Journal of Advances in Biology & Biotechnology
11(4): 1-15, 2017; Article no.JABB.30971
ISSN: 2394-1081

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Morphological and Ecological Characterization of Xylotrophic Fungi in Mangrove Forest Regions of Bangladesh

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Authors' contributions

This work was carried out in collaboration between both authors. Author KD wrote the protocol, carried out research and wrote the first draft of the manuscript. Author FMA designed and supervised the study and identified the xylotrophic fungi. Both authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JABB/2017/30971
Editor(s):
(1) Laura Pastorino, Laboratory of Nanobioscience and Medical Informatic, Department Informatics, Bioengineering, Robotics and Systems Engineering (DIBRIS), University of Genoa, Italy.
Reviewers:
(1) Blagoy Angelov Uzunov, Sofia University "St. Kliment Ohridski", Bulgaria.
(2) Debendra Nath Roy, Jessore University of Science and Technology, Jessore, Bangladesh.
(3) Girish Gogoi, Rain Forest Research Institute, Jorhat, Assam, India.
Complete Peer review History: http://www.sciencedomain.org/review-history/17991

Original Research Article

Received 12th December 2016
Accepted 14th February 2017
Published 28th February 2017

ABSTRACT

Sundarban (Mangrove), the largest tidal halophytic forest in the world 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. In a survey program 20 species of xylotrophic fungi belongs to 13 genera were identified under seven families such as Polyporaceae, Ganodermataceae, Hymenochaetaceae, Fomitopsidaceae, Xylariaceae, Steccherinaceae and Gloeophyllaceae. The predominant genera were *Ganoderma*, *Trametes* and *Inonotus*. 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 *Pycnoporus sanguineus* which was found on the Sundari (*Heritiera fomes*) tree. This is the first detailed investigation on Xylotrophic fungi in mangrove forest regions of Bangladesh.

Keywords: Mangrove; xylotrophic fungi; polypore; morphology; ecology.

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1. INTRODUCTION

A mushroom is a spore bearing fruiting body of a fungus, typically produced above ground soil or on its food source. Mushrooms have been existing on earth even long time before man appeared on earth as it is evident from the fossil records of the lower cretaceous period. Mushroom is a general term used mainly for the fruiting body of the macro fungi (*Ascomycota* and *Basidiomycota*) and represents only a short reproductive stage in their life cycle [1]. Mushrooms are typically found in waste lands, where generally absence of artificial activities of any human-being such as, forest lands, field lands or, on the moist branches of trees. Throughout this investigation, we tried to represent the existing biodiversity of mushroom in this forest region. Besides, they are valued for food and medicinal properties by people. However, the food value and acceptance of these edible fungi by the scientific and civilized world have not been recognized. 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 [2]. Wild edible fungi were being collected and consumed by people for thousands of years. Many mushrooms have been used as food and medicines. So they contribute towards diet, income and human health. Some mushrooms have been important source of revenue for rural communities in India and other developing countries [3].

Mushrooms are well known for their nutritional as well as therapeutic values worldwide. Interest in mushrooms has peaked because immunity and cellular protection are important issues for health conscious consumers and for those individuals who are dealing with serious health issues. Wild mushrooms provide a significant source of nutrients that can be used as food or in traditional medicine, particularly for local people in South East Asia, India, Europe, and Africa. In addition, there is an exponentially increasing interest in research into nutritional and medicinal properties of wild mushrooms, as compared to limited cultivated mushroom strains [4]. The literature shows a body of information on collection, medicinal properties and nutritional composition of wild mushrooms from many countries [5]. These are invariably high protein rich and have been considered as potential source of proteins, amino acids, vitamins and minerals. Indigenous peoples are utilizing mushroom for the treatment of different type of diseases and also as an aphrodisiac and tonic [6].

Nowadays, they attract attention because of their bioactive compounds, beneficial effects and possible use in the prevention or treatment of diseases, being classified as functional foods and sources of nutraceuticals [7,8]. Some of the mushrooms bioactive properties are related with their antioxidant activity and antioxidant compounds. In fact, antioxidants are in constant activity in living organisms, being required to be in sufficient amounts to neutralize the toxic effects of reactive oxygen species (ROS), reactive nitrogen species (RNS) and reactive sulphur species (RSS) that are produced continuously [9,10]. 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. Mangrove forest is one of the diversified forest in the world which is very much favourable for the growth and development of fleshy and xylotrophic fungi.

The present research investigation was conducted by a systematic survey in the mangrove forest regions of Bangladesh that covers maximum part of mangrove forest regions with the objective of identifying the mushrooms up to the genus and species level. Man has lived in a hunter-gatherer society for most of the time since their origin and has depended entirely on biodiversity for their sustenance. The world demand of mushrooms is high rocketing just for the fulfillment of our nutritional deficiency. It is our duty to identify and also differentiate the beneficial and harmful mushrooms from the mangrove forest regions of Bangladesh.

2. MATERIALS AND METHODS

2.1 Collection Site

Mangrove (Sundarbans) forest regions of Bangladesh is located between the latitudes 21°30'N and 22°30'N, and longitudes 89°00'E and 89°55'E belongs to Bagerhat, Satkhira and Khulna districts. The collection sites were mangrove natural forests, residential areas, roadside and nearby villages of Mongla, Rampal, Sarankhola and Shamnagar.

2.2 Experimental Site

The analytical experiments were conducted in the Laboratory of the Department of Plant

Pathology, Sher-e-Bangla Agricultural University (SAU), Dhaka, Bangladesh.

2.3 Sampling Procedure

A pre-designed collection procedure and data analysis procedure was applied to collect information on biodiversity, distribution, habitat and morphology of mushrooms from the above mentioned regions of Bangladesh.

2.4 Collection of Mushrooms

A detailed survey was carried out in Bagerhat, Satkhira and Khulna districts under the mangrove forest regions of Bangladesh (Fig. 1) from June to October, 2015 to determine the morphological variability of mushroom's population following standard protocol [11]. Furthermore, the spotted and fleshy mushrooms were minutely inspected, collected and brought to the laboratory for detailed inspection.

2.5 Morphological Observation during Collection

The data for the identification of mushrooms were recorded after collection on the following parameters, such as locality, habitat, type of soil, forest type, size of the fructification, basidiocarps, 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 [12].

