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ARTICLE

Diversity and distribution of wild mushrooms in different forest areas of Bankura district, WB, India

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ABSTRACT Mushrooms are macroscopic fruit bodies of fungi; one of the most diverse groups of living organisms distributed all over the world. In recent past, they have gained significant scientific attention for their profound nutraceutical potentiality. The objective of the present study was to explore the diversity and ecological distribution of mushrooms in different forest areas of Bankura district. The study area includes intermittent dense forest and flood plains from middle-east to eastern part of Bankura district. However, this area received very little attention from a conservation perspective, and there is no such documentation on mushrooms of this area. The survey was conducted from August 2019 to October 2020 including vivid field surveys in the forest depots. The study has revealed a total of 53 identified mushroom species belonging to 40 genera and 30 families. The study has also identified 25 edible, 18 inedible and 15 medicinally potential mushrooms. The genus *Russula* and the family *Russulaceae* dominates the myco-population. The finding shows that this region is rich in macrofungal diversity complicatedly linked to the functioning of the local ecosystem. The present study opens new possibilities regarding the exploration and utilization of wild mushrooms in India.
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Introduction

Fungi are one of the most diverse groups of organisms on earth. They are eukaryotic heterotrophs that obtain their energy by absorption of nutrients. The large visible fructification of the underground mycelia of macro-fungi is known as 'Mushrooms'. They mainly belong to the phylum Basidiomycota and Ascomycota with observable spore bearing structure. Mushrooms are abundant in nature and they are the first known fungi. Wild edible mushrooms have been collected and consumed by people from the very early stage of civilization, even when people didn't know about its nutritive value.

Macrofungi varies widely in their habitats. The species diversity of mushrooms is directly related to the habitat. They are found on soil (terrestrial), dead leaves (folicolous), wood (lignicolous) or dung and decomposing organic materials (coprophilous). Macrofungi, based on their nutrition, can be categorized into three groups: saprophytes, parasites, and symbiotic (Kinge et al. 2017). Mushrooms predominantly grow during rainy season in forests and can be epigeous or hypogeous. They vary mostly in shape, size and colour. Some of them are edible whereas some are proven to be poisonous. The various environmental factors that affect the growth of mushrooms are temperature, humidity, light and the substrate over which they grow. All the species of mushrooms shows remarkable diversity in their morphological characteristics.

Mushrooms contain high amounts of nutritious compounds including vitamins, proteins, minerals, fiber and trace elements. Edible mushrooms have been considered to be an ideal food for obese persons due to high fibre, low fat and low starch content. They are considered as "poor man's protein" because of their high nutrient content (Singha et al. 2017b). Chang and Buswell (1996) coined the term 'mushroom nutraceuticals' to describe those compounds that have considerable potentiality as dietary supplements, used for the enhancement of health and prevention of various human diseases.

Mushrooms are seasonal fungi, which earn additional ecological significance. They appear in between reaching a highest point of development with the diverse niches in the forest ecosystem. Their habitat and climate are the

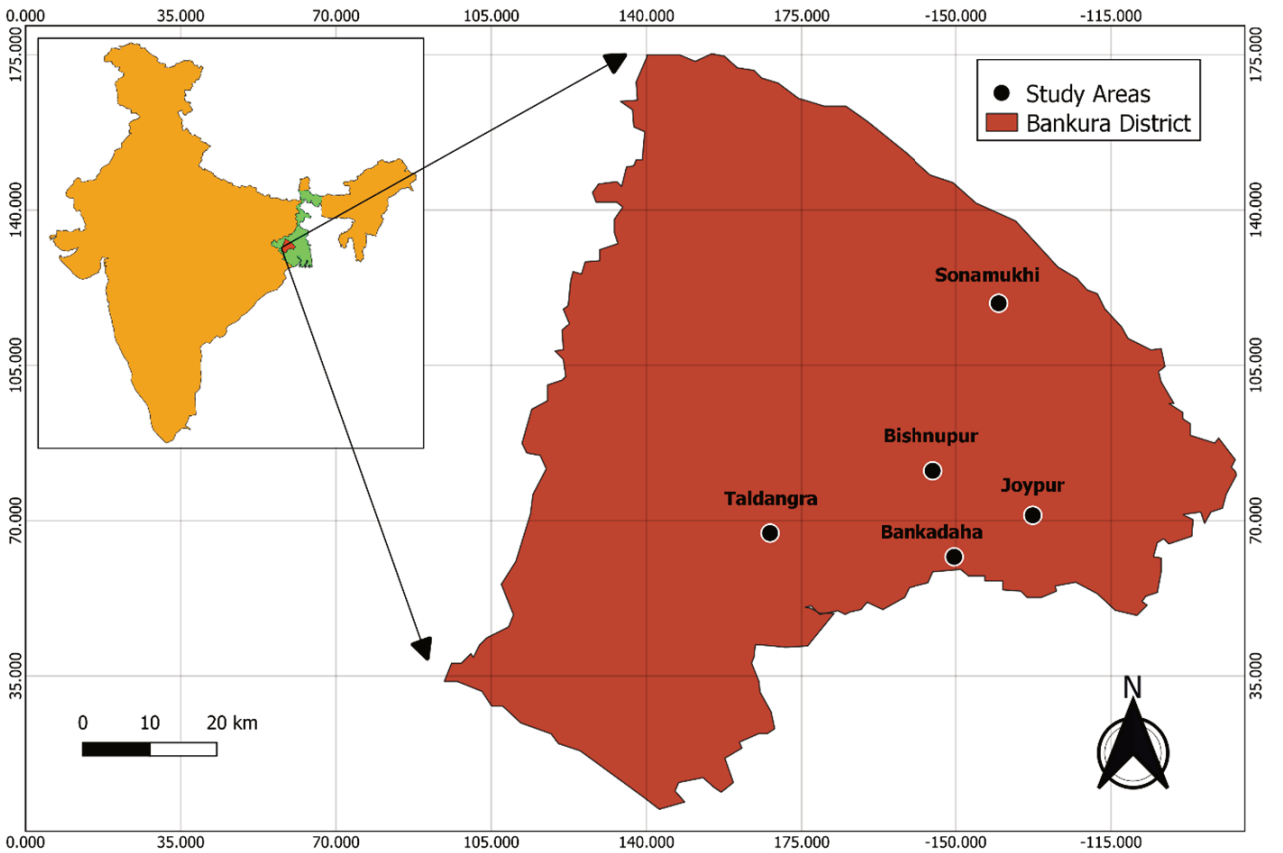

Figure 1. Study location and map of Bankura forest areas.

major factors that indicate their biodiversity. Fungi also play an important role as decomposers. They breakdown plant components like lignin and cellulose and thus are particularly important in woody-ecosystems. They also degrade surface waste and release nitrogen back into the soil in the form of ammonium nitrate, an important nutrient that plants need for their survival. Mushrooms are also known to produce several bioactive compounds that have therapeutic uses. However, they protect themselves from deleterious effect of plant phenolic tannins by producing a hydrolytic enzyme, called tannase that form gallic acid and glucose (Das Mohapatra et al. 2020). It is often been noticed that local people who consume the mushroom *Astraeus hygrometricus* (*Kurkure chhatu*) on regular basis enjoy several health benefits (Dutta and Acharya 2014). This mushroom possesses antitumor, anti-Leishmanial, anti-Candidal, antioxidant and immune-modulatory activity (Biswas et al. 2017).

