU Bot. 90, 8-9-2007.

Plate I

Fig.A

Fig.B

Fig.C

Fig.D

Fig.E

Plate I Fig, A. the upper surface of sporocarps of *Ganoderma sessile*, Fig B. sporophore showing upper surface of *Ganoderma applanatum,* Fig. C. Sporocap of *Ganoderma applanatum* showing upper surface with small stalk, Fig. D the upper surface of *Ganoderma colossum*, Fig. E. The lower surface of *Ganoderma colossum*

***Ganoderma curtisii* (Berk.) Murill N. Am. Fl. 9: 120, 1908,**

Basidiocarp annual, stipe lateral, aplanate, covered with cuticle, pileus rusty brown to grayish brown, golden brown zones (Plate II Fig. A), glabrous, undulate, usually slightly laccate, 10.8 x 7.5 x 06 -1cm thick, margin was blunt to entire, wavy, rusty brown. Hymenium rusty brown to grayish brown with yellow line of zone, 0.4 cm thick, pores circular (Plate II Fig. C), 3 – 5 per mm, tubes separate (Plate II Fig. B). Context brown, 0.3 cm thick, black line absent, Hyphal system dimitic, skeletal hyphae were thick-walled, rusty brown, septate, branched, clamped with narrow lumen, 5.9 µm. generative hyphae were pale yellow to brown, thin-walled, septate, clamped, branched, 3.12 µm. Cuticle was made up of golden yellow, thick-walled with 3.12 µm diameter, bottle shaped, 25 – 46.8 x 9.3 µm. Basidia light yellow, clamped at base, clavate, 21.8 x 3.12 µm , 2 sterigmata. Basidiospores brown, truncate, ellipsoidal to oveal, 8.5 – 11.4 x 5.7 – 6.2 µm (Plate II Fig. D, E).

Collection examined: Found at the base of living tree *Emblica officinalis* from Ratanmahal wildlife sanctuary, (Gujarat), Accession no. MSU Bot. 84, 7-12-2006 and found on trunk of *Peltophorum rouxbergii* from sawmill of station road, Baroda, (Gujarat), collected by N. Praveen Kumar, Accession no: MSU Bot. 90. 4-4-2007. Steyaert, (1980) reported this polypore fungus on dead wood, especially dead stumps in summer and fall, from North California USA. But in present study it was Found at the base of living tree *Emblica officinalis* and trunk of *Peltophorum rouxbergii.*

***Ganoderma lucidum* (Fr.) Karsten. Rev. Mycol. (Toulouse) 3(9): 17, 1881**.

The sporophores perennial, stiptiate corky becoming woody later, 14-16 x 10-12 x 1-3 cm. many grow up to 30cm. stalk lateral, varnished and encrusted, up to 10 cm long and 0.5 to 4.5 cm thick, upper surface shiny with laccate crust, reddish brown, smooth (Plate IV Fig. E). hymenium surface light brown, pores small, 90-250 µ diameter, pore tubes 6-7 mm long Plate IV, Fig. F) Cutis thin, a fraction of 1 mm, Cutis of hymenioderm type composed of anticline inflated extremities of hyaline context, hyphae swollen by melanoid substances leaving usually a central lumen; the melanoid substances are easily saponifed by KOH; Context brown, 2-10 mm thick, hyphal system timitic; Basidiospores brown, thick walled, minutely verrucose, truncate at base, 9.33 – 11.25 x 5 - 6.25 µm. It causes white rot. A large number of sporophores were collected from the base of *Feronia elephantum* from arboratum and *Emblica officinalis* from Rathanmahal.