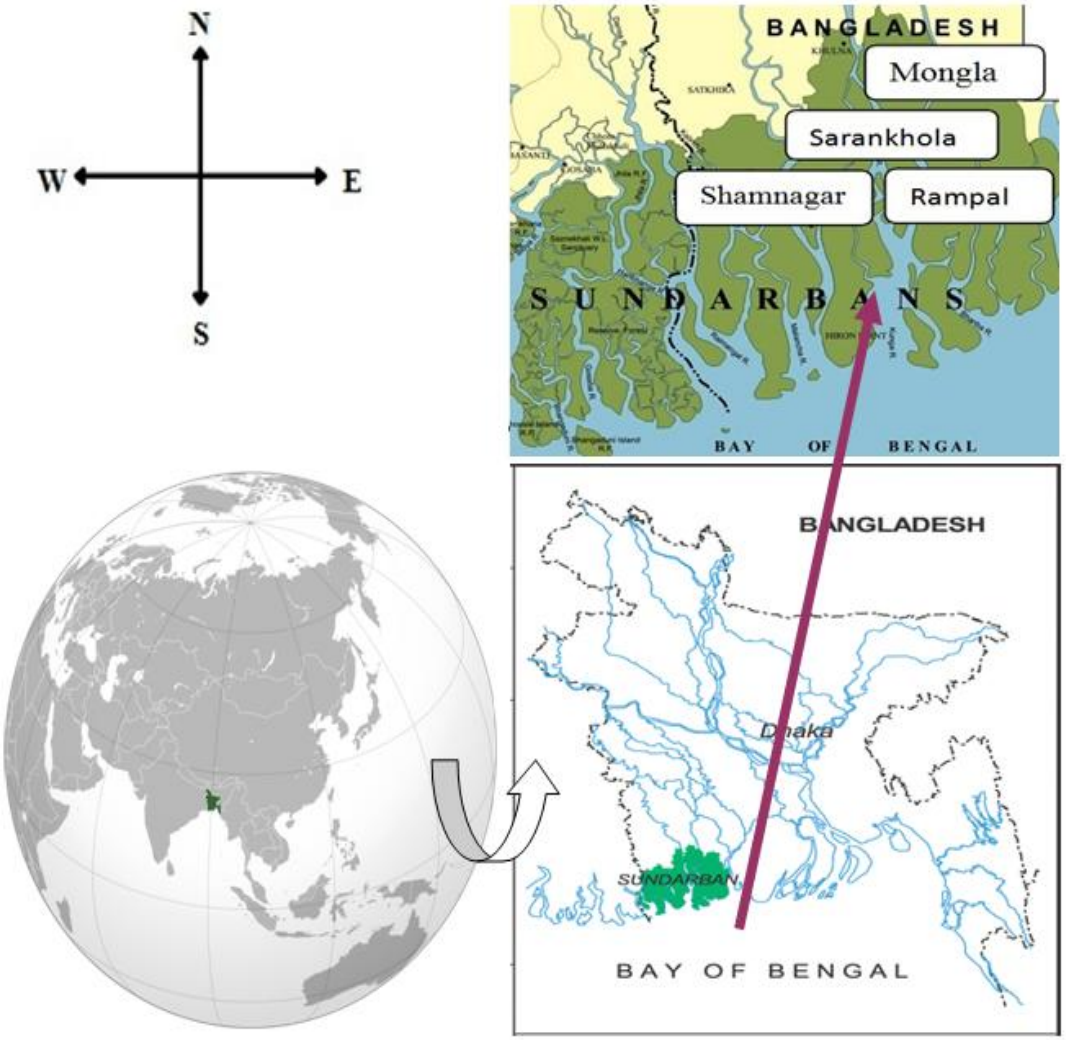

Fig. 1. Survey areas of mangrove forest regions of Bangladesh

2.6 Mushroom Processing

The photographs were taken in different angles and some morphological data, viz. size of fructification, pileus diameter, stipe length and their color were recorded after the collection of mushrooms. Mushrooms were dried and processed following the predefined method [13].

2.7 Drying

Collected samples were cleaned and dried by using electrical air flow drier controlling the1000 voltage, which can easily remove the moisture content from the collected mushrooms within 3-7 hours with a regular interval basis power supply (15 minutes switch off and 30 minutes switching) depending on the structure and texture of the species [13].

2.8 Storage

Dried mushrooms were stored into a zip-lock type polybag during the survey period for further studies. Silica gels were used at the rate of 10% of dry basis during the storage period [13].

2.9 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. Permanent glass slides were made from rehydrated basidiocarps with the aid of a sharp surgical blade for the microscopic characterization. Basidiocarps were immersed in cotton blue stain and glycerin and placed on glass slides and covered with cover slips. Furthermore, the spore size was measured using Motic microscope with the magnification of 40x [14]. The final identification and classification done by comparing the previously recorded characteristics of mushroom following the color dictionary of mushroom written by Dickinson and John [15], the mushroom guide and identifier by Jorden [16] and the mushroom identifier by Pegler and Spooner [17].

2.10 Habitat, Distribution and Diversity Analysis

The mushrooms were found in an association with various substrata. The surrounding environment, temperature, soil pH, moisture condition and vegetation were recorded for the biodiversity of mushroom. The soil pH and moisture were measured by pH meter. On the other hand, the air temperature was measured by thermometer during the collection. Collected samples were wrapped with polybag and brought into the laboratory for further study. The distribution of mushrooms on the locality was also recorded. The frequency and density of different species has been determined by the following formulas [18]:

Frequency of fungal sp. (%) = (Number of site in which the species is present/ Total number of sites) x100

Density = (Total no. of individual of a particular species/ Total number of species) x 100

3. RESULTS AND DISCUSSION

Throughout the investigation, 20 species of xylotrophic fungi belong to 13 genera under 7 families were identified (Fig. 2 to Fig. 6). The dominant host tree species of the collected macro fungi are Sundari (*Heritiera fomes*), Bohera (*Terminalia bellirica*), Mahagoni (*Swietenia mahagoni*), Sissoo (*Dalbergia sissoo*), Garjan (*Rhizophora apiculata*), Goran (*Ceriops decandra*), Coconut (*Cocos nucifera*), Rain tree (*Albizia saman*), River Abony (*Diospyros ebony*), Palm (*Borassus flabellifer*) and so on. Biodiversity, distribution and morphological characterization of collected mushrooms are described below:

There is increasing interest in the mapping of macromycetes of many areas to obtain the distribution records similar to those already existing for flowering plants. However, the food value and acceptance of these edible fungi by the scientific and civilized world have not been recognized. 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 [2].