Macrofungal diversity is an integral component of the global diversity. Diverse abundance of macrofungal species is a helpful indicators to interpret the current status of the ecosystem. Most healthy forest ecosystem contains at least 45% mycorrhizal fungi (Arnolds 1988). Native people living in nearby forest areas relate to the wild mushrooms in respect to their socio-economic lifestyles by means of both food ingredients as well as small business elements. Chang and Miles (2004) reported that out of 14000 known mushroom species, there were nearby 7000 well-studied species that possesses varying degree of edibility. Among them, only 200 species were experimentally cultured; 100 were economically cultivated, 60 were commercially cultivated and about 10 species have gained industrial importance.

The total recorded mushrooms in India are approximately 850 species (Deshmukh 2004). The collection and scientific study of mushrooms in India has started during 19th century (Kaul et al. 2002). Butler and Bisby (1931) published the first list on Indian fungi which was further revised by Vasudeva (1960). Purkayastha and Chandra (1985) published the first comprehensive account of Indian edible mushrooms and their cultivation technology.

India has an ancient history of using mushrooms as food, medicine, minerals and drugs. It has become a centre of herbal therapy (Nad et al. 2021). However, such kind

of studies is very rare in West Bengal. Dutta and Acharya (2014) obtained 31 edible and 3 medicinally important macrofungi that were used by local and indigenous communities in eight districts of West Bengal. Das et al. (2015) reported 16 wild edible mushrooms with ethno-medical value from tropical dry deciduous forest of Eastern *Chota Nagpur* plateau. Deshmukh et al. (2006) reported that, around 40 species found from all over India were lethal. Singha et al. (2017b) explored the nutritional and antibacterial potentiality of some wild edible mushrooms from Gurguripal Eco-forest, Paschim Medinipur, West Bengal, India. Thus, the studies on mushroom diversity are often significant and contribute to the knowledge of the ecosystem of a forest.

The forest region of Bankura district is one of the enriched forest areas of West Bengal. The district possesses dense forest dominated by Sal (*Shorea robusta*). Other trees found in the forests include *Azadirachta indica* (Neem), *Dillenia indica* (Chalta), *Syzygium cumini* (Jam) (Basu et al. 2013). A higher proportion of mycorrhizal fungi is generally correlated with a region that contain better conserved forests (Pradhan et al. 2016). Bankura is surrounded with low-lying alluvial-laterite soil (Das and Paul 2015) with an average annual rainfall of 1329 mm (Majumder and Patra 1993). Overall, the biogeological environment provide favourable climatic zone for fungal growth. However, there is no valid documentation on diversity of mushrooms in this area till date. Hence, the present study is focused on the diversity and distribution of mushrooms in Bishnupur and adjacent forest areas of Bankura district, West Bengal.

Materials and Methods

Study area

Five major forest areas namely Bishnupur (23°04′48″N, 87°19′12″E; Altitude 59 m), Joypur (23°02′N, 87°27′E; Alt.74 m), Sonamukhi (23°18′11.5848″N, 87°24′56.4948″E; Alt. 66 m), Taldangra (23°01′1.092″N, 87°06′29.3688″E; Alt. 74 m), and Bankadaha (22°58′03.64″N 87°21′05.43″E; Alt. 74 m) of Bankura district were selected as the study area (Fig. 1). These forest areas have a tropical climate with dry and rainy season (annual average rainfall: 11000-15000 mm), dominated by 'Sal' trees with a laterite and alluvial type soil. The average temperature of this locations ranges between 20-30 °C during rainy season. The field study was conducted from August 2019 to October 2020 to obtain the maximum outcome.

Collection of samples

Opportunistic sampling method was being performed and conspicuous specimens were collected precisely from the study area (Mueller et al. 2004). After finding a colony or a single species of mushroom, the fruiting bodies were collected with the help of knife. Their habitat conditions and occurrence frequency were recorded. The samples were photographed (Nikon D5300 camera), both in their natural habitats and with the reference of a scale or coin, for identification. The samples were then taken in a container, labelled and kept for further study.

Identification of the specimens

The collected samples were examined in laboratory by observing the formation of the cap, arrangements of the gills, presence of pores on the under surface of the fruit bodies or not, presence of stipe and volva or not, the type of the surface (smooth or rough), etc. Then according to their characteristics, they were then identified with the help of standard literatures (Pradhan et al. 2010; Pushpa and Purushothama 2012; Acharya and Pradhan 2017).

Preservation of the specimens

All the samples were preserved immediately in liquid preservative (25:5:70 ml rectified alcohol + formalin + distilled water) for further studies (Hawksworth et al. 1995).

Data analysis

The frequency of occurrence for each species was calculated by following formula as suggested by Aung et al. (2008).

$$\frac{\text{Occurrence frequency of species A}}{\text{Total number of all species}} \times 100$$

Simpson Index of Diversity was calculated as suggested by Simpson (1949).

Simpson Index of Diversity =1-D; where,

$$D = \frac{\Sigma n\,(n-1)}{N\,(N-1)}\text{; where,}$$

n = total number of organisms of a particular species
N = total number of organisms of all species

Shannon diversity index for mushroom was calculated as suggested by Margalef (2008).

$$H = -\Sigma\,(n/N)\log(n/N)\text{; where,}$$

H = diversity index
N = total number of individuals of all the species
n = total number of individuals of a particular species

Considering the values of diversity index, the evenness of the mushrooms was calculated according to Pielou (1996).

$$e = H/\log S;\ \text{where,}$$

e = evenness
H = Shannon index
S = the number of species

Menhinick's index of species richness was calculated as suggested by Menhinick (1964).

$$D = s/\sqrt{N};\ \text{where, D = species richness}$$

s = the number of different species
N = total number of individuals

Results

The study areas were spread over the central eastern part of Bankura district (Agro Climatic Zone), marked by flood plains and interfluves. The climate of the study area is tropical, slightly warm and humid with average annual rainfall of 1400 mm. The mean temperature is around 33 °C. Relative humidity during the study time was found around 80%. From this point of view, the study areas possess a good geographical environment for the growth of mushrooms.

In the span of survey, a total number of 53 species were identified, among which 29 specimens were identified up to species level. Majority of the identified mushrooms (96.07%) belongs to Basidiomycota (51 specimens), where only 2 species belong to Ascomycota. All the identified mushrooms are distributed in diverse group of 40 genera belonging to 30 families (Table 1). The family/ genus ratio of 0.75 and genus/ species ratio of 0.75 suggest the presence of comparatively high familial and generic diversity in the region.

The study revealed that members of *Russulaceae* (12%) grow predominantly in the study area, followed by *Agaricaceae* (10%), *Polyporaceae* (10%), *Ganodermataceae* (6%) and *Psathyrellaceae* (6%) as shown in Fig. 2. Among the two species of Ascomycota, one was *Xylaria* sp. belonging to the family *Xylariaceae* and the other was *Daldinia concentrica* from the family *Hypoxylaceae.*

Most diverse specimens were obtained from the family *Russulaceae* which was found to be the most dominant in overall survey. As per sampling areas, *Polyporaceae* and *Russulaceae* in Bishnupur (16.66% each) and Bankadaha (13.33% each), *Agaricaceae* in Taldangra (36.36%), *Marasmiaceae*, *Agaricaceae* and *Psathyrellaceae* in Sonamukhi (10% each) and *Russulaceae* in Joypur (27.27%) were found most frequently. *Marasmius*, *Polyporus* and *Ganoderma* were the most common genera in all five study areas.

