Int.J.Curr.Microbiol.App.Sci (2016) *5*(12): 207-218

International Journal of Current Microbiology and Applied Sciences
ISSN: 2319-7706 **Volume 5 Number 12 (2016) pp. 207-218**
Journal homepage: http://www.ijcmas.com

Original Research Article http://dx.doi.org/10.20546/ijcmas.2016.512.023

Morphological Characterization of Some Wild Macrofungi of Gorakhpur District, U.P., India

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Keywords

Macrofungi,
Mushrooms,
Diversity,
Wild Macrofungi
Abundance.

Article Info

Accepted:
12 November 2016
Available Online:
10 December 2016

A B S T R A C T

Gorakhpur district is situated in North-East part of Uttar Pradesh in India, near the border of Nepal. It harbors different types of micro climatic conditions and habitats along with different kinds of vegetation, which provide suitable environment for the growth of different types of macrofungi. The extensive survey was made in different Tehsils of Gorakhpur district in order to know the biodiversity of wild macrofungi, including edible species during the period of January, 2014 – July, 2016. In present study, 20 different species of macrofungi belonging to 12 genera of 9 families were identified based on their morphology and microscopic characteristics. *Termitomyces heimii*, *Tuber aestivum* and *Macrolepiota procera* were edible and found to be most abundant but *Agaricus arvensis* was rarely found during the survey. This study indicates that the area embrace high diversity of macrofungi and their application as medicines may be exploited.

Introduction

Mushrooms are seasonal fungi, which occupy diverse role in nature across the forest ecosystem. They predominantly occur during the rainy as well as spring season when the snow melts. Mushrooms are in fact the 'fruit' of the underground fungal mycelium. Macrofungi may be edible, inedible, medicinal and poisonous. Some macrofungi are not edible but they have some tonic and medicinal qualities (Chang and Miles, 2004). They are macromycetes forming macroscopic fruiting bodies such as agarics, boletes, jelly fungi, coral fungi, stinkhorns, bracket fungi, puffballs and bird's nest fungi. They are fleshy, subfleshy or sometimes leathery or woody and bear their fertile surface either on lamellae or lining the tubes, opening out by means of pores.

Fungi are the second largest biotic community after insects in world (Sarbhoy *et al.*, 1996). Out of 1.5 million fungi around the earth, only 50% are characterized until now and one third of total fungal diversity exists in India (Butler and Bisby, 1960; Bilgrami *et al*., 1981, 1991; Manoharachary, 2002; Manoharachary *et al.*, 2005). Mushrooms alone are represented by about 41,000 species, of which approximately 850 species are recorded from India (Deshmukh, 2004) mostly

belonging to Agaricales, also known as gilled mushrooms (for their distinctive gills), or Euagarics. Various workers also identified and classified various types of macrofungi from different parts of India (Butler and Bisby, 1931; Vasudeva, 1960).

All types of mushrooms are important in decomposition processes, because of their ability to degrade cellulose and other plant polymers (Arora, 2008). Though India has rich macrofungal biodiversity, most traditional knowledge about mushrooms come from the far Eastern countries. Most of the mushrooms grow abundantly in nature and their commercial harvest is being undertaken for benefit in these countries. The mushrooms like *Ganoderma*, *Lentinus*, *Grifola* etc. were collected and used since time immemorial. Recent reports show a tradition of wild mushroom picking, their consumption and sale in the market in other countries (Guzman, 2008; Sitta and Floriani, 2008).

The current area of survey is Gorakhpur which is situated in North-East part of Uttar Pradesh near the border of Nepal. It covers about 3483.8 square kilometers with latitude of 26^0 13' N and 27^0 29' N and longitude of 83^0 05' E. Average annual temperature is 26^0 C. It ranges from 30^0- 40^0 C in summer and 2^0-18^0 C in winter. Annual rainfall is 1393.1 mm and 87% of rainfall is recorded during period of June to September (Singh *et al*., 2014). The soil of the region is part of the trans-Sarju plain and comprises Gangetic alluvium brought down by rivers like Ghaghara, Rapti, Rohin and Gandak from the Himalayas in the North. The texture is sandy loam and pH is about neutral. The general vegetation of Gorakhpur district is interspersed with patches of forest, old fields, open pasture, uplands (mounds or dhus), lowlands, orchards, playgrounds and human settlements (Srivastava *et al*., 2015).

