GSC Biological and Pharmaceutical Sciences, 2020, 13(01), 078-085

Available online at GSC Online Press Directory

GSC Biological and Pharmaceutical Sciences

e-ISSN: 2581-3250, CODEN (USA): GBPSC2

Journal homepage: https://www.gsconlinepress.com/journals/gscbps

(REVIEW ARTICLE)

Prospects of biodiversity and distribution of mushroom fungi in India

B. Meena [1,*], V. Sivakumar [2] and S. Praneetha [3]

[1] *Associate Professor (Plant Pathology), TNAU, Coconut Research Station, Aliyarnagar - 642 101, Tamil Nadu, India.*
[2] *Assistant Professor [Horticulture], TNAU, Coconut Research Station, Aliyarnagar-642 101, Tamil Nadu, India.*
[3] *Professor and Head, TNAU, Coconut Research Station, Aliyarnagar- 642 101, Tamil Nadu, India.*

Publication history: Received on 03 October 2020; revised on 12 October 2020; accepted on 15 October 2020

Article DOI: https://doi.org/10.30574/gscbps.2020.13.1.0329

Abstract

Mushrooms are precious fungi, which exists as an important and integral component of the ecosystem. They are the macro or larger fungi which possess fleshy, subfleshy, or sometimes leathery, umbrella like fructifications, which bear their spore producing surface either on lamellae (gills) or lining the tubes, opening out by means of pores. Usually the lamellate members are called 'mushrooms' or "toadstools' depending upon whether or not they are edible or poisonous and therefore the tube bearing poroid members, as boletes. Mushrooms are seasonal fungi, which occupy diverse niches in nature within the forest ecosystem. Different types of edible mushrooms are cultivated on large scale for commercial use and many more species of mushrooms grow wildly in nature which has much nutritional and medicinal value. They predominantly occur during the season and also during spring when the snow melts. In the globe, biodiversity includes not only many species that exist, but also the range of populations that makeup a species and the genetic diversity among individual life forms. Macrofungi are important economically due to their importance in food, medicine, biocontrol, chemical, biological and other industries. Macrofungi are diverse in their uses as food and medicine and a number of other species function as decomposers and also form mycorrhizal associations.

Keywords: Macrofungi; Biodiversity; importance; Agaricales; Amanita; Morels.

1. Introduction

The diversity of mushroom and their natural beauty inhabit major threat within the biological world and India has been a frame for these fungi. Mushrooms are a wide group of fleshy fungi, which include bracket fungi, fairy clubs, toadstools, puffballs, stinkhorns, earthstars, bird's nest fungi and jelly fungi. Generally, they live as saprophytes, however some are severe agents of wood decay. All types of mushrooms are important in decomposition processes, because of their ability to degrade cellulose and other polymers. Some mushrooms are found growing in association with trees of a particular family. Mushrooms have been extensively studied in the western countries, while tropical countries like India especially in central India (Amarkantak forest) they were less explored. The variety and diversity of basidiomycetes fungi were found more in Amarkantak region [1].

Large fungi are those that form large fructifications visible without the help of the microscope and include Basidiomycota and Ascomycota with large observable spore bearing structures [2]. Fungi belonging to various taxonomic groups producing conspicuous sporocarps are collectively known as macrofungi which include "gilled fungi," "jelly fungi," "coral fungi," "stink fungi," "bracket fungi," "puffballs," "truffles," and "birds nest" [3]. Macrofungal diversity is an important component of the global diversity, particularly community diversity, which is an essential part of fungal diversity [4]. Mushrooms are widespread in nature and they still remain the earliest form of fungi known to

* Corresponding author: B. Meena
Associate Professor [Plant Pathology], TNAU, Coconut Research Station, Aliyarnagar - 642 101, Tamil Nadu, India.

mankind[5].Wild edible mushrooms are one of the most important natural resources on which majority of the people rely and play a key role in nutrition. Fungi play a significant role in industry, agriculture, medicine, food industry, textiles and bioremediation.

