

Biological insights of forest mushrooms of Chhattisgarh with special reference to *Termitomyces-termitarium-carpus*

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ABSTRACT

In the present investigation a systematic survey was carried out during 2018 and 2019 to prepare an inventory as well as document the wild edible macrofungi of Chhattisgarh. The first macrofungi appearing post first rains both on forest floors as well as in the Chhattisgarh markets were *Amanita loosii* (Sugamunda), *Amanita caesarea* (Haldi phutu), *Amanita vaginata*, *Agaricus perobscurus*, *Astraeus hygrometricus* (Sal boda, Sarai boda), *Russula rosea* (Paan Phutu), *Russula xerampelina*, *Russula emetica*, *Boletus* sp. (Jam phutu), *Boletus edulis*, *Bovista dermoxantha*, *Russula congoana*, *Lactarius piperatus* (White), *Lactarius* sp. (Light yellow), *Russula albonigra* (Black), *Cantharellus subalbidus* (Baans phutu). Most of them were found to be in symbiotic association with roots of Sal (Sarai) trees as well as with bamboo plantations. They were documented as ectomycorrhizal fungi contributing to the biomass of Chhattisgarh forests. The termitophilous fungi in symbiotic association with termites were documented and identified as *Termitomyces heimii* (white), *T. heimii* (greyish), *T. eurrhizus*, *T. clypeatus*, *T. robustus*, *T. microcarpus* (small), *T. umkowaan*, *T. globulus*, *T. striatus*, *T. mammiformis* and *T. aurantiacus*. Other edible and some non edible fungi recorded were *Auricularia* sp., *Dacryopinax spathularia*, *Ganoderma lucidum*, *Hericium erinaceus*, *Lycoperdon pyriforme*, *Lentinus cladopus*, *Lentinus tigrinus*, *Macrocybe gigantea*, *Macrolepiota procera*, *Pleurotus ostreatus*, *Trametes versicolor*, *Sparassis* sp., *Schizophyllum commune*, *Ramaria* sp., *Volvariella bombycina*, *Volvariella volvacea* and *Xylaria* sp. Different species were distinguishable based on macroscopic characters. Spore prints were obtained.

Keywords: Ectomycorrhizal, macrofungi, spore print, symbiotic association

The word mushroom may mean different things to different people and countries. Mushrooms are epigeal or hypogaeal fruiting body of macrofungi (Ascomycota and Basidiomycota). Globally an estimated 1,069 species of mushrooms have been reported to be used for food purposes (Boa, 2004). Some macrofungi are mycorrhizal with roots of higher plants determining the ecosystem dynamics of forests.

The fruiting bodies of these macrofungi visible with the naked eyes as well as easily harvested by hand, develop from the underground fungal mycelium (Chang and Miles, 1992).

The diverse agroclimatic zones of the Indian sub-continent are treasure trove of macrofungal diversity. However Indian fungi have a chequered though

beleaguered history. Butler and Bisby (1931) published the first list on Indian Fungi, which was further revised by Vasudeva (1960) and later by Bilgrami *et al.* (1991). The Indian Agaricales was systematically documented first by Sathe and Rahalkar (1976). The agarics from India as well as Nepal has further exhaustively studied and documented by Manjula in 1983. Further the collection of mushrooms in India has been documented by several mycologists periodically (Kamat *et al.*, 1971; Sathe and Rahalkar, 1976; Purkayastha and Chandra, 1985).

Macrofungi and their visible fruitbodies, provide an easy and direct method of investigating microorganisms within a community. Macrofungi also typically fruit during specific season of the year, sometimes during the same week every year. Seasonally produced sporocarps typically exist ephemerally for a few weeks, sometimes fruit multiple times in one season. Even though macrofungal sporocarps have different fruiting patterns, mycelium in the soil or wood exists throughout the year. The macrofungal development and fructifications is according to season or climate (Munguia *et al.*, 2006) and dry conditions will generally reduce the growth of mycelium along fewer productions of sporocarps (Newbound *et al.*, 2010). Sporocarp based surveys also provide information on habitat and substrate preferences of different fungi and phenology. One of the major difficulties with sporocarp based surveys is that, not all macrofungi fruit at the same time or on a regular basis (Straatsma *et al.*, 2001; Lodge *et al.*, 2004). Variation in the occurrence of species fruiting from year to year can be enormous (Watling, 1995; Lodge *et al.*, 2004).

Several studies have also examined the relationships between mushrooms and soil attributes. Living within the soil, mycorrhizal fungi form a network of hyphae (mantle) and permeating the root tips of trees. These fungi facilitate tree species to absorb water, nutrients and impart resistance to soil pathogens (Laliberte *et al.*, 2015). Because of this mutualistic

association they are critical for survival and growth of several forest tree species in a wider context throughout the world. Mushrooms have also been observed to be in symbiotic association with ants (subfamily, Myrmicinae) and termites (subfamily Macrotermitinae, Isoptera). *Microtermes*, *Canthotermes*, *Odontotermes*, *Hypotermes*, *Macrotermes*, and *Protermes* form an obligatory symbiotic association with *Termitomyces*, a paleotropical genus of lamellate agarics.

Termitomyces as a new genus was classified by Heim (1941) containing all the “termitophilic agaricales.” Grassé and Noirot (1958) was the first to demonstrate that the only family of termites found specifically in the Asian and African continents in symbiotic association with *Termitomyces* was belonging to Macrotermitinae. *Termitomyces* is a wild growing mushroom associated with termite nests in Central Africa and East Asia (Pegler and Vanhaecke, 1994). The global scientific knowledge about these species is almost a century old. *Termitomyces* belongs to family Lyophyllaceae, order Agaricales, class Agaricomycetes, and the division Basidiomycota. According to the Index Fungorum database, there are 66 names published but studies have been described only 30 species of the *Termitomyces* (Kirk *et al.*, 2008). There are about 92 taxa that have been found to be listed in mycological databases such as Index Fungorum (<http://www.indexfungorum.org/>), CABI (<http://www.cabri.org/>) and Catalogue for Life (<http://www.catalogueoflife.org/>).

Neither of the two partners can exist without the other. For both partners this ‘agricultural’ mutualism is obligatory. The fungal symbionts transform large compounds like lignin or cellulose into smaller compounds that are to be digestible for termites and *Termitomyces* mycelium also serves as a protein source. These symbiotic fungi grow on an unique substrate called the “fungus comb” or “fungus garden,” prepared and preserved by termites, which provide the optimal atmosphere for the development of the fungus, preventing the development of intruders

by constructing a hill structure and inoculation chambers within the nest. Fungus nodules (asexual stage) are also found on the fungus comb surface. Fungal mycelium develops on termite combs and produce mushrooms in rainy season. *Termitomyces* species is one of the choice edible mushrooms which grow wild in symbiotic association of termites. Since mycelial structures give poor information about the taxonomy. The diversity and taxonomy of Basidiomycetes fungi is primarily dependent on the structure of the fruiting bodies or cultural characteristics of fungi. The environmental conditions can show the species with different phenotypes, this make a big pseudo interpretation for mycologist to have a proper identification of *Termitomyces*. *Termitomyces* species are usually characterized by association with termites. The spore print is pinkish, basidiospores are smooth, the pileus bearing a prominent perforatorium and pseudorhiza subterranean in nature which connects the comb in the termite nest (Heim, 1977; Froslev *et al.*, 2003).

Chhattisgarh is bestowed with richness of mushroom flora as it sustains high plant endemism (tree species representing maximum varieties of tree species in the country). It has the largest tropical forest cover with huge diversity and richness in ecological systems. Chhattisgarh is the third largest undulated hilly state in the country containing maximum varieties of tree species. Chhattisgarh is divided into three agroclimatic zones *viz.*, Chhattisgarh Plains, Northern Hilly regions and Bastar Plateau. The state lies between latitude 17°46' N to 24°62' N and longitude 80°15' E to 84°51' E and is characterized by a marked difference in climate, vegetation and topography due to its forms of geological bedrock and the ranges over altitude belts. Shukla *et al.* (2014) reported that the forest ranges of northern and southern parts in uplands (500–1050 m) are defined for semi-evergreen true Sal forests and the central part at low elevation gradients (250–400 m) is defined for mixed Sal forest.