Table 1. Characterization on the morphology of identified xylotrophic mushroom samples

Name of the Species	Common name	Morphology
Trametes versicolor (L.) Lloyd	Turkey tail	Basidiocarp was 9.6 cm×6.3 cm. The color of pileus (cap) was brick red and creamy. Shape of cap was convex, umbonate and cap edge was triangular or round.The white color micro pores were present under the cap. The surface characters and zonation was dry in nature. The texture of the fruiting body was brittle and woody. Spore color was brown. Spores shaped were single walled, rough, irregular and oval shaped. The average spore size was 6.1µm×4.38µm.
Trametes elegans (Fr.) Spreng.	No common name found	Basidiocarp was 2.3 cm×3.7 cm. The color of pileus (cap) was brown and creamy. Shape of cap was flat and cap edge was undulating. Light yellow color scale was present on the cap.The white and brown color macro pores were present under the cap. The surface characters and zonation was dry in nature. The texture of the fruiting body was hard, brittle and woody. Spore color was dark black. Spore shaped was thick walled, ellipsoidal, rough and the average spore size was 6.8µm×5µm.
Trametes conchifer (Schw.: Fr.) Pil.	Little nest polypore.	Basidiocarp was 3.2 cm×3.8 cm. The color of pileus (cap) was white. Shape of cap was concave, flatand cap edge was round and wavy.The white color micro pores were present under the cap and scale was present on the cap. The surface characters and zonation was slightly moist in nature during the collection. The texture of the fruiting body was tough, rough, spongy and brittle. Spore color was hyaline. Spores structure was single walled, rough, irregular and the average spore size was 7.035µm×4.86µm.
Trametes sp.	No common name found	Basidiocarp was 6.2 cm×4.3 cm. The color of pileus (cap) was dark brown with the white margin. Shape of cap was irregular and cap edge was concentric. The micro pores were present under the cap. The surface characters and zonation was dry in nature. The texture of the fruiting body was tough, brittle and also woody. Spore color was light yellow. Spore structure was thick walled, sub-globose, rough, irregular and the average spore size was 7.7µm×4.8µm.
Tyromyces lacteus (Fr.) Murrill	No common name found	Basidiocarp was 4.5 cm×2.1 cm. The color of pileus (cap) was white and shape of cap was irregular. The white color micro pores were present under the cap. The surface characters and zonation was moderately moist during collection. The texture of the fruiting body was tough and woody. Spore color was light yellow. Spore shaped was thick walled, rough, ellipsoidal and irregular. The average spore size was 5.8µm×3.2µm.
Pycnoporus sanguineus (L.) Murrill	Bracket fungi	Basidiocarp was 3.2 cm×6.1 cm. The color of pileus (cap) was dark red with white margin. Shape of cap was hard, concave, flat and cap edge was round smooth and wavy. The red color micro pores were present under the cap. The surface characters and zonation was dry in nature and hardy pseudo stipe was tightly attached with the host. The texture of the fruiting body was brittle and woody. Spore color was red and slightly brown. Spore shaped was thick walled, smooth, oval and regular. The average spore size was 7.4µm×5.17µm.
Polyporus varirus (Fr.) Persoon	Elegant polypore.	Basidiocarp was 6.2 cm×4.8 cm. The color of pileus (cap) was dark brown. Shape of cap was concave and cap edge was round and slightly wavt.The light yellow color micro pores were present under the cap. Brown color scale was present on the cap. The surface characters and zonation was very dry in nature. The texture of the fruiting body was brittle and spongy. Spore color was dark black. Spore shaped was thick walled, smooth, ellipsoidal regular and the average spore size was 10.2µm×4.8µm.
Daedaleopsis confragosa (Bolton) J. Schrot.	Thin walled maze polypore or the blushing	Basidiocarp was 10.4 cm×16.1 cm. The color of pileus (cap) was light yellow, brown and white margin. Shape of cap was concave, flat and cap edge was round wavy.The light yellow color macro pores were present under the cap. The surface

Name of the Species	Common name	Morphology
	bracket	characters and zonation was moist and dry in nature. The texture of the fruiting body was tough and brittle. Spore color was slightly yellow and brown. Spore was single walled, smooth, irregular and the average spore size was 5.63µm×4.13µm.
Ganoderma praelongum Murrill	Bracket fungi	Basidiocarp was 11.2 cm×6.4 cm. The color of pileus (cap) was grey. Shape of cap was infundibuliform and cap edge was round. The brown color micro pores were present under the cap and scale was on the cap. The surface characters and zonation was very dry in nature during collection. The texture of the fruiting body was rough, tough and brittle. Spore color was hyaline. Spores were single walled, smooth, irregular and the average spore size was 8.25µm×4.6µm.
Ganoderma applanatum (Pat.) Persoon	The artist's bracket, artist's conk or bear bread	Basidiocarp was 12.6 cm×7.2 cm. The color of pileus (cap) was brick red and creamy with white margin. Shape of cap was concave, flat and cap edge was round, smooth and also wavy.The white color micro pores were present under the cap and wavy scale was on the cap. The surface characters and zonation was dry in nature. The texture of the fruiting body was brittle and woody. Spore color was hyaline. Spores was single walled, smooth, round and irregular. The average spore size was 4.67µm×4.3µm.
Ganoderma brownie (Murrill) Gilbertson	Artist's conk	Basidiocarp was 9.3 cm×7.4 cm. The color of pileus (cap) was brown and slghtly cramy. Shape of cap was concave, flat and cap edge was round smooth.The brown color micro pores were present under the cap. Wavy scale and powdery substance were present on the cap. The surface characters and zonation was dry in nature. The texture of the fruiting body was tough, brittle and woody. Spore color was brown. Spore were thick walled, rough, ellipsoidal and irregular. The average spore size was 6.4µm×5.07µm.
Ganoderma tsugae Murrill	Hemlock varnish shelf.	Basidiocarp was 4.2 cm×3.8 cm. The color of pileus (cap) was dark brown. Shape of cap was irregular and cap edge was wavy but irregular. Micro pores were present under the cap. The surface characters and zonation was very much dry in nature. The texture of the fruiting body was tough and woody. Spore color was dark yellow. Spores were thick walled, rough, ellipsoidal, irregular and the average spore size was 8.5µm×3.2µm.
Ganoderma curtisii (Berk.) Murrill	Wood decay polypore	Basidiocarp was 3.1 cm×0.7 cm. The color of young pileus (cap) was white. Shape of cap was stick like and fingerlike cap edge. Micro pores were present around the cap surface. The surface characters and zonation was dry in nature. The texture of the fruiting body was brittle, tough and woody. Spore color was hyaline. Spores were single walled, smooth, sub-globose and the average spore size was 7.83µm× 4.2µm.
Ganoderma sp.	No common name found	Basidiocarp was 6.3 cm×3.2 cm. The color of pileus (cap) was white. Shape of cap was irregular and cap edge was irregularly round but wavy. Micro pores were present around the cap surface. The surface characters and zonation was moderate moist in nature. The texture of the fruiting body was tough, brittle and woody. Spore color was hyaline. Spores were single walled, smooth, sub-globose, irregular and the average spore size was 6.2µm×3.9µm.
Inonotus hispidus (Bull.) P. Karst.	Shaggy Bracket	Basidiocarp was 4.3 cm×3.2 cm. The color of pileus (cap) was milky white. Shape of cap was concave and cap edge was round smooth.The white color micro pores were present under the cap. The surface characters and zonation was very dry in nature. The texture of the fruiting body was very hard and woody. Spore color was light yellow. Spores were single walled, ellipsoidal and irregular. The average spore size was 7.45µm×4.45µm.
Inonotus dryadeus (Pers.) Murrill	Oak bracket*, warted oak polypore,*	Basidiocarp was 5.2 cm×3.8 cm. The color of pileus (cap) was brown and slightly yellow. Shape of cap was concave and cap edge was round smooth. The white color micro pores were present under the cap. The powdery substance and sticky moisture

