



Biodiversity and Morphological Characterization of Mushrooms at the Tropical Moist Deciduous Forest Region of Bangladesh

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Authors' contributions

This work was carried out in collaboration with all authors. Author MIR carried out the research and wrote the first draft of the manuscript. Author FMA designed use supervised and edited the manuscript. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/AJEA/2015/17301

Editor(s):

(1) Sławomir Borek, Department of Plant Physiology, Adam Mickiewicz University, Poland.

Reviewers:

(1) Anonymous, Ghana.

(2) Anonymous, India.

(3) Eduardo Bernardi, Departamento de Microbiologia, Universidade Federal de Pelotas, Brazil.

Complete Peer review History: <http://www.sciencedomain.org/review-history.php?id=1078&id=2&aid=9182>

Original Research Article

Received 7th March 2015
Accepted 17th April 2015
Published 8th May 2015

ABSTRACT

Mushroom flora is an important component of the ecosystem and their biodiversity study has been largely neglected and not documented for the tropical moist deciduous forest regions of Bangladesh. This investigation was conducted 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. The entire mushroom flora and its morphological characteristics have been described and illustrated. This is the first investigation on mushroom flora associated with tropical moist deciduous forest region of Bangladesh.

Keywords: Tropical moist deciduous forest; biodiversity; mushroom; Bangladesh.

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1. INTRODUCTION

The term "Mushroom" is used mainly for the fruiting body produce by the macro-fungi and these are *Ascomycota* and *Basidiomycota*, some are edible and 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 [1]. Along with the cultivated mushrooms, wild mushrooms also have profound biological as well as economical features and have a great impact along with the beneficiaries' of human-kind. 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. Now-a-days, they are considered as an ideal food item. Besides these, mushrooms are the sources of various bioactive substances like, antibacterial, antifungal, antiviral, anti-parasitic, antioxidant, anti-inflammatory, anti-proliferative, anticancer, anti-tumor, cytotoxic, DNA damaging, anti-HIV, hypo-cholesterolemic, anti-diabetic, anti-coagulant, hepato-protective, insecticidal properties and an efficient tool for recycling of organic wastes [2]. Along with the beneficial impacts to mankind, large number of mushroom species is the wood-rotter's, which are causing serious damage to the forest trees [2]. That is why it is causing considerable economic loss to timber industry every year. Besides, some are toxic, even deadly when eaten [3]. Bangladesh is a sub-tropical country. Depending on location, nature and type of management, there are and four broad categories of forest in Bangladesh named mangrove forest, tropical evergreen and semi evergreen forest, tropical moist deciduous forest and village forest.

A number of species of mushrooms are found mainly during the rainy season, on almost all types of soils, on decaying organic matter, wooden stumps, etc. naturally. The climate and the forest vegetation of the tropical moist deciduous forest region of Bangladesh, supports the growth and reproduction of various mushroom flora. According to Bangladesh forest department, the central and northern districts covering an area of 1,20,000 hectares about 0.81% of total landmass of the country and 7.8% of the countries forest land are bestowed with tropical moist deciduous forests. Tropical moist deciduous forest region is under about 80% of Bangladesh's rainfalls area during the monsoon season extending from June to September and the mean annual rain fall for these region of

Bangladesh is ranged between 3,280 and 4,780 mm (129.1 and 188.2 inch) per year. The mean daily temperature ranged between 38°C and 41°C (100.4°F and 105.8°F) with relative humidity ranged from lower in March between 55% and 81% to higher in July between 94% and 100%. Winds are mostly from the north and northwest area in the monsoon, blowing gently at 1 to 3 kilometers per hour (0.6 to 1.9 mph). Thus, the northern region of Bangladesh was expected to furnish with diverse macro fungal population.

The search for diverse macro fungal population in the country is important as the demand and consumer preference of mushrooms for utilization among the people and farmers in the country is increasing day by day. Discovery of new biomolecules from mushrooms controlling human and crop diseases and pests is a challenging field of study. The purpose of the present survey was to collect, morphologically characterize and preserve macro fungal species present in the tropical moist deciduous forest region of Bangladesh.

2. MATERIALS AND METHODS

2.1 Survey on Wild Mushrooms

The survey and collection of different wild mushrooms were done after the rainy season starting from July to October, 2013 and 2014. The survey was conducted in Dhaka, Gazipur, Bogra, Rajshahi, Pabna, Jaipurhat and Dinajpur biosphere reserved areas, which are situated in tropical moist deciduous forest region of Bangladesh. According to the National Mapping Organization of Bangladesh, Dhaka is located at 23°42'37" N (Latitude), 90°24'26" E (Longitude) and it has an average elevation of 4 meters (13.12 ft.). Gazipur is located at 24.00°N (Latitude), 90.43°E (Longitude) and it has an average elevation of 10 meters (32.8 ft.). Bogra is located at 24°51'00"N (Latitude), 89°22'00"E (Longitude) and it has an average elevation of 24 meters (78 ft.). Rajshahi is located at 24°22'00"N (Latitude), 88°36'00"E (Longitude) and it has an average elevation of 31 meters (101 ft.). Pabna is located at 24°00'00"N (Latitude), 89°15'00"E (Longitude) and it has an average elevation of 8 meters (26 ft.). Jaipurhat is located at 25.1°N (Latitude), 89.02°E (Longitude) and it has an average elevation of 29 meters (94.25 ft.). Dinajpur is located at 25°37'37"N (Latitude), 88°38'19"E (Longitude) and it has an average elevation of 34 meters (111 ft.). The collection sites were forests, university campus, residential area, botanical garden, parks and nearby villages

of those above mentioned areas of tropical moist deciduous forest region (Fig. 1).

2.2 Collection of Mushroom Samples

The collection was made following the method of Hailing [4]. 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, heat convector card board were arranged and collection of samples were usually made during day time and field characteristics of mushrooms were recorded in the data sheet which was prepared following Molina et al. [5]. Then the specimens were dried in hot air oven at 40-50°C and stored in air tight containers with silica gel for further microscopic studies. Spotted mushrooms were minutely inspected in their natural habitats and brought to laboratory for detailed study. Photographs were taken by means of a Sony Cyber-shot Digital Camera with the power of 14.2 megapixels.

2.3 Identification of Wild Mushrooms

The collected mushroom samples were identified on their morphological, macroscopic,

physiological and ecological features according to the previously published documents by Arora, Singer, Singer [6-8]. The morphological parameters used for identification of mushrooms specimens were cap color, cap surface, cap margin, cap diameter, stipe length, gill attachment, gill spacing and spore diameter [9]. The spore diameter and the photograph of spores were calculated using the Motic microscope (Motic Images Plus 2.0) with the magnification of 40x. One mature and one immature (growing) mushroom were sampled for each collection to record accurate information. Through comparing recorded characteristics the mushrooms were identified following Dickinson and John, Jorden, Pegler and Spooner [10-12].