MATERIALS AND METHODS

Study area

A preliminary survey of wild macrofungi of Chhattisgarh was carried out during rainy season of 2018 and 2019 in the field as well as local markets of 12 districts of Chhattisgarh *viz.* Balod, Balodabazar, Bastar, Bilaspur, Dantewada, Dhamtari, Gariyaband, Kanker, Kondagaon, Korba, Mahasamund and Raipur.

Collection of wild macrofungi

Specimens of fresh fruit bodies were collected through random sampling during monsoon season from fertile termitarium, forest, ground, and bunds as well as from local markets of the study area. Specimens were collected by using forceps or trowel with a great care to avoid damage to the base of the stipe, volva, pseudorhiza and attachment to buried substrata. The specimens were wrapped in the aluminum foil or waxed paper for protection of fruitbody. Fruiting bodies were well photographed *in situ* and information such as date of collection, locality, habitat, colour, size and shape of the specimen in their natural condition were also recorded as field notes. The representative collections were brought to the laboratory and soon preserved in a preservative liquid and as dried specimens. All samples were deposited in the Mushroom Research Laboratory, Department of Plant Pathology, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh for future reference.

Identification of wild macrofungi

Collected specimens were identified using standard literature and published keys for macromorphological characters *viz.*, Das (2009), Karun and Sridhar (2013), Mohanan (2011), Morris (1986), Pegler and Vanhaecke (1994), Pearce (1987), Purkayastha and Chandra (1985), Purkayastha and Chandra (1975), Semwal *et al.* (2014), Tibuhwa *et al.* (2010), Tibuhwa (2012), Wei *et al.* (2004), Wei

et al. (2009). We also considered available web resources (<https://www.mushroomexpert.com>), (<https://mushroomobserver.org/>), (<http://kamat-termitomyco-pedia.blogspot.com>) for identification and confirmation of wild mushrooms.

RESULTS AND DISCUSSION

In this study, macrofungi were randomly collected from twelve districts of Chhattisgarh. Mushroom specimens were identified on the basis of their morphometric characteristics. The first macrofungi appearing post first rains both on forest floors as well as in the Chhattisgarh markets were *Amanita loosii* (Sugamunda), *Amanita caesarea* (Haldi phutu), *Amanita vaginata*, *Agaricus perobscurus*, *Astraeus hygrometricus* (Sal boda, Sarai boda), *Boletus edulis*, *Boletus* sp. (Jam phutu), *Russula rosea* (Paan Phutu), *Russula congoana*, *Russula emetica*, *Russula xerampelina*, *Russula albonigra*, *Lactarius piperatus* (White), *Lactarius* sp. (Light yellow), *Cantharellus subalbidus* (Baans phutu). Other edible and non-edible but medicinal fungi recorded were *Auricularia* sp., *Dacryopinax spathularia*, *Ganoderma lucidum*, *Hericium erinaceus*, *Lycoperdon pyriforme*, *Lentinus tigrinus*, *Lentinus cladopus*, *Macrocybe gigantea*, *Macrolepiota procera*, *Pleurotus ostreatus*, *Trametes versicolor*, *Sparassis* sp., *Schizophyllum commune*, *Ramaria* sp., *Volvariella bombycina*, *Volvariella volvacea*, *Xylaria* sp. and ten termitophilous fungi viz., *Termitomyces heimii* (white), *T. heimii* (greyish), *T. eurhizus*, *T. clypeatus*, *T. robustus*, *T. microcarpus* (small), *T. umkowaan*, *T. globulus*, *T. striatus*, *T. mammiformis* and *T. aurantiacus* in symbiotic association with termites.

Mushroom map of Chhattisgarh was also prepared after a systematic survey was carried out during 2018 and 2019 (Fig. 1). Spore prints of termitophilous mushrooms were taken (Fig. 10). Most of them were found to be in symbiotic association with roots of Sal (Sarai) trees as well as with bamboo

plantations. They were documented as ectomycorrhizal fungi contributing to the biomass of Chhattisgarh forests. A Checklist of the identified mushroom species bearing their vernacular name, their GPS data as well as their habitat/ecological niche or the substrate on which they appear was documented (Table 1).

In the present investigation 45 different macrofungi were collected and identified from twelve different districts of Chhattisgarh by their macro-morphological characters. The present results are closely corroborates with investigations of Natarajan (1995) who reported list of 230 species of agarics and boletes distributed among 67 genera from southern Indian states excluding Kerala in his series entitled "South Indian Agaricales". An inventory and description of the 300 species agarics belonging to 59 genera and 15 families of Agaricales from the North West Himalayas that enter into relationship with forest trees as nonconventional edible mycorrhizal species of mushrooms was reported by Lakhanpal (1995, 1997) and Lakhanpal *et al.* (2010). Doshi and Sharma (1997) provided a detailed list of macrofungi from Rajasthan. They recorded 173 species belonging to 95 genera. Saini and Atri (1995) recorded descriptions of 94 taxa spread over 24 genera reviewed exploratory work on mushrooms from Punjab. A list of 212 species of agarics spread over 63 genera from Maharashtra was reported by Patil *et al.* (1995). A record of 92 species of the genus *Lepiota* from India was made by Kumar and Manimohan (2009). A number of species of *Leucocoprinus* from Jammu and Kashmir, North West India, Orissa and Kerala was reported by several workers Vasudeva (1960); Bilgrami *et al.* (1991), Kaur (2000), Kour (2005), Jamalludin *et al.* (2001), Rawla *et al.* (1982), Natarajan and Raman (1981), Natarajan and Manjula (1983), Atri *et al.* (1996, 2000). Butler and Bisby (1931), Vasudeva (1960), Bilgrami *et al.* (1991) and Jamalludin *et al.* (2001) listed number of agarics including species of *Leucocoprinus* and *Macrolepiota* in Fungi of India.