Gorakhpur region is a rich reservoir of macrofungi. Lots of work had been done in this area to explore its macrofungal diversity by various workers (Srivastava *et al.*, 2011; Vishwakarma *et al*., 2014; Chandrawati *et al*., 2014). An attempt was made to explore the macrofungal diversity in the region emphasizing morphological features of the collected samples.

Materials and Methods

Systematic and periodical survey of different Tehsils (Sadar, Sahajanwa, Gola, Bansgaon, Khajni, Chauri-Chaura, Campierganj), associated forests and other habitats rich with organic matter of Gorakhpur district (U.P.) were visited during January, 2014 – July, 2016. The ecological habitats *viz*., humid soil, wood log, leaf litter, wood, sandy soil, leaf heaps, wheat straw, paddy straw, calcareous soil, wet soil, troops of rotten wood, termite nests, decaying wood log and humus were taken in consideration for their presence of macrofungi. Regular field trips were made for collection of macrofungi but it was more frequent during (June to September) monsoon season.

The collected samples were wrapped in wax paper and brought to the laboratory for the study and identification. The identification was made on the basis of macroscopic and microscopic characteristics using relevant literatures (Purakasthya, 1985; Alexopolous *et al*., 1996) and information available at www.mushroomexpert.com or www.mycokeys.com (Henry and Sullivan, 1969; Rapsang and Joshi, 2012). The soft textured samples were preserved in 2% formaldehyde and leathery textured samples were preserved in 4% formaldehyde. Alternately, the samples were also oven dried at 80^0 C for 5 consecutive days, wrapped in aluminum foil and packed in the

polythene bags with naphthalene balls for further study. The traditional knowledge of the wild mushrooms like their edibility and medicinal value were also gathered from the local tribes. All the identified and unidentified specimens were deposited to the herbarium of Department of Botany, DDU Gorakhpur University, Gorakhpur, U. P. India.

Data Analysis

Frequency and density were analyzed following Gogoi and Sarma (2012).

$$Frequency\ of\ fungal\ species(\%) = \frac{No.of\ sites\ in\ which\ the\ sp.is\ present}{Total\ no.of\ sites} \times 100$$

$$Density = \frac{Total\ no.individual\ of\ a\ particular\ species}{Total\ no.of\ sites}$$

Results and Discussion

A total of 20 macrofungi belonging to 12 genera of 9 families were identified, out of which 10 species belong to family Agaricaceae. The informations regarding the species name, family, edibility and host/substratum, frequency and density of collected macrofungi are given in Table 1.

Macroscopic and microscopic study of collected samples

1. ***Agaricus arvensis***

   Family: Agaricaceae

   Description: Cap 5cm broad, broadly convex, often with a low umbo, decurved to occasionally upturned in senescent specimens, margin incurved, surface dry and smooth, fibrillose to finely scaled in dry weather, white to ashy-grey colour. Stipe 6 cm long, tapering to a pointed base, stuffed, veil thin, fragile, membranous, either leaving remnants on the young cap margin, temporary ring. Gills close, pink, free, becoming blackish brown at maturity. Spore 6.71 x 4.32 µm, smooth, spore print blackish brown.

   Habitat: Found scattered in grassy areas.

   Place of collection: Campierganj, Gola

   Date of collection: 21-08-2015

2. ***Agaricus campestris***

   Family: Agaricaceae

   Description: Cap 5.5 cm broad, convex, often with a low umbo, margin incurved, dry and smooth surface, fibrillose to finely scaled in dry weather, white to ashy grey colour. Stipe 5 cm long, tapering to pointed base, veil thin, membranous, fragile, either leaving remnants on the young cap margin or forming a median to superior, evanescent ring. Gills close, pink, free, becoming blackish brown at maturity. Spore 6.5 x 4.31 µm.

   Habitat: Scattered or forming arcs and rings in grassy areas.

   Place of collection: Sadar

   Date of collection : 17-03-2015

3. Agaricus trisulpharatus

Family: Agaricaceae

Description: Cap 3 cm broad, bell-shaped then umbonate and flat, margin distinctly lined in mature specimens, bright yellow to greenish yellow or pale yellow or white. Gills free, yellow or pale yellow, crowded. Stipe 5 cm long, dry or powdery, slender, smooth but slightly enlarged at the base, yellow. Veil yellow, partial veil forms a small, collar-like ring on the upper stalk which may disappear. Flesh very thin, yellow. Spores ellipsoid, with an apical pore, smooth, 9.40 x 5.51µm.

Habitat: Found single or in bunch on rich organic matter, decaying hay and leaf piles.