3. RESULTS

Through the investigation, 14 genera and 24 mushroom species were identified [Figs. 2 to 6]. The identified genera were *Ganoderma* sp., *Hebeloma* sp. *Craterellus* sp. *Lepiota* sp. *Ramariopsis* sp. *Ampulloclitocybe* sp. *Lycoperdon* sp. *Volvariella* sp. *Russula* sp. *Termitomyces* sp., *Amanita* sp., *Marasmius* sp., *Collybia* sp. and *Mycena* sp. These genera are described below:

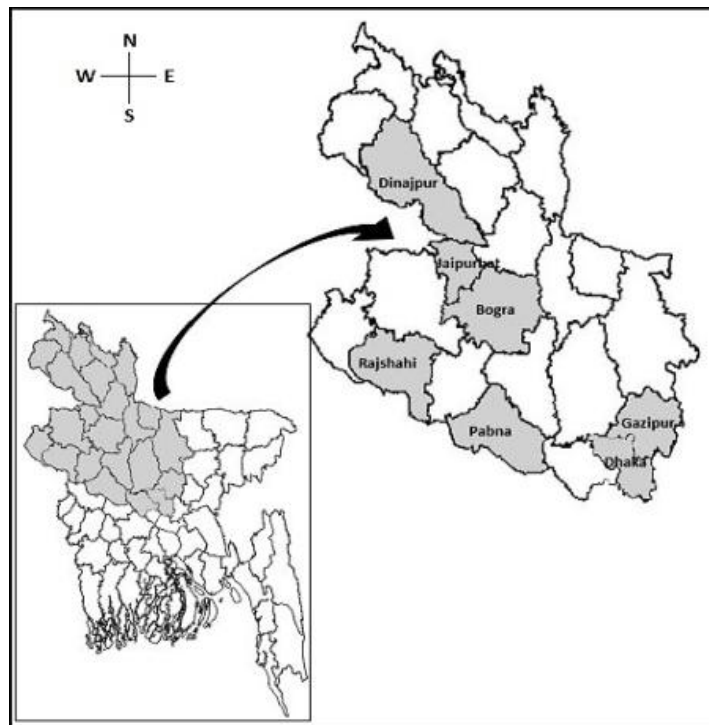


Fig. 1. Survey area of tropical moist deciduous forest region of Bangladesh

Genus: *Ganoderma* sp.

Ganoderma lucidum

Family: Ganodermataceae

Common name: Lingzhi or Reishi mushroom

Color: Red (Young and mature stage)

Length (Mature): 13.5 cm

Width (Mature): 9.6 cm

Spore bearing surface under cap: Pores on hymenium

Spore diameter (Average): Length: 9.57 µm; Width: 6.77 µm

Spore shape: Single walled, smooth and ellipsoidal

Cap of the carpophore: Size: 9.6 cm; Shape: Offset

Pileus: Color: Pinkish; Surface character and Zonation: Smooth, Silky, some kind of leathery having cracking property and dry in nature; Margin: Incurved in shape

Texture of the fruiting body: Brittle, tough, leathery and woody

Flesh odor: Pleasant

Lamellae: Pores present; Pores attachment: Free in nature; Pores color: Yellowish to white in color; Pores shape: Broad; Pores spacing: Crowded

Stipe: Present; Size: 11.8 cm; Shape: Unequal; Position: Lateral; Surface characteristics: Dry and polished in nature; Color: Pink to chocolate in color; Firmness: Solid or sometime in fleshy

Ecological features: Locality found: Gazipur, Dhaka, Tropical Moist Deciduous Forest region, Bangladesh; Habitat: On soil, in an association near the Ipil-Ipil (*Leucaena leucocephala*) and Golden shower (*Acacia auriculiformis*) trees; Habit: Scattered; Type of association: Root associated; Forest type: Leveled; Constancy of occurrence in specific habitat: Abundant; Type of soil: Sandy soil in nature; Weather at the time of collection: Literally dry weather around the habitat

Ganoderma boninense

Family: Ganodermataceae

Common name: Young resinous polypore mushroom

Color: Center is orange in color with white boarder

Length: 07 cm

Width: 0.9 cm

Spore diameter (Average): Length: 4.9 µm; Width: 4.12 µm

Spore shape: Single walled, smooth and more or less circular

Cap of the carpophore: Size: 7.0 cm x 5.3 cm; Shape: Flat

Pileus: Color: Center is orange in color with white boarder; Margin: Regular in shape

Texture of the fruiting body: Soft and spongy

Flesh odor: Unpleasant

Ecological features: Locality found: Rajshahi University, Rajshahi, Tropical Moist Deciduous Forest region, Bangladesh; Habitat: On root of the Bamboo (*Bambuseae*) tree; Habit: Caespitose cluster and closely merged with the root; Type of association: Root associated; Forest type: Leveled; Constancy of occurrence in specific habitat: Not abundant; Type of soil: Loamy soil in nature; Weather at the time of collection: Less moist weather around the habitat

Ganoderma tsugae

Family: Ganodermataceae

Common name: Reishi mushroom

Color: Mature: Red in center with white boarder; Young: Yellow at the top with red in the bottom

Length (Mature): 8.5 cm

Width (Mature): 9.3 cm

Spore bearing surface under cap: Pores on hymenium

Spore diameter (Average): Length: 5.8 µm; Width: 4.7 µm

Spore shape: Single walled, smooth and oval

Cap of the carpophore: Size: 9.6 cm x 5.3 cm; Shape: Flat in the top around

Pileus: Color: Creamy; Surface character and Zonation: Leathery; Margin: Irregular in shape

Texture of the fruiting body: Brittle, leathery and woody

Flesh odor: Pleasant (chocolate)

Stipe: Present; Size: 3 cm; Shape: Unequal; Position: Central; Surface characteristics: Dry and Polished in nature; Color: Pink to chocolate in color; Firmness: Solid or sometime in erect

Ecological features: Locality found: Sujanagar, Pabna; Nature: Saprotrophic or parasitic; Habitat: On soil, in the bark of Golden shower (*Acacia auriculiformis*) tree; Habit: Scattered; Type of association: Closely root associated; Forest type: Leveled; Constancy of occurrence in specific habitat: Abundant; Type of soil: loamy soil in nature; Weather at the time of collection: Literally dry weather around the habitat.

