

**BIODIVERSITY AND MORPHOLOGICAL CHARACTERIZATION OF
GANODERMA SPP. FROM TROPICAL MOIST DECIDUOUS FOREST
REGION OF BANGLADESH**

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GANODERMA SPP. FROM TROPICAL MOIST DECIDUOUS FOREST
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BY

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This is to certify that the thesis entitled, “**BIODIVERSITY AND MORPHOLOGICAL CHARACTERIZATION OF *GANODERMA* SPP. FROM TROPICAL MOIST DECIDUOUS FOREST REGION OF BANGLADESH**” submitted to the Department of Plant Pathology, Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in the partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE in PLANT PATHOLOGY**, embodies the result of a piece of bona fide research work carried out by **MST. MAFIA ISLAM, Registration No. 11-04293** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

I further certify that such help or source of information, as has been availed of during the course of this investigation has duly been acknowledged.

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**DEDICATED TO
MY
BELOVED PARENTS**



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ABSTRACT

An investigation was carried out to collect, identify and preserve *Ganoderma* spp. on the basis of morphological characteristics from Pabna, Dhaka and Rajshahi under the tropical moist deciduous forest region in Bangladesh during June to September 2016 and July to October 2017 to record the morphological variability, distribution, habitat, and biodiversity of the *Ganoderma* population. A total of 40 *Ganoderma* samples were collected and identified to eight species under Ganodermataceae family. The highest density of occurrence (23%) was recorded for *Ganoderma lucidum* followed by *Ganoderma applanatum* (20%), *Ganoderma praelongum* (19%), *Ganoderma lesklokorka* (18.5%), *Ganoderma pfeifferi* (17%), *Ganoderma boninense* (15%), *Ganoderma lipsiense* (13%) and *Ganoderma tsugae* (11%). The highest frequency of occurrence (10%) was recorded for *Ganoderma applanatum* followed by *Ganoderma lucidum* (9%), *Ganoderma pfeifferi* (8%), *Ganoderma boninense* (8%), *Ganoderma praelongum* (7%), *Ganoderma lesklokorka* (7%), *Ganoderma tsugae* (6%) and *Ganoderma lipsiense* (5%). During survey, *Albizia procera* (Koroi), *Terminalia arjuna* (Aurjun), *Dalbergia sissoo* (Sisso plant), *Azadirachta indica* (Neem), *Acacia auriculiformis* (Golden shower) and *Albizia lebbeck* (Rain tree) were found as hosts of *Ganoderma* spp. The specimens were preserved in the SAU Herbarium of Macro fungi (SHMF).

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LIST OF ABBREVIATED TERMS

ABBREVIATION	FULL WORD
<i>et al.</i>	And others
cm	centimeter
0C	Degree centigrade
μm	Micrometer
etc.	Etcetera
ed.	Edition
J.	Journal
%	Percent

CHAPTER I

INTRODUCTION

The term “Mushroom” is used mainly for the fruiting body produced by the macro-fungi and these are Ascomycota or Basidiomycota, some are edible, many are poisonous and non-edible. More than 10,000 species of mushrooms are present in and around the world and about 2000 of them are considered as edible (Rumainul *et al*, 2015). These edible fungi are more important for a tropical/subtropical country like Bangladesh, which has a climate, most congenial for the natural growth of such fungi (Purkayastha and Chandra, 1985). Mushroom have high nutritional value along with high proteins, vitamins, minerals, fibers, trace elements content and even low or more or less no calories and cholesterol contents. The number of recognized mushroom species has been reported to be 14,000, Which is about 10% of the total estimated mushroom species on the earth (Cheung, 2008). Mushrooms have been found in fossilized wood that are estimated to be 300 million years old and almost certainly, prehistoric man has used mushroom collected in the wild as food. Edible mushrooms are considered as healthy food because their mineral content is higher than that of meat or fish and most vegetables, apart from their nutritional value mushrooms have potential medicinal values (Chan, 1981; Chang and Miles, 1991).

Ganoderma is regarded as the ‘King of all herbs’ all around the world *Gano* means shine, *Derma* means skin – it has shining skin which is of red color. *Ganoderma* is the greatest herb on earth which can enhance immunity to optimum levels. *Ganoderma* is a genus of polypore mushrooms that grow on wood, and include about 80 species, many from tropical regions (Kirk and Cannon, 2008). Because of their extensive use in traditional Asian medicines, and their potential in bioremediation, they are a very important genus economically. *Ganoderma* can be differentiated from other polypores because they have a double-walled basidiospore. They are popularly referred to as shelf mushrooms or bracket fungi. *Ganoderma* are characterized by basidiocarps that

are large, perennial, woody brackets also called "conks". They are lignicolous and leathery either with or without a stem. The fruit bodies typically grow in a fan-like or hoof-like form on the trunks of living or dead trees. They have double-walled, truncate spores with yellow to brown ornamented inner layers. *Ganoderma*, more than 5000 years old, has various names. In China, it is known as Lingzhi, Japan – Reishi, Arab – Al Kam'ah, Indonesia – Jamur. It has more than 200 natural active elements, divided into three categories 30% water soluble elements, 65% organic soluble elements, 5% volatile elements. Romainul *et al.*, (2016) recorded several *Ganoderma* species as *Ganoderma lucidum*, *Ganoderma boninense* (Growing stage); *Ganoderma tsugae*; *Ganoderma zonatum* (Young stage); *Ganoderma applanatum* and *Ganoderma resinaceum* from Bangladesh. They have high nutritive and medicinal values and contribute to a healthy diet, because of their rich source of vitamins, minerals and proteins (Garcha *et al.*, 1993) There are 38,000 varieties of mushroom found on earth. 36,000 are poisonous, 2,000 are edible, 200 are having special medicinal properties. And out of these 200 – top 6 have greatest medicinal properties – far superior than any other in this group. Therefore, it is essential to give an efforts to introduce new mushrooms as a source of food and medicinal interest. The *Ganoderma* red mushroom has exceptional anti-stress qualities that can help improve memory, reduce tension and sharpen your concentration. The knowledge on biodiversity at the community and species level is more important for monitoring the effectiveness and effects of natural and artificial disturbances (Packhamet *et al.*, 2002). Data on their diversity in different vegetation types is important for planning and managing ecosystem biodiversity (Engola *et al.*, 2007). The biodiversity of mushroom is recently reported from the tropical moist deciduous forest region of Bangladesh (Romainul *et al.*, 2015; Romainul and Aminuzzaman, 2016). Tropical moist deciduous forest region is under about 80% of Bangladesh's rainfalls area during the monsoon season extending from June to September. Dhaka, Gazipur, Bogra, Rajshahi, Pabna, Jaipurhat, and Dinajpur, which are situated in the tropical moist deciduous forest region of Bangladesh. Keeping this view in mind the present research work was

conducted by a systematic survey in tropical moist deciduous forest regions of Bangladesh with the following objectives –

1. To study the distribution, diversity and habitat of *Ganoderma* spp. from the tropical moist deciduous forest region of Bangladesh.
2. To identify *Ganoderma* spp. up to the genus and species level.
3. To study morphological and characterization of identified *Ganoderma* spp. from the tropical moist deciduous forest region of Bangladesh.

CHAPTER II

REVIEW OF LITERATURE

The forest of Bangladesh can be grouped in to four broad categories depending on their location, nature and type of management. They are mangrove forest, tropical moist deciduous forests, tropical evergreen and semi evergreen forests and village forests. Among them the mushroom biodiversity of tropical moist deciduous forest and mangrove forest have been described. The main purpose of this chapter is to review the previous studies, which are related to the present study. Therefore, an attempt has been made here to compile the research work carried out on the subject elsewhere.

Marzana *et al.* (2018) conducted a survey in Rangamati district of Chittagong hill tracts from July to October, 2016 to collect and record the morphological and ecological variability of macrofungi fruiting body. A total of 66 samples of macrofungi were collected, recorded, photographed and preserved. They identified twenty species of macrofungi under 17 genera and 15 families. The highest frequency of occurrence (44.44%) was recorded for *Xylaria polymorpha*. The highest density was found for *Xylaria polymorpha* (55.56%) also followed by *Coprinus disseminates* (52.78%), *Auricularia cornea* (38.89%), *Xylaria hypoxylon* (27.78%) and *Clavulina coralloides* (16.67%). This is the first detail reports on macrofungi collected from Rangamati Hill Tracts forest of Bangladesh.

Rubina *et al.* (2017) conducted a survey in National Botanical Garden, Dhaka located at 24°00' N (Latitude), 90°00' E (Longitude) to document the morphology, diversity and distribution of macro fungi during the rainy seasons of July to October, 2015. A total of 23 macro fungi samples were collected and identified to 20 species under 10 genera and 10 families. The predominant genera were *Ganoderma* sp., *Lepiotasp.*, *Daedaleopsis* sp., *Russula* sp.,

Psythyrella sp., *Lycoperdon* sp., *Crepidotus* sp., *Psilocybe* sp, *Flammulina* sp. and *Cantharellus* sp. The survey revealed that five species are edible, six species have medicinal value, three species are inedible and three are unknown. The maximum density of occurrence was exhibited by *Psilocybe cubensis* (45%) followed by *Lepiota* sp. (40%), *Ganoderma pfeifferi* (35%) and *Ganoderma lucidum* (25%).

Das and Aminuzzaman (2017) first time investigated the largest tidal halophytic forest in the world which lies a little south to the Tropic of Cancer between the latitudes 21°30'N and 22°30'N, and longitudes 89°00'E and 89°55'E. This forest is the greatest source of diverse xylotrophic fungi and the predominant families were recorded under Polyporaceae, Ganodermataceae, Hymenochaetaceae, Fomitopsidaceae, Xylariaceae, Steccherinaceae and Gloeophyllaceae families. The maximum frequency (75%) was recorded for *Daedaleopsis confragosa* and 50% for *Trametes elegans*, *Trametes conchifer*, *Polyporus sanguineus*, *Ganoderma curtisii* and *Irpex lacteus*. The maximum density was 31.82% for *Polyporus sanguineus* which was found on the Sundari (*Heritiera fomes*) tree.

Rashid *et al.*(2017) survey was conducted to study the biodiversity, habitat and morphology of mushroom grown in leaved, deciduous and mixed forest of Bangladesh. A total of 117 samples were collected from nine selected districts of Bangladesh viz. Barisal, Borguna, Patuakhali, Pirojpur, Jhalokathi, Bandorban, Dhaka, Gazipur and Tangail. About 12 different species were found under 10 families' viz. Amanitaceae (*Amanita bisporigera*), Pyronemataceae (*Aleuria aurantia*), Boletaceae (*Boletus subvelutipes*), Agaricaceae (*Agaricus* sp.), Tricholomataceae (*Callistosporium* sp.), Marasmiaceae (*Gymnopus* sp.), Cortinariaceae (*Cortinarius corrugatus*), Mycenaceae (*Mycena epipterygia*), Entolomataceae (*Nolanea strictia*), Ganodermataceae (*Ganoderma lucidum*, *Ganoderma applanatum*, *Ganoderma tsuaga*). The predominant genera were *Amanita*, *Aleuria*, *Agaricus*, *Boletus*, *Mycena*, *Cortinarius*, *Nolanea* and *Ganoderma*.