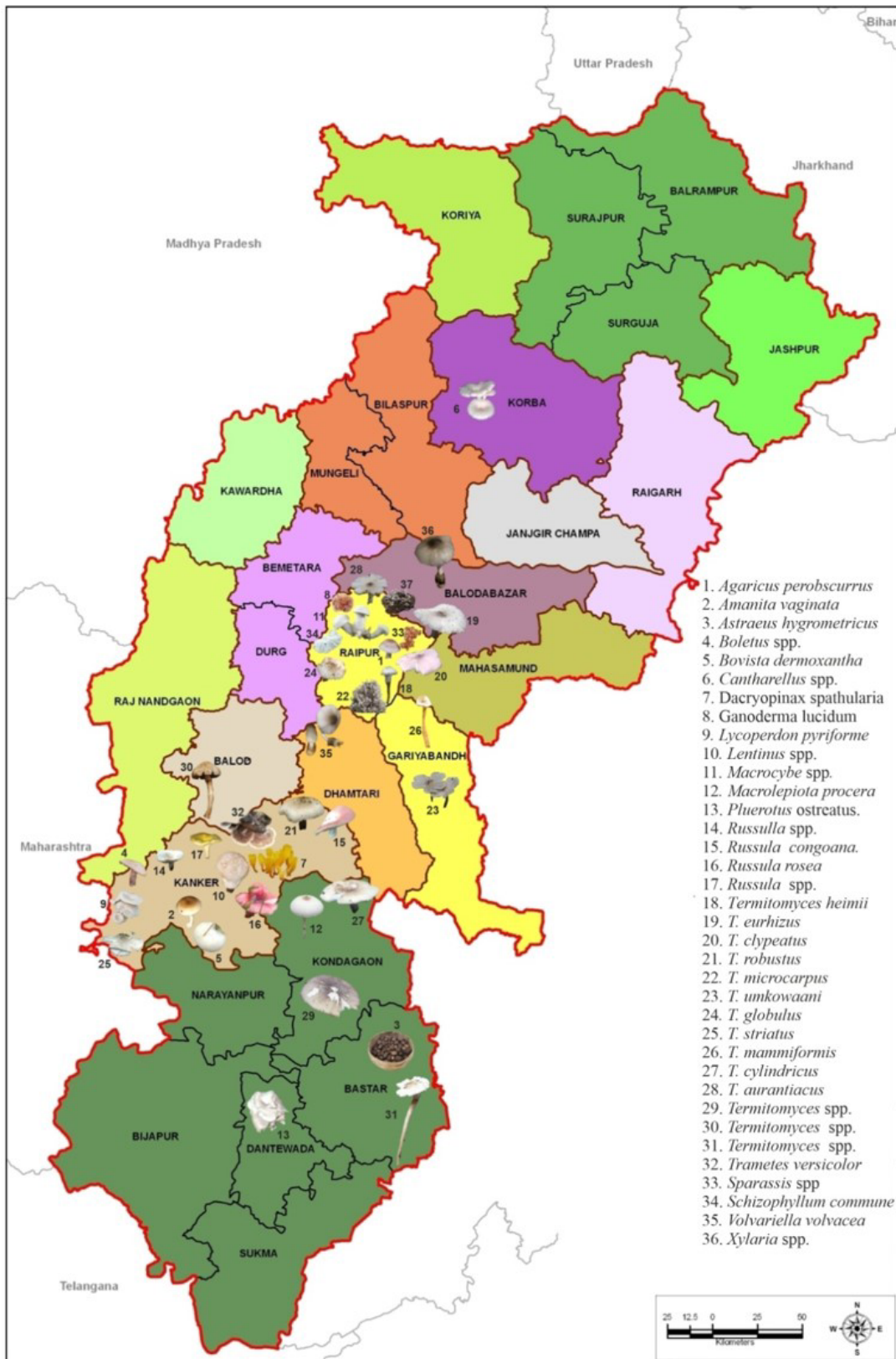


Fig. 1. Mushroom map of Chhattisgarh

BIOLOGICAL INSIGHTS OF FOREST MUSHROOMS OF CHHATTISGARH

Table 1. Checklist of the identified mushroom species bearing their vernacular name, their GPS data as well as their habitat/ecological niche or the substrate on which they appear was documented.

Sl. No.	Scientific Name	Local Vernacular name	Family	Location	District	GPS Data	Habitat/ Substrate	Distinguishing features
1	<i>Agaricus perobscurus</i>	Button mushroom	Agaricaceae	IGKV, Campus, Raipur	Raipur	21°14'05.0"N 81°43'06.9"E	On soil (under Babool tree)	Pileus 8–12 cm convex to flattened, dry, with a uniformly dark-brown disc. The disc can be either flattened or depressed, and is appressed fibrillose-squamulose. Towards the margin, it begins to diffuse. It is brown over a pallid ground color; stipe can be 6–12 x 1.5–2.0 cm. The gills are free, close, and relatively broad.
2	<i>Amanita vaginata</i>	Sugamunda	Amanitaceae	Bhanupratappur	Kanker	20°18'36.0"N 81°03'32.1"E	On soil (<i>Shorea robusta</i> forest) Ectomycorrhizal association	Fruit body small to medium, cap 6-8 cm wide, convex to plano-convex, plane with age, slightly umbonate, grayish brown to brown over the disc, becoming light grayish brown to brownish grey outwards, with a strongly tuberculate-striate margin, surface dry, shiny, but viscid when wet. Gills free, whitish. Stipe 5-16 x 1-2.3 cm, Volva saccate, membranous with 2-3 lobes, 2-4.5 cm long
3	<i>Amanita caesarea</i>	Haldi Phutu, Hardula phutu	Amanitaceae	-	Korea, Jashpur, Kawardha, Korba, Jagdalpur	-	On forest floor on dead and decomposed litter	Yellow-orange cap, The surface is smooth, and margins striated, 8-15 cm in diameter. The gills free, light yellow, stipe cylindrical, which is 6–12 cm long and 1–2 cm wide. The annulus present. The base of the stipe is thicker than the top and cup-like volva is whitish grey, The spore prints are white.
4	<i>Amanita loosii</i>	Sugamunda Safed anda	Amanitaceae	Banjari forests	Kawardha	22°08.308' N 81°08.803' E	On forest floors on dead and decomposed litter	The cap of <i>A. loosii</i> is 10 - 13 cm wide, plano-convex, smooth, white becoming creamy, with a striate margin. Volval remnants are absent. The gills are free, crowded. The stem is 7 - 10 cm long and 1.5 - 2 cm wide, cylindrical pure white, smooth. The ring membranous, skirt-like, pure white, and attached near the top of the stem. Volva present. The flesh is white.
5	<i>Amanita vaginata</i> var. <i>fulva</i>	Munjar dhunda	Amanitaceae	Forests near Bhooteswarnath Temple	Gariyaband - Kawardha	-	On forest floors on dead and decomposed litter	Fruit body small to medium, cap 5-7 cm wide, convex to plano-convex, grayish brown to brown over the disc, brown to brownish grey outwards, with a strongly tuberculate-striate margin, surface dry, shiny, but viscid when wet. Gills free, whitish. Stipe 5-16 x 1-2.3 cm, Volva saccate, membranous with 2-3 lobes, 2-4.5 cm long

Sl. No.	Scientific Name	Local Vernacular name	Family	Location	District	GPS Data	Habitat/ Substrate	Distinguishing features
6	<i>Astraeus hygrometricus</i> (albino-white)	Sal boda, Sarai Boda, Rugda, Gohiya, Bastariya phutu Phutka	Diplocystaceae	Jagdalur	Bastar	-	On soil (<i>Shorea robusta</i> forest) Ectomycorrhizal association	Fruit body small, albino whitish, globose to subglobose, 2.5-4.2 cm diam., with the mature fruit body having the appearance of an earth star when the outer peridium ruptures to form triangular-shaped lobes that radiate outward from the apex of globose fruit body, exposing the inner peridium with a conspicuous ostiole.
7	<i>Astraeus hygrometricus</i> (niger-black)	Sal boda, Sarai Boda, Rugda Chharkeni phutu, Jaat boda, Rakhdi boda, Sargi phutu Patras phutu	Diplocystaceae	Bhanupratappur	Kanker	-	On soil (<i>Shorea robusta</i> forest) Ectomycorrhizal association	Fruit body small, niger-black, globose to subglobose, 2.5-4.2 cm diam., with the mature fruit body having the appearance of an earth star when the outer peridium ruptures to form triangular-shaped lobes that radiate outward from the apex of globose fruit body, exposing the inner peridium with a conspicuous ostiole.
8	<i>Auricularia</i> sp.		Auriculariaceae	Bhanupratappur	Kanker		On wood logs	3 to 6 centimeters across, brown to dark brown, flappy or cup shaped, jelly like.
9	<i>Boletus edulis</i>		Boletaceae	Bhanupratappur	Kanker	20°18'29.4"N 81°03'33.6"E	On soil (<i>Shorea robusta</i> forest) Ectomycorrhizal association	The cap is 7-30 cm broad at maturity. Slightly sticky to touch, it is convex in shape when young and flattens with age. The colour is generally reddish-brown fading to white in areas near the margin, and continues to darken as it matures. The stipe or stem, is 8-25 cm
10	<i>Boletus</i> sp.	Jam Phutu	Boletaceae	Jagdalur	Bastar	-	On soil (Near Jamun Tree) Ectomycorrhizal association	The cap is 7 to 15 cm in diameter, convex in shape an adnate attachment. The color of the pore surface is initially brownish-creamy. The stem is 8 to 13 cm long and 2.5 to 4 cm thick, thicker at the base. Its color is wine to jam colored.
11	<i>Bovista dermoxantha</i>	Dhela phutu	Lycoperdaceae	College campus, Bhanupratappur	Kanker	20°18'29.6"N 81°03'34.5"E	On soil (<i>Shorea robusta</i> forest) Ectomycorrhizal association	The fruiting body of the sporocarp is 1.5-3.0 (4.0) cm broad, subglobose, and attached to the substrate by a white mycelial cord. The exoperidium, which is white, felty, and shrivels in age, leaving buff to light-brown, grows up to 1.0 mm thick. The gleba is soft, white, and becomes yellowish-olive to olive-brown, and finally to medium-brown at maturity.
12	<i>Cantharellus subalbidus</i>	Baans Phutu (Khukhadi)	Cantharellaceae	Rampur	Korba	-	On or near Bamboo tree Ectomycorrhizal association	Pileus 3-12cm, convex when young then flattened and finally become funnel shaped creamy whitish with some brown dots in the center when young. Stipe 2.5-11 cm long and 6-11mm thick.