Ganoderma zonatum

Family: Ganodermataceae

Common name: Lingzhi or Reishi mushroom

Color: Young: White

Length (Young): 3.4 cm to 1.7 cm

Width (Young): 3.3 cm to 2.1 cm

Spore bearing surface under cap: Pores present

Spore diameter (Average): Length: 6.63 µm; Width: 4.47 µm

Spore shape: Single walled, smooth and ellipsoidal

Pileus: Color: Milky white to Creamy; Surface character and Zonation: Dry in nature

Texture of the fruiting body: Woody

Flesh odor: Pleasant

Lamellae: Absent; Pores color: Milky white in color; Pores shape: Broad; Pores spacing: Crowded; Firmness: Solid or somewhat in fleshy

Ecological features: Locality found: Kalai, Jaipurhat; Nature: Parasitic; Habitat: On bark of the tree, in an association with the Mahogany (*Swietenia mahogany*) trees; Habit: Closely associated on the bark of the tree; Type of association: Scattered and somewhat caespitose cluster; Forest type: Leveled; Constancy of occurrence in specific habitat: Not in abundant; Type of soil: Clay loam soil in nature; Weather at the time of collection: Moderate moist weather around the habitat

Ganoderma applanatum

Family: Ganodermataceae

Common name: Lingzhi or Reishi mushroom

Color: Mature: Red with white color pores

Length (Mature): 6.4 cm

Width (Mature): 3.5 cm

Spore bearing surface under cap: Pores on hymenium

Spore diameter (Average): Length: 7.46 µm; Width: 6.0 µm

Spore shape: Single walled, smooth and oblong or spherical

Pileus: Surface character and Zonation: Dry in nature; Margin: Incurved in shape

Texture of the fruiting body: Woody

Flesh odor: Disagreeable

Pores color: White

Ecological features: Locality found: Kalai, Jaipurhat; Nature: Parasitic; Habitat: On bark wood of the tree, in an association with the Golden shower (*Acacia auriculiformis*) tree; Habit: Scattered; Type of association: Closely associated; Forest type: Leveled; Constancy of occurrence in specific habitat: Un-abundant; Type of soil: Loamy soil in nature; Weather at the time of collection: Moist weather around the habitat.

Ganoderma resinaceum

Family: Ganodermataceae

Common name: Bracket fungi or Reishi mushroom

Color: Blackish with grayish color boarder (Mature)

Length: Mature: 06 cm; Young: 05 cm

Width: Mature: 4.1 cm; Young: 3.2 cm

Spore bearing surface under cap: Pores on hymenium

Spore diameter (Average): Length: 14.9 µm; Width: 10.0 µm

Spore shape: Single walled, smooth and ellipsoidal

Pileus: Color: Whitish to Creamy; Surface character and Zonation: Smooth, leathery and moist in nature; Margin: Regular in shape

Texture of the fruiting body: Spongy, leathery and woody

Flesh odor: Unpleasant

Lamellae: Absent; Pores color: White in color; Pores spacing: Crowded

Ecological features: Locality found: Kalai, Jaipurhat; Habitat: On bark wood of the tree, in an close association with the Golden shower (*Acacia auriculiformis*) trees; Habit: Scattered; Type of association: Closely associated; Forest type: Leveled; Constancy of occurrence in specific habitat: Un-abundant; Type of soil: Loamy soil in nature; Weather at the time of collection: Moderately moist weather around the habitat.

Genus: *Hebeloma* sp.

Hebeloma crustuliniforme

Family: Hymenogastraceae

Common name: Poison pie or fairy cakes

Color: White (Young); Creamy (Mature)

Length: Mature: 6.2 cm; Young: 3.7 cm

Width: Mature: 3.3 cm; Young: 1.2 cm

Spore bearing surface under cap: Gills

Spore diameter (Average): Length: 5.85 µm; Width: 3.7 µm

Spore shape: Single walled, smooth and ellipsoidal

Cap of the carpophore: Size: Mature: 3.3 cm; Young: 1.2 cm; Shape: Umbonate and flatten

Pileus: Color: Creamy; Surface character and Zonation: Smooth and dry in nature; Margin: Regular

Texture of the fruiting body: Soft and spongy

Flesh odor: Pleasant

Lamellae: Present; Gill attachment: Adnate; Gill color: Yellowish white; Gill shape and width: Moderately broad; Gill spacing: Close; Lamellulae: Present; Forking pattern: Branched

Stipe: Present; Size: Mature: 3.9 cm; Shape: Bare; Position: Central; Surface characteristics:

Dry and polished; Color: Creamy; Firmness: Solid but fleshy.

Ecological features: Locality found: Botanical garden, Mirpur, Dhaka; Habitat: On soil and root of the tree; in an association with the stem of Bamboo (*Bambuseae*) tree; Habit: Scattered; Type of association: Close; Forest type: Leveled; Constancy of occurrence in specific habitat: Unabundant; Type of soil: Sandy; Weather at the time of collection: Less moist weather

Genus: *Craterellus* sp.

Craterellus cornucopioides

Family: Cantharellaceae

Common name: Black trumpet mushroom

Color: Violet (Young); Black with whitish color boarder (Mature)

Length (Mature): 7.4 cm

Width (Mature): 3.8 cm

Spore diameter (Average): Length: 4.46 μm ; Width: 3.96 μm

Spore shape: Single walled, smooth and cylindrical

Cap of the carpophore: Size: 3.4 cm \times 2.6 cm; Shape: Infundibular

Pileus: Color: Pinkish and somewhat mixed; Surface character and Zonation: Smooth, leathery, sticky and moist; Margin: Incurved

Texture of the fruiting body: Brittle but moist in nature

Flesh odor: Pleasant

Ecological features: Locality found: Botanical garden, Mirpur, Dhaka; Habitat: On soil and root of the tree; in an association with the stem of Bamboo (*Bambuseae*) tree; Habit: Scattered; Type of association: Close; Forest type: Leveled; Constancy of occurrence in specific habitat: Unabundant; Type of soil: Sandy; Weather at the time of collection: Moist weather

Genus: *Lepiota* sp.

Lepiota Americana

Family: *Agaricaceae*

Common name: Rogers mushroom

Color: Brown (Young); Brown or dark brown having pinkish spots or scales (Mature); Color changed from dark brown to black in the border region after one hour of collection

Length: Mature: 3.0 cm to 4.5 cm; Young: 4.0 cm

Width: Mature: 3.8 cm to 5.1 cm; Young: 1.8 cm

Spore bearing surface under cap: Gills

Spore diameter (Average): Length: 6.28 μm ; Width: 4.32 μm

Spore shape: Single walled, smooth and ellipsoid

Cap of the carpophore: Size (Mature): 3.8 cm to 5.1 cm; Shape: Convex

Pileus: Color: Pinkish, brownish or mixed; Surface character and Zonation: Smooth and dry in nature; Margin: Regular

Texture of the fruiting body: Soft and spongy

Flesh odor: Pleasant

Lamellae: Present; Gill attachment: Emarginated; Gill color: Light brown; Gill shape: Broad; Gill spacing: Close; Lamellulae: Present; Forking pattern: Unbranched

Stipe: Present; Size: 2.4 cm \times 5.8 cm; Shape: Equal; Position: Central; Surface characteristics: Dry, glabrous and polished; Color: Grey to light brown; Firmness: Tubular

Annulus (position): Present and single

Scale: Present and brown in color

Umbo: Present and convex well shaped

Ecological features: Locality found: Botanical garden, Mirpur, Dhaka; Habitat: On soil; in an association with the mango (*Magifera indica*) tree; pH in soil: 5.6; Moisture: 7.0%; Temperature: 34°C; Habit: Scattered; Type of association: Distant; Forest type: Leveled; Constancy of occurrence in specific habitat: Unabundant; Type of soil: Loam; Weather at the time of collection: Dry weather

Lepiota helveola

Family: *Agaricaceae*

Color: White and creamy (Young); White and creamy with dark brown spots on cap and stipe (Mature)