Aminuzzaman and Das (2016) carried out a research in Bogra district under the Social forest region of Bangladesh to study the biodiversity, distribution and morphology of wild macro fungi during June to October, 2015. A total of 32 fungal samples were collected and identified to 16 species belong to two genera under 7 families. The polypore genera were *Ganoderma* sp. (87.5% of collected samples) and *Polyporus* sp. (12.5%). The maximum frequency of occurrence (75%) was exhibited by *Ganoderma lucidum*, *Ganoderma multipileum*, *Ganoderma boninense*, *Ganoderma* sp. and the maximum density was exhibited by *Ganoderma resinaceum* (66.67%).

Das *et al.* (2016) investigated the largest single block of tidal halophytic forest. Mangrove (Sundarban) and collected 72 macro fungal samples identified to 21 genera and 32 species. The dominant species were *Agaricus campestris*, *Agaricus xanthodermus*, *Agaricus silvicola*, *Agaricus aungustus*, *Agaricus arvensis*, *Agaricus bitorquis*, *Coprinus silvaticus*, *Coprinus plicatilis*, *Marasmius* sp., *Marasmius siccus*, *Marasmius nigrodiscus*, *Marasmiellus albuscorticis*, *Volvariella hypopithys*, *Volvariella speciosa*, *Crepidotus alabamensis* and *Crepidotus applanatus*. The maximum frequency (75%) was recorded for *Agaricus silvicola*, *Lepiota* sp., *Marasmiellus albuscorticis* and *Volvariella speciosa*. The maximum density was 287.5% recorded for *Coprinus silvaticus*. The predominant families were Agaricaceae, Marasmiaceae, Pluteaceae, Crepidotaceae and Mycenaceae.

Rahaman *et al.* (2016) conducted a survey from June to October, 2014 in 5 districts namely Kushtia, Chuadanga, Jessore, Satkhira and Khulna. A total of 16 mushroom species belong to 10 genera, under 8 families were recorded during the survey. *Lepiota cristata* was found abundantly in the survey areas among the other collected species and it exhibited the maximum frequency of occurrence (25%), whereas the maximum density (13.51%) was recorded for *Hypholoma fasciculeare* and *Coprinellus micaceus*, followed by *Lepiota cristata*, *Coprinus comatus* and *Mycena californiensis* (10.81%). Furthermore,

the density of *Gymnopilus purpuratus*, *Coprinus sterquilinus*, *Marasmius oreades*, *Hypholoma capnoides* and *Coprinellus plagioporus* were recorded as 8.10%. Moreover, *Lepiota cristata* was distributed in Daulatpur of Kushtia and Koira of Khulna districts in the south western region of Bangladesh.

Rumainul and Aminuzzaman (2016) the survey was conducted Dhaka, Gazipur, Bogra, Rajshahi, Pabna, Jaipurhat and Dinajpur of central and northern biosphere reserved areas of tropical moist deciduous forest region of Bangladesh during the end of rainy season starting from July to October, 2013 and 2014, respectively. Among 50 samples, 8 genera and 9 species were able to identify through this investigation, including 2 species of *Daedaleopsis* and 1 species each of the genera. The predominant genera were *Trametes*, *Daedaleopsis*, *Collybia* and *Armillaria*. This preliminary investigation suggested that, the central and northern region of Bangladesh under tropical moist deciduous forest region is enriched with diversity of wild. *Trametes*, *Pycnoporus*, *Boletus*, *Tuber*, *Collybia*, *Panaeolus* and *Armillaria*. The genus *Trametes* was found in Dinajpur district of tropical moist deciduous forest region at the northern part of Bangladesh. It was first described by Elias Magnus Fries as a saprobion on the deadwood of hardwoods.

Rashid *et al.* (2016) survey was conducted to study the biodiversity as well as the distribution of wild mushrooms, which naturally grow, in different localities, at different seasons, in the southern region of Bangladesh. A total 24 species of mushrooms belonging to 17 genera and 14 families were identified. Those mushrooms were collected between July and October, 2013 and 2014, accordingly from 16 sub-districts of Barisal, Patuakhali, Borguna, Pirojpur, Jhalokhati districts, which situated in the southern region of Bangladesh. The identified genera were viz., *Amanita* sp., *Agaricus* sp., *Ganoderma* sp., *Armillaria* sp., *Coprinus* sp., *Cortinarius* sp., *Hebeloma* sp., *Mycena* sp., *Lepiota* sp., *Lycoperdon* sp., *Macrolepiotia* sp., *Daldinia* sp., *Tuber* sp., *Volvariella* sp., *Steccherinum* sp., *Hypholoma* sp. and *Coprinellus* sp. Moreover, the maximum

frequency of occurrence in this survey was exhibited by *Ganoderma applanatum*, *Amanita vaginata* and *Agaricus silvicola* (18.75%), whereas, the maximum density was recorded for *Coprinus silvaticus* (48.83%).

Beuy and Viroj (2016) stated that Linzhi (*Ganoderma lucidum*) is a well-known medicinal mushroom. This mushroom originated from China becomes the widely used supplementation worldwide. The active ingredient in the mushroom is mentioned for anti-oxidative, glucose controlling and anti-cancerous proliferative activities. In nephrology, the advantage of Linzhi on kidney is also mentioned. However, the evidence in human beings is limited. In this short manuscript, the authors discuss on evidence of Linzhi's clinical usefulness in renal diseases.

Sharareh *et al.* (2016) reported that the wild macrofungi provide a significant source of nutritional and medicinal bioactive compounds. They have been collected and consumed by people from many countries for thousands of years. However, there is a shortage of information in the literature regarding Iranian wild macrofungi. Thus, this mini-review tries to outline recent efforts made in order to collect, identify, and maintain wild macrofungi of Iran. This review may also encourage more research on collection, assessment, and biochemical analysis of Iranian wild macrofungi in order to establish a germplasm bank of wild macrofungi for the future identification and further research.

Rumainul *et al.* (2015) investigated mushrooms flora in seven different areas of tropical moist deciduous forest region of Bangladesh namely Dhaka, Gazipur, Bogra, Rajshahi, Pabna, Jaipurhat and Dinajpur. Mushroom flora associated with these forest regions were collected, photographed and preserved. A total of fifty samples were collected and identified to fourteen genera and twenty four species. The predominant genera were *Ganoderma* sp., *Lepiota* sp., *Marasmius* sp. and *Collybia* sp.

Krishna *et al.* (2015) collected the fruiting bodies of macrofungi from some forests, fences, waste fields, timber depots during rainy season to give a broad picture of diversity of macrofungi belonging to the class Basidiomycetes of Telangana region. A total number of 50 fruiting bodies were collected and cultured and among them only ten were identified based on their macroscopic features and molecular identification since they showed good lignolytic activity.

Kinge and Mih (2015) studied the diversity and distribution of species of *Ganoderma* in south western Cameroon. They collected 57 samples of *Ganoderma* from oil palm and other hosts for identification using comparative morphology and molecular techniques. Morphological and molecular characterization of the 57 species showed that they belonged to 17 species of *Ganoderma* of which two species, *Ganoderma tornatum* and *Ganoderma chalconeum* are new records for Cameroon. Four species, *Ganoderma weberianum*, *Ganoderma cupreum*, *Ganoderma steyaertianum*, *Ganoderma zonatum* are new records for Cameroon. The remaining 11 species belong to *Ganoderma ryvardenae*, *Ganoderma lobenense* and *Ganoderma* species 1-9 with different affinities might be new to science. Six plant species were identified as hosts to different species of *Ganoderma*. They are *Elaeis guineensis*, *Cassia* sp., *Acacia* sp., *Pinus sylvestris*, *Avocado* sp. and unidentified hardwood, with *E. guineensis*, hosting the highest number of species.

Manna *et al.* (2014) reported, *Astraeus hygrometricus*, *Amanita vaginata* var. *alba*, *Amanita bannigiana*, *Russula nigricans*, *Termitomyces eurrhizus* and *Termitomyces microcarpus* among 18 mushroom species related to tribal use as the most usable species. Monsoon and post-monsoon periods which fall during the second half of August are found to be the optimum time for the production of 11 wild edible mushrooms. Out of the total calculated production, 47.2% of the same was noted during this time. These regions with

tribal populations, especially the Santals in the forest fringes, have traditional knowledge related to mushrooms.

Vyas *et al.* (2014) conducted an experiment on Patharia forest which is mixed and dry deciduous type, dominated by *Acacia* sp., *Butea monosperma*, *Tectona grandis* and ground flora consisting of *Biophytum sensitivum*, *Cynodon dactylon*, *Lanata camara* etc. During the period of July 2011-July 2013, wild macrofungi were collected from Patharia forest and identified to 18 species belonging to 12 families. They were *Vascellum pretense*, *Lycoperdon pyriform*, *Coniphora puteana*, *Clitocybe geotropa*, *Ganoderma tsugae*, *Microglossum virde*, *Panaeolus sphinctrinus*, *Pleurotus cornucopiae*, *Fomes fomentariuc*, *Tyromyces lacteus*, *Lenzites betulina*, *Hypholoma elongatum*, *Pholita highlandensis*, *Serpula lacrymans*, *Tremella mesenterica*, *Lepisa nuda*, *Collybia butyracea* and *Omphalina ericetorum*, belonging to 12 families.

Chelela *et al.* (2014) conducted a survey to assess mycological knowledge and socio-economic benefits along the wild edible mushrooms value chain among Benna and Hehe ethnic groups in the Southern Highlands of Tanzania. They collected wild edible mushrooms in the Miombo woodland surrounding six villages during rainy season in January 2014. From the survey, mushroom collection and selling was gender oriented dominated by women at 70% and 93.5%, respectively. Moreover, it was found that 30% of men were involved in collecting and only 6.5% in selling. About 45 species of wild edible mushrooms were collected mainly from *Lactarius*, *Russula*, *Cantharellus* and *Amanita* species.

Andrew *et al.* (2013) reported the diversity and distribution of macrofungi in the Mount Cameroon Region. These were assessed at low and high altitudinal ranges in the four flanks of the mountain during the rainy and early dry seasons of 2010 and 2011. A total of 177 macrofungal species belonging to 83

genera and 38 families were recorded. Species richness was higher in the rainy seasons (134 species) than in the early dry seasons (89 species) and tended to decrease with altitude, with 116 and 112 species for low and high altitudes, respectively. Eighty-eight species were recorded only in the rainy seasons, 43 species in the early dry seasons only, and 46 species were common to both seasons. Sixty-five species were found only in the low altitude, 61 species only in the high altitude, and 51 species were common to both altitudes. *Auricularia auricular* was the most abundant species during the rainy seasons, while *Coltricia cinnamomea* was rare during the rainy seasons, and the most abundant during the dry seasons. Six of the 12 morpho-groups identified occurred across the sites, with the gilled fungi being the most frequent. *Cyathus striatus* was found only in Buea Town during the rainy seasons.