Collection examined: Arboratum of Botany department and Ratanmahal Wildlife Scantuary, Gujarat; collected by N. Praveen Kumar, Accession no. MSU Bot. 92, 93, 7-12-2006 and 4-7-2007

***Ganoderma zonatum* Murrill.**

Sporophore white when young Surface brown to dark brown at maturity, woody, concentric zones, 5.4 cm to 3.7 cm in length and 4.3 cm to 3.1 cm in width, Solid or somewhat fleshy in nature, the tip is entire with milky white color, Dry in nature (Plate II Fig, F), lower surface milky white in color, broad shaped, pores crowded 5 -7 per mm, circular; basidiospore: Single walled, smooth and ellipsoidal with 6.63 µm in length, 4.47 µmin width, it is infecting the dead wood of pterocarpus santalum (Plate II Fig. G)

Collection examined: Arboratum of Botany department, The M.S. university of Baroda, Gujarat; collected by N. Praveen Kumar, Accession no. MSU Bot. 94, 4-7-2009

Plate II

Fig.A

Fig.B

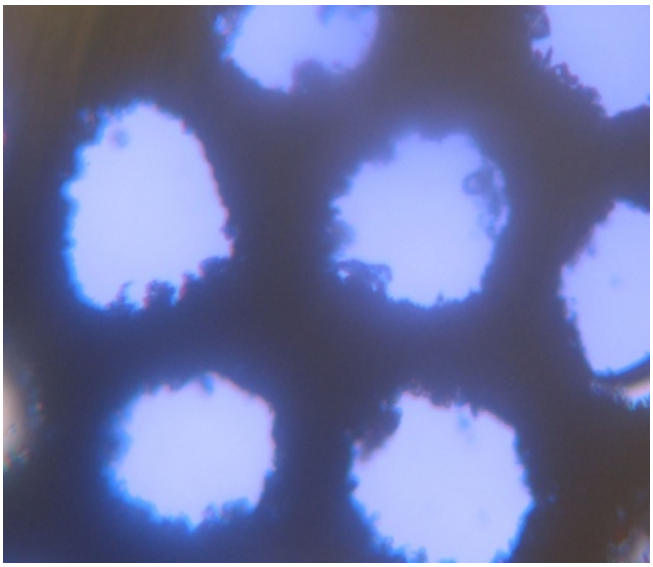

Fig.C

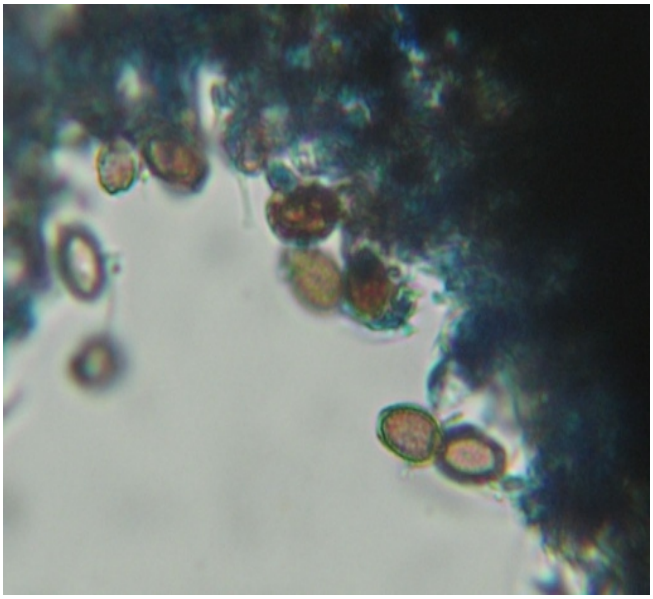

Fig.D

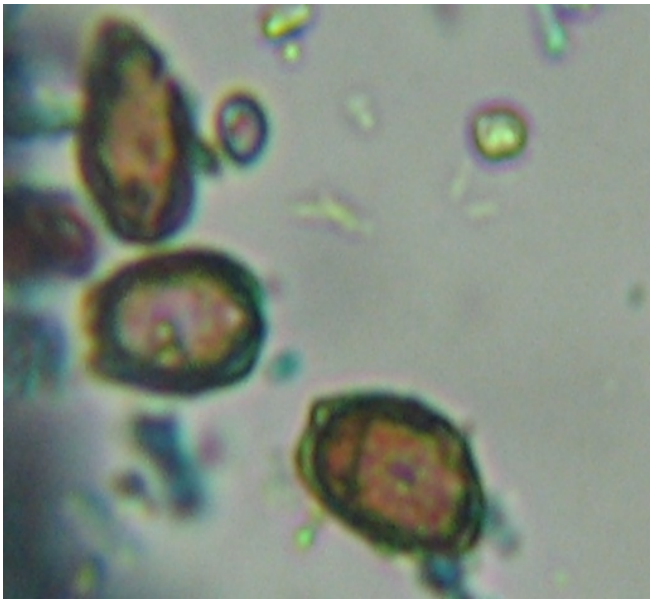

Fig.E

Fig.F

Fig.G

Plate II Fig A. The upper surface of *Ganoderma curtisi*, Fig B. lower surface of *Ganoderma curtissi*, Fig C. Transverse section of spore surface showing pores with spores, Fig. D. The microscopic pore area showing basidiospores, Fig. E. The enlarged view of Basidiospores of *Ganoderma curtissi*, Fig. F, the circular zones on the upper surface of *Ganoderma zonnatum*, Fig. G. the *Ganoderma zonatum* on the wood of *Pterocarpus santalum*

Ganoderma resinaceum Boud.

sporophore Blackish with grayish color, like greass, boarder at Maturity Spongy, woody, Zoned, Smooth, leathery and moist in nature; Margin: Regular in shape with entire, with unpleasent odor, 4 cm in length X 2.1 cm in width (Plate III Fig. A); hymenium surface is grayish brown to White in color with crowded pores (Plate III Fig. B), Basidiospore Single walled, smooth, ellipsoidal 14.9 µm in length, 10.0 µm width it is infecting the wood of pterocarpus santalum living tree,