Name of the Species	Common name	Morphology
	weeping *polypore* or weeping conk	were present on the cap. The surface characters and zonation was dry in nature. The texture of the fruiting body was very hard, tough and woody. Spore color was hyaline. Spores were single walled, smooth, sub-globose, round and regular. The average spore size was 8.0µm×5.17µm.
Coltricia cinnamomea (Jacq.) Murrill	Shiny Cinnamon Polypore	Basidiocarp was 7.1 cm×4.2 cm. The color of pileus (cap) usually concentric bands of color. Shape of cap was brown and pale with white margin and cap edge was round and funnel like structure. The white color micro pores were present under the cap. The surface characters and zonation was dry in nature. The texture of the fruiting body was tough, brittle and woody. Spore color was light yellow. Spores were thick walled, rough, oval, ellipsoidal and the average spore size was 7.1µm×4.1µm.
Daedalea quercina (L.) Persoon	Oak mazegill or maze-gill fungus	Basidiocarp was 7.2 cm×5.3 cm. The color of pileus (cap) was brown and slightly yellow with white margin. Shape of cap was concave, flat and cap edge was round smooth.The milky white color macro pores were present under the cap. The white and brown wavy margins were present on the cap. The surface characters and zonation was dry in nature. The texture of the fruiting body was spongy, tough and brittle. Spore color was hyaline. Spores were single walled, smooth, sub-globose, round, ellipsoidal, irregular and the average spore size was 5.06µm×4.18µm.
Daldinia concentrica (Ces.) Bolton & De Not.	King Alfred's Cakes, Cramp Balls	Basidiocarp was 2.1 cm×2.0 cm. The color of pileus (cap) was Dark and creamy. Shape of cap was like ball and cap edge was round smooth.The black color micro pores were present under the cap. The surface characters and zonation was dry and powdery substance was present on the surface of the balls. The texture of the fruiting body was hardy and woody. Spore color was brown. Spores were thick walled, smooth, ellipsoidal, oval and the average spore size was 7.7µm×5.1µm
Irpex lacteus (Fr.) Fr.	Milk-white toothed polypore.	Basidiocarp was 4.6 cm×6.8 cm. The color of pileus (cap) was white. Shape of cap was flat and cap edge was round and rough. The whitish and grayish tooth were present under the cap. The surface characters and zonation was velvety and dry in nature. The texture of the fruiting body was thin, tough without stem. Spore color was brown. Spores were thick walled, smooth, oval, ellipsoidal shaped. The average spore size was 7.2µm×4.2µm.
Steccherinum ochraceum (Pers.) Gray	Ochre spreading tooth.	Basidiocarp was 9.8 cm×6.7 cm. The color of pileus (cap) was milky white. Shape of cap was flat and cap edge was rough and crenate.The dark brown color micro pores were present under the cap which was tightly attached with the host. The surface characters and zonation was dry in nature. The texture of the fruiting body was thin, rough and brittle. Spore color was hhyaline. Spores were single walled, ellipsoidal and irregular. The average spore size was 13.2µm×7.06µm.
Gloeophyllum sepiarium (Wulfen) P. Karst	Rusty gilled polypore	Basidiocarp was 2.3 cm×2.6 cm. The color of pileus (cap) was yellow and brown with margin. Shape of cap was infundibuli form and cap edge was round wavy. Macro pores were present under the cap. The surface characters and zonation was moderate dry in nature. The texture of the fruiting body was brittle and tough. Spore color was dark yellow. Spores were thick walled, smooth, sub-globose, ellipsoidal and the average spore size was 5µm×4.1µm.

Table 2. Characterization on the ecology of identified xylotrophic fungi samples

S.L.	Species	Family	Host (Tree)	Location	Habit	F (%)	D	RH (%)	T (°C)	Soil P^H
1	*Trametes versicolor*	Polyporaceae	Coconut (*Cocos nucifera*)	Mongla	Solitary	25%	4.55	88	30°c	6.8
2	*Trametes elegans*	Polyporaceae	Coconut (*Cocos nucifera*)	Rampal, Shamnagar	Scattered	50	18.18	83	32°c	6.5
3	*Trametes conchifer*	Polyporaceae	Sissoo (*Dalbergia sissoo*)	Mongla	Caespitose clustered	50	27.27	85	30°c	6.8
4	*Trametes* sp.	Polyporaceae	Soil surface	Mongla	Solitary	25	4.55	86	29°c	6.5
5	*Tyromyces lacteus*	Polyporaceae	Coconut (*Cocos nucifera*)	Shamnagar	Solitary	25	4.55	81	31°c	6.8
6	*Pycnoporus sanguineus*	Polyporaceae	Sundari (*Heritiera fomes*)	Mongla, Sarankhola	Scattered	50	31.82	81	33°c	6.5
7	*Polyporus varirus*	Polyporaceae	Rain (*Albizia saman*)	Rampal	Solitary	25	4.55	80	32°c	6.6
8	*Daedaleopsis confragosa*	Polyporaceae	Palm (*Borassus flabellifer*)	Mongla, Rampal and Shamnagar	Scattered	75	22.73	83	31°c	6.8
9	*Ganoderma praelongum*	Ganodermataceae	River Abony (*Diospyros ebony*)	Rampal	Solitary	25	9.10	81	31°c	6.5
10	*Ganoderma applanatum*	Ganodermataceae	Mahagoni (*Swietenia mahagoni*)	Mongla	Scattered	25	13.64	84	30.5°c	6.6
11	*Ganoderma brownii*	Ganodermataceae	Rain (*Albizia saman*)	Sarankhola	Solitary	25	4.55	83	32°c	6.5
12	*Ganoderma tsugae*	Ganodermataceae	Coconut(*Cocos nucifera*)	Shamnagar	Solitary	25	4.55	83	29°c	6.5
13	*Ganoderma curtisii*	Ganodermataceae	Coconut(*Cocos nucifera*)	Sarankhola,Mongla	Solitary	50	9.10	82	30°c	6.4
14	*Ganoderma* sp.	Ganodermataceae	Humus	Mongla	Solitary	25	4.55	84	30°c	6.4
15	*Inonotus hispidus*	Hymenochaetaceae	Goran (*Ceriops decandra*)	Sarankhola	Solitary	25	4.55	81	33°c	6.4
16	*Inonotus dryadeus*	Hymenochaetaceae	Garjan (*Rhizophora apiculata*)	Shamnagar	Solitary	25	4.55	80	32°c	6.6
17	*Coltricia cinnamomea*	Hymenochaetaceae	Mahagoni (*Swietenia mahagoni*)	Rampal	Caespitose clustered	25	22.73	83	31°c	6.7
18	*Daedalea quercina*	Fomitopsidaceae	Sissoo (*Dalbergia sissoo*)	Sarankhola	Solitary	25	4.55	82	31°c	6.5
19	*Daldinia concentrica*	Xylariaceae	Mehagony (*Swietenia macrophylla*)	Mongla	Scattered	25	22.73	86	32°c	6.6
20	*Irpex lacteus*	Steccherinaceae	Mango (*Mangifera indica*)	Rampal, Sarankhola	Caespitose clustered	50	13.64	85	31°c	6.6
21	*Steccherinum ochraceum*	Steccherinaceae	Mahagoni (*Swietenia mahagoni*)	Rampal	Caespitose clustered	25	9.10	81	33°c	6.7
22	*Gloeophyllum sepiarium*	Gloeophyllaceae	Bohera (*Terminalia bellirica*)	Mongla	Solitary	25	4.55	88	29°c	6.7