Chandulal *et al.*(2013) identified 17 species belonging to two different classes namely, Gastromycetes – *Daldinia concentrica* [(Xylariaceae) (cramp ball)], *Lycoperdon pyriforme* [(Lycoperdaceae, edible) (wood or stump puff ball)], *Scleroderma citrinum* (sclerodermataceae, edible); *Hymenomyces Cantharrellus umbonatus*, *Coriolus versicolor* (polyporaceae, inedible), *Schizophyllum commune* (Schizophyllaceae, inedible) (the split gill), *Ganoderma lucidum* (Ganodermataceae), *Ganoderma applanatum* (ganodermataceae), *Laetiporus sulphureus* (Polyporaceae, edible), *Lepiota organensis*, *Collybia butyracea*, *Lentinellus cochleatus* (Auriscalpiaceae, edible), *Galerina unicolor* (Hymenogastreae), *Citocybe flaccid* (Trichomataceae, edible), *Oudemansiella redicata* (Physalacriaceae, edible), *Hygrophorus eburneus* (Hygrophoraceae, edible) and *Agaricus campestris* (Agaricaceae, edible). The investigation proves the existence of a distinct biodiversity in mushroom population.

Pandey *et al.* (2013) conducted a study in Jeypore Reserve Forest located in Assam, India to investigate the diversity of macro fungi associated with different tree species. Thirty macro fungal species representing 26 genera belonging to 17 families were collected from six different sites in the study area. Out of these

maximum six genera assignable to family Polyporaceae, five genera to Russulaceae, three genera to Agaricaceae, two genera to Ganodermataceae and Cantharellaceae each and rest of the families were represented by single genus only. The study revealed that maximum frequency of occurrence was exhibited by *Trametes versicolor* and *Schizophyllum commune* (83.33%), followed by *Microporus xanthopus* *Pycnoporus sanguineus* (66.67%) and *Coprinus disseminates* (50%). The rest of the species exhibited the frequency distribution ranging between 16.67-33.33%. The maximum density was recorded for *Schizophyllum commune* (126.67%) followed by *Trametes versicolor* (120%) and *Xylaria polymorpha* (93.33%).

Hosen *et al.* (2013) described a new monotypic genus in the boletaceae, *Borofutus*, typified by *B. dhakanus*, using morphological and molecular evidence. This is a putatively ectomycorrhizal fungus associated with *Shorea reobusta*. *Borofutus* is sister to *Spongi* forma in molecular phylogenetic analysis using DNA nucleotide sequences of single or multiple loci. They presented a description, line drawings, phylogenetic placement and comparison with allied taxa

Pushpa and Purushothama (2012) conducted a survey on the biodiversity of mushrooms belonging to the class Basidiomycetes in Bangalore. The survey were conducted from June 2007 to November 2010 in eight different places which included scrub jungles and urban places in a around Bangalore. 18A total number of 90 species in 48 genera belonging to 19 families in 05 orders were recorded, 28 species were found to be recorded for the first time in India. Among the collected species *Coprinus disseminates* followed by *Coprinus fibrillosis* and *Schizophyllum communae* was found to be abundant in their occurrence. The Simpson and Sannon divers ity biodiversity index was found to be 0.8 and 1.24, respectively.

Dwivedi *et al.* (2012) studied on the taxonomy and diversity of macro fungi in semi evergreen and moist deciduous forest of Amarkantak where more

than 50 samples were collected which is situated in Madhya Pradesh in India. Extensive surveys were conducted from July 2010 to September 2010, where collection, characterization, preservation and photo of macro fungal carried the genera like is *Agaricus*, *Amanita*, *Nyctalis*, *Russula*, *Boletus*, *Macrolapiota*, *Ganoderma* and *Termitomyces*. Out of 50 samples only 16 samples were identified up to species level. This preliminary study shows that the forest is very rich in mushroom diversity.

Bankole and Adekunle (2012) conducted an experiment on biodiversity of macrofungi in Lagos State, Nigeria as they collected in Lagos State for 12 months. The predominant macrofungi collected included *Agaricus campestris*, *Coprinus comatus*, *Daldinia concetrica*, *Ganoderma adspersum*, *Ganoderma applanatum*, *Ganoderma lucidum*, *Mycena haematopus*, *Mycena* sp., *Pleurotus ostreatus*, *Pleurotus tuber-regium*, *Polyporus* sp., *Polyporus squamosus*, *Polyporus sulphureus*, *Trametes versicolor*, *Xylaria polymorpha* and *Xylaria* sp. during investigation.

Zhou (2012) said that the Japanese thought that the true *Ganoderma* should be with red color, *Ganoderma* species with a different colour was due to variations in its growing environmental conditions which included temperature, humidity, light condition, etc. The Chinese believed that the true Lingzhi should be with black color because there are a lot of reports about black Lingzhi that had unusual medicinal benefits.

Pithak and Pukahute (2012) conducted a survey on the diversity of mushrooms in dry dipterocarp forest at Phuphan National Park to study the variety of mushrooms grown in the Dry Dip- terocarp forest during the year 2008-2009 by releve method and to study the relationship between *Shoreaasia mensis* Miq. and ectomycorrhizal of the Amanitaceae and the Belotaceae families. The findings of the study reveals the presence of a total 34

types of mushrooms in Dry Dipterocarp forest at the Phuphan where there were 26 types found in both years.

Onyango and Ower (2011) investigated morphological characters and spawn production procedures of three Kenyan native strains of wood ear mushroom [*Auricularia auricula* (L. ex Hook.) Underw]. Nine basidiocarps were selected from collections made in three forest reserves within Kakamega Forest in Western Kenya and morphologically characterized of macrofungi fruiting bodies.

Buchalo *et al.* (2011) proposed the criteria for the correct identification of the taxonomic position of mushrooms such as presence and morphology of teleomorph stage; colour, morphology and growth rate of mycelia colony; type of anamorph; presence, dislocation and morphology of clamp connections; special hyphal structures and other characteristics.

Ram *et al.* (2010) conducted a field experiment for collection of various edible fleshy fungi from different localities of Eastern Uttar Pradesh forest during the rainy season on dead and decaying plant or animal remains. However there are only few species of fungi which have been accepted as safe food by the civilized world, while many fleshy fungi have not yet recognized. The collected edible fleshy fungi were studied for their macroscopic detail pertaining the habit, habitat, morphology and other phenotypic parameter noted in fresh form.

Karwa and Rai (2010) reported on the tapping into the edible fungi biodiversity of Melghat forest in Central India for occurrence of wild edible fungi and their prevalent favorable ecological factors in consecutive years in the months of June to February (2006-2008). A total of 153 species of mushrooms were recorded, collected, photographed and preserved. The

enormous biomass in the forest favors variety of edible and medicinal mushrooms. Dominating species belong to genera *Agaricus*, *Pleurotus*, *Termitomyces*, *Cantharellus*, *Ganoderma*, *Auricularia*, *Schizophyllum*, *Morchella*, etc.

Sanodiyas (2009) found *Ganoderma* occurs in Coconut palm causing Basal Stem Rot diseases, referred as Thanjavur wilt. *Ganoderama lucidum* is less frequently found on coniferous trees (e.g., *Larix*, *Picea*, *Pinus*) in Europe, Asia, and North and South America (in temperate rather than subtropical regions).

Agrahar and Subbuakshmi (2005) conducted an experiment on Meghalaya mushrooms. Meghalaya (25°47'N and 26°10'N latitude and 89°45'E and 92°47'E longitude) is a hilly state projecting like a monument between the two plains of Assam in the north and Bangladesh in south. It has a wide variation in altitude, topography and agro climate. The region in general is blessed with a rich forest growth, with about 0-50% of the geographical area covered with lush green forests. These forests abound in macro fungi which are found growing on the forest-floor, wigs and branches, rotting plant parts, in mycorrhizal association with higher plants, etc. They conducted a survey to identify the edible fungi of this region with respect to their morphology distribution, habitat and edibility.

Wang *et al.* (2012) described that *Ganoderma* P. Karst. (Basidiomycetes, Ganodermataceae) is a genus of well-known medicinal mushrooms, *Ganoderma* in English, belongs to a kind of wood decaying polypore fungi of economic importance, and a widely distributed fungal genus with high diversity of species especially in the tropics in the ancient China, *Ganoderma* had been regarded as a herb of longevity and used for preventing and treating diseases for more than two thousand years. Because of the unique pharmacological function and without toxic and side effects, the genus

Ganoderma has got a good reputation in some Asian and African countries as the folk herbal medicine.

Lalitha (2004) found the pore surface is cream in colour and the spores are brown. *Ganoderma lucidum* is widely distributed all over in tropical and temperate regions. In natural forests, it occurs on old declining trees and decayed wood stumps causing white rots removing lignin as well as cellulose and related polysaccharides.

Dreistadt *et al.* (2004) reported a species of fungus that digests moist wood, and causing it to rot. Some species of wood-decay fungi attack dead wood causes brown rot like *Ganoderma applanatum* (artist's conk), *Ganoderma lucidum* (varnish fungus rot).

Cromack and Caldwell (1992) reported that Wood-decay fungi have key-roles in the ecology of nemoral and boreal forests since they are the major agents of wood decomposition and nutrient cycling.

Nilsson and Presson (1978) found that color, shape and size of the fruiting body of fleshy fungi can vary tremendously and to avoid a poisonous species it is most important to properly identify the mushrooms. They reported mushroom species as the indicators of the forest life system. Data of different vegetation types is important for planning to determine biodiversity and habitat at the community and species level they reported. Their habitat and climate are major factors that indicate their biodiversity.

Steyaert *et al.* (1961) described originally the genus *Ganoderma* (Ganodermataceae, Polyporales) was established by Petter Adolf Karsten based on a single species, *Boletus lucidus* Leyss. *Ganoderma lucidum* (Curtis) P. Karst.), from Europe.

Anonymous (1955) found that Ling-zhi is a famous fungus for its medicinal values well documented in the Chinese literature which can be dated back nearly

two thousand years to the *Shen Nong Materia Medica* (102–200AD). It symbolises happiness, good fortune, good health and even immortality in Chinese traditional culture. There are thousands of publications relating to this fungus and it is now commercially cultivated on a large scale. Isolates used in medicinal studies and the commercially cultivated strains are generally named ‘*Ganoderma lucidum*’.

Karsten (1881) described the named of the members of the family Ganodermataceae were traditionally considered difficult to classify because of the lack of reliable morphological characteristics, the overabundance of synonyms, and the widespread misuse of names. Until recently, the genus was divided into two sections – Section *Ganoderma* with a shiny cap surface (like *Ganoderma lucidum*) and *Elfvingia*, with a dull cap surface, like *Ganoderma applanatum*.