2. Ethnomycology

Ethnomycology investigates the indigenous knowledge of mushroom utilization and consumption patterns like in nutrition, medicine and other uses [6]. In Cameroon, mushrooms are known and consumed in many households, in the country sides and in forest areas [6]. During the onset of the rainy season when mushrooms are abundant, most people in the rural areas collect them from the forest for consumption and sale [7]. The species richness tends to decrease with increase of altitude with the very best one at the lowermost altitude and therefore the lowest one at the very best altitude. Totally, thirty-six species were collected from the low altitude, 16 species from the mid altitude and 16 species from the high altitude. No species was common to all or any the three altitudes, one species was common to both high and low altitudes and five species were common to both high and mid altitudes and one species was common to both the mid and low altitudes.

3. Mushroom diversity

Mushroom belongs to the group of organisms referred to as macrofungi under the phylum Ascomycotina and Basidiomycotina. Mushroom is that the fleshy and spore - bearing organ of the fungi that called as plant organ. Mushrooms are seasonal fungi that occupy diverse niches in forest and territory ecosystem. The famililes *viz*., Ganodermataceae, Agaricaceae, Lycophyllaceae, Schizophyllaceae, Xylariaceae, Polyporaceae, Marasmiaceae, Psanthyrellaceae and Strophaniaceae showed rich Biodiversity. The families Auriculariaceae, Botetaceae, Fornitopsidaceae, Mycenaceae, Tremellaceae and Tricholomataceae shows less diversity. Indian mycologists have reported many species of Agaricaceae, mostly represented by *Agaricus* from different states of India. Manoharachary *et al.* [8] reported different uses of medicinal mushroom *viz*., *Lentinus* sp., *Pleurotus* sp., *Schizophyllum* sp., *Pisolithus* sp., *Ganoderma lucidum*, *Agaricus bisporus*, *A. campestris*, *Pleurotus* sp. and *Termitomyces heimii*. Senthilarasu and Kumaresan [9] reported 132 species in 60 genera belonging to Agaricales, Polyporales and Russulales. *Xylaria* species grows on a variety of substrates especially on decorticated wood, dung and nests of termites/ants [10].The cosmopolitan *Ganoderma applanatum* or bracket fungus may be a unique woody Polyporaceae among all mushrooms because it is employed for its pharmaceuticals value instead of food [11].

3.1. Ecology of mushrooms

Most fungi including mushrooms grow at heart underground as a vegetative mycelium and lots of do indeed filter toxins out of the soil, act as a natural sponge and as a natural recycler. They break down dead organic matter, plants, dead trees and wood, carcass, termite comb, leaf litter and will help in the recreation of new nutrients and fertile soil. Mushroom emergence in natural ecosystem may be a complex phenomenon. It is linked to multitude of factors such as rainfall, temperature, microclimate, soil, season, humidity, association with plants, microbes and others. Senthilarasu and Kumaresan [9] studied morphological taxonomy of 15 agaric species belonging to order Agaricales collected from dipterocarp forests of Western Ghats of Karnataka. Biodiversity includes not only many species that exist, but also the range of populations that makeup a species, the genetic diversity among individual life forms and therefore the many various habitats and ecosystem around the globe. The variation observed in occurrence of mushroom species in various habitats may be due to their particular mode of nutrient and the macrofungi growing on the soil are symbiotic, on rotting and dead wood are saprophytic and on trees are parasitic, cosmopolitan distribution of microfungi have also been reported [12]. Termitomyces grow symbiotically with termites as evaluated antioxidant activity [13]. Termite combs serve as one of the prominent ecological niches of *Xylaria*, mostly owing to microclimatic conditions favors growth of *Xylaria* [14].

3.2. Tropical mushrooms

Mushrooms have been extensively studied in the western countries, while tropical countries such as India are less explored. In general, fungal diversity is greater in the tropics than that of temperate regions. Dutta and Acharya [15] reported about traditional and ethno-medicinal knowledge of mushrooms in West Bengal. Lakhanpal [16] recorded 11 species of edible mushroom from the upper hilly region of Shimla. Kumar and Manimohan [17] recorded one new species of *Leucocoprinus* from state of Kerala. Basidiomycota contains about 30,000 described species, which is 37% of the described species of true fungi reported [18]. Fungal species are especially important components of biodiversity in tropical forests where they are major contributors to the maintenance of the earth's ecosystem, biosphere and biogeochemical cycle. Fungi have beneficial roles in nutrient cycling, agriculture, biofertilizers, antibiotics, food and

biotechnological industries. Dwivedi*et al*. [19] studied on taxonomy and biodiversity of macro fungi (Agaricales) as they're securing more importance as many macrofungi are getting extinct or facing the threat of extinction. Biodiversiy of macro fungi is vital for ecosystem functioning and stability.