Length (Mature): 13 cm to 15 cm; Young: 8.0 cm

Width (Mature): 6.0 cm to 6.3 cm; Young: 4.4 cm

Spore bearing surface under cap: Gills

Spore diameter (Average): Length: 8.8 μm ; Width: 5.88 μm

Spore shape: Single walled, smooth and ellipsoid

Cap of the carpophore: Size: 6.0 cm to 6.3 cm; Shape: Convex or flat

Pileus: Color: White, creamy and brownish with brown spot; Surface character and Zonation: Smooth, scaly and dry in nature; Margin: Regular

Texture of the fruiting body: Soft and spongy

Flesh odor: Fragrant

Lamellae: Present; Gill attachment: Free; Gill color: White; Gill shape: Broad; Gill spacing:

Close; Lamellulae: Present; Forking pattern: Unbranched

Stipe: Present; Size: 10.5cm; Shape: Clavate; Position: Central; Surface characteristics: Dry and glabrous; Color: Grey to light brown with dark brown spots; Firmness: Tubular;

Annulus (position): Present and single

Scale: Present and brown in color

Umbo: Present and oyster shaped

Ecological features: Locality found: Jahangirnagar University, Savar, Dhaka; Habitat: On humus; Habit: Solitary; Forest type: Mixed; Constancy of occurrence in specific habitat: Abundant; Weather at the time of collection: Moist weather

Lepiota aspera

Family: Agaricaceae

Common name: Freckled dapperling

Color: Brown (Young and maturity)

Length: 4.0 cm

Width: 1.5 cm

Spore bearing surface under cap: Gills

Spore diameter (Average): Length: 3.77 μm ; Width: 3.6 μm

Spore shape: Single walled, smooth and cylindrical

Cap of the carpophore: Size: 1.5 cm; Shape: Campanulate

Pileus: Color: Brownish; Surface character and Zonation: Scaly and dry in nature; Margin: Regular

Texture of the fruiting body: Soft and spongy

Flesh odor: Pleasant

Lamellae: Present; Gill attachment: Free; Gill color: Pale light brown; Gill shape: Moderately broad; Gill spacing: Crowded; Lamellulae: Present; Forking pattern: Branched

Stipe: Present; Size: 3.9 cm; Shape: Equal; Position: Central; Surface characteristics: Dry but spiny scale present and pruinose; Color: Grey to light brown; Firmness: Solid

Ecological features: Locality found: Sher-e-Bangla Nagar, Dhaka; Habitat: On humus; Habit: Scattered; Forest type: Leveled; Constancy of occurrence in specific habitat: Un-abundant; Type of soil: Clay loam; Weather at the time of collection: Moist weather

Macrolepiota procera

Family: Lepiotaceae

Color: Creamy (Young); Creamy with dark brown scale (Mature)

Length: 13 cm

Width: 7.0 cm

Spore bearing surface under cap: Gills

Spore diameter (Average): Length: 8.82 μm ; Width: 5.82 μm

Spore shape: Single walled, smooth and elongated, ellipsoid

Cap of the carpophore: Size: Length: 7.0 cm; Width: 0.8 cm; Shape: Umbonate

Pileus: Color: Creamy with spots; Surface character and Zonation: Smooth, scaly and dry in nature; Margin: Regular

Texture of the fruiting body: Soft and spongy

Flesh odor: Pleasant

Lamellae: Present; Gill attachment: Free; Gill color: Pale white; Gill shape: Broad; Gill spacing: Close; Lamellulae: Present; Forking pattern: Unbranched

Stipe: Present; Size: 11.5 cm; Shape: Bulbous; Position: Central; Surface characteristics: Dry and polished; Color: White to light brown with spots; Firmness: Tubular and fleshy

Annulus (position): Present and single

Scale: Present and brown in color

Umbo: Present and oyster shaped

Ecological features: Locality found: Jahangirnagar University, Savar, Dhaka; Habitat: On humus; Habit: Solitary; Forest type: Mixed; Constancy of occurrence in specific habitat: Un-abundant; Weather at the time of collection: Moist weather

Ramariopsis sp.

Ramariopsis kunzei

Family: Clavariaceae

Common name: White coral

Color: White (Young and mature)

Length (Mature): 5.2 cm

Width (Mature): 2.5 cm

Spore diameter (Average): Length: 4.0 μm ; Width: 3.6 μm

Spore shape: Single walled, smooth and spherical

Texture of the fruiting body: Soft, spongy and brittle

Flesh odor: Unpleasant

Forking pattern: Branched

Surface characteristics: Dry

Color: White

Firmness: Fistulose and narrow

Ecological features: Locality found: Botanical garden, Mirpur, Dhaka; Habitat: On soil; in an association with the Ipil-Ipil (*Leucaena leucocephala*) and Golden shower (*Acacia auriculiformis*); Habit: Solitary and some others are caespitose cluster; Type of association: Distant and some are closely crowded; Forest type: Leveled; Constancy of occurrence in specific habitat: Un-abundant; Type of soil:

Sandy; Weather at the time of collection: Moist weather

Genus: *Ampulloclitocybe* sp.

Ampulloclitocybe clavipes

Family: Hygrophoraceae

Common name: Club footed ditocybe

Color: White (Young and mature)

Length: Mature: 2.4 cm; Young: 1.8 cm

Width: Mature: 1.4 cm; Young: 0.6 cm

Spore bearing surface under cap: Gills

Spore Diameter (Average): Length: 4.56 μm ; Width: 4.56 μm

Spore shape: Single walled, smooth and spherical

Cap of the Carpophore: Size: Mature: 1.4 cm; Young: 0.6 cm; Shape: Ovate

Pileus: Color: White; Surface character and Zonation: Smooth and dry in nature; Margin: Regular

Texture of the fruiting body: Soft and spongy

Flesh odor: Pleasant

Lamellae: Present; Gill attachment: Free; Gill color: White; Gill shape: Moderately broad; Gill spacing: Close; Lamellulae: Present; Forking pattern: Unbranched

Stipe: Present; Size: 2.4 cm; Shape: Bare; Position: Central; Surface characteristics: Dry and glabrous; Color: White and some became grey to light brown after one hour; Firmness: Solid and tubular

Ecological features: Locality found: Botanical garden, Mirpur, Dhaka; Habitat: On soil; in an association with the Golden shower (*Acacia auriculiformis*); Habit: Scattered; Type of association: Distant; Forest type: Mixed; Constancy of occurrence in specific habitat: Un-abundant; Type of soil: Clay loam; Weather at the time of collection: Moderately moist weather

Genus: *Lycoperdon* sp.