CHAPTER III

MATERIALS AND METHODS

3.1 Collection site

The survey was conducted in Dhaka, Pabna, Rajshahi biosphere reserved areas, which are situated in tropical moist deciduous forest region of Bangladesh. Survey and collection of *Ganoderma* spp. was conducted during rainy season starting from June to October, 2016 and 2017, respectively. The collection sites were forests, residential area, botanical garden, parks and nearby villages of those above mentioned areas of tropical moist deciduous forest region.

3.2 Experimental site

The analytical experiments were conducted in the Laboratory of the Department of Plant Pathology, Sher-e-Bangla Agricultural University (SAU), Dhaka, Bangladesh.

3.3 Sampling procedure

A standard collection procedure and data recorded procedure was applied to collect information on biodiversity, distribution, habitat, cultivation and morphology *Ganoderma* spp. from the above mentioned regions of Bangladesh.

3.4 Collection of *Ganoderma* spp. samples

The collection was made following the method of Hailing *et al.*, (1996). Systematic and periodical survey of different locations and other habitats were done in the tropical moist deciduous forest region of the country. Necessary materials and equipment such as isolation kit, slants, isolation chamber, data recording sheet, digital camera for photography, digging equipment, were arranged. Collection of samples were usually made during day time. A field characteristics of samples were recorded in the data sheet which was prepared following Molina *et al.* (1995). Spotted samples were

minutely inspected in their natural habitats and brought to laboratory for detailed study.

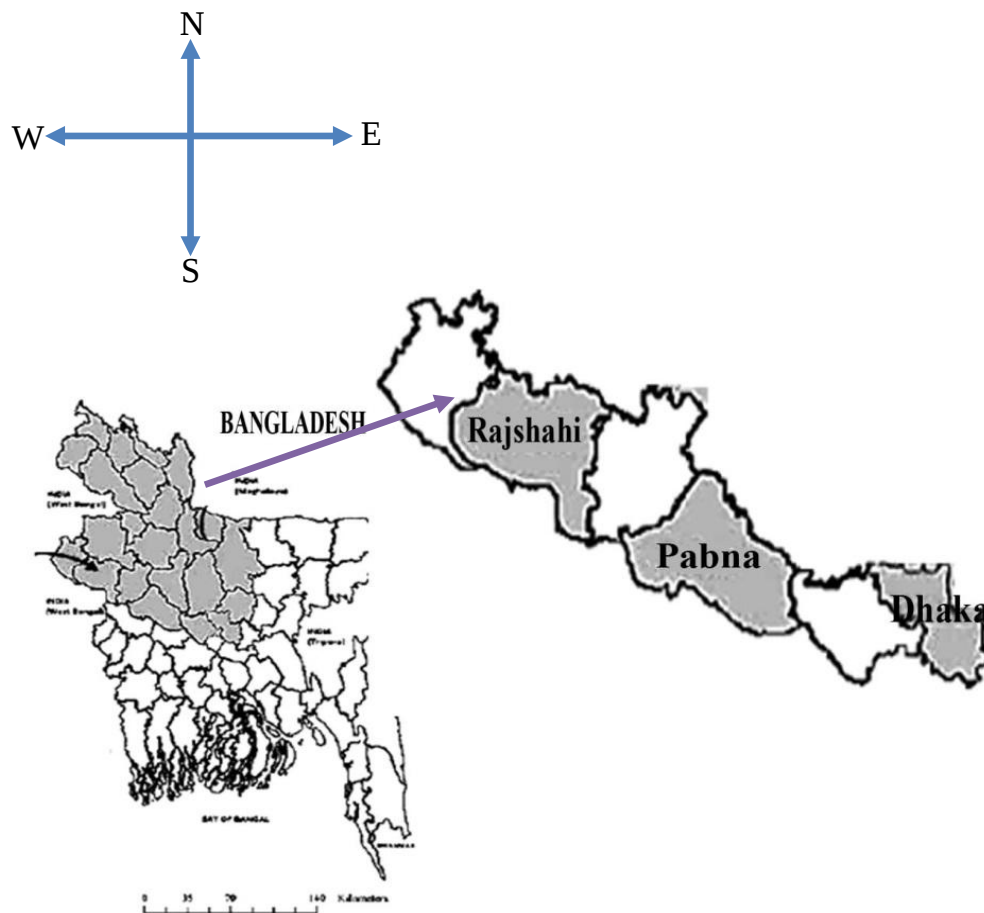


Figure 1. Survey areas of tropical moist deciduous forest region of Bangladesh

3.5 Morphological observation during collection

The data for the identification of *Ganoderma* samples were recorded after collection on the following parameters, such as locality, habitat, type of soil, forest type, size of the fructification, carpophores shape, umbo, cap color, cap surface, cap margin, cap diameter, scale, gill color, gill edges, gill attachment, gill spacing, stipe length, width, color, shape, type of veil, annuls (position) and volva (Srivastava and Bano, 2010). Spore character were recorded and photographed using motic microscope with help of motic Images plus 2.0 software. Final identification and classification were done by comparing recorded characteristics of mushrooms with the color dictionary of mushroom given by Dickinson and Lucas (1982), the mushroom guide and followed by the reference of Jorden (2004) and Pegler and Spooner (1997).

3.6 Processing of *Ganoderma* spp.

For removing debris freshly harvested mushroom was washed by tap water. During the analysis period some precautions were followed before processing of mushroom. Mainly two types of preservation process-one is short term preservation and another is long term preservation were followed on the basis of study purpose and structure of the samples (Kim, 2004).

3.6.1 Drying

Collected samples were cleaned and dried by using electrical air flow drier the 1000 voltage, which can easily remove the moisture content from the collected mushrooms within 3-7 controlling hours with a regular interval basis power supply (15 minutes switch off and 30 minutes switch on) depending on the structure and texture of the species (Kim, 2004).

3.6.2 Storage

Dried mushrooms were stored into a zip-lock type polybag for further studies. Silica gels were used at the rate of 10% of dry basis during the storage period (Kim, 2004).

3.7 Habitat, distribution and diversity analysis

The specimens were found attached to various substrata. The surrounding environment temperature, soil pH, moisture condition, vegetation recorded for biodiversity of macro fungi. Soil pH, soil moisture were measured by pH meter and air temperature by thermometer during collection period. Collected samples were wrapped in polybag and brought to the laboratory for their further study. The frequency and density of different species has been determined by using the following formulas (Zoberi, 1973).

$$\text{Frequency of fungal species(\%)} = \frac{\text{Number of site in which the species is present}}{\text{Total number of sites}} \times 100$$

$$\text{Density (\%)} = \frac{\text{Total number of individual of a particular species}}{\text{Total number of species}} \times 100$$

3.8 Morphology and microscopic characterization

The basidiocarps were rehydrated by soaking in water for few minutes before analyzing their morphology. Qualitative characters such as color, shape, and presence of hymenia were evaluated by eye observation while texture was

determined by feeling the back and top surfaces using fingers. Most of the morphological data were recorded during collection period that is when the mushroom was in fresh form. For microscopic characters, permanent glass slides were made from rehydrated basidiocarps with the aid of a sharp surgical blade. Basidiocarps were immersed in cotton blue stain and glycerin and placed on glass slides and covered with cover slips. Motic compound microscope (40x) were used to observe the slides. Spore size was measured by Motic Images plus 2.0 software.

CHAPTER IV

RESULTS

This investigation was carried out at Dhaka, Pabna and Rajshahi under tropical moist deciduous forest region of Bangladesh to record the morphology, diversity and distribution of *Ganoderma* spp.

Biodiversity, distribution and morphological characterization of collected *Ganoderma* spp. are presented in Table 1 and Table 2.

4.1. Scientific Name: *Ganoderma applanatum*

Common name: Lingzhi or Reishi mushroom

Family: Ganodermataceae

Morphological features

Pileus shape: Flat; dark brown color with the white at end of the edge

Length; 6.5 to 7.5 cm and Width; 3.5 to 9 cm

Surface character : Dry in nature

Texture of the fruiting body: Woody, tough and brittle

Spore bearing surface under cap: Micro pores

Pores color: Whiten Pores

Pores spacing: Crowded,

Stipe: Pseudo stipe present.

Spore morphology

Spore size (Average): Length: 8.8 μm and Width: 6.3 μm

Spore shape: Ellipsoid, rough and moderately thick walled

Spore Color: Dark brown

Ecological features

Habitat: On Bark wood of the *Terminalia Arjuna* (Aurjun). Temperature of the location: 28°C.

Habit: Scattered and constancy of occurrence was abundant.

Type of soil: Sandy to sandy loam around the tree; factor affecting their distribution was dry weather.

Region/Division: Different forest areas in Dhaka district.

Biodiversity: The frequency of its presence was 9% and the density was 20%.



A



B



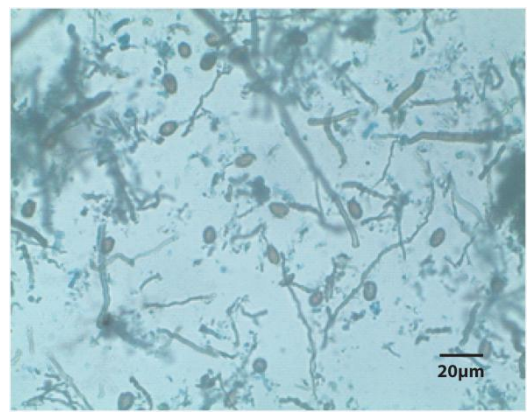
C



D



E



F

Plate1. *Ganoderma applanatum*; (A, B, C) Mature fruiting body, (D, E) Pores, (F) Spores.