Place of collection: Campierganj, Shahjanwa, Sadar

Date of collection: 22-09-2015

4. Amanita cokeri

Family : Amanitaceae

Description: Cap 8 cm broad, expanding to convex, oval, dry or sticky when wet, pointed and white, the margin not lined. Stipe 12 cm long, tapering slightly to apex, white, bald above or somewhat shaggy, with a fairly large basal bulb that is shallowly "rooted", with more or less concentric zones of distinctive, down-turned scales on the upper bulb and lower stem, sometimes bruising and staining reddish or rusty, especially on the bulb. Gills free from the stem or slightly attached to it, nearly distant, white or creamy, with frequent short-gills. Spores 10.99 x 6.88 µm.

Habitat: Found single or scattered on the ground under hardwood trees.

Place of collection: Campierganj, Khajni, Sadar

Date of collection: 21-07-2015

5. Amanita fulva

Family : Amanitaceae

Description: Cap 4 cm across, expanding to almost flat with a low umbo and a distinctly grooved margin, ovoid at first, orange or brown, slightly paler toward the margin, smooth, slightly sticky when moist then dry. Gills free, close, broad, white to creamy. Stipe 5 cm long, hollow, slender, quite fragile, tapering toward the top, white tinged with orange or brown and very fine white hairs, no ring, but base of stem encased in large baglike volva, white tinged with orange-brown. Flesh white. Spores 10.5 x 9.7 µm, globose, nonamyloid.

Habitat: Found singly or in small groups on litter soil.

Place of collection: Gola

Date of collection: 11-08-2015

6. Auricularia auricula judae

Family : Auriculariaceae

Description: Fruit body 5 cm across, ear-shaped, gelatinous when fresh drying hard and horny, outer surface tan-brown with minute greyish downy hairs, inner surface grey-brown, smooth or often wrinkled and ear-like. Spores white, sausage-shaped, 17.8 x 7.3 µm.

Habitat: Found on branches of trees, usually dead wood.

Place of collection: Campierganj, Shahjanwa, Sadar

Date of collection: 17-06-2014

7. Coprinus comatus

Family : Agaricaceae

Description: Cap 3 cm across, more or less a tall ovoid when young, white and very shaggy-scaly, becoming more cylindrical as it expands, often with a pale brownish "skullcap" at apex. Gills free, very narrow, crowded, white becoming black and inky from the margin upward. Stipe 5 cm long, straight, with a slightly bulbous base, hollow in center, white, smooth, with a ring of veil tissue left lower down on the stem. Flesh soft, fibrous and white. Spores 14.3 x 8.4 µm, ellipsoid, smooth.

Habitat: Found on roadsides, lawns and other urban sites.

Place of collection: Sadar, Gola

Date of collection: 20-08-2014

8. Coprinus domesticus

Family : Agaricaceae

Description: Cap 3 cm across, ovoid at first expanding convex or bell-shaped, splitting at margin, pale buff with darker tawny centre powdered at first with whitish or buff remains of veil, later smooth and becoming grooved from the margin inwards. Stipe 7 cm long, swollen at base, white tinged buff towards the ridged base. Gills white at first rapidly purplish date then black. Spore print dark brown. Spores cylindric ellipsoid, 9.5 x 4.5 µm.

Habitat: Found on dead wood of broad-leaved trees.

Place of collection: Bansgaon

Date of collection: 23-07-2014

9. Coprinus extinctorius

Family : Agaricaceae

Description: Cap 3.5 cm across, cylindrical-ovate to conical, broadly bell-shaped when expanded, white then sepia-grey finally black covered in white to clay-pink patches of veil remnant. Stipe 8 cm long, with woolly bulbous base, white. Gills white then clay-pink, finally black and deliquescing. Spore print black. Spores ellipsoid, 13.4 x11 µm.

Habitat: Found scattered on leaf litter.

Place of collection: Bansgaon

Date of collection: 20-08-2014

10. Daldinia concentric

Family : Xylariaceae

Description: Fruit body 5 cm across, hemispherical to subglobose, brown at first soon black and shiny. Flesh concentrically zoned silver-grey and blackish. Spores black elliptical to fusiform, 13.05 x 7.3 µm.

Habitat: Saprobic on decaying wood log.