Collection examined: Arboratum of Botany department, The M.S. university of Baroda, Gujarat; collected by N. Praveen Kumar, Accession no. MSU Bot. 95, 4-5-2009

***Ganoderma carnosum* Pat., Bull. Soc. Mycol. Fr. 5:66, 1889.**

Basidiocarps annual, laterally stipitate, dimidiate, reniform, imbricate. 15 x 19 x 12 cm. coriaceous; upper surface glabrous. shiny and laccate, undulating, occasionally with sulcate zones, vinaceous brown to almost black, actively growing margin white and rounded, later yellowish (Plate III Fig. C); pore surface cream, becoming brown when old, pores round, 3-4 per mm; stipe when present laccate and concolorous with the pileus. 6 cm long, 3.5 cm in diam and irregular thickness (Plate III Fig. D); context of stipe and pileus whitish to cream, soft and fibrillose, up to 3.5 cm thick; tube layer up to 2.5 cm thick, pale brown, not decurrent on the stipe and usually separated from the stipe by a groove. Hyphal system trimitic; surface crust composed of a palisade of claviform hyphal ends, also known as pileocystidia, these pale brown, thick-walled, with strongly amyloid inner walls. 6.25 -12.35 µm in diam, arising from clamps which may be difficult to observe, up to 75 µm from clamp to apex, apical parts covered with a resinous substance responsible for the laccate surface. Cystidia absent. Basidia ovoid, 16.8 x 12.65 µm, 4-sterigmate, with a basal clamp. Basidiospores ellipsoid, truncate at the apex. pale brown, with a thick dark inner wall and a hyaline, very thin exospore separated by interwall pillars, appearing rough under light microscope. negative in Melzer's reagent. 12.25 x 8.5 µm in size; cause White rot of conifers like Abies, but also found on Taxus. Larix, Picea. Pinus and Pseudotsuga; rarely on Betula, Carpinus, Fagus and Quercus.

Collection examined: Arboratum of Botany department, The M.S. university of Baroda, Gujarat; collected by N. Praveen Kumar, Accession no. MSU Bot. 96, 4-5-2009