Table 1. Morphology of basidiocarp and characterization of basidiospore of collected *Ganoderma* from tropical moist deciduous forest region of Bangladesh

Characterization			
Species name	Common name	Basidiocarp	Spore
<i>Ganoderma applanatum</i>	Lingzhi or Reishi mushroom	Pileus shape: Flat; dark brown color with the white at end of the edge Length; 6.5 to 7.5 cm and Width; 3.5 to 9 cm Surface character : Dry in nature Texture of the fruiting body: Woody, tough and brittle Spore bearing surface under cap: Micro pores Pores color: Whiten Pores Pores spacing: Crowded, Stipe: Pseudo stipe present.	Spore size (Average): Length: 8.8µm and Width: 6.3µm Spore shape: Ellipsoid, rough and moderately thick walled Spore Color: Dark brown
<i>Ganoderma lipsiense</i>	Lingzhi and Reishi mushroom	Pileus shape: Convex; dark brown to cocoa coloured, Length: 16 cm and Width: 18 cm, Surface character: Dry in nature Margin: Incurved in shape and margin thick, coffee colour Texture of the fruiting body: Corky and tough, Spore bearing surface under cap: Pores on hymenium, Pores color: Milky coffee; Pore spacing: Crowded.	Spore size: Length: 8 µm; Width: 6.3µm. Spore shape: Ellipsoid; smooth and thin walled Spore Color: Pale brown

Species name	Common name	Basidiocarp	Spore
<i>Ganoderma pfeifferi</i>	Lingzhi or Reishi mushroom	Pileus shape: Convex Color: Black Length: 3.8 to 7 cm and Width: 4.5 cm to 8.5 cm, Surface character: Dry in nature and blackish, Margin: Incurved in shape, Texture of the fruiting body: Woody and corky, Spore bearing surface under cap: Pores on hymenium, Pores color: Milky white in color	Spore size: Length: 7µm; Width: 5 µm. Spore shape: Ovoid; smooth and thick walled. Color: Brownish
<i>Ganoderma tsugae</i>	Reishi mushroom	Pileus shape: Flat, Color: Dark brown and white, Length: 8cm, Width: 6 cm, Surface character : Dry in nature Texture of the fruiting body: Woody, tough and brittle, Spore bearing surface under cap: Micro pores, Pores: White, Pores spacing: Crowded Stipe: Present.	Spore size (Average): Length: 8.2µm; Width: 5.9µm, Spore shape: Ellipsoid, rough and moderately thick walled Color: Dark Brown

Species name	Common name	Basidiocarp	Spore
<i>Ganoderma lesklokorka</i>	Self forming white rot fungus	Pileus shape: Convex; Color: Dark brown to red colored, Length: 16 cm; Width:18.5 cm, Surface character and zonation: Dry in nature, .Margin: Incurved in shape and margin thick, red color Texture of the fruiting body: Corky and tough, Spore bearing surface under cap: Pores on hymenium, Pores color: white Pore spacing: Crowded	Spore size: Length: 6.5 µm; Width: 4.5 µm Spore shape: Ellipsoid; smooth and thin walled. Color: Pale brown
<i>Ganoderma boninense</i>	Lingzhi or Reishi mushroom	Pileus shape: Concave; Color: White color cap, Length: 20 cm; Width: 6.5 cm, Surface character : Dry in nature, Margin: Incurved in shape Texture of the fruiting body: Brittle and woody, Spore bearing surface under cap: Pores on hymenium, Stipe: Present; Size: 3.2 m. Shape; Equal Position: Central Color: Chocolaty Firmness: Solid	Spore size: Length:7.7µm; Width: 4.0 µm. Spore shape: Elongated, smooth and thin walled Color: Brown

Species name	Common name	Basidiocarp	Spore
<i>Ganoderma lucidum</i>	Lingzhi or Reishi mushroom	Pileus shape: Flat; Color: Dark red with white border, Length: 6.5 to 8 cm; Width: 7.5 to 7 cm, Surface character: Brittle, reddish brown and dry in nature., Margin: Incurved in shape, thick and coffee color , Texture of the fruiting body: Corky to woody, Spore bearing surface under cap: Pores on hymenium, Pores color: Whitish; Pore spacing: Crowded, Stipe: Absent or short	Spore size: Length: 8.0 µm, Width: 6.6 µm. Spore shape: Ellipsoid; smooth and thick walled Color: Brown
<i>Ganoderma praelongum</i>	Lingzhi or Reishi mushroom	Pileus shape of cap was infundibuliform shaped. Size of fructification was 3.5×4.5 cm. The color of pileus (cap) was grey. The cap edge was round and hardy. Beneth the cap hymenophores were absent. Regular shaped pores were present underside of the cap. The color of pores was grey. Surface characters and zonation was dry. The texture of the fruiting body was brittle and corky.	Spore size (Average): 7.2 × 4.6 µm. Spore shaped: Irregular shaped, smooth and single walled Spore color: Hyaline

Species name	Common name	Basidiocarp	Spore
<i>Ganoderma tsugae</i>	Lingzhi or Reishi mushroom	Pileus shape: Finger to funnel shaped; Color: Brown, Length: 15 cm; Width: 10.5 cm, Surface character and zonation: Redish yellowish and dry in nature, Margin: Incurved in shape; Texture of the fruiting body: Woody to corky, Spore bearing surface under cap: Pores on hymenium, Pores color: Yellowish to white in color, Pore spacing: Crowded, Stipe: Present; Size: 2.3 cm-3.3 cm., Shape: Equel; Color: Brick red	Spore size: Length: 6.9 µm; Width: 8.4 µm. Spore shape: Ellipsoid; smooth and thick walled Color: Brownish
<i>Ganoderma sp.</i>	Lingzhi or Reishi mushroom	Pileus shape: Convex; Color: White Length: 25.1 cm; Width: 15.2 cm, Surface character and zonation: Dry in nature, slightly zonate, solitary, crust and rigid. Margin: Incurved in shape and margin thick, white color . Texture of the fruiting body: Corky and tough Spore bearing surface under cap: Pores Pores color: white color Pore spacing: Crowded	Spore size: Length: 10.9 µm; Width: 8.4 µm. Spore shape: Ellipsoid, smooth and thin walled Color: Pale brown

Species name	Common name	Basidiocarp	Spore
<i>Ganoderma</i> sp.	Lingzhi or Reishi mushroom	Pileus shape: convex; Color: Milky white to Creamy, Length (mature): 10.4 cm to 8.4 cm. Width (Young): 5.2 cm to 6.5 cm Surface character and Zonation: Dry in nature. Texture of the fruiting body: Woody Flesh odor: Pleasant, Lamellae: Absent; Spore bearing surface under cap: Pores present. Pores color: Milky white Pores shape: Broad; Pores spacing: Crowded; Firmness: Solid or somewhat in fleshy.	Spore diameter (Average): Length: 5.32 μm; Width: 3.25 μm, Spore shape: Ellipsoid, smooth and single walled Color: Brown
<i>Ganoderma lucidum</i>	Lingzhi or Reishi mushroom	Pileus shape: Flat; Color: Dark red Length: 13.5 to 15 cm; Width: 15 to 17.5 cm , Surface character and zonation: Brittle, rugose, reddish brown and dry in nature., Margin: Incurved in shape, thick and coffee color , Texture of the fruiting body: Corky to woody, Spore bearing surface under cap: Pores on hymenium, Pores color: Whitish	Spore size: Length: 8.0 μm, Width: 6.6 μm. Spore shape: Ellipsoid; smooth and thick walled Color: Brown

4.2. Scientific Name: *Ganoderma lipsiense*

Common name: Lingzhi and Reishi mushroom

Family: Ganodermataceae

Morphological features

Pileus shape: Convex; dark brown to cocoa coloured,

Length: 16 cm and Width: 18 cm,

Surface character: Dry in nature

Margin: Incurved in shape and margin thick, coffee colour

Texture of the fruiting body: Corky and tough,

Spore bearing surface under cap: Pores on hymenium,

Pores color: Milky coffee;

Pore spacing: Crowded.

Spore morphology

Spore size: Length: 8 μm ; Width: 6.3 μm .

Spore shape: Ellipsoid; smooth and thin walled

Spore Color: Pale brown

Ecological features

Habitat: On bark of the tree in an association with *Azadirachta indica* (Neem) plant.

Habit: Scattered and constancy of occurrence was unabundant.

Type of soil: Sandy; factor affecting their distribution was moderately moist weather,

Temperature of the Location: 29°C.

Region/ Division: Different forest areas in Pabna district.

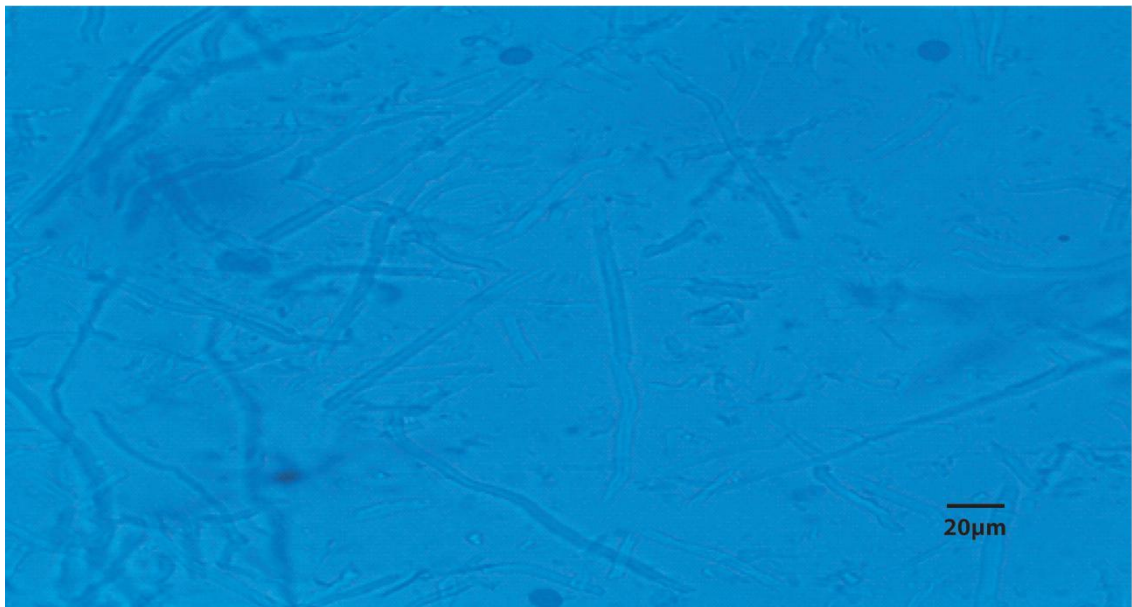
Biodiversity: The density of its presence was 13 % and frequency 5%.



A



B



C

Plate 2. *Ganoderma lipsiense*; Fruiting body (A), Pores (B), Spores (C)

4.3. Scientific Name: *Ganoderma pfeifferi*

Common name: Lingzhi or Reishi mushroom.

Family: Ganodermataceae.

Morphological features

Pileus shape: Convex

Color: Black

Length: 3.8 to 7 cm and Width: 4.5 cm to 8.5 cm,

Surface character: Dry in nature and blackish,

Margin: Incurved in shape,

Texture of the fruiting body: Woody and corky,

Spore bearing surface under cap: Pores on hymenium,

Pores color: Milky white in color

Spore morphology

Spore size: Length: 7 μm ; Width: 5 μm .

Spore shape: Thick walled, smooth and ovoid;

Color: Brownish

Ecological features

Habitat: On the wood of the *Acacia auriculiformis* (Golden shower).

Habit: Scattered and constancy of occurrence was abundant.

Type of soil: Loam; factor affecting their distribution was moderately moist weather. Temperature of the location: 32°C,

Division/ Region: Forest area in Dhaka district.

Biodiversity: The density of its presence was 17 %.and frequency 8%.