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Sl. No.	Scientific Name	Local Vernacular name	Family	Location	District	GPS Data	Habitat/Substrate	Distinguishing features
13	<i>Dacryopinax spathularia</i>	-	Dacrymycetaceae	Bhanupratappur	Kanker	20°18'28.8"N 81°03'34.0"E	On Bamboo	The fruit bodies of <i>Dacryopinax spathularia</i> are spatula-shaped, usually 1–1.5 cm (0.4–0.6 in) tall and between 0.5–3 mm wide. The color is orange when fresh, but it darkens to orange-red when dry.
14	<i>Ganoderma lucidum</i>	Lakdi phutu	Ganodermataceae	IGKV Campus, Raipur	Raipur	21°14'03.9"N 81°42'54.1"E	On dead stumps/wood logs	It almost always has a stipe present, which is tawny to russet colored and 1.5 times the diameter of the cap. Context tissue is pink-buff to cinnamon-buff and corky, showing concentric growth zones and no resinous or melanoid deposits.
15	<i>Hericium erinaceus</i>	-	Hericiaceae	Jagdishpur	Mahasamund	-	Rotten wood stump	Compact rounded structure from which spines hang down, white, becoming cream colored with age, with little or no real stem.
16	<i>Lactarius piperatus</i>	-	Russulaceae	Bhanupratappur	Kanker	20°18'31"N 81°03'34"E	Ectomycorrhizal association <i>Shorea robusta</i> forest	Cap that varies from 6–16 cm across and is convex with a widely funnel-shaped center. The cap is creamy-white in colour, glabrous and not glossy; its surface may become cracked in dry locales., The stipe is white in colour, smooth, 3–7 cm long by 2–3 cm thick and is cylindrical, sometimes tapering towards the base.
17	<i>Lactarius sp.</i>	-	Russulaceae	Bhanupratappur	Kanker	-	Ectomycorrhizal association	Pileus 5-13 cm wide, convex, funnel shaped center. The cap is creamy yellow in colour. Stipe is creamy white, cylindrical, 3-5 cm long and 2-3 cm thick.
18	<i>Lentinus cladopus</i>	Pihiri, phutu	Polyporaceae	Bhanupratappur	Kanker	20°18'31.9"N 81°03'33.8"E	On dead wood logs	Pileus 6-12 cm in diam., initially convex with a depressed centre, becoming deeply infundibuliform; surface initially pale yellow. Lamellae deeply decurrent, crowded, yellowish white. Stipe 3-10 cm x 3-20 mm, central or eccentric, almost equal or slightly tapering towards base.
19	<i>Lentinus tigrinus</i>	Pihiri, phutu	Polyporaceae	Bhanupratappur	Kanker	--	On dead wood logs	Pileus 5 to 10 cm across; umbilicate to deeply funneled; whitish to buff or pale tan with matt black or brown radial scales; margin often downturned or slightly inrolled when young, sometimes flattening at maturity. Flesh white or yellowish, tough and firm. Stipe Centrally attached or sometimes slightly excentric, 2-5mm in diameter and 2 to 4cm long; initially smoothish or scaly as the cap. Gills White or yellowish, crowded.

Sl. No.	Scientific Name	Local Vernacular name	Family	Location	District	GPS Data	Habitat/ Substrate	Distinguishing features
20	<i>Macroclybe gigantea</i>	Dudhiya phutu	Tricholomataceae	Dharam-pura, Raipur	Raipur	21°12'55.9"N 81°42'37.9"E	Under Banyan tree	The caps are convex to depressed, and sometimes have a central boss (umbo), and are white to cream or pale ochre or grey. The white gills are sinuate. The stipe is also white. The species form huge pale fleshy mushrooms that often grow in clumps on dead wood in the ground. The weight of the cluster may exceed 30 kg.
21	<i>Macrolepiota procera</i>	Bhiden phutu	Agaricaceae	Kesharpal	Kondagaon	19°22'58.4"N 81°54'13.6"E	On land with undisturbed vegetation	Fruit body medium to large, cap 7-14 cm wide, hemispherical, to convex to plano-convex with age, with flat umbo in the middle, often covered with light brown to brownish small squamules, split and scattered due to the expansion of fruit body, disc smooth, brownish. Gills free to remote, densely crowded, thin, and white. Stipe cylindrical, 15.5-24 x 1.0-2 cm, annulus superior, whitish
22	<i>Pleurotus ostreatus</i>	Pihiri, phutu	Pleurotaceae	Dholkal hill, Dantewada	Dantewada	18°55'01.4"N 81°13'55.6"E	On Mango wood logs Ectomycorrhizal association	The mushroom has a broad, fan or oyster-shaped cap spanning 5–25 cm; natural specimens range from white to gray or tan to dark-brown. The margin is inrolled when young, and is smooth and often somewhat lobed or wavy. The flesh is white, firm, and varies in thickness due to stipe arrangement. The gills of the mushroom are white to cream.
23	<i>Ramaria</i> sp.	-	Gomphaceae	Jora, Krishak nagar	Raipur	-	On soil	Fruit bodies are leathery, and brittle when dry. They are small, measuring 2–5 cm tall by 1–3 cm wide, and branch from the central stem up to five times. The color of the fruit body is white to creamy white.
24	<i>Russula emetica</i>	Paan Phutu	Russulaceae	College Campus, Bhanupra-tappur	Kanker	20°18'31"N 81°03'33"E	On soil (<i>Shorea robusta</i> forest) Ectomycorrhizal association	It has a red, convex to flat cap up to 8.5 cm (3.3 in) in diameter, with a cuticle that can be peeled off almost to the centre. The gills are white to pale cream, and closely spaced. A smooth white stem measures up to 10.5 cm (4.1 in) long and 2.4 cm (0.9 in) thick.
25	<i>Russula rosea</i>	Murga Chundar, Paan Phutu, Paan ki begum, Sargi phutu Lal badar Khukhdi	Russulaceae	College Campus, Bhanupra-tappur	Kanker	20°18'35"N 81°03'35"E	On soil (<i>Shorea robusta</i> forest) Ectomycorrhizal association	Fruit body small, cap 4-6cm wide, convex to applanate, slightly depressed in the middle, pinkish red, discolor or light in color with age, margin incurved with age. Gills adnate, narrow, whitish to creamish, sub-distant, fragile as fruit body. Stipe 5.5-7 x 0.7 cm, cylindrical, attenuates at the base, whitish

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26	<i>Russula congoana</i>	-	Russulaceae	Bhanupratappur	Kanker	20°18'34"N 81°03'34"E	On soil Ectomycorrhizal association	Fruit body small to medium size. Pileus 4-6 cm, at first convex then expanded with slight central depression. Surface uniformly light red to red. Lamellae adnate, white to pale cream. Stipe 2.5-3.5cm x 7-12 mm, central cylindrical
27	<i>Russula albonigra</i>	-	Russulaceae	Jagdalpur	Bastar	19°03'06.6"N 81°56'48.7"E	On soil (<i>Shorea robusta</i> forest) Ectomycorrhizal association	The cap is convex to infundibuliform, whitish, sticky. The stipe is dusky, or white above, pale grey-ochreous towards the base. The gills are decurrent, crowded, thick, unequal, connected by veins, dusky whitish or yellowish. The flesh is white, turns black or sooty.
28	<i>Russula xerampelina</i>	-	Russulaceae	Jagdalpur	Bastar	19°03'06.6"N 81°56'48.7"E	Ectomycorrhizal association <i>Shorea robusta</i> forest	The cap is 6-12 cm wide, domed, flat, or with a slightly depressed centre, and sticky. The colour is variable, most commonly purple to wine-red, or greenish, and darker towards the centre of the cap. There are fine grooves up to a centimeter long running perpendicular to the margin. The gills have a mild to rather bitter taste, narrowly spaced, and turn creamy-yellow on ageing specimens.
29	<i>Schizophyllum commune</i>	-	Schizophyllaceae	IGKV, Campus, Raipur	Raipur	21°14'05.0"N 81°43'06.9"E	On mango dead woods	Gillies or Split Gillies vary from creamy yellow to pale white in colour. The cap is small, 1-4.5 cm wide with a dense yet spongy body texture.
30	<i>Sparassia</i> sp.	Dimag phutu	Sparassidaceae	IGKV, Campus, Raipur	Raipur	21°14'05.0"N 81°43'06.9"E	On soil (under babool tree)	Fruit body medium to large, 13-28 cm in diam., made up of curly and folded fronds, giving appearance of lettuce leaf or cauliflower, cream to cream-yellow to egg yellow with age. Stipe thick, stout, short and yellowish white.
31	<i>Trametes versicolor</i>	-	Polyporaceae	Bhanupratappur	Kanker	-	On wood	The top surface of the cap shows typical concentric zones of different colours. The flesh is 1-3 mm thick and has leathery texture. It commonly grows in tiled layers. The cap is rust-brown or darker brown, sometimes with blackish zones. The cap is flat, up to 8 x 5 x 0.5-1 cm in area. It is often triangular or round, with zones of fine hairs. The pore surface is whitish to light brown, pores round and with age twisted.