Plate III

Fig.A

Fig.B

Fig.C

Fig.D

Fig.E

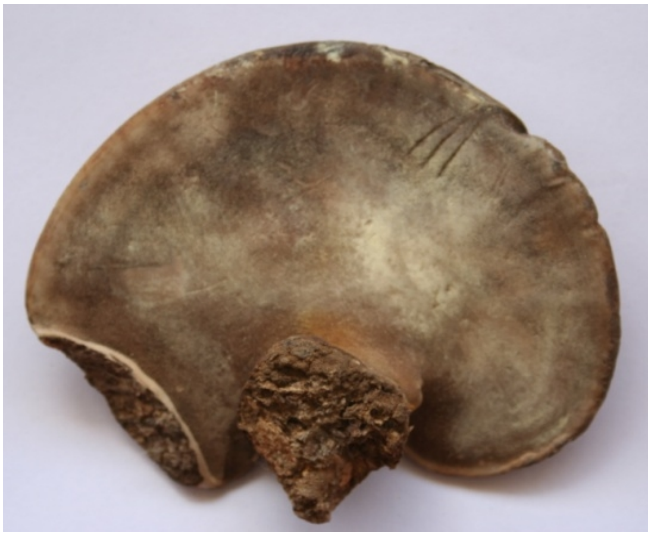

Fig.F

Plate III Fig. A. the sporocarp of Ganoderma resinaceum showing upper surface, Fig. B. the lower surface of Ganoderma resinaceum, Fig, C. upper surface of Ganoderma carnosum, Fig, D. Lower surface of Ganoderma carnosum, Fig. E. upper surface of Ganoderma megaloma, Fig. F. lower surface of Ganoderma megaloma

***Ganoderma tsugae* Murrill.**

Sporophore elongated to fan shaped; with a shiny, varnished surface, zonate; reddish brown; when young often with zones of bright yellow and white toward the margin14 X 16 X2 cm in size (Plate IV Fig. C). Hymenium surface whitish; usually bruising brown; with 4–6 tiny circular pores per mm; tubes to 1 cm deep; Stipe: Sometimes absent, but more commonly present; 3–14 cm long; up to 3 cm thick; equal; varnished and colored like the cap; often distinctively angled away from one side of the cap context: Whitish in fresh; fairly soft, but soon tougher; concentric growth zones and melanoid bands absent. In KOH instantly black on flesh and tubes. Basidiospores 8.35 x 5.65 µm; hyaline vesicular appendix; ellipsoid, with a truncated end; appearing double-walled, with a series of "pillars" between the walls; finely stippled; inamyloid; brown in KOH. Cystidia and setae not found. Hyphal system trimitic. Clamp connections present. Terminal cells on cap surface clavate; 6.5 – 12.65 µm wide; thick-walled; golden in KOH.

Collection examined: Arboratum of Botany department, The M.S. university of Baroda, Gujarat; collected by N. Praveen Kumar, Accession no. MSU Bot. 97, 4-5-2009

***Ganoderma sessile* Murrill.**

sporophore annual, sessile. found growing on trunks or root flares of living or dead hardwood trees, Laccate, reddish-brown, often with a wrinkled margin when dry. shelf-like 20 X 14 X 4 cm in size (Plate I Fig, A). Hymenium white to brown, and poroid with circular to angular pores. The context tissue is cream colored and can be thin to thick and on average the same length as the tubes. Black resinous deposits are never found embedded in the context tissue, but concentric zones are often found. Hyphal system di to trimitic, Basidiospores smooth, due to the fine echinulations from the endosporium, elliptical 6.52 X 4.65 µm n size chlamydospores formed in vegetative mycelium, and are abundant in cultures.

Collection examined: Arboratum of Botany department, The M.S. university of Baroda, Gujarat; collected by N. Praveen Kumar, Accession no. MSU Bot. 98, 4-5-2009

***Ganoderma megaloma* (Lév.) Bres.**

Sporophore annual to perennial, hard, woody, dimidiate, applanate, 15 X 30 X 4 cm.; upper surface milk-white, glabrous, concentrically sulcate, encrusted, fasciate with obscure lines (Plate III Fig. E), conidia-bearing, usually brownish during the growing season from the covering of conidia; margin obtuse, broadly sterile, slightly cremeous, entire: context corky, usually rather hard, zonate, fulvous, 5 to 8 mm. thick, thinner with age; tubes very evenly stratified, separated by thin layers of context, 5 mm. long each season, umbrinous within, pores circular, 5 per mm., whitish-stuffed when young, edges obtuse, entire, white or slightly yellowish to umbrinous, quickly changing color when bruised (Plate III Fig. F): Basidiospores ovoid, smooth or very slightly roughened, pale yellowish-brown, truncate at the base, 8 X 5.45 um.