Mushrooms were found to be largely saprophytic (30 specimen), whereas rest of them were mycorrhizal (17 specimen) and parasitic (6 specimen) in the present study (Fig. 3). Ectomycorrhizal specimens were notable in the overall survey as it is one type of reflexion of the forest health. *Russulaceae*, *Lyophyllaceae*, *Sclerodermataceae* and *Hydnangiaceae*; the common ectomycorrhizal families were found to be predominant in the study area. The most common mycorrhizal species were *Russula rosea*, *Russula nobilis*, *Scleroderma citrinum* and *Laccaria laccata*. On the other hand, *Pleurotus ostreatus* and *Russula cyanoxantha* were identified as rare species from this area. Some species like *Aleuria aurantia*, *Daldinia concentrica*, *Coprinus logopus*, *Podoscypha venustula*, *Cyathus striatus*, *Coprinus logopus* mostly fruited upon decaying logs and organic matters. However, this occasional sighting at the base of diseased and/or infected trees indicate their facultative parasitic nature. Majority of mushroom were found to grow on soil (25 specimen) and wood (23 specimen), rest were found to grow on leaf (2 specimen) and decaying organic materials (3 specimen) (Fig. 4).

Through interaction with the local people living nearby the study areas, it was revealed that 25 species were edible, 15 species have medicinal importance and rest are inedible (18 species) and with unknown significance (10 species) (Fig. 5). Moreover, the mushroom species *Termitomyces heimii*, *Russula cyanoxantha*, *Agaricus* sp., *Auricularia* sp., *Calocybe indica*, *Tremella fuciformis* were found to be potential food sources for local livelihood. It also contributes to local economy. On the other hand, some poisonous fungi like *Coprinus logopus*, *Amanita* sp., *Lepiota* sp., *Conocybe* sp. were also found in the forest regions of Bankura. Among the medicinally important mushrooms, *Ganoderma lucidum*, *Auricularia* sp., *Ganoderma applanatum* were traditionally used by local physicians for the treatment of diabetes, hyper cholesterol, muscle pain and flu, respectively.

Mushroom richness and abundance in different forest areas

There are several factors through which biological diversity of a species can be quantified. Among them, the two major factors are species richness and species abundance. In the present study, mushrooms collected from five forest areas namely Sonamukhi, Bishnupur, Bankadaha, Joypur and Taldangra were analysed for mushroom diversity. Species diversity richness and abundance of mushrooms in forest areas of Bankura district were analysed thoroughly (Table 2).

The forest area of Sonamukhi had 20 species of mushrooms belonging to 18 genera and 17 families. A family/

Table 1. Mushroom diversity, habitat, significance, and mode of nutrition in forest areas of Bankura District, West Bengal, India.

Family	Scientific name	Observed frequency	Site of collection	Habitat	Significance	Mode of nutrition	Common/ Local name
Agaricaceae	*Agaricus campestris*	1	Taldangra	Soil	Edible & medicinally important	Saprophytic	Field or Meadow mushroom
	Lepiota sp.	5	Taldangra	Soil	Inedible	Saprophytic	––
	Leucocoprinus birnbaumii	1	Sonamukhi	Soil	Inedible (poisonous)	Saprophytic	Flowerpot parasol
	Leucocoprinus sp.	13	Taldangra, Sonamukhi	Decaying matter	Inedible	Saprophytic/ Mycorrhizal	––
	Lycoperdon pyriforme	1	Taldangra	Soil	Edible	Saprophytic	Pear shaped puffball
Amanitaceae	*Amanita* sp.	6	Bankadaha, Bishnupur	Soil	Inedible	Saprophytic/ Mycorrhizal	––
Auriculariaceae	*Auricularia* sp.	6	Bankadaha, Sonamukhi	Wood	Edible & medicinally important	Saprophytic	Wood ear/ jelly ear
Bolbitiaceae	*Conocybe* sp.	2	Bishnupur	Soil	Unknown	Saprophytic	––
Boletaceae	*Boletus* sp.	14	Joypur	Soil	Edible	Mycorrhizal	––
	Tylophilus sp.	2	Bishnupur	Soil	Edible	Mycorrhizal	Bitter bolete
Bondarzewiaceae	*Amylosporus* sp.	4	Bankadaha	Wood	Unknown	Saprophytic	––
Clavariaceae	*Clavaria* sp.	38	Bishnupur	Soil	Edible	Saprophytic	Fairy fingers
Clavulinaceae	*Clavulina cristata*	6	Sonamukhi, Bankadaha	Soil	Edible	Saprophytic	White coral fungus
Crepidotaceae	*Crepidotus* sp.	15	Bankadaha	Wood	Inedible	Saprophytic	Jelly crep
Dacrymycelaceae	*Dacryopinax spathularia*	7	Bankadaha	Wood	Edible	Saprophytic	Jelly fungus
Diplocystaceae	*Astraeus* sp.	1	Sonamukhi	Soil	Edible & medicinally important	Mycorrhizal	––
Fomitopsidaceae	*Daedalea quercina*	3	Sonamukhi	Wood	Inedible & medicinally important	Saprophytic	Oak mazegill
Ganodermataceae	*Ganoderma lucidum*	7	Taldangra, Joypur	Wood	Inedible & medicinally important	Parasitic	Lingzhi or Reishi mushroom
	Ganoderma applanatum	2	Sonamukhi, Bankadaha	Wood	Edible & medicinally important	Parasitic	Artist's conk/ bear bread
	Ganoderma sp.	2	Bishnupur	Wood	Unknown	Parasite	Conks
Hydnangiaceae	*Laccaria laccata*	3	Sonamukhi	Wood	Edible & medicinally important	Mycorrhizal	Waxy Laccaria
Hypoxylaceae	*Daldinia concentrica*	7	Bankadaha, Bishnupur	Organic matter	Inedible	Saprophytic	Cramp balls/ coal fungus/ Kath chhatu
Lyophyllaceae	*Calocybe indica*	7	Taldangra	Soil	Edible	Mycorrhizal	Doodh chhatu/milky mushroom
	Termitomyces heimii	22	Joypur, Bishnupur	Soil	Edible	Terricolous-saprotrophic	Sib chhatu/ Sikh chhatu
Marasmiaceae	*Marasmius vladimirii*	9	Sonamukhi	Soil	Unknown	Saprophytic	––
	Marasmius sp.	103	Bankadaha, Bishnupur, Taldangra, Sonamukhi, Joypur	Wood/ leaf/soil	Unknown	Saprophytic	––
Meripilaceae	*Grifola frondosa*	4	Joypur, Bishnupur	Soil	Edible & medicinally important	Parasitic	Hen of the woods
	Rigidoporus lineatus	1	Taldangra	Wood	Edible	Parasitic	––
Meruliaceae	*Podoscypha vensustula*	1	Sonamukhi	Leaf	Unknown	Saprophytic/ Parasitic	Bracket fungi
Nidulariaceae	*Cyathus striatus*	7	Sonamukhi	Organic matter	Inedible	Saprophytic	Fluted bird's nest
Phallaceae	*Phallus indusiatus*	1	Sonamukhi	Soil	Edible	Mycorrhizal	Basket Chhatu
Pleurotaceae	*Pleurotus ostreatus*	2	Taldangra	Wood	Edible & medicinally important	Saprophytic	Pearl oyster mushroom
	Pleurotus sp.	12	Bishnupur, Sonamukhi	Wood	Edible	Saprophytic	Oyster mushroom

Table 1. Continued.