Lycoperdon pyriforme

Family: Lycoperdaceae

Common name: Pear-shaped puffball or stump puffball

Color: White (Young and mature)

Length: 1.15 cm

Width: 1.3 cm

Spore diameter (Average): Length: 5.27 μm ; Width: 4.07 μm

Spore shape: Single walled, smooth and ellipsoid

Cap of the carpophore: Size: 1.3 cm; Shape: Flat

Pileus: Color: White; Surface character and Zonation: Smooth

Texture of the fruiting body: Soft and spongy

Flesh odor: Pleasant

Firmness: Solid but fleshy

Ecological features: Locality found: Gazipur, Dhaka; Habitat: On bark wood of the tree; in an association with the stem of Bamboo (*Bambuseae*) tree; Habit: Scattered; Type of association: Close; Forest type: Leveled; Constancy of occurrence in specific habitat: Un-abundant; Type of soil: Loam; Weather at the time of collection: Moist weather.

Genus: *Volvariella* sp.

Volvariella gloiocephala

Family: Pluteaceae

Common name: Big sheath mushroom, rose-gilled grisette, or stubble rosegill

Color: White (Young and mature)

Length: 10.5 cm

Width: 6.8 cm

Spore bearing surface under cap: Gills

Spore diameter (Average): Length: 10.5 μm ; Width: 10.1 μm

Spore shape: Single walled, smooth and ellipsoidal

Cap of the carpophore: Size: 6.8 cm; Shape: Ovate or flat

Pileus: Color: Creamy, brownish and some are mixed; Surface character and Zonation: Smooth and dry in nature; Margin: Incurved

Texture of the fruiting body: Soft and spongy

Flesh odor: Disagreeable after half an hour of collection

Lamellae: Present; Gill attachment: Free; Gill color: Pale white; Gill shape: Broad; Gill spacing: Close; Lamellulae: Present; Forking pattern: Branched

Stipe: Present; Size: 9.2 cm; Shape: Clavate; Position: Central; Surface characteristics: Dry and glabrous; Color: White to creamy; Firmness: Tubular and narrow

Volva: Present

Ecological features: Locality found: Sujanagar, Pabna; Habitat: On soil; in an association with the Mahogany (*Swietenia mahogany*) tree; Habit: Scattered; Type of association: Close; Forest type: Leveled; Constancy of occurrence in specific habitat: Un-abundant; Type of soil: Loam; Weather at the time of collection: Moist weather

Note: Started rotting after half an hour of collection

Genus: *Russula* sp.

Russula nobilis

Family: Russulaceae

Common name: Beech wood sickener
Color: Red and white mixture (Young and mature)
Length: 4.8 cm
Width: 5.3 cm
Spore bearing surface under cap: Gills
Spore diameter (Average): Length: 8.78 μm ;
Width: 7.6 μm
Spore shape: Single walled, smooth and spherical
Cap of the carpophore: Size: 6.0 cm \times 5.3 cm;
Shape: Convex
Pileus: Color: Reddish; Surface character and Zonation: Dry and rough in nature; Margin: Regular
Texture of the fruiting body: Soft and spongy
Flesh odor: Aromatic
Lamellae: Present; Gill attachment: Free and some are emarginated; Gill color: White; Gill shape: Broad; Gill spacing: Close; Lamellulae: Present; Forking pattern: Unbranched
Stipe: Present; Size: 3.8 cm; Shape: Bare; Position: Central; Surface characteristics: Dry and polished; Color: Creamy; Firmness: Tubular and fleshy
Ecological features: Locality found: Sujanagar, Pabna; Habitat: On soil; in an association with the Golden shower (*Acacia auriculiformis*) tree; Habit: Scattered; Type of association: Close; Forest type: Leveled; Constancy of occurrence in specific habitat: Un-abundant; Type of soil: Loam; Weather at the time of collection: Moderately moist weather

Genus: *Termitomyces* sp.

Termitomyces heimii
Family: Lyophyllaceae
Color: White (Young and mature)
Length: 21.1 cm
Width: 12 cm
Spore bearing surface under cap: Gills
Spore diameter (Average): Length: 14.0 μm ;
Width: 10.8 μm
Spore shape: Single walled, smooth and cylindrical as well as ellipsoid
Cap of the carpophore: Size: 12 cm; Shape: Convex
Pileus: Color: Creamy; Surface character and Zonation: Smooth and dry in nature; Margin: Regular
Texture of the fruiting body: Soft and spongy
Flesh odor: Fragrant
Lamellae: Present; Gill attachment: Adnexed; Gill color: White; Gill shape: Broad; Gill spacing: Crowded; Lamellulae: Present; Forking pattern: Unbranched

Stipe: Present; Size: 20.0 cm; Shape: Bulbous; Position: Central; Surface characteristics: Dry and polished; Color: Creamy; Firmness: Solid; Scale: Present and white in color
Ecological features: Locality found: Dinajpur sadar, Habitat: On humus; near the mango (*Magifera indica*) tree; Habit: Scattered; Type of association: Distant; Forest type: Leveled; Constancy of occurrence in specific habitat: Un-abundant; Type of soil: Clay loam; Weather at the time of collection: More moist weather

Genus: *Amanita* sp.

Amanita muscaria
Family: Amanitaceae
Common name: Fly agaric
Color: Red (Young and mature)
Length: 4.2 cm
Width: 2.5 cm
Spore bearing surface under cap: Gills
Spore diameter (Average): Length: 4.8 μm ;
Width: 3.28 μm
Spore shape: Single walled, smooth and ellipsoid
Cap of the carpophore: Size: 2.5 cm; Shape: Convex
Pileus: Color: Pinkish; Surface character and Zonation: Smooth and dry in nature; Margin: Regular
Texture of the fruiting body: Spongy
Flesh odor: Pleasant
Lamellae: Present; Gill attachment: Free; Gill color: White; Gill shape: Moderately broad; Gill spacing: Crowded; Lamellulae: Present; Forking pattern: Branched
Stipe: Present; Size: 4.3 cm; Shape: Equal; Position: Central; Surface characteristics: Dry and polished; Color: Pinkish; Firmness: Solid; Annulus (position): Present and single; Scale: Present and reddish to pinkish in color
Ecological features: Locality found: Sher-e-Bangla Nagar, Dhaka; Habitat: On humus; Habit: Scattered; Forest type: Leveled; Constancy of occurrence in specific habitat: Un-abundant; Type of soil: Loam; Weather at the time of collection: Moderately moist weather

Genus: *Marasmius* sp.