F= Frequency, D= Density, T= Temperature, RH= Relative Humidity

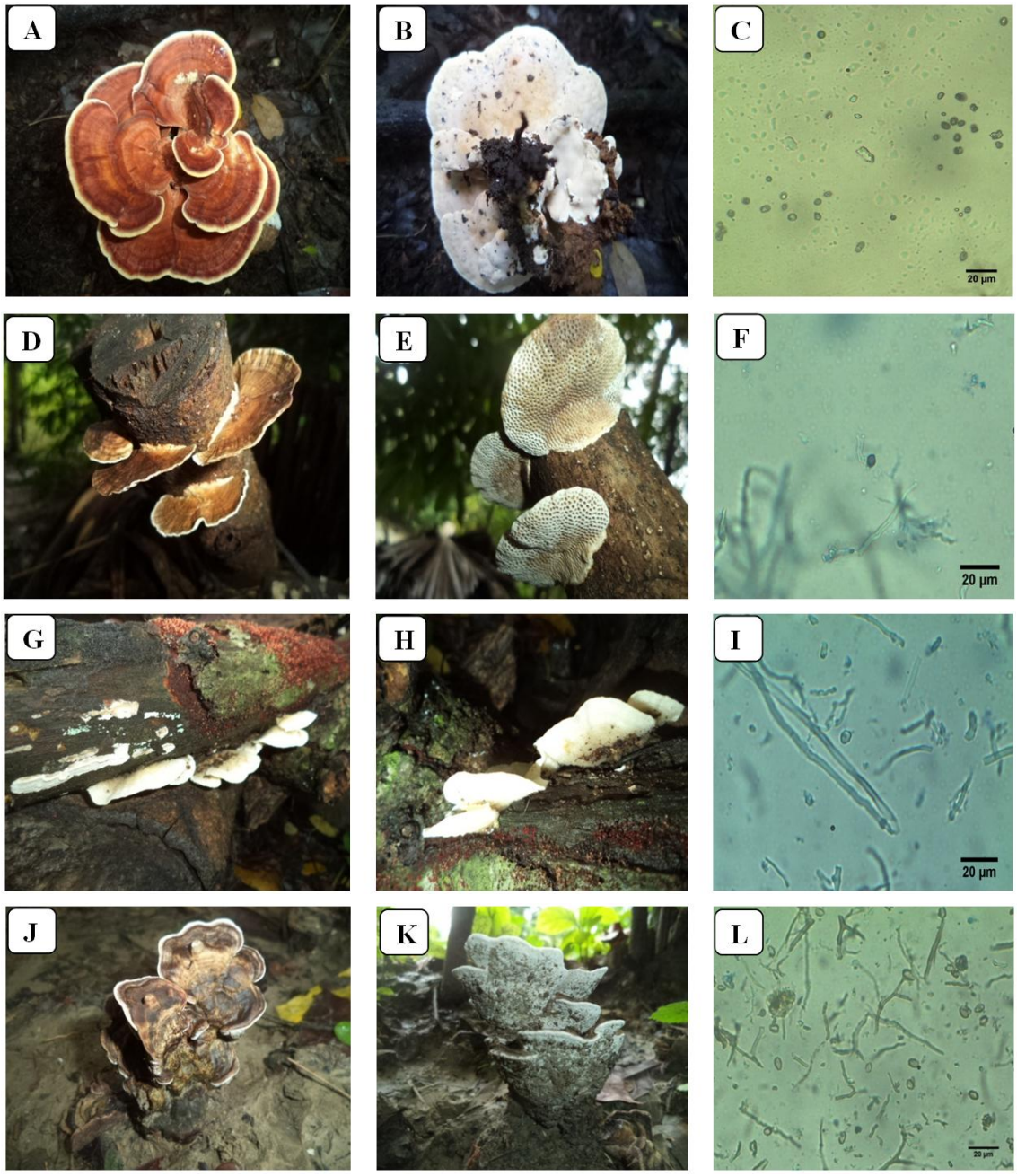

Fig. 2. Fruiting body of *Trametes versicolor* (A), Pores (B), Spores (C); *Trametes elegans* (D), Pores (E), Spores (F)*; Trametes conchifer* (G), Pores (H), Spore (I); *Trametes* sp. (J), Pores (K), Spores (L)

An investigation was conducted in the mangrove forest regions of Bangladesh among four Upazillas viz. Mongla, Rampal, Sarankhola and Shamnagar of two districts such as Khulna and Satkhira from June to October, 2015 to record the morphological variability, distribution and biodiversity of mushrooms population. Through this investigation, 12 genera and 22 species were identified including four species of *Trametes*, viz. *Trametes versicolor, Trametes elegans, Trametes conchifer, Trametes* sp., were identified, which were found in Mongla, Rampal, Sarankhola and Shamnagar Upazillas of mangrove forest regions of Bangladesh. Among

all the species, the frequency of *Trametes elegans* and *Trametes conchifer* was 50% and density of those were 18.18 and 27.27, respectively.