Family	Scientific name	Observed frequency	Site of collection	Habitat	Significance	Mode of nutrition	Common/ Local name
Polyporaceae	*Coriolopsis occidentalis*	7	Bankadaha	Wood	Unknown	Saprophytic	––
	Coriolopsis sp.	5	Bishnupur	Wood	Unknown	Saprophytic	––
	Polyporus sp.	6	Bishnupur, Bankadaha, Joypur	Wood	Edible	Saprophytic	Spring polypore
	Pycnoporus cinnabarinus	3	Sonamukhi	Wood	Inedible	Saprophytic	Cinnabar polypore
	Pycnoporus sp.	5	Bishnupur, Taldangra	Wood	Inedible	Saprophytic	Cinnabar-red polypore
Psathyrellaceae	*Coprinus lagopus*	1	Sonamukhi	Organic matter	Edible & medicinally important	Saprophytic	Hare's foot inkcap
	Cystoagaricus sp.	1	Sonamukhi	Soil	Inedible	Saprophytic	––
	Coprinopsis sp.	1	Bishnupur	Soil	Inedible	Saprophytic	Ink cap
Pyronemataceae	*Aleureia aurantia*	12	Bankadaha	Wood	Edible	Saprophytic	Orange peel fungus
Russulaceae	*Lactarius* sp.	6	Bankadaha Sonamukhi	Soil	Edible	Mycorrhizal	Milkcaps
	Russula cyanoxantha	3	Bankadaha, Bishnupur	Soil	Edible & medicinally important	Mycorrhizal	The sickener or vomiting/ jam patra
	Russula emetica	2	Bishnupur	Soil	Inedible	Mycorrhizal	Beechwood sickener/ murgi oat
	Russula nobilis	1	Joypur	Soil	Inedible	Mycorrhizal	Beechwood sickener
	Russula rosea	2	Joypur	Soil	Edible	Mycorrhizal	Rosy russula
	Russula sp.	4	Joypur, Bishnupur	Soil	Unknown	Mycorrhizal	Charcoal burner
Schizophyllaceae	*Schizophyllum commune*	24	Taldangra	Wood	Edible & medicinally important	Mycorrhizal	Pakha chhatu
	Schizophyllum sp.	23	Bishnupur, Bankadaha	Wood	Inedible & medicinally important	Mycorrhizal	Split gill mushroom
Sclerodermataceae	*Scleroderma citrinum*	8	Joypur	Soil	Inedible	Mycorrhizal	Common earthball
Tremellaceae	*Tremella fuciformis*	7	Sonamukhi	Wood	Edible & medicinally important	Saprophytic	Snow fungus
Xylariaceae	*Xylaria* sp.	160	Sonamukhi, Joypur	Wood	Inedible & medicinally important	Saprophytic	Dead man's finger

Table 2. Species diversity richness and abundance of mushrooms in forest areas of Bankura District, West Bengal, India.

	Sonamukhi	Bishnupur	Bankadaha	Joypur	Taldangra
No. of families	17	14	13	8	8
No. of genera	18	16	15	9	11
Family/ genus ratio	0.94	0.88	0.87	0.89	0.73
No. of species (s)	20	18	15	11	11
Genus/ species ratio	0.9	0.89	1.0	0.82	1.0
Total number of individuals (N)	185	114	86	142	69
Simpson diversity index (1-D)	0.2763	0.1532	0.0949	0.2998	0.1914
Shannon diversity index (H)	0.83	1.11	1.25	0.74	1.03
Richness (S)	1.47	1.69	1.62	0.92	1.32
Evenness (e)	0.83	1.81	2.06	1.52	1.82

genus ratio of 0.94 and genus/ species ratio of 0.90 suggest the presence of higher familial and generic diversity in the area. Out of 20 species in Sonamukhi, *Pycnoporus cinnabarinus*, *Tremella fuciformis*, *Marasmius vladimirii*, *Leucocoprinus birnbaumii*, *Cyathus striatus*, *Podoscypha venustula*, *Daedalea quercina*, *Laccaria laccata*, *Coprinus logopus*, *Phallus indusiatus*, *Cystoagaricus* sp. and *Astraeus* sp. were collected only at this site. The Simpson and Shannon's diversity index were found to be 0.2763 and 0.83 respectively; evenness was found to be 0.83 and species richness was

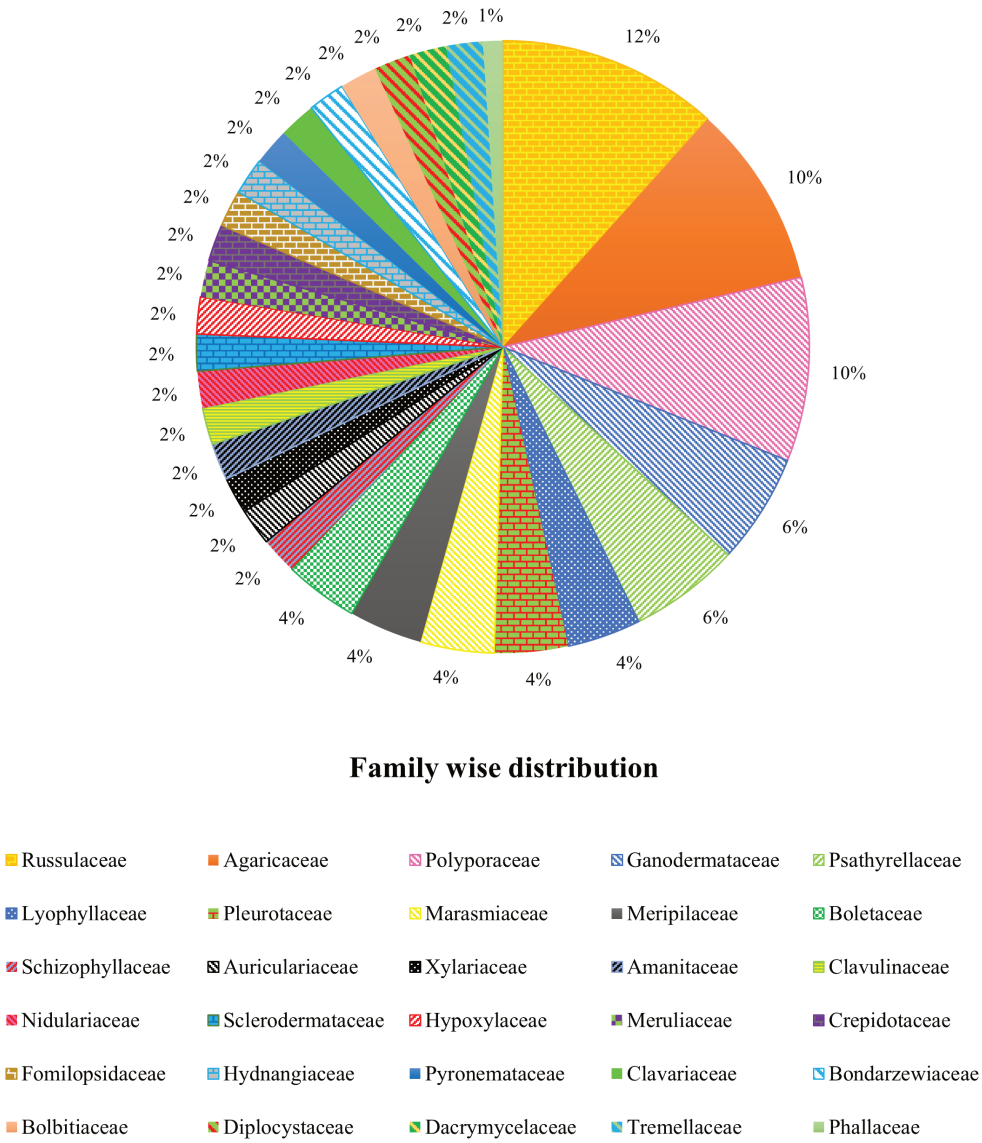

Figure 2. Diversity of mushrooms in forest areas of Bankura District, West Bengal, India.

found to be 1.47. Though the species richness is more in this collection area, but species evenness is comparatively less. Hence, the mushroom diversity was found to be less, may be due to the interference of anthropogenic activities.