Collection examined: Arboratum of Botany department, The M.S. university of Baroda, Gujarat; collected by N. Praveen Kumar, Accession no. MSU Bot. 99, 4-5-2009

***Ganoderma sichuanense* J.D. Zhao & X.Q. Zhang, Acta Mycologica Sinica 2:159. 1983**

Basidiome perennial, with stipitate, corky, becoming woody hard when dry 4.5 X 8 X 3 cm, up to 0.5 cm thick at the base. dimidiate, subreniform; upper surface when young pale yellow, becoming brownish orange when old, partly laccate, concentrically sulcate, rugose. Margin pale orange, abruptly paler, slightly lobate (Plate IV Fig. A). Pore surface pale yellow when young, becoming brownish orange when old; tubes up to 0.2 cm long in total, without context layer between tube layers; pores sub circular (Plate IV Fig. B); Context duplex, not completely homogeneous in color, greyish orange corky; Hyphal system trimitic, Basidiospores with a dark brown eusporium bearing thick echinulae, overlaid by a hyaline myxosporium, ellipsoid, 1.37 x. 9.29 x 6.27µm in size, Cutis 4–12 mm thick, pale brown streaks the cutis, a closely-packed palisade, yellowish brown, clavate terminal elements, about 16–29 µm long. Stipe flattened or sub cylindrical to cylindrical, lateral to horizontally lateral or eccentric, 6 × 1.5 cm, along stipe dark brown.

Collection examined: Arboratum of Botany department, The M.S. university of Baroda, Gujarat; collected by N. Praveen Kumar, Accession no. MSU Bot. 100, 4-5-2009

***Ganoderma multipileum* Ding Hou**

Basidiocarp annual, mostly stipitate, rarely sessile or only with a short base, corky. Pileus 1.5-9 × 2.8-16.5 cm, up to 2 cm thick, flabellate, reniform, dimidiate, sometimes with pilei growing from the lower pilei or growing together, up to 36 cm long and 54 cm wide in total; upper surface orange-yellow, orange-red to red-brown (Plate IV Fig. D), weakly to strongly laccate, conspicuously sulcate or not, rugose or not; margin obtuse or not, white to orange-yellow. Pore surface cream when young, becoming straw or pale brown with age; tubes up to 1.1 cm long, pale brown or brown; pores circular or subcircular, 6-8 per mm, 60-220 µm in diam., dissepiments 25-110 µm thick. Stipe when present, 1-9 × 0.4-3 cm, flattened lateral, dorso-lateral, red-brown, strongly laccate. Context 0.1-1.8 cm thick, yellow-brown to dark brown, sometimes with melanoid substances, corky; Hyphal system trimitic; Basidiospores 13.5 × 7.5 µm (with myxosporium), 10.5 × 6.5 µm (without myxosporium), ellipsoid, mostly truncate, brown, with a dark-brown eusporium bearing fine but slightly conspicuous echinulae, walls 0.5-0.8 µm thick. Cutis composed of clavate cells, 60.75 × 12.56 µm, dextrinoid to slightly or strongly amyloid