Marasmius confertus
Family: Marasmiaceae
Color: Pink and purple (Young and mature)
Length: 5.5 cm
Width: 2.1 cm
Spore bearing surface under cap: Gills
Spore diameter (Average): Length: 4.28 μm ;
Width: 3.9 μm

Spore shape: Single walled, smooth and oval
Cap of the carpophore: Size: 1.8 cm to 2.1 cm; Shape: Flat
Pileus: Color: Pinkish; Surface character and Zonation: Glabrous and dry in nature; Margin: Incurved
Texture of the fruiting body: Soft
Flesh odor: Pleasant
Lamellae: Present; Gill attachment: Adnexed; Gill color: White; Gill shape: Moderately broad; Gill spacing: Crowded; Lamellulae: Present; Forking pattern: Unbranched
Stipe: Present; Size: 5.0cm; Shape: Radicating; Position: Central; Surface characteristics: Dry and glabrous; Color: White to pinkish; Firmness: Narrow
Ecological features: Locality found: Sher-e-Bangla Nagar, Dhaka; Habitat: On humus; Habit: Solitary; Forest type: Leveled; Constancy of occurrence in specific habitat: Abundant; Type of soil: Loam; Weather at the time of collection: Moist weather

Marasmius elegans

Family: Marasmiaceae
Common name: Velvet parachute
Color: Pink and purple (Young and mature)
Length: 4.5 cm
Width: 1.3 cm
Spore bearing surface under cap: Gills
Cap of the carpophore: Size: 1.3 cm; Shape: Convex.
Pileus: Color: Brownish; Surface character and Zonation: Smooth; Margin: Regular
Texture of the fruiting body: Soft and spongy
Flesh odor: Pleasant
Lamellae: Present; Gill attachment: Adnate; Gill color: Pale reddish; Gill shape: Narrow; Gill spacing: Close; Lamellulae: Present; Forking pattern: Branched
Stipe: Present; Size: 4.5 cm to 4.8 cm; Shape: Bare; Position: Central; Surface characteristics: Dry and glabrous; Color: White to light brown; Firmness: Solid

Ecological features: Locality found: Ramna park, Dhaka; Habitat: On humus; Habit: Scattered; Forest type: Leveled; Constancy of occurrence in habitat: Abundant; Type of soil: Loam; Weather at the time of collection: Moist weather

Marasmius oreades

Family: Marasmiaceae
Common name: California fungi or Scotch bonnet

Color: Brown (Young and mature)
Length: 2.2 cm to 2.5 cm
Width: 1.3 cm to 1.4 cm
Spore bearing surface under cap: Gills
Spore diameter (Average): Length: 11.05 μm ; Width: 7.75 μm
Spore shape: Single walled, smooth and ellipsoid
Cap of the carpophore: Size: 1.2 cm to 1.5 cm; Shape: Convex
Pileus: Color: Brownish; Surface character and Zonation: Glabrous and dry in nature; Margin: Regular
Texture of the fruiting body: Soft
Flesh odor: Pleasant
Lamellae: Present; Gill attachment: Adnate; Gill color: Pale brown; Gill shape: Narrow; Gill spacing: Close; Lamellulae: Present; Forking pattern: Branched
Stipe: Present; Size: 2.2 cm to 2.5 cm; Shape: Bare; Position: Central; Surface characteristics: Dry and glabrous; Color: Grey to light brown; Firmness: Solid
Umbo: Present and oyster shaped
Ecological features: Locality found: Ramna park, Dhaka; Habitat: On bark wood of the tree; Habit: Solitary; Type of association: Close; Forest type: Leveled; Constancy of occurrence in specific habitat: Un-abundant; Type of soil: Loam; Weather at the time of collection: Moist weather

Genus: *Collybia* sp.

Collybia cookei
Family: *Tricholomataceae*
Color: White (Young and mature)
Length: 5.0 cm
Width: 2.5 cm
Spore bearing surface under cap: Gills
Spore diameter (Average): Length: 7.8 μm ; Width: 6.46 μm
Spore shape: Single walled, smooth and elongated
Cap of the carpophore: Size: 1.5 cm to 2.5 cm; Shape: Convex
Pileus: Color: White; Surface character and Zonation: Smooth; Margin: Regular
Texture of the fruiting body: Spongy
Flesh odor: Fragrant
Lamellae: Present; Gill attachment: Adnate; Gill color: White; Gill shape: Moderately broad; Gill spacing: Crowded; Lamellulae: Present; Forking pattern: Unbranched
Stipe: Present; Size: 4.5 cm to 5.0 cm; Shape: Bare; Position: Central; Surface characteristics: Dry and glabrous; Color: White; Firmness: Solid

Ecological features: Locality found: Sher-e-Bangla Nagar, Dhaka; Habitat: On the bark wood of the tree; in an association with the Mahogany (*Swietenia mahogany*) and Eucalyptus (*Eucalyptus citriodora*) tree; Habit: Solitary; Type of association: Close; Forest type: Leveled; Constancy of occurrence in specific habitat: Abundant; Type of soil: Loam; Weather at the time of collection: Moist weather

Genus: *Mycena* sp.

Mycena alba

Family: *Mycenaceae*

Common name: Tropical white mushroom

Color: White (Young and mature)

Length: 1.0 cm

Width: 2.1 cm

Spore bearing surface under cap: Gills

Spore diameter (Average): Length: 5.32 μ m;

Width: 4.43 μ m

Spore shape: Single walled, smooth and elongated

Cap of the carpophore: Size: 2.0 cm to 2.1 cm, Shape: Conical

Pileus: Color: Creamy, Surface character and Zonation: Smooth, Margin: Regular

Texture of the fruiting body: Soft and spongy

Flesh odor: Fragrant

Lamellae: Present; Gill attachment: Adnate; Gill color: White; Gill shape: Moderately broad; Gill spacing: Close; Lamellulae: Present; Forking pattern: Branched

Stipe: Present; Size: 1.0 cm; Shape: Bare; Position: Lateral; Surface characteristics: Dry and polished; Color: White and creamy; Firmness: Solid.

Ecological features: Locality found: Botanical garden, Mirpur, Dhaka; Habitat: On bark wood of the tree; in an association with the Mahogany (*Swietenia mahogany*) and Eucalyptus (*Eucalyptus citriodora*) tree; Habit: Solitary; Type of association: Close; Forest type: Leveled; Constancy of occurrence in specific habitat: Unabundant; Type of soil: Loam; Weather at the time of collection: Moderately moist weather.



Fig. 2. Fruiting body of collected mushrooms; a. *Ganoderma lucidum*; b. *Ganoderma boninense* (Growing stage); c. *Ganoderma tsugae*; d. *Ganoderma zonatum* (Young stage); e. *Ganoderma applanatum*; f. *Ganoderma resinaceum*; g. *Hebeloma crustuliniforme*; h. *Craterellus cornucopioides*; i. *Lepiota americana*



Fig. 3. Fruiting body of collected mushrooms; a. *Lepiota helveola*; b. *Lepiota aspera*; c. *Macrolepiota procera*; d. *Ramariopsis kunzei*; e. *Ampulloclitocybe clavipes*; f. *Lycoperdon pyriforme*; g. *Volvariella gloiocephala*; h. *Russula nobilis*; i. *Termitomyces heimii*

4. DISCUSSION

Mushrooms alone are represented by about 41,000 species [13]. Due to their beneficial properties as well as the economic importance, it increases the interest to the modern research. The occurrence of such familiar substrate as wood, litter and soil, implies a role for them in these micro habitats [14]. Usually in the rainy season (July to October), fleshy mushrooms are found. Some are also found in the summer as well as in the winter season and it basically grown in everywhere, where they get adequate moisture or their favorable environment. They actually emerge from substrates such as peat,

along or soil, humus, dung, sawdust, charcoal heaps etc. [15].