4. Agaricales

The basis for mushroom taxonomy started from "The Agaricales in Modern Taxonomy" proposed [20]. A new revised systematic treatment of all the fungi including mushrooms has been presented [18] in the "Dictionary of Fungi" based on molecular characters. The first list on Indian Fungi was published [21]. The systematics of Agaricales can be divided into three phases; Phase I (1825-1899), Phase II (1900-1969) and Phase III (1970-onwards). Berkeley [22] made major notable contributions to the field of Agaricology in India. He dealt with 159 species of mushrooms collected from Assam, Darjeeling, Sikkim, Calcutta, Masulipatnam and Madhya Pradesh. The pine species, *Pinus roxburghii, P. wallichiana, P. gerardiana* and high altitude conifers (*Piceas mithiana, Abies pindrow, Abies specabilis)* were predominant in Himalayan vegetation. These forests serve a congenial habitat for all sorts of fungi, especially mushrooms[16]. The wild mushroom seem to have been traditionally consumed by man since very early times, but these were then probably considered as food in wilderness, which now have come to occupy a very popular place in the modern dietic regimen because of its nutritive value.

4.1. Biodiversity of Agaricales

Agaricales are considered as cosmopolitan fungi. They can grow very easily in a wide variety of habitats. In ecologically defined areas, mushrooms have preferences for specific substrates. Chemical substances existing in mushroom may change according to soil and climate of the region in which they grow. Knowledge on morphology of Agaricales is very important related to taxonomy of badidiomycetes for understanding the physiological and phylogenetic aspects. In India, there are number of studies on mushroom diversity especially on Amanitaceae and Russalaceae.

Agaricales is a large assemblage of mushrooms and toadstools, comprising more than 20 families [22]. In the Boletaceae7 genera and 57 species were recorded. The seven genera recorded are *Austro boletus, Boletus, Gyproporus, Leccinum, Strobilomyces, Suillus* and *Tylopilus*. The mushroom exploration was further extended to the families Amanitaceae, Russulaceae and Cantharellaaceae. The family Cantharellaceae was represented by two genera *Cantharellus* and *Craterellus.* In the Russulaceae, the genus *Lactatius* is represented by 14 species and Russula by 22 species. The systematic work was further extended to families Agaricaceae, Hygrophoraceae, Pluteaceae and Tricholomatatceae [23]. In the family Agaricaceae six genera have been recorded: *Agaricus, Cystoderma, Lepiota, Macrolepiota, Leucoagaricus* and *Leucocoprinus*. In the family Pleurotaceae, the genus *Pleurotus* is represented by 6 species, all collected from Jammu & Kashmir [24]. In the *Lentinus,* only two species are known from North West Himalayas, *L. strigosus* (Schwein) Fr. and *L. tigrinus* [24]. The family Tricholomataceae is one of the largest families of the *Agricales* with its members distributed far and wide and occupying a variety of ecological niches. The fungus has gained much prominence in the last few decades being a good mycorrhizal species, which forms mycorrhizal associations with many trees. *Tricholoma*, a cosmopolitan and represented genus the planet over, has only *T. terreum* (Bull. ex Fr.) Kummar recorded from North West Himalayas [24].

4.2. Systematics of Morels

The genus Morchella (Ascomycetes) commonly known as morels. The different aspects of morel biology has been investigated in 'Guchhi', the Indian marke. The fungi, *Lactarius delicious, L. sanguifluus, Macrolepiota procera* and *Russula brevipes* among gilled members and *Boletus edulis, B. erythropus, B. horakii, Cantharellus cibarius, Hydnum repandum, Ramaria botrytoides* and *Sparassis crispa* among the non-gilled members of Basdiomycotina were identified. Mushrooms can be exploited for cultivation as they are already accepted for consumption by local people. Morels are even a better source of polysaccharides, crude fibre, nucleic acids, minerals especially Se, Zn, K, Cu, Na, and Ca, Vitamin (B1, B2, C, A, D and K), proteins and all the essential amino acids. They are free from cholesterol. Hence they are of good nutraceutical use.