Sl. No.	Scientific Name	Local Vernacular name	Family	Location	District	GPS Data	Habitat/Substrate	Distinguishing features
32	<i>T. eurhizus</i>	Desi Chhattisgarhiya Phutu	Lyophyllaceae	IGKV Campus, Raipur	Raipur	21°14'09.8"N 81°43'03.2"E	Either singly or spread over a large area on soils, bunds of rice fields	Pileus 9-18cm diam., conical, expanding to flat at maturity, broadly umbonate perforatorium, surface brown at the center, black brown and becoming pale brown toward the margin, Lamellae free to adnexed, whitish to pinkish cream. Stipe 4 - 9x1.5 - 3 cm, tapering and bulbous at ground level, surface cream with shade of brown. Partial veil none. Pseudorhiza 8-15x0.2 cm. Spore deposit pink to pale brown.
33	<i>T. heimii</i> (albino-white) <i>T. heimii</i> (niger-black)	Bhadwahi/Bhundu/ Dusherra phutu, Bhimboora phutu, Goncha phutu (appearing during Dusshera), Dengur phutu (appearing in termitarium) Khukhdi	Lyophyllaceae	IGKV Campus, Raipur	Raipur	21°14'09.8"N 81°43'03.6"E	<i>T. heimii</i> (niger-black) either singly or spread over a large area on soils which may bearing Termitarium inside. <i>T. heimii</i> (albino-white) in groups on exposed Termitarium	Pileus 7 -15 cm diam., parabolic to campanulate with a broad, umbonate perforatorium, surface silky white to pale gray, margin at first incurved, later fissile and often upturned. Lamellae free, white then pale pink, crowded. Stipe 5 - 10 x 1.5 - 2 cm, solid, cylindrical, surface white paler than pileus, scabrous below the annulus. Pseudorhiza 25 - 45 cm long, tapering to 0.4 mm at the base, hollow. Annulus attached to upper portion of stipe (2 - 3 cm distance from pileus). Spore deposit pinkish to pale brown.
34	<i>T. clypeatus</i>	Patera Phutu,	Lyophyllaceae	IGKV Campus, Raipur	Raipur	21°14'08.0"N 81°43'07.0"E	Either singly or spread over a large area on forest floors, rice fields	Pileus 4 - 10 cm diam., pointed conical, later expanding to convex with sharp and spiniform perforatorium, surface brown to grayish brown becoming paler toward the margin, margin incurved. Lamellae free, white to pale pink at maturity. Stipe 5 - 12 x 0.4 - 1.2 cm, cylindrical, solid, whitish to grayish but very pale. Pseudorhiza 5 - 17 cm long, narrowing to 3 mm at base. Spore deposit pinkish cream.
35	<i>T. robustus</i>	Kumha Khukdi/ phutu	Lyophyllaceae	Kurna, Kanker	Kanker	20°22'29.4"N 81°29'39.4"E	Either singly or spread over a large area on forest floors	Pileus 4 -7 cm in diam., surface whitish with greyish brown centre, appanate with scrobiculate dark coloured obtusely nipped perforatorium, which is concolourous with hair like lines running along the surface, slightly incurved, splitting at maturity; cuticle fully peeling. Lamellae free, crowded. Stipe central, 4-6 cm long, 0.8 cm broad, expanded to 1.7 cm in width near the soil level, solid, creamy white, with 6.4 cm long dark brown pseudorhiza. annulus absent. spore deposit light cream.

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Sl. No.	Scientific Name	Local Vernacular name	Family	Location	District	GPS Data	Habitat/ Substrate	Distinguishing features
36	<i>T. microcarpus</i>	Kanki Phutu, Chowk Phutu, Chapat phutu	Lyophyllaceae	IGKV Campus, Raipur	Raipur	21°14'09.6"N 81°43'04.2"E	In groups on exposed Termitarium near	Pileus 0.4 - 2 cm diameter, convex to campanulate, finally expands to plane with sharp pointed perforatorium, surface white to pale gray darker at center. Lamella adnexed, white then become pink, moderately crowded lamellae. Stipe 2 - 6 × 0.2 - 0.3cm, slender, cylindrical; surface white and paler than pileus, lacking a true pseudorhiza, connected directly to comb at 1cm below the soil surface. Veil none. Spore deposit whitish cream.
37	<i>T. umkowaan</i>	Patera Phutu	Lyophyllaceae	Gariyaband	Raipur	20°35'45.1"N 82°02'14.5"E	On Soil singly or in groups widely spaced	Pileus 5.4-11.2 cm in diam., at first campanulate becoming expanded to shallowly convex and later upturned with spiniform to broadly conical umbo and straight to incised or split margin, context of pileus white to creamy. Lamellae white, free, crowded. Stipe 6.6-10.4 × 0.7-1.4 cm, cylindrical. Pseudorhiza tapering downwards. Annulus absent.
38	<i>T. globulus</i>	Patera Phutu	Lyophyllaceae	IGKV, Campus, Raipur	Raipur	21°14'05.0"N 81°43'06.9"E	On Soil singly or in groups widely spaced	Pileus 6 - 20 cm diam. at maturity, sub-globose at first then convex and expanding to plane, perforatorium scarcely developed, sometimes nil; surface pale brown, black brown at center and become paler toward margin, margin incurved. Lamellae free, cream to pale pink, densely crowded. Stipe 6 - 12 × 1 - 2.5cm, cream, cylindrical slightly expands at base. Veil none. Pseudorhiza 10 - 30 × 0.5 - 0.2 cm, slender, pale brown. Spore deposit pinkish cream.
39	<i>T. striatus</i>	Patera Phutu	Lyophyllaceae	Bhanupratappur	Kanker	20°18'36.2"N 81°03'31.0"E	On Soil singly or in groups widely spaced	Pileus 3 - 5.6 cm in diam., conico-convex, finally expanded with a prominent broad greyish brown conical perforatorium, splitting at maturity; veil prominently hanging from the margin. Lamellae free, crowded. Stipe central, 3 - 5.2 cm long, 0.5 - 1.3 cm broad, 12.5 long cm pale to light brown pseudorhiza. Fibrillose below the annulus, which is membranous and attached on the upper quarter of the stipe. spore deposit pinkish cream
40	<i>T. mammiformis</i>	Phutu	Lyophyllaceae	Shashtri Market, Raipur	Raipur	21°14'26.8"N 81°38'18.7"E	On Soil singly or in groups widely spaced	Pileus 3 - 7cm diam. convex to campanulate, and then appanate with a mammiform perforatorium, surface dark, grayish brown at perforatorium and cream to pale grayish, covered with pale cream partial veil when young, margin at first incurved, later fissile. Lamellae free, white then pale pink, crowded. Stipe 3 - 5 × 1 - 2cm cylindrical, solid, surface; white and glabrous above annulus. Pseudorhiza 20 - 37 cm long tapering to 0.5 cm at the base, white to cream, smooth, hollow. Annulus attached to upper part of Stipe.