Place of collection: Shahjanwa, Sadar, Campierganj

Date of collection: 20-03-2014

11. Daldinia vernicosa

Family : Xylariaceae

Description: Fruit body 4.5 cm across, hemispherical to subglobose, brown at first soon black and shiny or more in extent and is black and carbonaceous at maturity. The spores are

about the same size but are somewhat smaller and less variable in size. Spores black, 11.8 x 7.5 µm.
Habitat: Saprobic on decaying wood log.
Place of collection: Sadar
Date of collection: 15-06-2014

12. Leucoagaricus americanus
Family : Agaricaceae
Description: Cap 8 cm broad, oval and broadly convex then flat with an umbo, background whitish at first, then reddening when mature, dry and smooth, reddish-brown or dingy pinkish-buff scales. Gills free, close, broad, white staining pinky-buff. Stipe 11 cm long, often enlarged at or below the middle and tapering toward the base, white at first, staining or aging pinkish or reddish brown, smooth with adpressed silky hairs. Flesh thick, white staining yellowish then reddish brown. Spores broadly ellipsoid, smooth, dextrinoid, 9.8 x 7.5 µm.
Habitat: Found singly or in dense clusters in fields on leaf litter.
Place of collection: Sadar, Campierganj
Date of collection: 23-08-2015

13. Leucoagaricus leucothites
Family : Agaricaceae
Description: Cap 7 cm broad, convex expanding to almost flattened, smooth and silky, whitish becoming flushed flesh colour or pale cream. Stipe 10 cm long, concolorous with the cap, ring concolorous, narrow, free of the stem. Flesh thick and white in the cap, browning in the stem. Taste and smell not distinctive. Gills white becoming pale flesh colour with age. Spore print white. Spores ovoid, dextrinoid, 8.5 x 4.8 µm.
Habitat: Found in gardens or at roadsides.
Place of collection: Gola
Date of collection: 19-08-2015

14. Macrolepiota procera
Family: Agaricaceae
Description: Cap 10 cm across, button spherical or egg-shaped expanding flattened with a prominent umbo, pale buff or grey-brown covered in darker shaggy scales. Stipe 13 cm long, white, with a grey-brown felty covering which becomes split into snake-like markings as the stem expands, ring large, white on upper surface, brown below, movable on the stem. Flesh thin, soft, white. Taste sweet, smell slight indistinctive. Gills free, white. Spore print white. Spores ovate with a germ-pore, dextrinoid, 17.2 x 11.5 µm.
Habitat: Found in field on grassy area.
Place of collection: Sadar, Gola, Campierganj, Chauri-Chaura
Date of collection: 2-07-2014

15. Macrolepiota rhacodes
Family : Agaricaceae
Description: Cap 10 cm broad, ovate then expanding to almost flat, disrupting into broad, pallid, often slightly reflexed scales on a fibrous background, giving the cap a shaggy, torn

appearance. Stem 12 cm long, thickened towards the bulb which is usually oblique, whitish tinged dirty pinkish-brown, bruising reddish brown when fresh. Flesh white becoming orange to carmine red on cutting. Taste pleasant, smell strongly aromatic. Gills white, tinged reddish in older specimens, bruising reddish. Spore print white. Spores elliptical with germ-pore, dextrinoid, 10.48 x 7.4 µm.
Habitat: Found singly or in group on grassy area.
Place of collection: Bansgaon, Sadar, Gola, Campierganj, Chauri-Chaura
Date of collection: 12-08-2015

16. Panaeolus ater

Family : Bolbitiaceae
Description: Cap 3 cm across, hemispherical with slight umbo, dark brown when moist drying buff or tan from margin inwards. Stipe 12 cm long, buff or tan to darker brown, paler at apex, base covered in fine white down. Flesh thin, brown. Taste not distinctive, smell none. Gills adnate, grey at first soon becoming mottled black then finally totally black. Spore print black. Spores lemon-shaped, 11.7 x 7.8 µm.
Habitat: Found on lawns or in short grass under trees.
Place of collection: Sadar, Gola
Date of collection: 2-01-2015

17. Phallus duplicates

Family : Phallaceae
Description: Fruit body starting as a large white "egg" 5 cm across, then rupturing to release the spongy stem and head. Head bell-shaped, deeply pitted-reticulate, attached to stem at center by a white circlet surrounding the open pore at top of stem, lower margin of head is free with a prominent yellow net like indusium. Stem 12 cm long, hollow, of a cellular, sponge-like structure; white. Spores ellipsoid, smooth, 4.2 x 1.8 µm.
Habitat: Found on moist soil.
Place of collection: Shahjanwa, Sadar
Date of collection: 12-08-2015