An investigation was carried out to collect identify and preserve mushrooms from the tropical moist deciduous forest region in Bangladesh. Through this investigation, 14 genera and 24 species were identified including 6 species of *Ganoderma*, 4 species of *Lepiota*, 3 species of *Marasmius* and 1 species each of the genera *Collybia*, *Hebeloma*, *Craterellus*, *Ramariopsis*, *Ampulloclitocybe*, *Lycoperdon*, *Volvariella*, *Russula*, *Termitomyces*, *Amanita* and *Mycena*.



Fig. 4. Fruiting body of collected mushrooms; a. *Amanita muscaria*; b. *Marasmius confertus*; c. *Marasmius elegans*; d. *Marasmius oreades*; e. *Collybia cookie*; f. *Mycena alba*

Ganoderma sp. was found at Rajshahi, Pabna, Jaipurhat and Dhaka district of the tropical moist deciduous forest region in Bangladesh. It was first found in 1905 by American mycologist named William Murrill [16]. This species was also reported in China [17] and India [18-21]. Furthermore, *Ganoderma lucidum* and *Ganoderma appalantum* both were reported in India and Nigeria [19-23] whereas, *Ganoderma boninense* and *Ganoderma tsugae* were reported by Hushiarian et al. [24] and Vyas et al. [25] accordingly. On the other hand, *Ganoderma resinaceum* was also reported by Mohanty et al. in India [26]. *Hebeloma* sp. was found at Dhaka district of the tropical moist deciduous forest region in Bangladesh, whereas, it was also common all over the world especially in Western Australia. It was also reported in the western United States [27]. The similar type of *Hebeloma crustuliniforme* was also reported by both Geml et al. and Romano et al. [28-29]. Meanwhile, *Craterellus* sp. was found at Dhaka district whereas, the genus was described by some

other researchers [30]. Later on the genus was more specified by the DNA studies [31]. During the investigation all *Lepiota* species were found at Dhaka district of Bangladesh, whereas, around 400 species were already identified all over the world and most of them are poisonous. The species was first reported in South Africa [32] and also reported in India [19-20]. Furthermore, the similar genus of *Lepiota americana* was reported in India [33]. *Lepiota hevelvo* was reported by Sysouphanthong et al. [34]. On the other hand, *Lepiota aspera* was also reported from India and Philippines [34-35] and *Macrolepiota procera* was reported in India and Burma [34-36] as well. Throughout the investigation, *Ramariopsis* sp. was found in Dhaka district of the tropical moist deciduous forest region in Bangladesh. This genus has a widespread distribution and contains 44 species [37]. Two species of this genus were reported in Western Ghats, Kerala, India [38] whereas, *Ramariopsis kunzei* was also reported in Northeast Ohio [39].

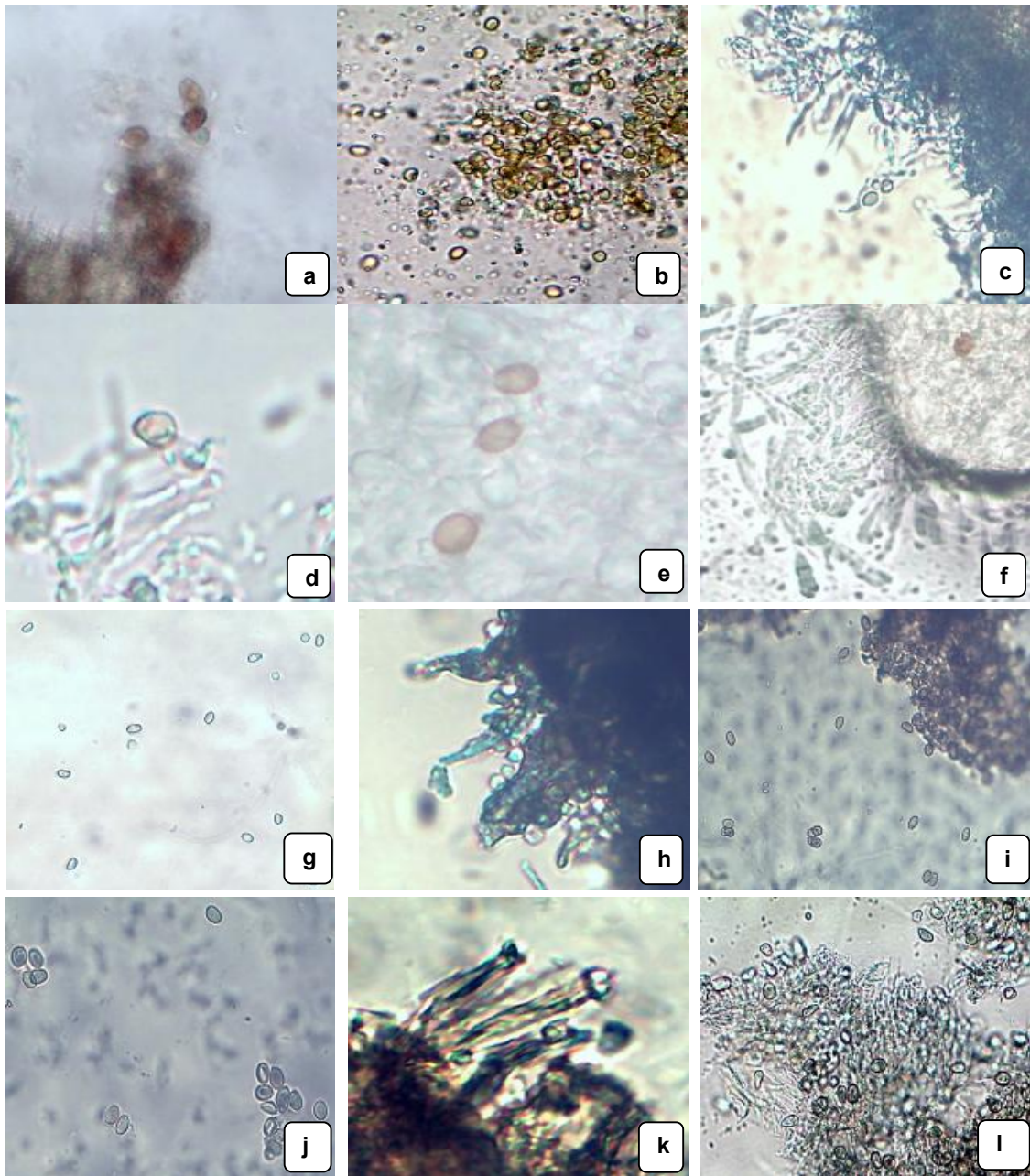


Fig. 5. Spores of the collected mushrooms; a. *Ganoderma lucidum*; b. *Ganoderma boninense*; c. *Ganoderma tsugae*; d. *Ganoderma zonatum*; e. *Ganoderma applanatum*; f. *Ganoderma resinaceum*; g. *Hebeloma crustuliniforme*; h. *Craterellus cornucopioides*; i. *Lepiota americana*; j. *Lepiota helveola*, k. *Lepiota aspera*; l. *Macrolepiota procera*