Plate IV

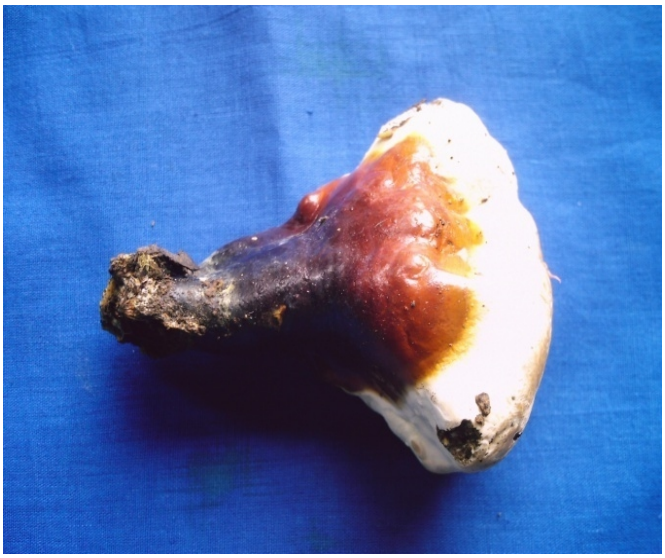

Fig.A

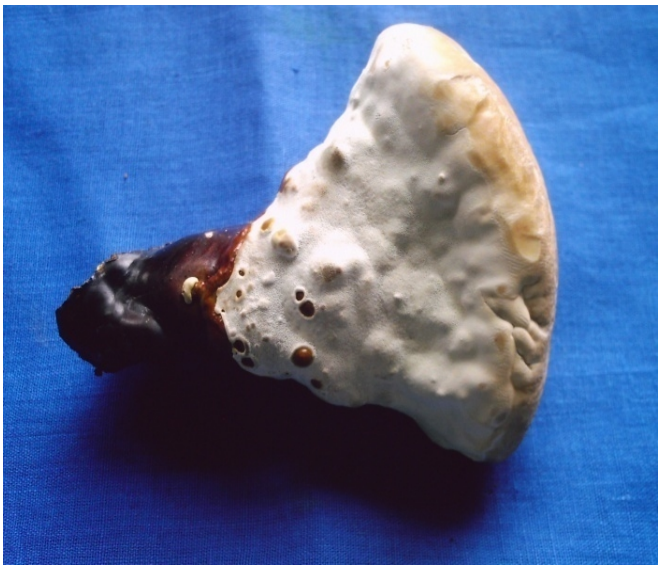

Fig.B

Fig.C

Fig.D

Fig.E

Fig.F

Plate IV Fig. A. upper surface of Ganoderma sichuanense, Fig. B lower surface of Ganoderma sichuanense, Fig. C. upper surface of Ganoderma tsugae, Fig. D. different small pileus fuse to form as single sporocarp of Ganoderma multipileus, Fig. E. upper surface of young bud like sporocarp Ganoderma lucidum, Fig. F lower surface of young bud like sporocarp Ganoderma lucidum

Collection examined: Arboratum of Botany department, The M.S. university of Baroda, Gujarat; collected by N. Praveen Kumar, Accession no. MSU Bot. 101, 4-5-2009

The new record of *Ganoderma curtisii* from India was reported by Nagadesi and Arya (2012). Nagadesi and Arya (2014) reported two species of *Ganoderma* i.e. *G. lucidum* and *G. applanatum* from Gujarat. Rajput et al. (2015) reported six different species of Ganoderma from forest regions of Gujarat. Kokni and Solanki (2019) reported seven different species of Ganoderma from south Gujarat, India. In the present study different species of Ganodermataceae were reported from different parts of the Gujarat, India.

IV. CONCLUSIONS

Ganodermataceae has different species important for cultural, economic, Medicinal, Industrial, and pathogenic point of view. A vast extensive field work was carried during 2009 to 2019 for fungal bodies collected from living or partially dead trees, fallen wooden logs and leaf litter of forest present in different ecological regions of Gujarat, India. The collected sporophores of wood rotting fungi were belong to family Ganodermataceae. The fungal samples were Phenotypical or morphologically identified as *Ganoderma applanatum* (Per.) Pat., *G. colossum* (Fr.) Bers. *G. curtisii* (Berk.) Murill *G. lucidum* (Fr.) Karsten. *G. zonatum* Murrill. *G. resinaceum* Boud. *G. carnosum* Pat., *G. tsugae* Murrill *G. sessile* Murrill, *G. megaloma* (Lév.) Bres. *G. sichuanense* J.D. Zhao & X.Q. Zhang, *G. multipileum* Ding Hou. In the present study found that the wood rot fungi belong to Ganodermatace were new records and host records to Ecoregions of Gujarat, India. *Ganoderma megaloma* (Lév.) Bres *Ganoderma sessile* Murrill, *Ganoderma sichuanense* J.D. Zhao & X.Q. Zhang, were reported for first time from India.

V. ACKNOWLEDGEMENT

The author is thankful to the Head, Department of Botany, The Maharaja Sayajirao University of Baroda for laboratory facilities.

VI. REFERENCES

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