4.3. Hypogeous fungi

The survey on biodiversity was conducted in Bangladesh for the distribution of untamed mushrooms, which naturally grow, in several localities, at different seasons, within the southern region of Bangladesh. Twenty four species of mushrooms belonging to 17 genera and 14 families were identified during the survey. The identified genera were *Amanita* sp., *Agaricus* sp., *Ganoderma* sp., *Armillaria* sp., *Coprinus* sp., *Cortinarius* sp., *Hebeloma* sp., *Mycena* sp., *Lepiota* sp., *Lycoperdon* sp., *Macrolepiotia* sp., *Daldinia* sp., *Tuber* sp., *Volvariella* sp., *Steccherinum* sp., *Hypholoma* sp. and *Coprinellus* sp. The collected specimens were deposited to SAU herbarium of mushroom flora (SHMF) [25]. Truffle and

truffle like fungi were explored in India except *Tuber indicum* Cooke &Massee. There have been no systematic explorations. These are least representative of the vast Himalayan ranges with so great diversity of vegetation and climate. These need to be explored more intensively and extensively[16].

Mushrooms became attractive as functional foods and as a source of physiologically beneficial bioactive compounds. Various fleshy fungi are traditional food use which were collected from Vindhya forest region and other location for his or her morphological characterization. The diversity of fleshy fungi in Vindhya forest of northern India was studied. Vindhya forest region is extremely common for diversity of fleshy fungal population. Eight species of *Pleurotus*, two species of *Volvariella*, *Lentinus, Lycoperdon* and *Agaricus* and one species of *Cococybe, Calocybe, Flammulina, Tricholoma, Auricularia, Hypomyces, Armillaria, Russula* and *Ganoderma* were collected during the study [26].

4.4. Biodiversity of *Amanita* sp.

Size of fructification was 12-13×5-6 cm. The color of pileus (cap) was brown. The shape of cap was convex. The cap edge was round and smooth. Fleshy brown color scale was found on the cap. Beneath the cap hymenophores were absent. Regular shaped gills (lamellae) were present. The color of gills was white. *Amanita griseoverrucosa* were associated with Coconut (*Cocos nucifera)*. This mushroom was found on road side of forest. Humidity was 84%. The recorded soil pH was 6. Soil type was clay loam for *Amanita griseoverrucosa.* The average recorded temperature was 29°C.

4.5. Morphology of *Amanita vaginata*

Size of fructification was 9-10×3-5 cm. The color of pileus (cap) was brown. The shape of cap was convex. The cap edge was round smooth. Fleshy brown color scale was found on the cap. Beneath the cap hymenophores were absent. Regular shaped gills (lamellae) were present. The color of gills was white. Color of stipe was brown. The length and width of stipe was 5-7 cm and 2-3 cm, respectively. Ring or anal was absent on the stipe and volva was absent on the lower part of the stipe. Spore color was light brown, spore was single welled, round to oval shaped and spore size was 7-8×5-6 µm. *Amanita vaginata* was associated with Coconut (*Cocos nucifera)* and mushroom was found on road side of forest. Relative humidity was 75%. The recorded soil pH was 6.5-6.8. Soil type was clay loam for *Amanita vaginata.* The average recorded temperature was 29.5°C.

4.6. Morphology of *Agaricus silvicola*

Fructification size was 9-10x3-4 cm. The color of pileus (cap) was as like as soil color. The shape of cap was convex. The cap edge was lobed. Brown color scale was found on the cap. Beneath the cap hymenophores were present. Regular shaped gills (lamellae) were present underside of the cap of *Agaricus silvicola*. The color of gills was white to brown gills. Color of stipe was brown to white mixed. The length and width of stipe was 5-7 cm and 2-3 cm, respectively. Ring or anal was absent on the stipe and volva was absent on the lower part of the stipe in *Agaricus silvicola.* Spore color is deep brown and single walled, smooth, oval shaped and spore size were 10-11×7-8 µm.

4.7. Morphology of *Agaricus campestris*

Size of fructification was 10-11×3.5-4 cm. The color of pileus (cap) was ash to white mixed. The shape of cap was convex and umbonate shape. The cap edge was grooved and split. Brown color scale was found on the cap. Relative humidity was 77%, soil pH was 6 to 6.5 and soil type was clay loam. Average recorded temperature was 31^0C.