Ampulloclitocybe sp. *Lycoperdon* sp. and *Volvariella* sp. were collected from Dhaka district of the tropical moist deciduous forest region in Bangladesh. The genus *Ampulloclitocybe* has three species and widely distributed [37] whereas, *Ampulloclitocybe clavipes* was also

reported by Matheny et al. [40]. Recently, *Volvariella* sp. and *Lycoperdon* sp. were also reported from India [41,20]. Furthermore, *Russula* sp. *Termitomyces* sp. and *Amanita* sp. were found to be distributed at Pabna, Dinajpur and Dhaka district respectively. The genera

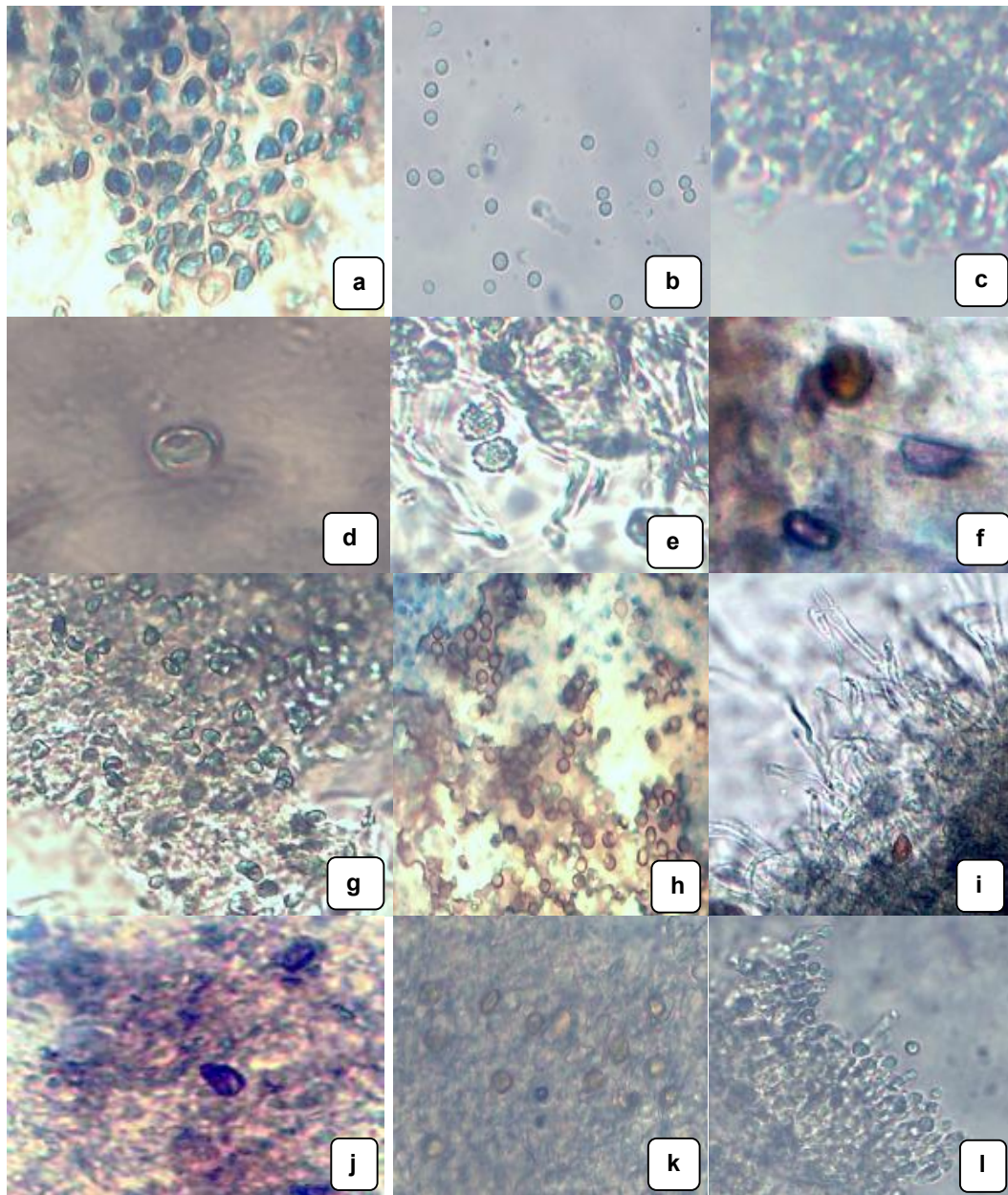


Fig. 6. Spores of the collected mushrooms; a. *Ramariopsis kunzei*; b. *Ampulloclitocybe clavipes*; c. *Lycoperdon pyriforme*; d. *Volvariella gloiocephala*; e. *Russula nobilis*; f. *Termitomyces heimii*; g. *Amanita muscaria*; h. *Marasmius confertus*; i. *Marasmius elegans*; j. *Marasmius oreades*; k. *Collybia cookii*; l. *Mycena alba*

Amanita and *Russula* were reported in India [19,20,38], whereas, *Termitomyces* sp. was circumscribed by Roger Heim [42]. *Termitomyces* sp. was also found in India [20] and the morphological characterization and yield potential of *Termitomyces* sp. mushroom was studied at Gorakhpur forest division in India [43]. On the other hand, the similar genus of *Russula*

nobilis and *Termitomyces heimii* species were reported by Pala et al. [44] and Dwivedi et al. [19] respectively. Furthermore, *Amanita muscaria* was also reported by Hawkeswood [45], Michelot and Melendez-howell [46] and Pala et al. [44].

In the Dhaka district of the tropical moist deciduous forest region in Bangladesh, all the

three species of *Marasmius* sp. were found. It was also reported in Madagascar and Mascarenes by Antonín and Buyck [47]. The similar genus of *Marasmius confertus* and *Marasmius elegans* were also reported by Farook et al. [48] and Horton [49] accordingly. Furthermore, *Collybia* sp. and *Mycena* sp. was also found at Dhaka district of the tropical moist deciduous forest region in Bangladesh throughout the investigation. However, the genera *Collybia* and *Mycena* have nearly 3 species and 33 species, respectively [50]. The genus *Collybia* is widespread but rarely distributed in north temperate areas [51]. On the other hand, *Mycena* sp. was also reported in India [20]. The surveys of different locations were done in the rainy season. Most mushrooms are found in forest areas, in field areas, on branches of trees and some time in waste land areas; although they may be found throughout the year.

5. CONCLUSION

This is the first investigation of mushroom biodiversity at tropical moist deciduous forest region of Bangladesh. Through this investigation, identified 24 species from those selected areas will provide an outline to the farmers as well as consumers of Bangladesh for the further utilization of mushrooms considering the increasing economic demand day by day. Moreover, future investigation is also needed in different seasons as well as in different forest regions to identify the new exotic species of mushroom flora, which will represent a complete overview about the available mushroom flora in Bangladesh.

ACKNOWLEDGEMENTS

We would like to thank, the Department of Plant Pathology, Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, Bangladesh for the support and help to carry-out this research work.

COMPETING INTERESTS

Authors have declared that no competing interests exist regarding the publication of this paper.

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