18. Russula emeticella

Family : Russulaceae
Description: Cap 5 cm broad, convex, later flattening or with a shallow depression, scarlet, cherry or blood red, sometimes with ochre-tinted to white areas, somewhat thin-fleshed, fragile, shiny, sticky when moist, skin easily peeling to show pink to red coloured flesh beneath, margin often furrowed when old. Stipe 6 cm long, white, cylindrical or more usually somewhat swollen towards the base, fragile. Flesh white, red immediately beneath cap cuticle. Taste very hot, smell slightly fruity. Gills adnexed to free, cream then pale straw. Spore print whitish. Spores broadly ovoid, with large warts, 9.46 x 8.22 µm.
Habitat: Found scattered on litter.
Place of collection: Chauri-Chaura
Date of collection: 22-09-2015

19. Termitomyces heimii

Family : Lyophyllaceae

Description: Pileus 2 cm across, plane to convex with prominent umbo, whitish in colour, surface smooth, viscid when moist. Stipe 16 cm height, cylindrical, more or less equal, whitish in colour, pseudorrhiza long, annulus single layered, thick, white, superior. Gills free, white, margin serrulate, crowded. Spores 7.61 x 4.11µm.

Habitat: Found on moist soil and in association with termitorium.

Place of collection: Sadar, Gola, Bannsgaon, Campierganj, Chauri-Chaura, Shahjanwa

Date of collection: 13-09-2014

20. Tuber aestivum

Family : Tuberaceae

Description: Fruit body 6 cm across, globose, covered in pyramidal warts, blackish brown. Flesh whitish becoming marbled grey-brown. Taste nutty, smell sweet. Spores ovoid, reticulate, 7.61 x 7.10 µm.

Habitat: Found buried usually under hardwood trees.

Place of collection: Sadar, Gola, Khajni, Bannsgaon, Campierganj, Chauri-Chaura, Shahjanwa

Date of collection: 20-09-2014

Table.1 Frequency and density of collected macrofungal species during survey period are listed below

Table.1: Species, family, edibility, frequency and density of collected samples

Macrofungal species	Family	Edibility	% Frequency	Density
Agaricus arvensis Schaeff.	Agaricaceae	Edible	28.57	0.28
A. campsetris L.	Agaricaceae	Edible	14.28	0.14
A. trisulpharatus Berk.	Agaricaceae	Edible	42.85	0.57
Amanita cokeri E.-J. Gilbert and Kühner ex. E.-J. Gilbert	Amanitaceae	Poisonous	57.14	1.57
A. fulva Fr.	Amanitaceae	Edible	14.28	0.14
Auricularia auricula judae (Bull.) Quěl.	Auriculariaceae	Medicinal	42.85	0.42
Coprinus comatus (O.F.Müll.) Pers.	Agaricaceae	Choicely edible	42.85	1.00
C. domesticus (Bolton) Gray	Agaricaceae	Inedible	14.28	1.00
C. extinctorius Fr.	Agaricaceae	Inedible	14.28	0.14
Daldinia concentrica (Bolton) Cesati and De Notaris	Xylariaceae	Medicinal	42.85	1.71
D. vernicosa Cesati and De Notaris	Xylariaceae	Medicinal	14.28	0.42
Leucoagaricus americanus (Peck) Vellinga	Agaricaceae	Edible	28.57	0.57
L. leucothites (Vitt.) Wasser	Agaricaceae	Edible	14.28	0.42
Macrolepiota procera (Scop.) Singer	Agaricaceae	Edible	57.14	1.85
M. rhacodes (Vitt.) Singer	Agaricaceae	Choicely edible	85.71	2.14
Panaeolus ater (Lange) Kuhn. and Romagn.	Bolbitiaceae	Inedible	28.57	1.28
Phallus duplicates Bosc	Phallaceae	Medicinal	28.57	1.14
Russula emeticella (Sing.) Romagn.	Russulaceae	Edible	14.28	0.14
Termitomyces heimii Natrajan	Lyophyllaceae	Edible	71.42	3.57
Tuber aestivum Vitt.	Tuberaceae	Edible	85.71	4.28

Fig.1 The Map shows various sampling locations in different Tehsils of Gorakhpur district.