The forest area of Bishnupur had 18 species of mushrooms belonging to 16 genera and 14 families. A family/ genus ratio of 0.88 and genus/ species ratio of 0.89 suggest the presence of higher familial and generic diversity in the area. Out of 18 species in Bishnupur, *Russula emetica*, *Conocybe* sp., *Coprinopsis* sp., *Tylophilus* sp. and *Clavaria* sp. were exclusively collected only at this site. This implies more diverse mushroom population. This increased diversity of mushrooms may be due to less interference of human activities and more availability of degradable organic materials.

The forest area of Bankadaha had 15 species of mushrooms belonging to 15 genera and 13 families. A family/ genus ratio of 0.87 and genus/ species ratio of 1.0 suggest the presence of higher familial and highest generic diversity in the area. Out of 15 species in Bankadaha, *Coriolopsis occidentalis*, *Aleuria aurantia*, *Dacryopinax spathularia*, *Crepidotus* sp. and *Amylosporus* sp. were obtained only at this site. The Simpson and Shannon's diversity index were found to be 0.0949 and 1.25, respectively; evenness was found to be 2.060, which was highest among all study areas and species richness was found to be 1.62. The diversity index found less in this collection area. This may be due to the reduced availability of

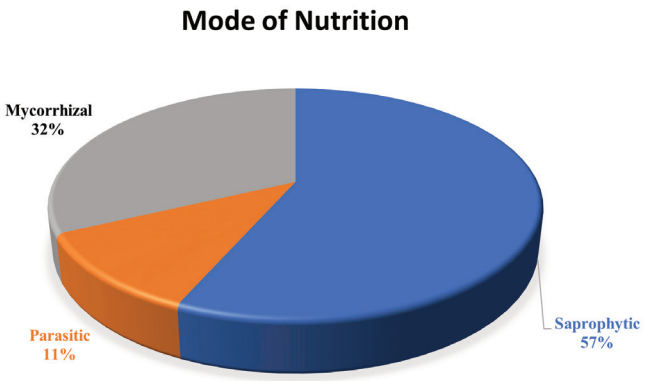

Figure 3. Distribution of mushrooms based on ecological mode of nutrition.

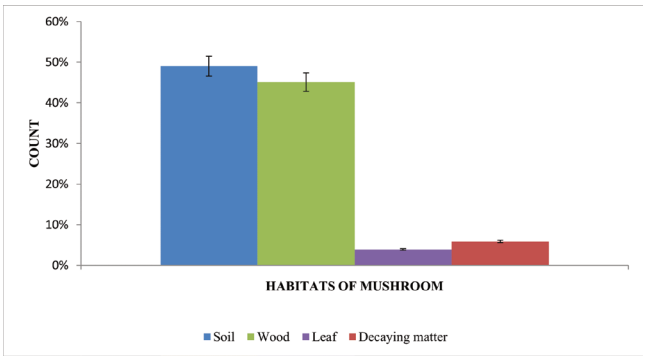

Figure 4. Distribution of mushrooms based on habitat of specimens.

degradable organic matter.

The forest area of Joypur had 11 species of mushrooms belonging to 9 genera and 8 families. A family/ genus ratio of 0.89 and genus/ species ratio of 0.82 suggest the presence of higher familial and generic diversity in the area. Out of 11 species in Joypur, *Scleroderma citrinum*, *Russula nobilis*, *Russula rosea* and *Boletus* sp. were collected only at this site. The Simpson and Shannon's diversity index were found to be 0.2998 and 0.74, respectively; evenness was found to be 1.524 and species richness was found to be 0.92. Though the evenness was more species were found as lowest among all collection areas. This infers to the increased human activity in the forest.

The forest area of Taldangra had 11 species of mushrooms belonging to 11 genera and 8 families. A family/ genus ratio of 0.73 and genus/ species ratio of 1.0 suggest the presence of moderately higher familial and highest generic diversity in the area. Out of 11 species in Taldangra, *Agaricus campestris*, *Calocybe indica*, *Lepiota* sp., *Lycoperdon pyriforme* and *Rigidoporus lineatus* were collected only at this site. The Simpson and Shannon's diversity index were found to be 0.1914 and 1.03 respectively; evenness was found to be 1.82 and species richness was found to be 1.324. The diversity index reflects the decreasing population of mushroom in this collection area due to less availability of organic matter in soil and drastic air pollution of anthropogenic origin.

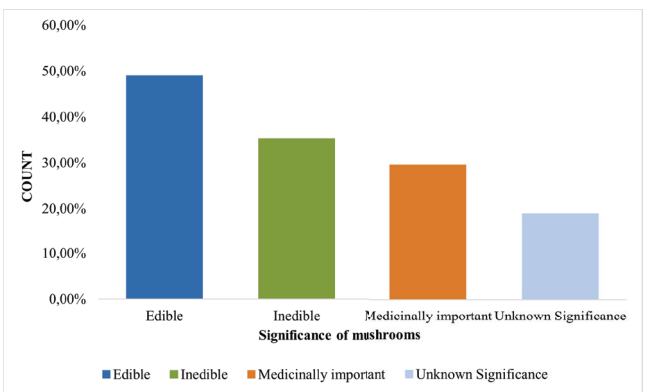

Figure 5. Distribution of mushrooms based on significance of specimens.

Discussion

Mushrooms play a major role in natural and managed ecosystems as ectomycorrhizal fungi. Some fruit bodies of mushrooms from different forest areas of Bankura District are depicted in Fig. 6. They become an important factor for reforestation programme worldwide (Wongchalee and Pukahute 2012). There are several ecological factors, such as geographic location, temperature, relative humidity; light and surrounding flora which greatly influence the growth and development of macrofungi (Kumar et al. 2013). Therefore, the myco-diversity along with the eco-climatic factors of an area is important in a forest community. Here in the study this is focussed in the natural forests of Bankura district, West Bengal.

The overall result shows that human activity and surrounding environment plays a significant role in the population of mushrooms. Less human interference, climatic condition, vegetation and availability of degradable materials in higher amount helps a greater number of litter decomposing and wood rooting mushrooms to colonise. Plant litter mainly grows in the dense forest where the atmosphere contains favourable moisture. It increases the fertility of soil. Thus, it becomes clear that the diversity of mushroom indicates the quality of the ecosystem.

Mushrooms have enormous significance as food material for human and other animals. A wide number of mushrooms are considered to have medicinal importance. The local tribal people also have informed about their