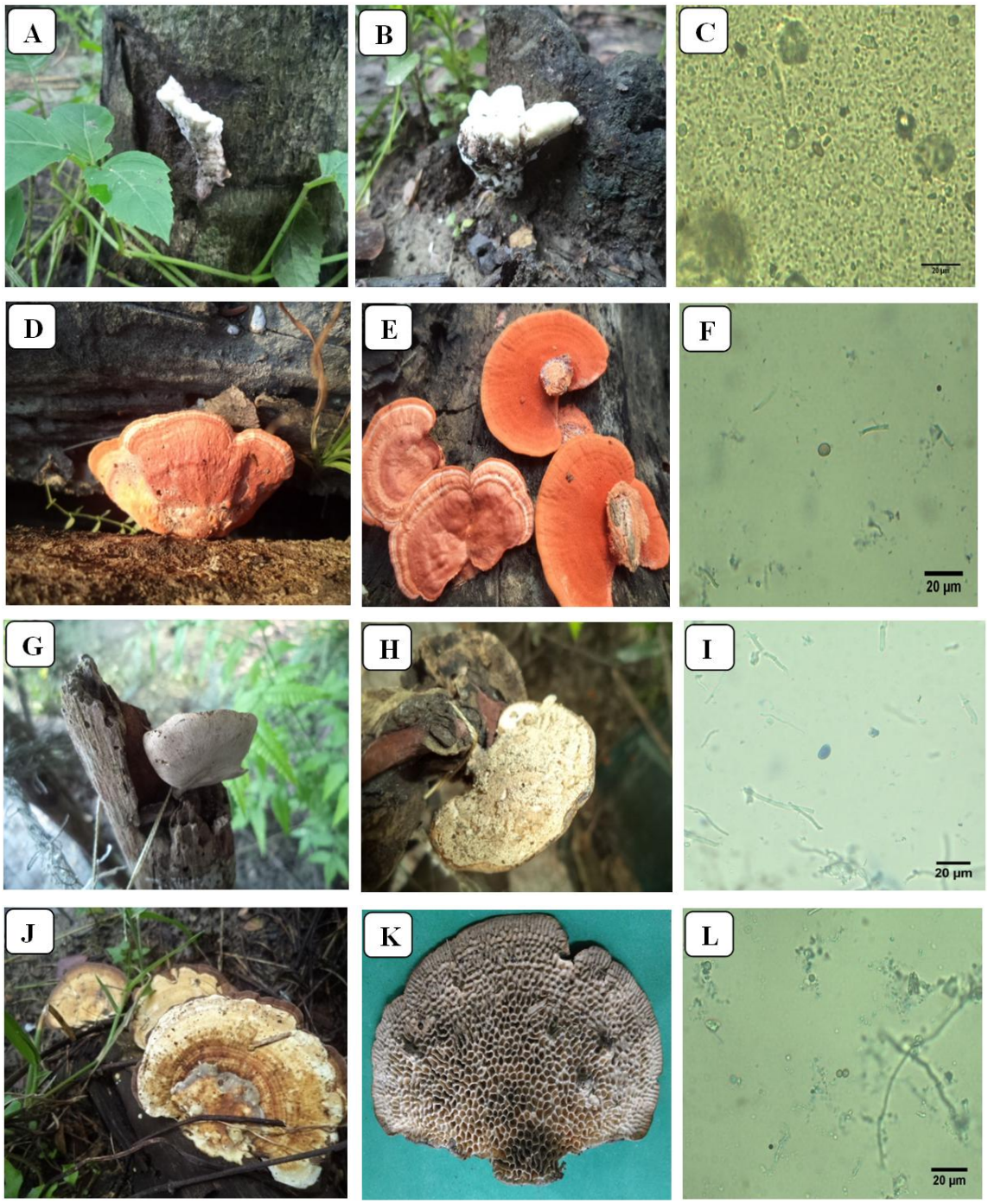

Fig. 3. Fruiting body of *Tyromyces lacteus* (A), Pores (B), Spores (C); *Polyporus sanguineus* (D), Pores (E), Spores (F); *Polyporus varirus* (G), Pores (H), Spore (I); *Daedaleopsis confragosa* (J), Pores (K), Spores (L)

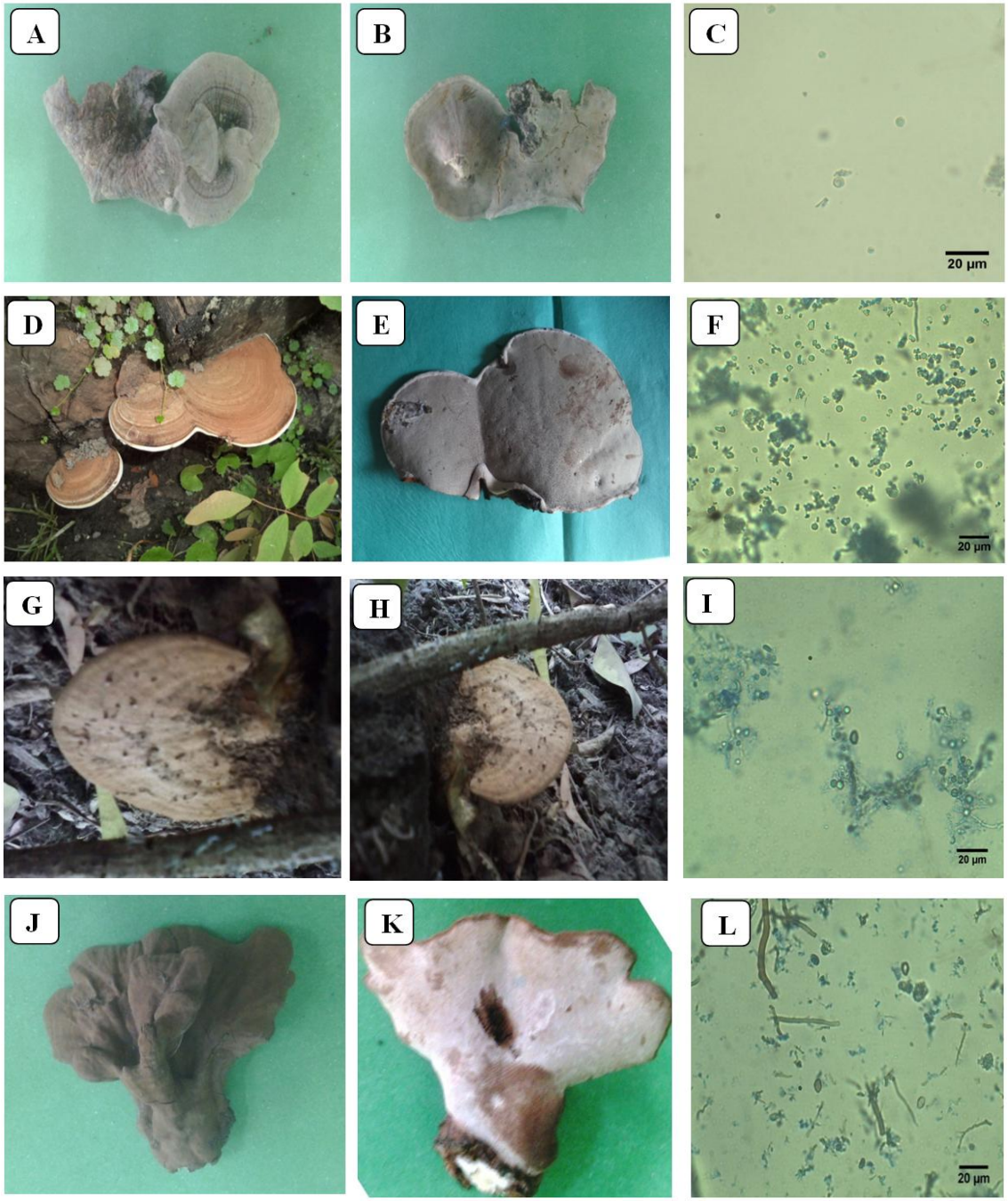

Fig. 4. Fruiting body of *Ganoderma praelongum* (A), Pores (B), Spores (C); *Ganoderma applanatum* (D), Pores (E), Spores (F); *Ganoderma brownii* (G), Pores (H), Spore (I); *Ganoderma tsugae* (J), Pores (K), Spores (L)

One species of *Tyromyces lacteus* was found in Shamnagar with the frequency and density of 25% and 4.55.This species of mushrooms was reported from Patharia forest of Sagar in India [19].