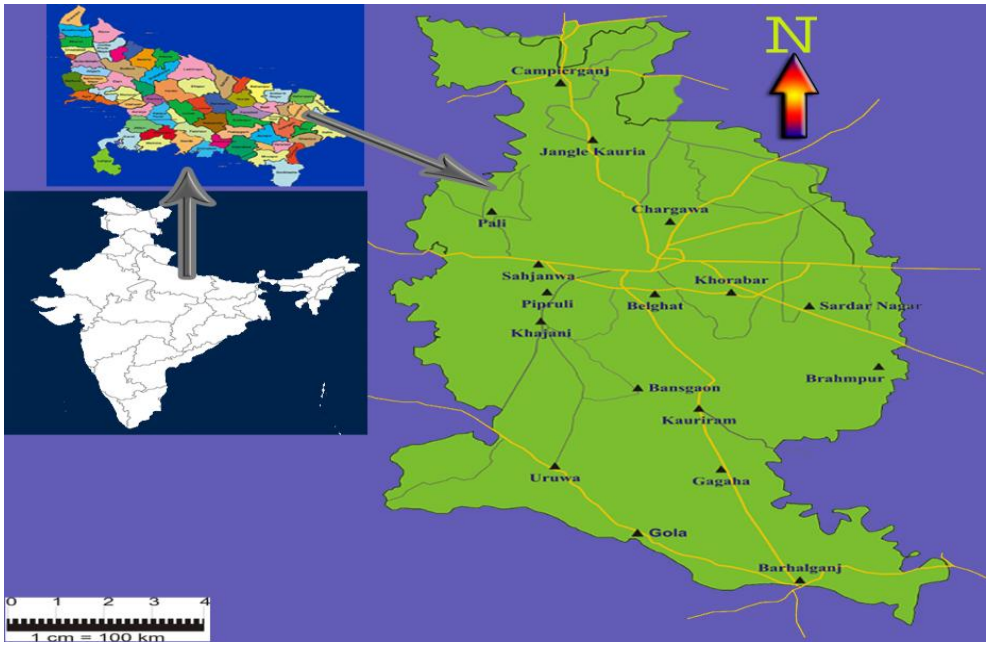

Fig.2 Collected samples of mushrooms.

Agaricus arvensis

Agaricus trisulpharatus

Agaricus campestris

Amanita cokeri

Amanita fulva

Auricularia auricula judae

Coprinus comatus

Coprinus extinctorius

Coprinus domesticus

Daldinia concentric

Daldinia vernicosa

Leucoagaricus leucothites

Leucoagaricus americanus

Macrolepiota rhacodes

Macrolepiota procera

Phallus duplicates

Panaeolus ater

Russula emeticella

Termitomyces heimii

Tuber aestivum

There are several other workers who worked on mushroom diversity of Gorakhpur. Chandrawati *et al*., (2014) collected 29 macrofungal species belonging to 12 families in which Tricholomataceae was predominant. Out of 29 spp. collected 4 were excellently edible, 6 edible, 18 inedible and 1 poisonous. As a result of extensive field survey and microscopic studies in laboratory 12 taxa belonging to 8 families were identified earlier (Vishwakarma *et al*., 2014). In present study the survey was made between January, 2014–July, 2016, 20 different species of macrofungi belonging to 12 genera and 9 families were identified based on their morphology and microscopic characteristics. Out of 20 species identified 3 were excellently edible, 9 edible, 3 inedible, 4 medicinal and one was found to be poisonous. *Termitomyces heimii*, *Tuber aestivum* and *Macrolepiota procera* were edible and found to be abundant but *Agaricus arvensis* was rarely found during the survey.

In conclusion, macrofungi play a vital role in maintaining the ecosystem, they have high nutritional, medicinal potentials and also help in biodegradation and recycling of organic matter. *Termitomyces heimii*, *Tuber aestivum* and *Macrolepiota procera* were abundantly found to be edible and also used for medicinal and cooking purposes by tribals living near forest regions of the Gorakhpur. Identification of some unknown wild macrofungi opens a new way for researchers and pharmaceuticals to exploits them for food, medicines and the other bioprospects to attempt its commercial cultivation.

Acknowledgement

The authors thank UGC, New Delhi, for financial support and Head, Department of Botany DDU Gorakhpur University, Gorakhpur, for providing necessary laboratory facilities.

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How to cite this article:

Ravinder Pal Singh, Pratima Vishwakarma, Aradhana Pal and N.N. Tripathi. 2016. Morphological Characterization of Some Wild Macrofungi of Gorakhpur District, U.P., India. *Int.J.Curr.Microbiol.App.Sci.* 5(12): 207-218. doi: http://dx.doi.org/10.20546/ijcmas.2016.512.023