Sl. No.	Scientific Name	Local Vernacular name	Family	Location	District	GPS Data	Habitat/ Substrate	Distinguishing features
41	<i>T. aurantiacus</i>	Patera Phutu	Lyophyllaceae	IGKV, campus, Raipur	Raipur	-	On Soil singly or in groups widely spaced	Pileus 4 - 10 cm, conical to applanate at first, finally expanding but margin usually remaining incurved, with a pointed, small perforatorium, striate at first then glabrous, surface brown in perforatorium dark brown and pale brown toward the margin, margin lacerate. Lamellae free to adnexed, white to pinkish at maturity, crowded with lamellulae. Stipe 5 - 11 × 0.4 - 0.9 cm, cylindrical and slightly swollen at the base, solid: surface white, fibrous. Pseudorhiza 12 - 18 cm long and tapering downward from the ground level, surface dark brown, solid, terminating with cylindrical at base. Partial veil membranous, ephemeral.
42	<i>Volvariella volvacea</i>	Paيرا phutu, Chhati, Paيرا ke phool	Pluteaceae	Rohansi	Balodabazar	-	On rotten paddy straw heap	Cap size 8-9 cm, brown dark grey, gills free, pinkish, annulus absent, stipe 6-7 cm long, volva present, stipe color is yellowish white
43	<i>Volvariella bombycina</i>	Paira phutu, Chhati, Paira ke phool	Pluteaceae	Jagdishpur	Mahasa-mund	21°14'08.8"N 81°43'06.8"E	Rotten paddy straw heap	Initially egg-shaped when still enclosed in the universal veil, Cap diameter of 5-20 cm, Its color is white to yellowish, becoming more pale approaching the margin, stipe 6-20 cm long, 1-3 cm thick, Gills are crowded close together, free from attachment to the stem, and initially white before turning pinkish as the spores mature.
44	<i>Volvariella volvacea</i>	Paira phutu, Chhati, Paira ke phool	Pluteaceae	Bagoud	Dhamtari	20°51'24.3"N 81°38'45.8"E	On rotten paddy straw heap	Cap size 9-10 cm, brown dark grey, gills free, pinkish, annulus absent, stipe 5-8 cm long, volva present, stipe color is yellowish white
45	<i>Xylaria</i> sp.	-	Xylariaceae (Ascomycota)	IGKV, Campus, Raipur	Raipur	21°14'17.1"N 81°42'35.0"E	Found on exposed fungus comb	It is erect, 3-7 cm tall, antler-like ascocarps (fruitbodies) which are black at the base (where the perithecia are embedded) but white and branched towards the top

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Fig. 2. Macrofungi species from Chhattisgarh. 1- *Agaricus perobscurus*, 2- *Amanita vaginata*, 3- *Amanita caesarea*, 4- *Amanita loosii*, 5- *Amanita vaginata* var. *fulva*, 6- *Astraeus hygrometricus* (albino white), 7- *Astraeus hygrometricus* (niger black), 8- *Auricularia* sp.



Fig. 3. Macrofungi species from Chhattisgarh. 9- *Boletus edulis*, 10- *Boletus* sp. (Jam phutu), 11- *Bovista dermoxantha*, 12- *Cantharellus subalbidus*, 13- *Dacryopinax spathularia*, 14- *Ganoderma lucidum*.



Fig. 4. Macrofungi species from Chhattisgarh. 15-*Lycoperdon pyriforme*, 16- *Lentinus cladopus*, 17- *Lentinus tigrinus*, 18- *Macrocybe gigantea*, 19- *Macrolepiota procera*, 20- *Pleurotus ostreatus*



Fig. 5. Macrofungi species from Chhattisgarh. 21- *Russula emetica*, 22- *Russula rosea*, 23- *Russula congoana*, 24- *Russula albonigra*, 25- *Russula xerampelina*, 26- *Lactarius piperatus*, 27- *Lactarius* sp.

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Fig.6. Macrofungi species from Chhattisgarh. 28- *Trametes versicolor*, 29- *Sparassis* sp., 30- *Hericium erinaceus*, 31- *Schizophyllum commune*, 32- *Volvariella volvacea*, 33- *V. bombycina*, 34- *V. volvacea*



Fig. 7. Macrofungi species from Chhattisgarh. 35- *Xylaria* sp., 36- *Ramaria* sp., 37 *Termitomyces eurhizus*, 38(a)- *T. heimii* (white), 38(b)- *T. heimii* (Greyish), 39- *T. umkooaan*, 40- *T. clypeatus*, 41- *T. robustus*

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Fig. 8. Macrofungi species from Chhattisgarh. 42- *T. microcarpus*, 43- *T. striatus*, 44- *T. globulus*, 45- *T. mammiformis*, 46- *T. aurantiacus*, 47- *Termitomyces* sp. grown by termites in the cupboard



Fig. 9. Macrofungi species from Chhattisgarh. A- *Termitomyces clypeatus*, B- *Termitomyces* sp., C- *Termitomyces* sp., D- *T. heimii* (White), E- *T. heimii* (Greyish), F- *T. microcarpus*, G- *T. mammiformis*

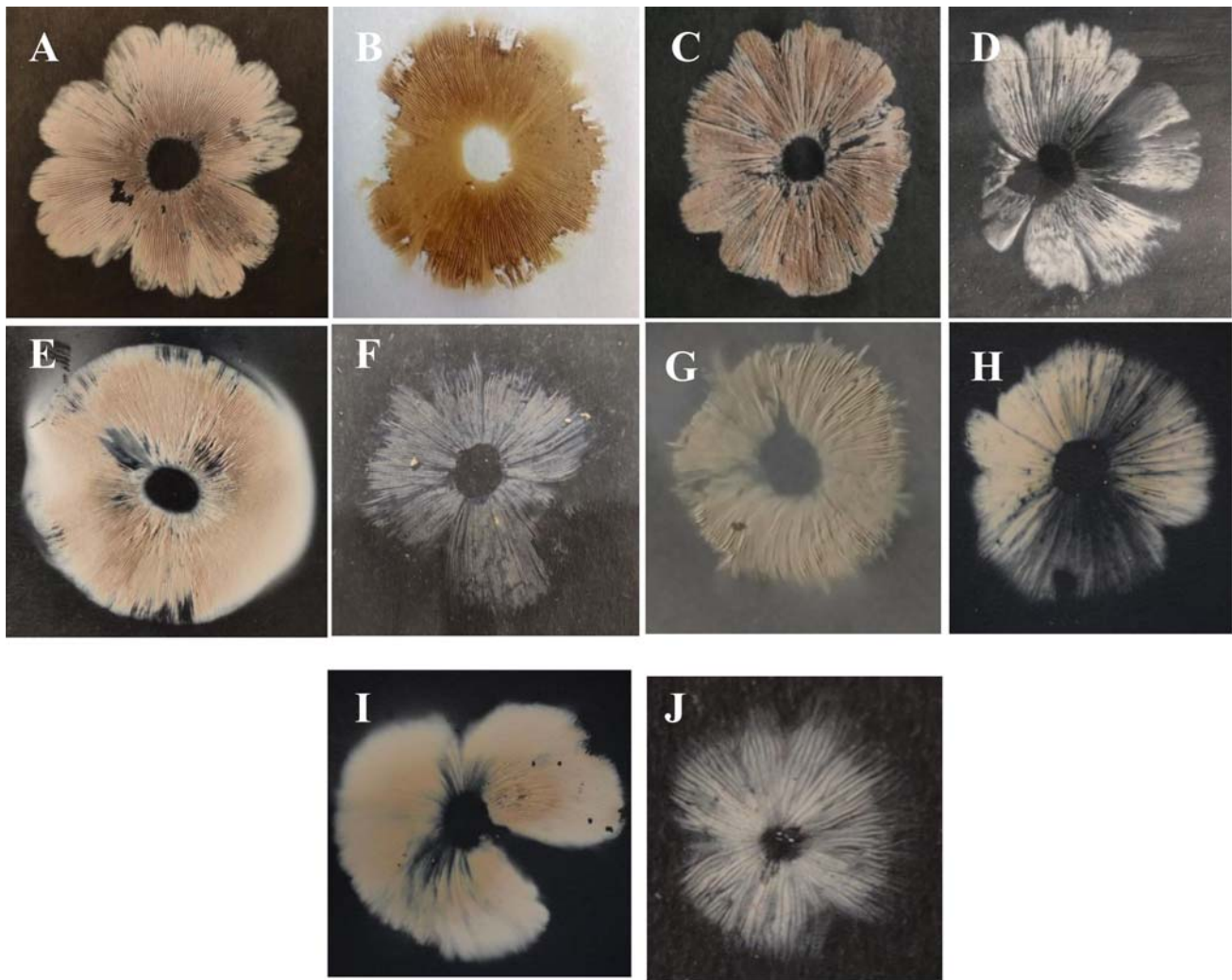


Fig. 10. Spore prints of *Termitomyces* species. A- *T. aurantiacus*, B- *Termitomyces* sp., C- *T. heimii*, D- *T. clypeatus*, E- *Termitomyces* sp., F- *T. striatus*, G- *Termitomyces* sp., H- *Termitomyces eurhizus*, I- *T. globulus*, J- *T. microcarpus*

In a study Vrinda and Pradeep (2014) has listed 85 edible mushrooms from Kerala. Rajak (2004) conducted surveys in 25 districts of Madhya Pradesh and Chhattisgarh during 1997-2000 and prepared a list of 150 mushrooms. Further they reported the edibility of 53 species. Upadhyay (2004) and Dwivedi *et al.* (2012) reported and documented about 110 macrofungi (in 20 genera) during survey in different parts of Madhya Pradesh and Chhattisgarh. Fifty-two mushrooms were collected from Amarkantak Biosphere Reserve, Madhya Pradesh and 16 mushrooms were identified up to species level. Vyas *et al.* (2014) documented 18 mushroom species from

Patharia forest (Madhya Pradesh), which include two edible (*Lepista nuda*, *Clitopilus prunulus*) and three medicinal (*Ganoderma tsugae*, *Microglossum viride*, *Tremella mesenterica*) species.