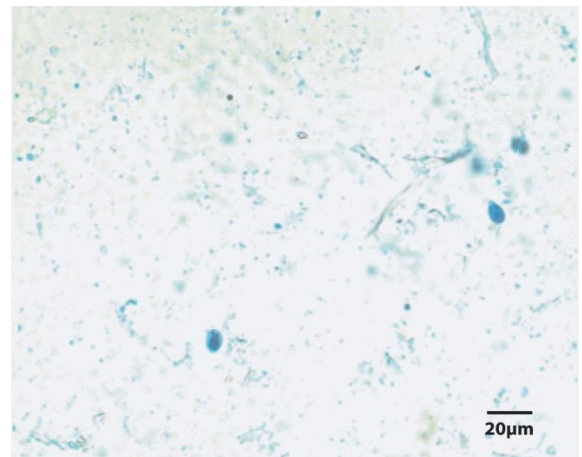
A



B



C



D

Plate3: *Ganoderma pfeifferi*; Fruiting body on the tree (A), Fruiting body (B), Pores(C), Spores (D).

4.4. Scientific Name: *Ganoderma tsugae*

Common name: Reishi mushroom

Family: Ganodermataceae

Morphological features

Pileus shape: Flat,

Color: Dark brown and white,

Length: 8cm, Width: 6 cm,

Surface character : Dry in nature

Margin: Incurved in shape and margin thick, white color

Texture of the fruiting body: Woody, tough and brittle,

Spore bearing surface under cap: Micro pores,

Pores: White,

Pores spacing: Crowded

Stipe: Present.

Spore morphology

Spore size (Average): Length: 8.2 μm ; Width: 5.9 μm ,

Spore shape: Ellipsoid, rough and moderately thick walled

Color: Dark Brown

Ecological features

Habitat: On the wood of *Terminalia bellirica* (Bohera),

Habit: Scattered and constancy of occurrence in specific habitat was unabundant.

Type of soil: Sandy to sandy loam; factor affecting their distribution was dry weather.

Temperature of the location: 38°C

Region : Different forest areas in Rajshahi district.

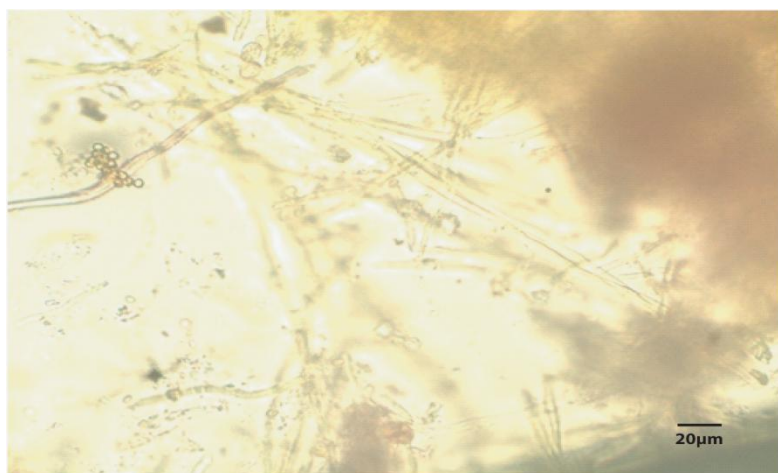
Biodiversity: The frequency of its presence was 6% and the density was 11%.



A



B



C

Plate 4. *Ganoderma tsugae*; Mature fruiting body (A), Pores (B), Spores (C).

4.5 Scientific Name: *Ganoderma lesklokorka*

Common name: Self forming white rot fungus

Family: Ganodermataceae

Morphological features

Pileus shape: Convex;

Color: Dark brown to red colored,

Length: 16 cm; Width: 18.5 cm,

Surface character and zonation: Dry in nature,

Margin: Incurved in shape and margin thick, red color

Texture of the fruiting body: Corky and tough,

Spore bearing surface under cap: Pores on hymenium,

Pores color: white

Pore spacing: Crowded

Spore morphology

Spore size: Length: 6.5 μm ; Width: 4.5 μm

Spore shape: Thin walled, smooth and ellipsoid;

Color: Pale brown

Ecological features

Habitat: On Bark wood of the *Samanea saman* (Rain tree),

Habit: Scattered and constancy of occurrence was unabundant.

Type of soil Sandy; factor affecting their distribution was moderately moist weather.

Temperature of the Location: 33°C

Division/Region: Social forest region of different thanas of Pabna district

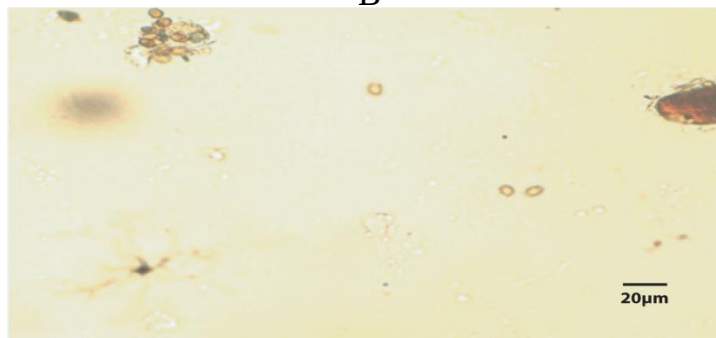
Biodiversity: The density of its presence was 18.5 % and frequency 9%.



A



B



C

Plate 5: *Ganoderma lesklokorka*; Fruiting body in an association with the host (A), Pores (B), Spores (C).

4.6. Scientific Name: *Ganoderma boninense*

Common name: Lingzhi or Reishi mushroom

Family: Ganodermataceae

Morphological features

Pileus shape: Concave;

Color: White color cap,

Length: 20 cm; Width: 6.5 cm,

Surface character : Dry in nature,

Margin: Incurved in shape

Texture of the fruiting body: Brittle and woody,

Spore bearing surface under cap: Pores on hymenium,

Stipe: Present;

Size: 3.2 μm

Shape; Equal

Position: Central

Color: Chocolaty

Firmness: Solid

Spore morphology

Spore size: Length:7.7 μm ; Width: 4.0 μm .

Spore shape: Elongated, smooth and thin walled

Color: Brown

Ecological features

Habitat: On Bark wood of the *Dalbergia sissoo* (Sisso tree).

Habit: Scatter and constancy of occurrence was unabundant. Type of soil Loamy; factor affecting their distribution was moderately moist weather.

Temperature of that location : 28°C

Region/ Division : Forest area in Pabna district.

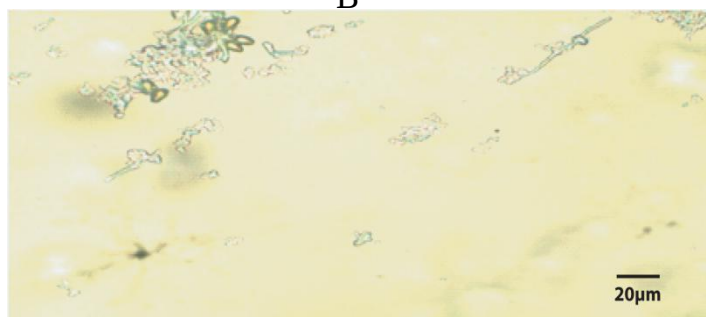
Biodiversity: The density of its presence was 15 % and frequency 8%.



A



B



C

Plate 6: *Ganoderma boninense*; Fruiting body in an association with the host (A), Pores (B), Spores(C).

Table 2. Ecological characterization of collected *Ganoderma* from tropical moist deciduous forest region of Bangladesh

Species name	Family name	Host	Location	Habit	Frequency (%)	Density (%)	Temp (°C)	Soil type	Weather conditions
<i>Ganoderma applanatum</i>	Ganodermataceae	<i>Terminalia arjuna</i>	Dhaka	Scattered and unabundant	10	20	28	Sandy	Dry
<i>Ganoderma lipsiense</i>	Ganodermataceae	<i>Azadirachta indica</i>	Pabna	Scattered and unabundant	5	13	29	Sandy	Moist
<i>Ganoderma pfeifferi</i>	Ganodermataceae	<i>Acacia auriculiformis</i>	Dhaka	Scattered and unabundant	8	17	32	Loam	Moist
<i>Ganoderma tsugae</i>	Ganodermataceae	<i>Terminalia bellirica</i>	Rajshahi	Scattered and unabundant	6	11	38	Sandy	Dry
<i>Ganoderma lesklokorka</i>	Ganodermataceae	<i>Samanea saman</i>	Pabna	Scattered and unabundant	7	18.5	33	Sandy	Moist
<i>Ganoderma boninense</i>	Ganodermataceae	<i>Dalbergia sissoo</i>	Pabna	Scattered and unabundant	8	15	28	Loamy	Moist
<i>Ganoderma lucidum</i>	Ganodermataceae	<i>Albizia procera</i>	Dhaka	Scattered and abundant	9	23	25	Loam	Moist

Species name	Family name	Host	Location	Habit	Freq uenc y (%)	Density (%)	Temp (°C)	Soil type	Weather conditions
<i>Ganoderma praelongum</i>	Ganodermataceae	<i>Terminalia arjuna</i>	Pabna	Scattered and unabundant	7	19	30	Loam	Moist
<i>Ganoderma tsugae</i>	Ganodermataceae	<i>Terminalia bellirica</i>	Dhaka	Scattered and unabundant	8	11	30	Loam	Moist
<i>Ganoderma</i> sp.	Ganodermataceae	<i>Dalbergia sissoo</i>	Pabna	Scattered and unabundant	9	18	36	Sandy	Moist
<i>Ganoderma</i> sp.	Ganodermataceae	<i>Dalbergia sissoo</i>	Rajshahi	Scattered and unabundant	8	16	38	Loam	Moist
<i>Ganoderma lucidum</i>	Ganodermataceae	<i>Terminalia arjuna</i>	Dhaka	Scattered and abundant	10	23	25	Loam	Moist

4.7. Scientific Name: *Ganoderma lucidum*

Common name: Lingzhi or Reishi mushroom

Family: Ganodermataceae

Morphological features

Pileus shape: Flat;

Color: Dark red with white border,

Length: 6.5 to 8 cm; Width: 7.5 to 7 cm,

Surface character: Brittle, reddish brown and dry in nature.,

Margin: Incurved in shape, thick and coffee color ,

Texture of the fruiting body: Corky to woody,

Spore bearing surface under cap: Pores on hymenium,

Pores color: Whitish;

Pore spacing: Crowded,

Stipe: Absent or short

Spore morphology

Spore size: Length: 8.0 μm , Width: 6.6 μm .

Spore shape: Ellipsoid; smooth and thick walled

Color: Brown

Ecological features

Habitat: On dead plant wood, *Terminalia arjuna* (Aurjun) and *Albizia procera* (Koroi).

Habit: Scattered and constancy of occurrence was abundant.

Type of soil Loam; factor affecting their distribution was moderately moist weather.

Temperature of the location: 25°C

Region/Division: Forest region of botanical garden, Dhaka.

Biodiversity: The density of its presence was 23 % and frequency 9%.