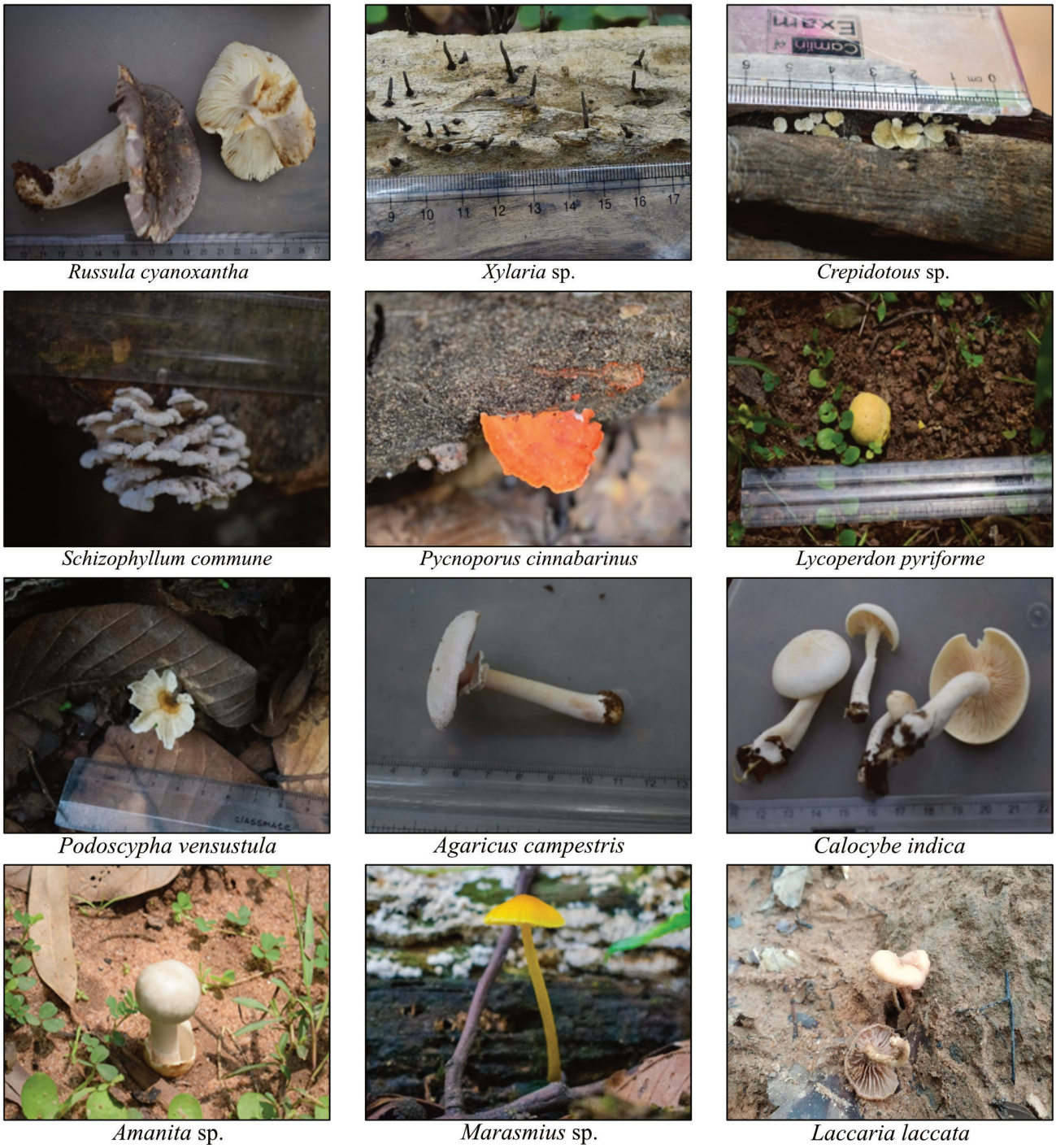

Figure 6(A). Some fruit bodies of mushrooms from the forest areas of Bankura District, West Bengal, India.

habit of consumption of mushrooms for the treatment of several ailments. Further literature study was then performed on the obtained mushrooms.

There is an important aspect regarding the local study on mushroom as they have medicinal importance. 12 obtained genera were medically important. *Ganoderma lucidum,* collected from both Taldangra and Joypur, shows anti-HIV, anti-tumor, anti-cancerous and anti-HSV activities. It is also cytotoxic to hepatoma cells. It is effective against atherosclerosis and type-2 diabetes (Sagar et al.

Figure 6(B). Some fruit bodies of mushrooms from the forest areas of Bankura District, West Bengal, India.

2007). Murrill (1905) found *G. lucidum* for the first time in 1905. *Ganoderma applanatum*, collected from Sonamukhi and Bankadaha, is antagonist to both Gram positive and Gram-negative bacteria. It produces D-glucans which activate the immune response of the host (Nomura et al. 1994). It also shows activity against influenza virus type A. It is useful in the treatment of pain (Sagar et al. 2007). *Russula cyanoxantha*, collected from Bankadaha, may have high phenolic concentration for which it shows great antioxidant and antimicrobial activity (Ribeiro et al. 2008,

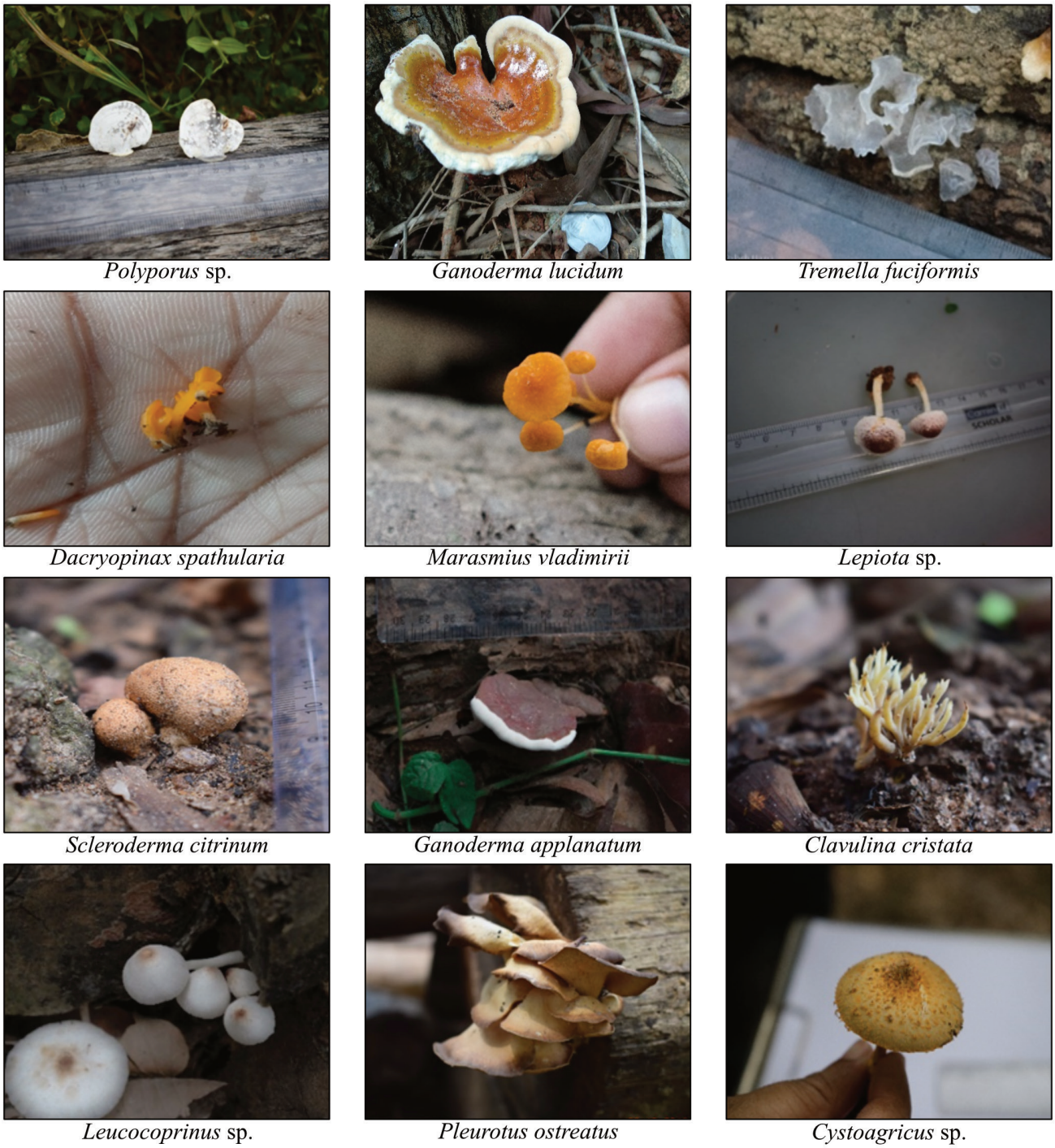

Figure 6(C). Some fruit bodies of mushrooms from the forest areas of Bankura District, West Bengal, India.