Two species under the Polyporaceae family were identified as- *Pycnoporus sanguineus* and *Polyporus varirus.*The frequency of *Pycnoporus sanguineus* was 50% and the density was 31.82. *Pycnoporus sanguineus* was found on dead

wood of Sundari (*Heritiera fomes*) tree in Mongla and sarankhola Upazilla of Bagerhat district. This bracket fungi was newly identified in the Mangrove forest region as well as our country. One species of *Daedaleopsis confragosa* was found with the highest frequency of 75% and this species was identified by Rumainul and Aminuzzaman in 2016 under tropical moist deciduous forest region of Bangladesh [20].

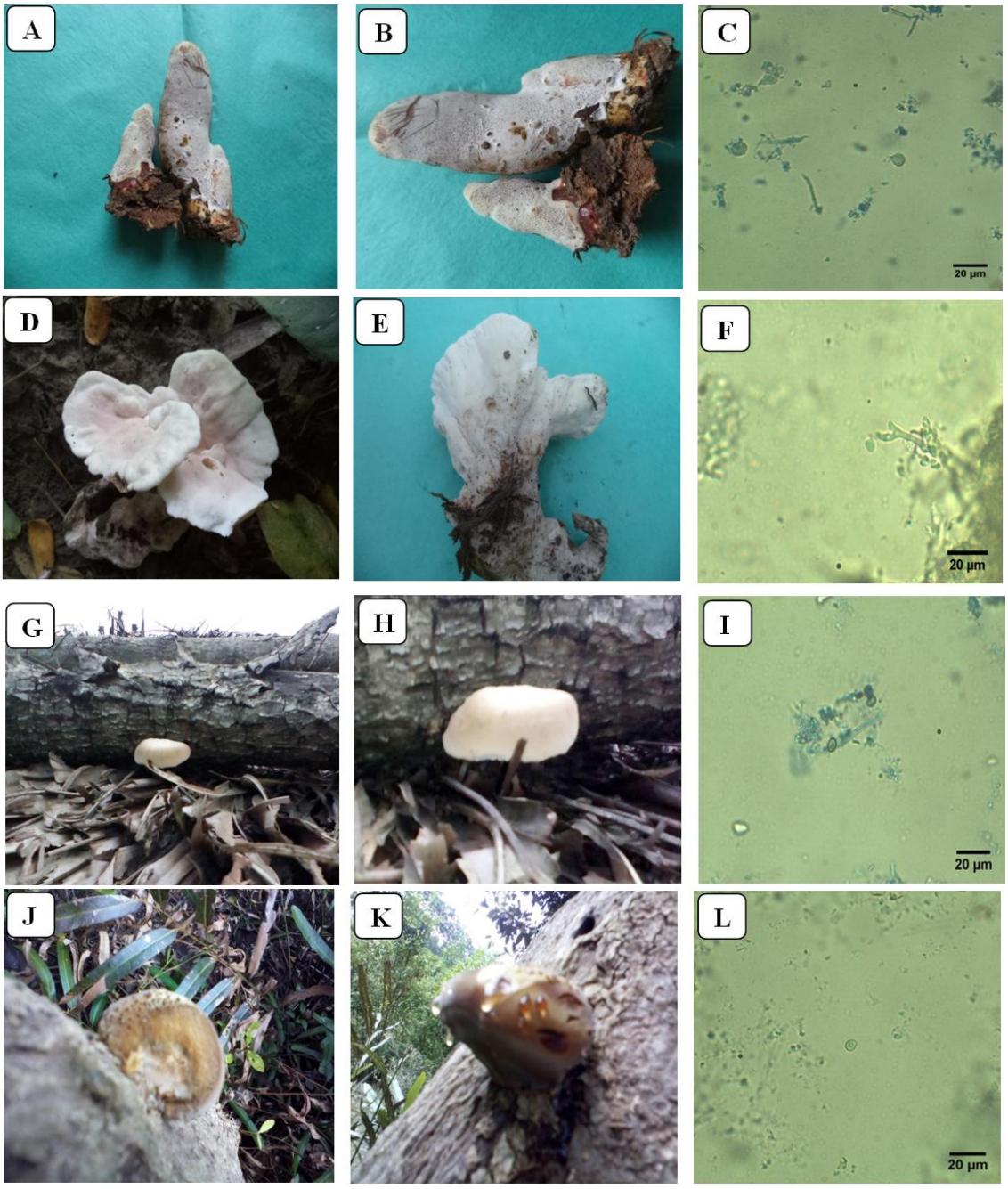

Fig. 5. Fruiting body of *Ganoderma curtisii* (Growing stage-A), Pores (B), Spores (C); *Ganoderma* sp. (D), Pores (E), Spores (F); *Inonotus hispidus* (G,H), Spore (I); *Inonotus dryadeus* (J), Pores (K), Spores (L)