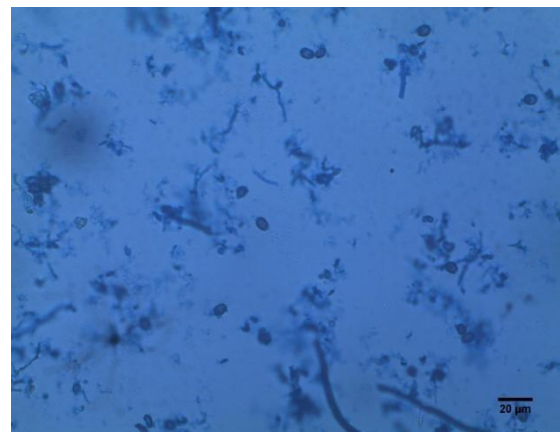
A



B



C



D

Plate 7: *Ganoderma lucidum*; in association with the host (A,) Fruiting body (B), Pores (C), Spores (D).

4.8. Scientific Name: *Ganoderma praelongum*

Common name: Lingzhi or Reishi mushroom

Family: Ganodermataceae

Morphological features

Pileus shape of cap was infundibuliform shaped.

Size of fructification was 3.5×4.5 cm.

The color of pileus (cap) was grey.

The cap edge was round and hardy. Beneath the cap hymenophores were absent. Regular shaped pores were present underside of the cap.

The color of pores was grey.

Surface characters and zonation was dry.

The texture of the fruiting body was brittle and corky.

Spore morphology

Spore size (Average): $7.2 \times 4.6 \mu\text{m}$.

Spore shaped: Irregular shaped, smooth and single walled

Spore color: Hyaline

Ecological features

Habitat : *Ganoderma praelongum* was found on the bark dead log of *Terminalia arjuna* (Aurjun) . Average Relative Humidity was 70%, soil pH was 6.8 and soil type was sandy to clay loam. Average recorded temperature was 30°C.

Habit: Scattered and constancy of occurrence was abundant.

Region/ Division: *Ganoderma praelongum* was found in Ishwardi Upazilla in Pabna district.

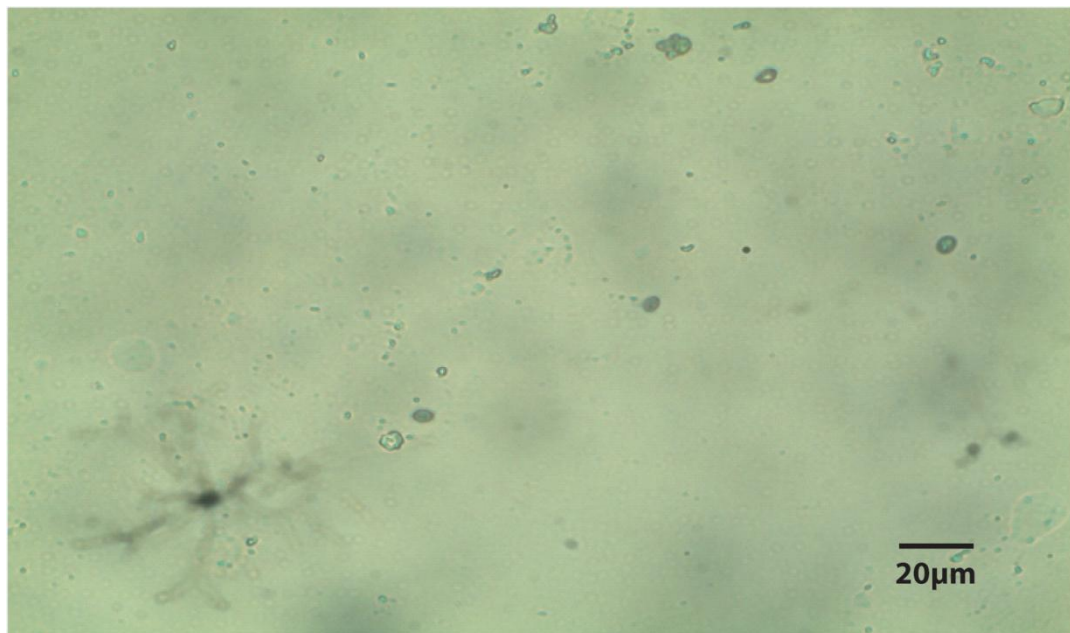
Biodiversity: The frequency of its presence was 7% and the density was 19%.



A



B



C

Plate 8: *Ganoderma praelongum*; Mature fruiting body (A, B), Spores (C).

4.9 . Scientific Name: *Ganoderma tsugae*

Common name: Lingzhi or Reishi mushroom

Family: Ganodermataceae

Morphological features

Pileus shape: Finger to funnel shaped;

Color: Brown,

Length: 15 cm; Width: 10.5 cm,

Surface character and zonation: Reddish yellowish and dry in nature,

Margin: Incurved in shape;

Texture of the fruiting body: Woody to corky,

Spore bearing surface under cap: Pores on hymenium,

Pores color: Yellowish to white in color,

Pore spacing: Crowded,

Stipe: Present;

Size: 2.3 cm-3.3 cm., Shape: Equal; Color: Brick red

Spore morphology

Spore size: Length: 6.9 μm ; Width: 8.4 μm .

Spore shape: Ellipsoid; smooth and thick walled

Color: Brownish

Ecological features

Habitat: On root of the tree, in an association with *Albizia procera* (Koroi) and *Terminalia bellirica* (Bohera).

Habit: Scattered and constancy of occurrence was abundant. Forest type mixed.

Type of soil: Loamy; factor affecting their distribution was moderately moist weather.

Average recorded temperature was 30°C.

Region/ Division: Forest areas in Dhaka district.

Biodiversity: The density of its presence was 11 % and frequency 8%.



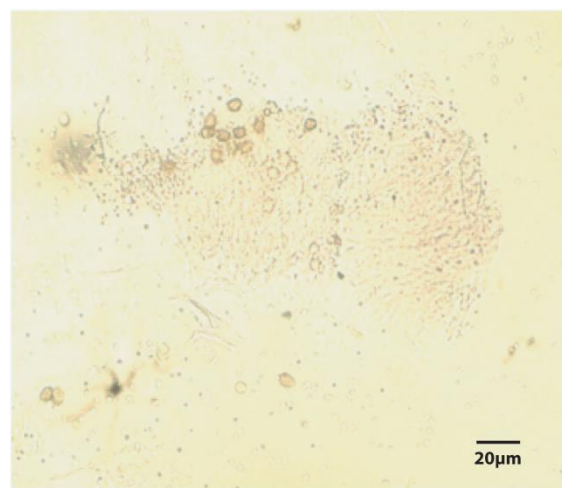
A



B



C



D

Plate 9: *Ganoderma tsugae* in association with the Fruiting body (A, B), Pores (C), Spores (D).

4.10. Scientific Name: *Ganoderma* sp.

Common name: Lingzhi or Reishi mushroom

Family: Ganodermataceae

Morphological features

Pileus shape: Convex;

Color: White

Length: 25.1 cm; Width: 15.2 cm,

Surface character and zonation: Dry in nature, slightly zonate, solitary, crust and rigid.

Margin: Incurved in shape and margin thick, white color .

Texture of the fruiting body: Corky and tough

Spore bearing surface under cap: Pores

Pores color: white color

Pore spacing: Crowded

Spore morphology

Spore size: Length: 10.9 μm ; Width: 8.4 μm .

Spore shape: Ellipsoid, smooth and thin walled

Color: Pale brown

Ecological features

Habitat: On Bark wood of the *Dalbergia sisso* (sisso tree).

Habit: Scattered and constancy of occurrence in specific habitat was unabundant.

Type of soil: Sandy; factor affecting their distribution was moderately moist weather.

Temperature of the Location: 36°C,

Division/Region: Social forest region of different thanas of pabna districts,

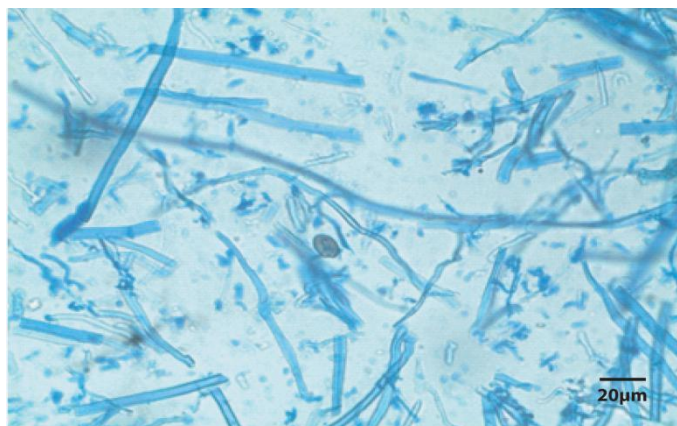
Biodiversity: The density of its presence was 18% and frequency 9%.



A



B



C

Plate 10: *Ganoderma* sp.; Fruiting body with the association of the host(A); pores(B); spores(C).

4.11. Scientific Name: *Ganoderma* sp.

Common name: Lingzhi or Reishi mushroom

Family: Ganodermataceae

Morphological features

Pileus shape: convex; Color: Milky white to Creamy,

Length (mature): 10.4 cm to 8.4 cm.

Width (Young): 5.2 cm to 6.5 cm

Surface character and Zonation: Dry in nature.

Texture of the fruiting body: Woody

Flesh odor: Pleasant, Lamellae: Absent;

Spore bearing surface under cap: Pores present.

Pores color: Milky white

Pores shape: Broad;

Pores spacing: Crowded; Firmness: Solid or somewhat in fleshy

Spore morphology

Spore diameter (Average): Length: 5.32 μm ; Width: 3.25 μm ,

Spore shape: Ellipsoid, smooth and single walled

Color: Brown

Ecological features

Habitat: On bark of the wood in an association with the trees *Dalbergia sissoo* (sisso plant).

Habit: Scattered and somewhat cluster; Forest type: Leveled; Constancy of occurrence, not in abundant.

Type of soil: Clay loam soil in nature

Weather at the time of collection: Moderate moist weather around the habitat.

Temperature of the Location: 38°C , Locality found in Rajshahi region.

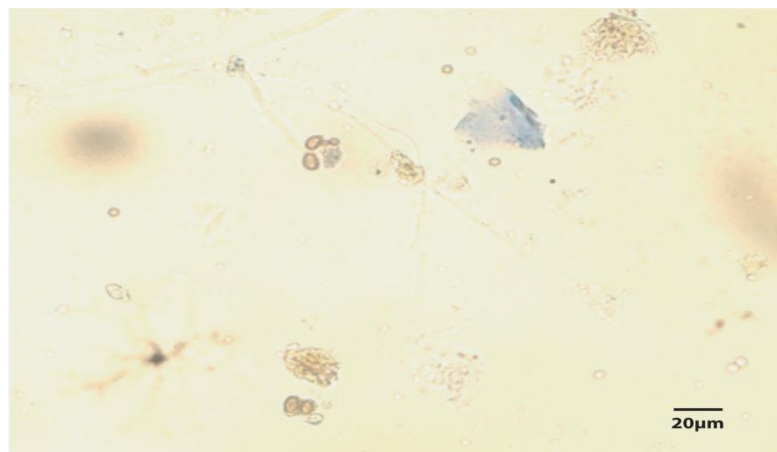
Biodiversity: The density of its presence was 16% and frequency 8%.