4.8. Morphology of *Ganoderma applanatum*

Fructification size was 4-5×2-3 cm. The color of pileus (cap) was brown with white margin. The shape of cap was hard and flat. The cap edge was undulating. Scale was not found on the cap. Beneath the cap, hymenophores were not present. Regular shaped gills (lamellae) were not present underside of the cap of *Ganoderma applanatum*. Pseudostem present under the cap. Ring and volva was absent. The color of spore was reddish and structure was single walled, smooth, oval shaped and spore size was 6.5-7x4-5 µm.

4.9. Morphology of *Armillaria mellea*

Honey fungus is the common name. Size of fructification was 15-17×8-9 cm. The color of pileus (cap) was white and tip portion brown. The shape of cap was umbonate or convex. The cap edge was split and grooved. Brownish scale was found on the cap. Beneath the cap, hymenophores were present. Regular shaped gills (lamellae) were present underside of the cap of *Armillaria mellea*. The color of gills was deep brown and the color of stipe was brown to whitish. The length and width of stipe was 11-12 cm and 3-4 cm, respectively. Ring or anal was absent on the stipe and volva was present on the lower part of the stipe. Spore color was brown, spore shaped were single walled, smooth and ellipsoidal and spore size was 7.5-8 × 3.75-4 µm.

4.10. Morphology of *Cortinarius corrugates*

Size of fructification was 22-23×8-9 cm. The color of pileus (cap) was ash color. The shape of cap was ovate. The cap edge was grooved. Ash color scale was found on the cap. Beneath the cap hymenophores were present. Regular shaped gills (lamellae) were present underside of the cap. The color of stipe was milky white. Black ring or anal was present on the upper part of stipe and volva was absent on the lower part of stipe. Average relative humidity was 87%, soil pH was 6.2 and soil type was clay. Average recorded temperature was 29℃.

4.11. Biodiversity of *Hebeloma* sp.

Poison pie or fairy cakes is the common name. Size of fructification was 5-7x2-3 cm. The color of pileus (cap) was white. The shape of cap was convex and umbonate shape. The cap edge was grooved. White color scale was found on the cap. Beneath the cap hymenophores were absent. Regular shaped gills (lamellae) were present underside of the cap. The color of gills was creamy white. Color of stipe was white to light brown. The length and width of stipe was 3-4 cm and 1.5-2 cm, respectively. The mushroom was found on the on the r~~oot zon~~e of Betal nut (*Areca catechu)*. Average relative humidity was 77%, soil pH was 6.2 and soil type was clay. Average recorded temperature was 29℃.

4.12. Biodiversity of *Tuber aestivum*

Fructification size was 2-3x4-7 cm. The color of pileus (cap) was white color. The shape of cap was irregular. The cap edge was thick, spongy heart. White mixed violet scale was found on the cap. Beneath the cap hymenophores were absent. Regular shaped gills (lamellae) were not present underside of the cap. Stipe was absent. Gills were not present. Ring or anal was absent. Spore color was deep brown, spore shaped were single walled, smooth and elongated shaped and size were 5.5-6 × 4-5 µm.

4.13. Biodiversity of *Lepiota sp.*

Rogers mushroom is the common name. Size of fructification was 17-19x7-8cm. The color of pileus (cap) was brown. The shape of cap was convex and umbonate shape. The cap edge was grooved and split, brown color scale was found on the cap. Beneath the cap hymenophores were present. Regular shaped gills (lamellae) were present underside of the cap. The color of gills was dark brown. Color of stipe was brown. The length and width of stipe was 8-9cm and 2.8-3cm, respectively. Ring or anal was present on the stipe and volva was absent on the lower part of the stipe. The color of spore was brown, structure was single walled, rough, elongated shaped and size of spore was 5.5-6×4.5-5µm. The mushroom was found on the o~~n the r~~oot zone of Betal nut (*Areca catechu)* tree. Average relative humidity was 78%, soil pH was 6.4 and soil type was clay loam. Average recorded temperature was 26℃.