Heim (1941, 1977); Singer (1949, 1975); Pegler (1971); Pegler & Vanhaecke (1994); Cheo (1942); Natarajan (1979); Zang (1981) who studied the nature and ecology of *Termitomyces*. A separate monotypic family Termitomycetaceae was erected to accommodate *Termitomyces* (Jülich, 1981). Molecular work however supports the placement of *Termitomyces* in the Tricholomataceae within or near

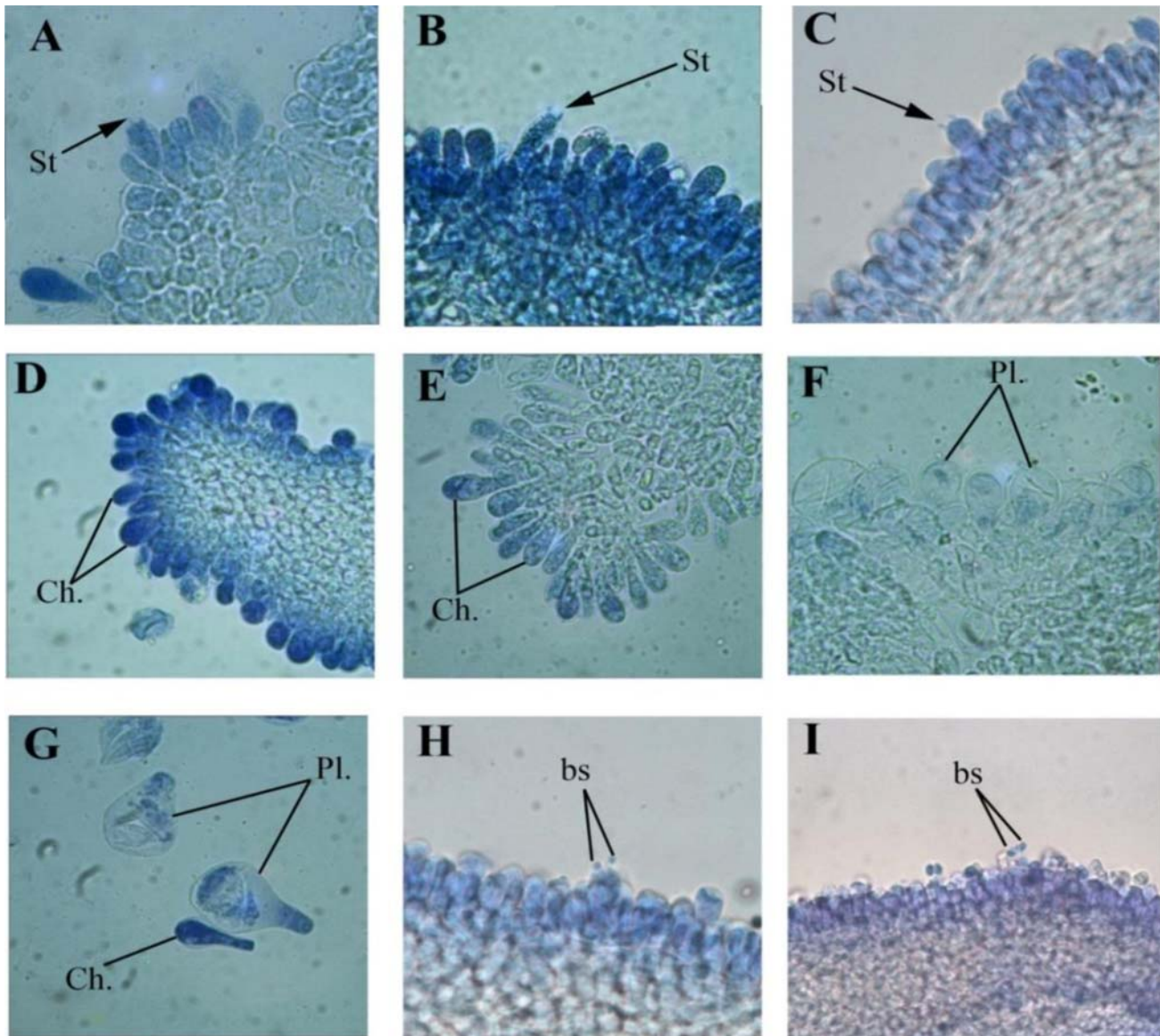


Fig. 11. Micro-structure of basidiocarp of *Termitomyces* species under the microscope. A) Sterigmata (St) of *T. eurhizus* B) Sterigmata of *T. heimii* C) Sterigmata of *Termitomyces* sp. D) Cheilocystidia (Ch.) of *T. heimii* E) Cheilocystidia of *T. clypeatus* F) Pleurocystidia (Pl.) of *T. clypeatus* G) Cheilocystidia and Pleurocystidia of *T. clypeatus* H) and I) Basidiospore of *Termitomyces* sp. attached to the basidia

Lyophyllae (Moncalvo *et al.* 2000; Kirk *et al.* 2001; Rouland-Lefevre *et al.* 2002) but new molecular studies by Matheny *et al.* (2007) proposed to place *Termitomyces* in Lyophyllaceae Jülich and the proposal was accepted in Dictionary of Fungi 10th edition (Kirk *et al.*, 2008).

Termitomyces species are commonly characterized by the dome-looking form of their well-

developed perforatorium on the pileus and the underground pseudorhiza attached to the fungal comb of the termite nest (Tang *et al.*, 2007). The genus has a broad variety of morphological variation between members, relative to other agarics (Pearce, 1987). *T. titanicus* (Pegler and Pearce, 1980) forms the world's largest agaric basidiomata with a pileus greater than 1 m in diameter that of *T. microcarpus* rarely exceeds 2.5 cm diam. The best duration for