A



B



C

Plate 11. *Ganoderma* sp.; Fruiting body with the association of the host (A,); pores (B); Spore(C)

4.12. Scientific Name: *Ganoderma lucidum*

Common name: Lingzhi or Reishi mushroom

Family: Ganodermataceae

Morphological features

Pileus shape: Flat; Color: Dark red

Length: 13.5 to 15 cm; Width: 15 to 17.5 cm ,

Surface character and zonation: Brittle, rugose, reddish brown and dry in nature.,

Margin: Incurved in shape, thick and coffee color ,

Texture of the fruiting body: Corky to woody,

Spore bearing surface under cap: Pores on hymenium,

Pores color: Whitish;

Pore spacing: Crowded,

Stipe: Absent or short .

Spore morphology

Spore size: Length: 8.0 μm , Width: 6.6 μm .

Spore shape: Ellipsoid; smooth and thick walled

Color: Brown

Ecological features

Habitat: On dead plant wood *Terminalia arjuna* (Aurjun).

Habit: Scattered and abundant. Type of soil Loam; factor affecting their distribution was moderately moist weather.

Temperature of the region 25°C and location Dhaka of different forest areas.

Biodiversity: The density of its presence was 23 % and frequency 10%.



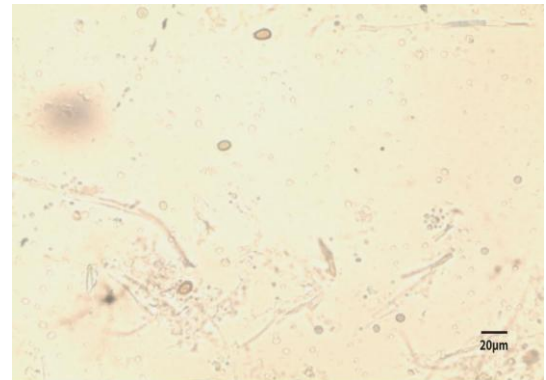
A



B



C



D

Plate 12: *Ganoderma lucidum*; in association with the host (A)
Fruiting body (B), Pores (C) and Spores (D)

CHAPTER V

DISCUSSION

An investigation was carried out to collect, identify and preserve *Ganoderma* spp. from the tropical moist deciduous forest region of Bangladesh covering the area of Pabna, Dhaka and Rajshahi, from June to October 2016 and 2017 to record the morphological variability, distribution, habitat, and biodiversity of the *Ganoderma* population.

A total of 40 *Ganoderma* samples were collected and identified to 8 species under Ganodermataceae family. The species were *Ganoderma lucidum*, *Ganoderma bonensis*, *Ganoderma tsugae*, *Ganoderma lipsiense*, *Ganoderma appalanatum*, *Ganoderma pfeifferi*, *Ganoderma lesklokorka* and *Ganoderma praelongum*.

In the present study *Ganoderma lucidum* was recorded in association with *Albizia procera* (Koroi), *Terminalia arjuna* (Aurjun) and *Dalbergia sissoo* (Sisso plant) and which was supported by Aminuzzaman and Das (2017) and Rubina *et. al.*, (2017). In another study Marzana *et. al.*, (2018) found *Ganoderma lucidum* in association with *Tectona grandis* (Shegun) in Kaptai, Rangamati of Chittagong Hill tracts under tropical evergreen and semi-evergreen forest of Bangladesh. In other study Rumanul *et. al.* (2015) found this species in association with *Leucaena leucocephala* (Ipil-Ipil) and *Acacia auriculiformis* (Golder shower) under tropical moist deciduous forest region of Bangladesh. The density of its presence was 19% and 23%. Marzana *et al.*, (2018) found this species from Chittagong Hill tracts with a frequency and density of 11.11% and 2.78% respectively. But Das and Aminuzzaman (2017) described the species from Bogra district under social forest region of Bangladesh with a frequency and density of 75% and 25% respectively. Rubina *et. al.*, (2017) found this species from national botanical garden, Dhaka, Bangladesh with a density of 25%. The difference in frequency and density of the species might be due to the difference in geographic area of the collection

sites. Ryvarden (1995) studied the morphology of 53 specimens of *Ganoderma lucidum* from Norway and he found large variation among the species.

Ganoderma boninense was recorded in association with *Dalbergia sissoo* (Sisso) tree which was supported by Aminuzzaman and Das (2017). But this species was also found in association with *Mangifera indica* from national botanical garden (Rubina *et. al.*, 2017) and *Bambusa* sp. from tropical moist deciduous forest region of Bangladesh (Rumainul *et. al.*, 2015). The frequency and density of its presence was 8% and 15%, respectively. Aminuzzaman and Das (2017) found this species in social forest region of Bogra, Bangladesh with frequency of 75% and density of 43.5%. The pathogenicity of *Ganoderma boninense* was examined (Cooper *et al.* 2011).

Ganoderma tsuaga was recorded in association with *Terminalia bellirica* (Bohera tree) which was supported by Aminuzzaman and Das (2017) and Rubina *et. al.*, (2017). But this species was also found in association with *Acacia auriculiformis* (Golden shower) as reported by Rumainul, *et.al.* (2015) under tropical moist deciduous forest region of Bangladesh. The frequency and density of its presence was 6-8% and 11% respectively. Aminuzzaman and Das (2017) found the density of this species 12.5% and frequency 50% under social forest region of Bogra. In another study Rubina *et.al.* (2017) recorded its density 10% in national botanical garden, Dhaka. *Ganoderma tsuaga* was also reported from India (Vyas, 2014).

Ganoderma lipsiense was recorded in association with Neem (*Azadirachta indica*) which was supported by Rubina *et. al.*, (2017). The density of its presence was 13% and frequency was 5%. This species was recorded from national botanical garden, Dhaka with a density of 5% (Rubina *et. al.*, 2017). On the other hand, *Ganoderma lipsiense* was also reported from India in association with *Dalbergia sissoo* plant (Bhosle *et al.*, 2010; Dwivedi *et al.*, 2012) and in China (Wang *et al.*, 2012).

Ganoderma applanatum was recorded in association with *Terminalia arjuna* (Aurjun). But the species was previously reported on *Acacia auriculiformis* (Rumainul *et al.*, 2015 and Rubina *et al.*, 2017) and *Swietenia mahagoni* (Das and Aminuzzaman, 2017) and on *Dalbergia sissoo* (Aminuzzaman and Das, 2017). The density of its presence was 20%. Moncalvo and Ryvarden (1997) published a world list of *Ganoderma* species. The study considered the species described in last 200 years listing 386 names for Ganodermataceae as whole. Taxonomy and 58 diversity of *Ganoderma lipsiense* and *Ganoderma applanatum* was also reported in India (Bhosle *et al.*, 2010).

Ganoderma pfeifferi was recorded in association with the *Acacia auriculiformis* (Golden shower) which was supported by Rubina *et al.*, (2017). The density of its presence was 17%. This species was recorded from national botanical garden, Dhaka with a density of 35% (Rubina *et al.*, 2017). On the other hand, *Ganoderma pfeifferi* was also reported in India (Bhosle *et al.*, 2010; Dwivedi *et al.*, 2012) and in China (Wang *et al.*, 2012).

One species of *Ganoderma* was recorded viz. *Ganoderma lesklokorka* in association with *Albizia lebbeck* (Rain tree). The density of its presence was 18.5%. Allen *et al.* (2009) reported that *ganoderma lesklokorka* a new bluing species from Ohio and Bethany, West Virginia. This was also reported in Germany (Passie *et al.*, 2002).

Ganoderma praelongum was recorded in association with the *Terminalia arjuna* (Aurjun). But the species was previously reported on *Diospyros ebony* (Das and Aminuzzaman, 2017).

Ganoderma spp. were recorded in association with the *Dalbergia sissoo* (Sisso plant) with the frequency and density of 9%, 8%, 18% and 16% respectively. *Ganoderma* spp. were also found at Rajshahi, Pabna, and Dhaka, and Bogora districts of Bangladesh in tropical moist deciduous forest (Rumainul *et al.*, 2015). It was also reported in China (Wang *et al.*, 2012) and in India (Dwivedi *et al.*, 2012; Thiribhuvanamala *et al.*, 2011; and Ram *et al.*, 2010).

CHAPTER VI

SUMMARY AND CONCLUSION.

The *Ganoderma* grown in the wild plays an important role to maintain the forest health besides their medicinal and nutritional values. Therefore, it becomes quite necessary to explore, document and conserve this natural wealth. A survey was conducted in Dhaka, Rajshahi and Pabna under tropical moist deciduous forest region of Bangladesh to collect, identify and morphologically characterize *Ganoderma* spp. during the period from June to October, 2016 and 2017. Laboratory experiments were conducted at the Laboratory of the Department of Plant Pathology, Sher-e-Bangla Agricultural University (SAU), Dhaka. A total of 40 *Ganoderma* samples were collected and identified to eight species also have 2 unknown species belong to genera *Ganoderma* and family Ganodermataceae there were *Ganoderma lucidum*, *Ganoderma bonensis*, *Ganoderma tsugae*, *Ganoderma lipsiense*, *Ganoderma appalanatum*, *Ganoderma pfeifferi*, *Ganoderma lesklokorka*, *Ganoderma praelongum*, *Ganoderma* sp. The highest density of occurrence (23%) was recorded for *Ganoderma lucidum* followed by *Ganoderma applanatum* (20%), *Ganoderma praelongum* (19%), *Ganoderma lesklokorka* (18.5%), *Ganoderma pfeifferi* (17%), *Ganoderma boninense* (15%), *Ganoderma lipsiense* (13%) and *Ganoderma tsugae* (11%). The highest frequency of occurrence (10%) was recorded for *Ganoderma applanatum* followed by *Ganoderma lucidum* (9%), *Ganoderma pfeifferi* (8%), *Ganoderma boninense* (8%), *Ganoderma praelongum* (7%), *Ganoderma lesklokorka* (7%), *Ganoderma tsugae* (6%) and *Ganoderma lipsiense* (5%).

Ganoderma lucidum were recorded in association with *Albizia procera* (Koroi) and *Terminalia Arjuna* (Aurjun). *Ganoderma boninense* was recorded in association with *Dalbergia sissoo* (Sisso plant). Both type of *Ganoderma tsugae* were recorded in association with *Terminalia bellirica* (Bohera). *Ganoderma lipsiense* was recorded in association with *Azadirachta indica* (Neem). *Ganoderma applanatum* were recorded in association with

Terminalia Arjuna (Aurjun). *Ganoderma pfeifferi* was recorded in association with the *Acacia auriculiformis* (Golden shower).

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