Kosanić and Ranković 2016). *Tremella fuciformis*, collected from Sonamukhi, is well known for its remarkable anti-aging, anti-wrinkle and nutraceutical properties. It also shows anti-tumor, anti-decrepitude and anti- thrombus activities (Zhang et al. 2007). *Auricularia* sp., collected from Bankadaha and Sonamukhi, have high antioxidative properties along with hyperglycaemia, immunomodulating, anti-inflammatory and anti-radiative bioactivity. It also lowers hyper-cholesterol and maintains blood sugar level (Zhang et al. 2007). *Astraeus* sp., collected from *Bishnupur,*

contains polysaccharide which increases macrophage stimulation (Mallick et al. 2007). *Laccaria laccata*, collected from Sonamukhi, acts as an effective biocatalyst in organic media (Rahi and Malik 2016). *Pleurotus ostreatus*, collected from Taldangra, has the potentiality to neutralize HIV through degradation of viral genetic material (Nomura et al. 1994). It shows bioactivity against hyperglycaemia, atherosclerotic and tumor patients (Sagar et al. 2007). It has also been reported for its hypocholesterolaemia and hypolipidemic properties (Wasser and Weis 1999). *Coprinus logopus*, collected from Sonamukhi, is reported to inhibit the growth of sarcoma 180 and Ehrlich Solid cancer by 100% and 90%, respectively, and is also effective against Gram-positive and Gram-negative bacteria (Coletto and Striano 2000). *Schizophyllum commune*, collected from Taldangra, is pharmacologically very important as it produces polysaccharide, schizophyllan (β-D-glucan), which shows anti-cancer activity in xenography and anti-tumoral activity in clinical practice (Ooi and Liu 2000). *Xylaria* sp., collected from Joypur and Sonamukhi had been proved as a valuable source of bioactive compounds such as chemokine receptor (CCR5) antagonist 19, 20-epoxycytochalasin Q (Ramesh et al. 2014). *Daedalea quercina*, collected from Sonamukhi forest, is capable of producing an anti-inflammatory compound named quercinol (Gebhardt et al. 2007).

The previous studies also indicated potential therapeutic and immunostimulatory role of wild mushrooms. Pushpa and Purushothama (2012) recorded 90 species in 46 genera belonging to 19 families in and around Bangalore, Karnataka and the Simpson and Shannon diversity index were found to be 0.8 and 1.24 respectively. Altogether 98 macrofungal species representing 72 genera belonging to 47 families were recorded in the Eastern Himalayan ecosystem and the Simpson and Shannon biodiversity index was found ranging from 0.07-0.86 and 0.16-2.13 respectively (Pradhan et al. 2016). Earlier, Pradhan et al. (2010) summarised the role of Wild Edible Mushrooms (WEMs) in the *Santal* livelihood in lateritic region of West Bengal and recorded 21 species of WEMs from the villages as well as Sal forests. In 2013, a case study of macrofungal diversity and habitat specificity of lateritic regions of West Bengal revealed 122 species, belonging to 11 orders, 29 families and 70 genera (Pradhan et al. 2013). Dutta et al. (2013) studied the macrofungal diversity and ecology of the mangrove ecosystem in the Indian part of *Sundarbans* and recorded 59 species over 25 families. A total number of 71 species in 41 genera belonging to 24 families were recorded in *Gurguripal* eco-forest of *Paschim Medinipur*, West Bengal and the Simpson and Shannon biodiversity index was found to be 0.92 and 2.206 respectively (Singha et al. 2017a). Chakraborty (2019) recorded a total number of 82 macrofungal species in 60 genera belonging to 30 families in 12 orders from the locality of 8 blocks of *Dakshin Dinajpur* district of West Bengal.

At the time of survey, some species may lack fruit bodies or have a sporulating strategy that is disproportional to their underground abundance (Baptista et al. 2010). This is the reason why the study conducted for a span of limited durations has a propensity for reflecting inadequate diversity profiles. Therefore, long term observation in specific time interval is required for betterment and adding to the current understanding of structure of regional mushroom assembles and species diversity (Straatsma and Krisai-Greilhuber 2003). The present study revealed the rich diversity of macrofungal population in the study area. The moderate rainfall in the study area supported a rich flora. However, the medicinal and edible properties of maximum mushrooms were mostly unknown to the local people. More studies are required to explore the cryptogamic mushrooms in the forest region of Bankura District.

Conclusion

The present study is the first systematic study of mushrooms distributed in the forest areas of Bankura District. There was no documentation on any ethno-mycological diversity of mushrooms till date. This is an important first step towards producing a checklist of mushrooms in this territory. However, the list of macrofungi in this study provides baseline information needed for the assessment of changes in biological diversity of mushroom.

The importance of mushrooms is not only in the ecosystem dynamics but also in human nutrition and health. Hence, it increases the need for the conservation of these non-timber forest product resources. Overall, the present study has revealed rich macrofungal diversity.

However, there are several mushrooms whose economic importance still unknown. Future investigation is needed in different seasons as well as in other different forest regions. It will result the identification of new exotic species of mushroom-flora, which will represent a complete overview on the mushroom flora of different forest areas of Bankura.

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References

Acharya K, Pradhan P (2017) Common Wild Mushrooms of West Bengal: (1-121, i-vi). West Bengal Biodiversity Board, Kolkata.

Arnolds E (1988) The changing macromycete flora in the Netherlands. Trans Brit Mycol Soc 90:391-406.

Aung OM, Soytong K, Hyde KD (2008) Diversity of entomopathogenic fungi in rainforests of Chiang Mai Province. Thailand. Fung Diver 30:15-22.

Baptista P, Martins A, Tavares RM, Lino-Neto T (2010) Diversity and fruiting pattern of macrofungi associated with chestnut (*Castanea sativa*) in the Trás-os-Montes region (Northwest Portugal). Fungal Ecol 3(1):9-19.

Basu PS, Banerjee A, Palit D (2013) Assessment of diversity and resource potential of non-timber forest product (NTFP) in selected sites of Bishnupur forest division of Bankura district, West Bengal, India. N Y Sci J 6:46-53.

Biswas G, Nandi S, Kuila D, Acharya K (2017) A comprehensive review on food and medicinal prospects of *Astraeus hygrometricus*. Phcog J 9(6):799-806.

Butler EJ, Bisby GR (1931) The Fungi of India, Scientific monograph. Indian Council of Agricultural Research 18:1-233.

Chakraborty TK (2019) Macrofungi of Dakshin Dinajpur of West Bengal, India. NeBio 10(2):66-76.

Chang ST, Buswell A (1996) Mushroom nutraceuticals. World J Microbiol Biotechnol 12(5):473-476.

Chang ST, Miles PG (2004) Mushrooms: cultivation, nutritional value, medicinal effect and environmental impact, CRC Press, United States.

Coletto MAB, Striano B (2000) Antibiotic activity in basidiomycetes. XIII. Antibiotic activity of mycelia and cultural filtrates. Allionia 37:253-255.

Das Mohapatra PK, Biswas I, Mondal KC, Pati BR (2020) Concomitant yield optimization of tannase and gallic acid by *Bacillus licheniformis* KBR6 through submerged fermentation: An industrial approach. Acta Biol Szeged 64(2):151-158

Das K, Paul PK (2015) Soil moisture retrieval model by using RISAT-1, C-band data in tropical dry and sub-humid zone of Bankura district of India. Egypt J Remote Sens Space Sci 18(2):297-310.