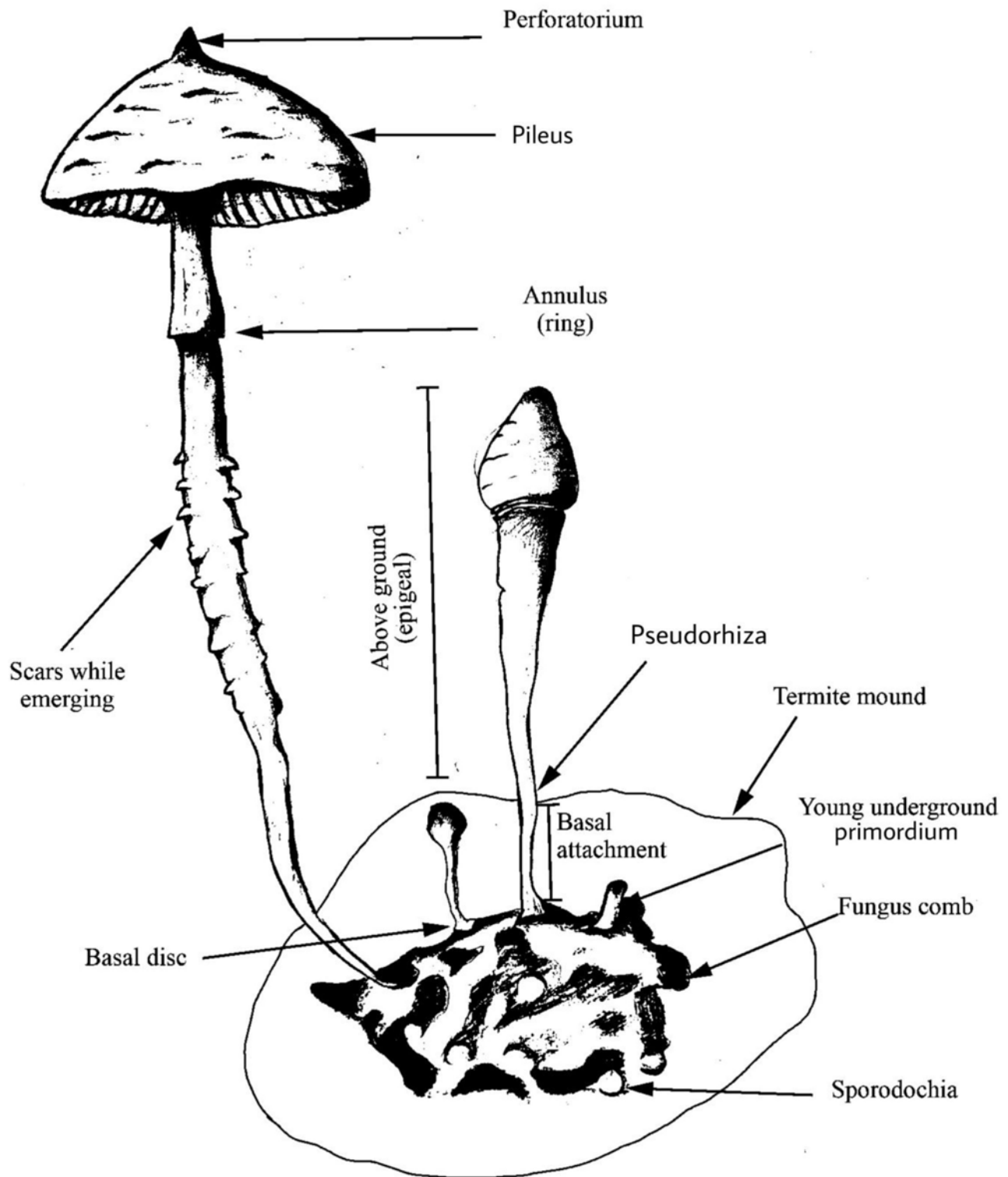


Fig. 12. Pictorial representation of *Termitomyces* associated with fungus comb

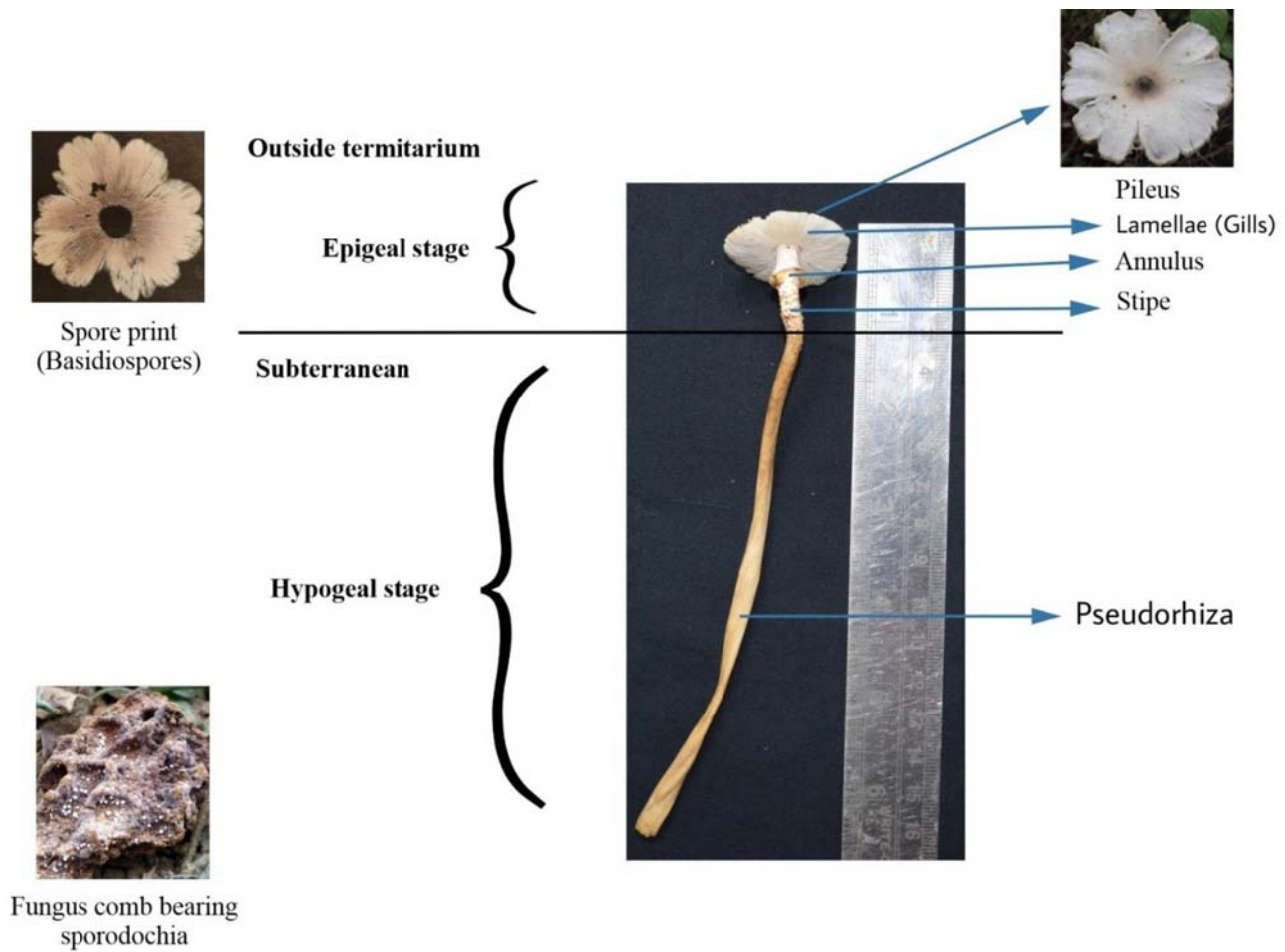


Fig. 13. Parts of *Termitomyces* fruit body

spore print was found to be about 2 to 3 h, because of more moisture of *Termitomyces* and mature basidiocarps infected with insects (Singer, 1975; Grimes, 1994; Mueller *et al.*, 2004). In Kerala, the inventory on *Termitomyces* reported a total of 15 species (Farook *et al.*, 2013). Ten species of *Termitomyces* have been recorded from Goa (Kamat, 2013) and nine species from Karnataka (Pahlevanlo and Janardhana, 2012; Karun and Sridhar, 2013). Among the *Termitomyces* species, *Termitomyces microcarpus* is predominantly distributed in these six states of the Western Ghats. The other species like *T. robustus*, *T. medius*, *T. perforans*, *T. indicus* (synonym of *T. microcarpus*, Pegler and Vanhaecke, 1994), *T. fuliginosus* (synonym of *T. robustus*; Pegler, 1977), *T. cylindricus* (synonym of *T.*

aurantiacus; Tang *et al.*, 2007), *T. sagittiformis* (Vrinda and Pradeep, 2009) and *T. schimperi* (Mohanani, 2011) are recorded from Western Ghats region.

Termitomyces eurrhizus was described by Purkayastha and Chandra (1975) from West Bengal. *Termitomyces umkowaan* from Western Ghats was described by Vrinda *et al.* (2002). *T. sagittiformis* was described by Vrinda and Pradeep (2009). Chakravarty and Khatua (1979) described *Termitomyces microcarpus* from India for the first time. Taxonomic studies on the genus *Termitomyces* was conducted by Atri *et al.* (1995). Atri and Kour (2003) and Atri *et al.* (2005) who documented 12 species of *Termitomyces* and one species of

Sinotermitomyces from India and gave a key to their determination. Chaubey *et al.* (2010) described three species of genus *Termitomyces* namely *T. heimii*, *T. indicus* and *T. microcarpus*, illustrated from various locations of Gwalior, Madhya Pradesh.

CONCLUSION

It was a journey to explore and investigate the ecological insights pertaining to the symbiosis between forest-wild mushrooms and mycologists to unearth the biological insights of their corpus. In this study forty five macro fungi among which ten wild edible *Termitomyces* sp. were frequently observed and characterized on the basis of macro-morphological characters. The forests of Chhattisgarh are a treasure-trove of macrofungi. Mushroom Map of Chhattisgarh was prepared after a systematic survey was carried out during 2018 and 2019. An inventory as well as status document of wild macrofungi was prepared.

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