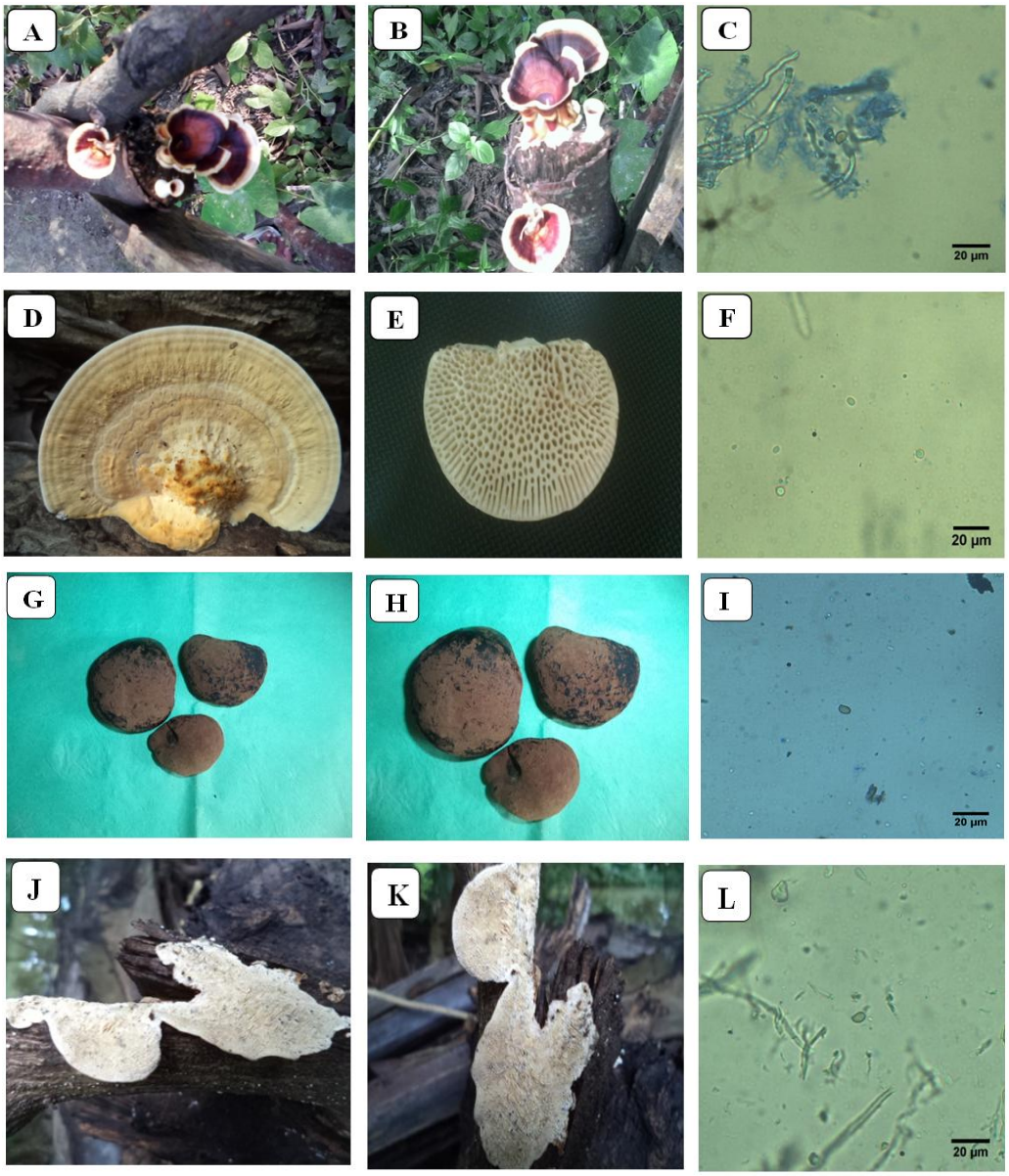

Fig. 6. Fruiting body of *Coltrica cinnamomea* (A), Pores (B), Spores (C); *Daedalea quercina* (D), Pores (E), Spores (F); *Daldinia concentrica* (G), Pores (H), Spore (I); *Irpex lacteus* (J),Teeth (K), Spores (L)

The maximum identified species were found under the genus of *Ganoderma*. There are six species were collected during the investigation, viz- *Ganoderma praelongum, Ganoderma applanatum, Ganoderma brownii, Ganoderma* tsugae, *Ganoderma curtisii, Ganoderma* sp. Among the species, the highest frequency of *Ganoderma curtisis* was 50% and the highest density of *Ganoderma applanatum* was13.64. The species of *Ganoderma* was reported at the tropical moist deciduous forest regions of Bangladesh and India [21,19,22].

Two species of *Inonotus* were identified in the Sarankhola and Shamnagar Upazillas of mangrove forest regions of Bangladesh. These were *Inonotus hispidus,* and *Inonotus dryadeus* with same frequency and density of 25% and 4.55, respectively. These *Inonotus* sp. are the newly identified woody mushrooms in our country.

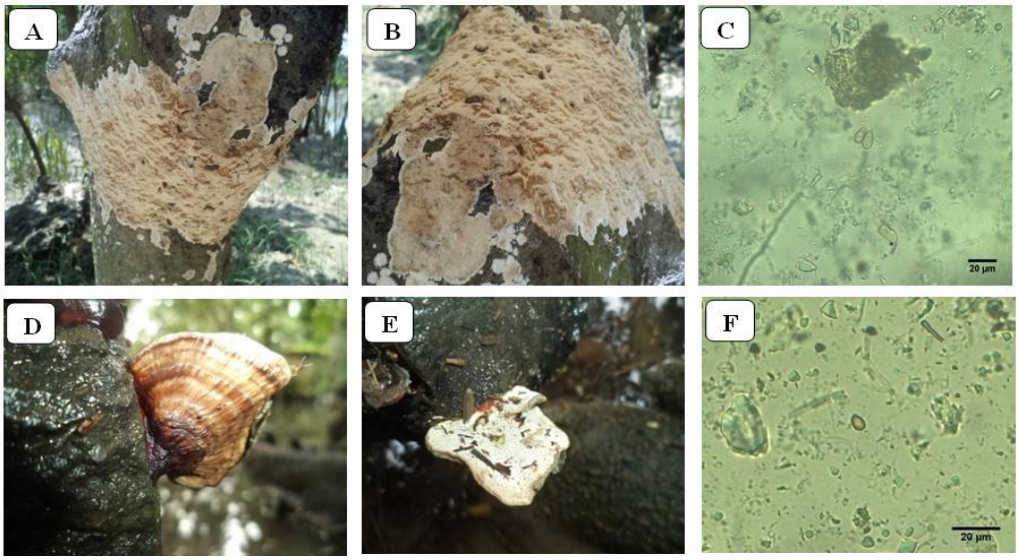

Fig. 7. Fruiting body of *Steccherinum ochraceum* (A), Pores (B), Spores (C); *Gloeophyllum sepiarium* (D), Pores (E), Spores (F)

Furthermore, one species of each mushrooms were found in Bagerhat district of mangrove forest regions of Bangladesh such as - *Coltrica cinnamomea, Daedalea quercina, Daldinia concentrica, Irpex lacteus, Steccherinum ochraceum, Gloeophyllum sepiarium*. Among all the species, the highest frequency was 50% of *Irpex lacteus* and the highest density of 22.73 the both of *Coltrica cinnamomea* and *Daldinia concentrica*. The macrofungi *Daldinia concentrica* was found on the dead log of Mehagony (*Swietenia macrophylla*) tree and this species was also identified in the same tree from the southern region of Bangladesh [23].

4. CONCLUSION

Throughout this investigation, the identified 22 species of xylotrophic fungi provide us the presence of wild mushrooms in the mangrove forest regions of Bangladesh. The increasing populations remind us to meet up the food to feed the every person would be more challenging in future. Because of demand now the scientist are more curious to find out the alternative food sources to feed the nation and that is why the research of mushrooms field is increasing dramatically now-a-days. The wild xylotrophic fungi are the greatest source of medicinal properties and which are available in our mangrove forest regions of Bangladesh. Even these wild mushrooms are the good source of income for the unemployed youth of our country which also contribute to our national economy. Moreover, future investigation is also needed in different seasons as well as in different forest regions to identify the new exotic mushroom species, which will represent a complete overview about the available mycota in Bangladesh.

ACKNOWLEDGEMENTS

This research was supported by Ministry of Science and Technology, P. R. Bangladesh (No. 39.00.0000.09.02.069.16-17/10/BS 63).

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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