Das SK, Mandal A, Dutta AK, Das D, Paul R, Saha A, Sengupta S, Gupta S, Halder S (2015) Identification of wild edible mushrooms from tropical dry deciduous forest of Eastern Chota Nagpur Plateau, West Bengal, India. Proc Natl Acad Sci India Sect B Biol Sci 85(1):219-232.

Deshmukh SK (2004) Biodiversity of tropical Basidiomycetes as sources of novel secondary metabolites. Microbiology and Biotechnology for Sustainable Development. CBS Publishers and Distributors, New Delhi, 121-140.

Deshmukh SK, Natarajan K, Verekar SA (2006) Poisonous and hallucinogenic mushrooms of India. Int J Med Mushrooms 8(3):251-262.

Dutta AK, Acharya K (2014) Traditional and ethno-medical knowledge of mushrooms in West Bengal, India. Asian J Pharm Clin Res 7:36-41.

Dutta AK, Pradhan P, Basu SK, Acharya K (2013) Macrofungal diversity and ecology of the mangrove ecosystem in the Indian part of Sundarbans. Biodiversity 14(4):196-206.

Gebhardt P, Dornberger K, Gollmick FA, Gräfe U, Härtl A, Görls H, Schlegel B, Hertweck C (2007) Quercinol, an anti-inflammatory chromene from the wood-rotting fungus *Daedalea quercina* (Oak Mazegill). Bioorg Med Chem Lett 17(9):2558-2560.

Hawksworth DL, Kirk PM, Sutton BC, Pegler DN (1995) Ainsworth and Bisby's Dictionary of the Fungi, 8th Ed., IMI CAB International, Wallingford, Oxon, U.K. 616.

Kaul TN, Watling R, Frankland JC, Anisworth AM, Isaac S, Robinson CH (2002) Conservation of mycodiversity in India: An appraisal. Tropical Mycology (CABI Publishing). 1:131-147.

Kinge TR, Apalah NA, Nji TM, Acha AN, Mih AM (2017) Species richness and traditional knowledge of macrofungi (mushrooms) in the Awing Forest Reserve and Communities, Northwest Region, Cameroon. J Mycol 2017(1):1-9.

Kosanić M, Ranković B (2016) Bioactivity of edible mushrooms. Zbornik radova 2. / XXI savetovanje o biotehnologiji sa međunarodnim učešćem 21(24):645-650.

Kumar R, Tapwal A, Pandey S, Borah RK, Borah D, Borgohain J (2013) Macro-fungal diversity and nutrient content of some edible mushrooms of Nagaland, India. Nusantara Biosci 5(1):1-7.

Majumder S, Patra S (1993) Prospects of dryland farming in West Bengal: A case study in Bankura district. Indian J Agric Econ 48:246-254.

Mallick SK, Bhutia SK, Maiti TK (2007) Macrophage stimulation by polysaccharides isolated from barometer earthstar mushroom, *Astraeus hygrometricus* (Pers.) Morgan (Gasteromycetideae). Int J Med Mushrooms 11(3):237-248.

Margalef R (2008) Correspondence between the classic types of lakes and the structural and dynamic properties of their populations: With 1 figure and 2 tables in the text. Verh Int Ver Theor Angew Limnol 15(1):169-170.

Menhinick EF (1964) A comparison of some species-individuals diversity indices applied to samples of field insects. Ecology 45:859-861.

Mueller GM, Bills GF, Foster MS (2004) Recommended protocols for sampling macrofungi. Elsevier Academic Press, Burlington.169-172.

Murrill WA (1905) Tomophagus for dendrophagus. Tor-

reya 5:197.
Nad S, Mandal A, Das Mohapatra PK, Ganguly A (2021) Herbal drug: A natural bioactive formulation & its scope against viral diseases. In Sinha D, Ed., Handbook of Agriculture & Plant Sciences. ABS Books Publisher, New Delhi, India. 187-230.
Nomura H, Inokuchi N, Kobayashi H, Koyama T, Iwama M, Ohgi K, Irie M (1994) Purification and primary structure of a new guanylic acid specific ribonuclease from *Pleurotus ostreatus*. J Biochem 116(1):26-33.
Ooi VEC, Liu F (2000) Immunomodulation and anti-cancer activity of polysaccharide-protein complexes. Curr Med Chem 7(7):715-729.
Pielou EC (1996) The measurement of diversity in different types of biological collections. J Theor Biol 13:131-144.
Pradhan P, Banerjee S, Roy A, Acharya K (2010) Role of wild edible mushrooms in the Santal livelihood in lateritic region of West Bengal. J Bot Soc Bengal 64(1):61-65.
Pradhan P, Dutta AK, Paloi S, Roy A, Acharya K (2016) Diversity and distribution of macrofungi in the Eastern Himalayan ecosystem. Eurasia J Biosci 10(1):1-12.
Pradhan P, Dutta AK, Roy A, Basu SK, Acharya K (2013) Macrofungal diversity and habitat specificity: a case study. Biodiversity 14(3):147-161.
Purkayastha RP, Chandra A (1985) Manual of Indian Edible Mushrooms. Today and Tomorrows Printers and Publishers, New Delhi. 192-194.
Pushpa H, Purushothama KB (2012) Biodiversity of mushrooms in and around Bangalore (Karnataka), India. Am Eurasian J Agric Environ Sci 12(6):750-759.
Rahi DK, Malik D (2016) Diversity of mushrooms and their metabolites of nutraceutical and therapeutic significance. J Mycol 1-18.
Ramesh V, Karunakaran C, Rajendran A (2014) Optimization of submerged culture conditions for mycelial biomass production with enhanced antibacterial activity of the medicinal macro fungus *Xylaria* sp. strain R006 against drug resistant bacterial pathogens. Curr Res Environ Appl Mycol 4(1):88-98.
Ribeiro B, Lopes R, Andrade PB, Seabra RM, Gonçalves RF, Baptista P, Quelhas I (2008) Comparative study of phytochemicals and antioxidant potential of wild edible mushroom caps and stipes. Food Chem 110(1):47-56.
Sagar A, Gautan C, Sehgal AK (2007) Studies on some medicinal mushrooms of Himachal Pradesh. Indian J Mushrooms 25:8-14.
Simpson EH (1949) Measurement of diversity. Nature 163:688.
Singha K, Banerjee A, Pati BR, Das Mohapatra PK (2017a) Eco-diversity, productivity and distribution frequency of mushrooms in Gurguripal Eco-Forest, Paschim Medinipur, West Bengal, India. Curr Res Environ Appl Mycol 7:8-18.
Singha K, Pati BR, Mondal KC, Das Mohapatra PK (2017b) Study of nutritional and antibacterial potential of some wild edible mushrooms from Gurguripal Ecoforest, West Bengal, India. Indian J Biotechnol 16:222-227.
Straatsma G, Krisai-Greilhuber I (2003) Assemblage structure, species richness, abundance, and distribution of fungal fruit bodies in a seven-year plot-based survey near Vienna. Mycol Res 107(5):632-640.
Vasudeva RS (1960) The Fungi of India (revised). Indian J Agric Sci, ICAR, New Delhi. 255.
Wasser SP, Weis AL (1999) Medicinal properties of substances occurring in higher Basidiomycetes mushrooms: current perspectives. Int J Med Mushrooms 1(1):31-62.
Wongchalee P, Pukahute C (2012) Diversity of mushrooms in Dry Dipterocarp forest at Phuphan National Park, Sakon Nakhon Province. Nat Sci 4:1153-1160.
Zhang M, Cui SW, Cheung PCK, Wang Q (2007) Antitumor polysaccharides from mushrooms: A review on their isolation process, structural characteristics and antitumor activity. Trends Food Sci Tech 18(1):4-19.