4.14. Biodiversity of *Lycoperdon* sp.

Common puffball, warted puffball, gem-studded puffball, or the devil's snuff-box are the common names. Size of fructification was 10-12x4-5 cm. The color of pileus (cap) was white. The shape of cap was button shaped. The cap edge was round smooth. Fleshy white color scale was found on the cap. Beneath the cap hymenophores were absent. Regular shaped gills (lamellae) were absent underside of the cap but tiny gills were present underside of the cap. The color of gills was white. Color of stipe was whitish. The length and width of stipe was 0.5-1 cm and 1.5-2 cm, respectively. The mushroom was found on the on the root zone of B~~abla (~~*Acacia nilotica)* tree. Average relative humidity was 82%, soil pH was 5-6 and soil type was clay loam. Average recorded temperature was 29℃.

The highest density of 48.83% recorded for *Coprinus silvaticus* followed by 39.53% for *C. micaceus* and the lowest density was 4.6% for *Tuber aestivum.* Among the total 24 species, highest 4 species were recorded under Pluteaceae family, 3 species under Agaricaceae family, 3 species under Amanitaceae and another 2 species were found under Mycenaceae family. The survey proved that, the southern region of Bangladesh has distinct biodiversity of mushroom population [25].

The collected fruit bodies showed different color like cinnamon brown in *Cococybe cyanopus;* dirty white in *Lycoperdon giganteum*; milky creamy in *C. indica*; brown in *Volvariella volvacea* and *V. esculenta*; whitish to cream in *Armillaria ponderosa, Pleurotus pulmonarius, P. flabellatus* and *P. eryngii*; grayish to brown in *P. ostreatus, P. onesti* and *P. florida*; orange-brown in *Flammulina velutipes*; golden oak in *Lentinus edodes*; brownish to cream in *P. sajorcaju*; creamy to brownish in *Agaricus placomyces*; white in *A. bisporus*and *P. porrigens.*

Studies on the taxonomy and diversity of macro fungi are gaining importance as many macro fungi are becoming extinct and facing threat of extinction because of habitat destruction. Amarkantak region was known for diverse macro fungal population. Extensive surveys were conducted for collection, characterization and preservation of macro fungi. The

genera *viz*., *Agaricus, Amanita, Nyctalis, Russula, Boletus, Macrolapiota, Ganoderma, Termitomyces* were identified. The preliminary study showed that the forest, Amarkantak was very rich in mushroom diversity [1].

5. Diversity of macromycetes

Spearman's correlation coefficient indicated that macromycete richness was positively correlated with relative air humidity, herbaceous plant coverage, slope, maximum tree height and tree basal area; and negatively correlated with air and soil temperature. Patterns of diversity and distribution of macromycetes along harvested/non-harvested areas are mainly determined by the intrinsic microclimatic variation between sites.It is broadly known that macromycete communities are strongly influenced by habitat heterogeneity and microclimatic variations. Several studies have suggested that humidity, precipitation and temperature are the main factors affecting macromycete fruiting and diversity in both temperate and tropical forests[27] and that temperature and humidity are the best predictors for fungal richness [28].

Mushroom harvesting is not likely affecting the assemblages of edible macromycetes, nor disturbing environmental factors of relevance for macrofungal communities. This is consistent with different long term studies evaluating the effect of mushroom harvesting on the number of macromycete species and fruit body production. It has been suggested that stability in the number of macromycete species and fruiting in areas under harvesting pressure may be explained by the hundreds of spores released from each fruit body before and during mushroom collection, or because enough spores disperse from adjacent areas [29]. Various studies have proposed that the composition and structure of host tree communities can influence macromycete richness and fruit body production by affecting fungal specialization and providing different habitats and resource quality and quantities Soil compaction by trampling has been proposed as one of the consequences from harvesting that can trigger a decrease in macromycete diversity and fruit body production by causing mycelium smashing [30].

6. Conclusion

The rich diversity of mushrooms offers huge socio-economic potentials around the globe. The biggest threat to biodiversity are habit fragmentation and degradation, over exploitation, pollution and diseases. Climate change is also increasingly being considered as a threat to diversity of species. There is a requirement for developing superior strains of cultivated mushrooms using available germplasm. Biotechnological approaches can be employed in order to achieve the in situ and ex situ conservation of mushroom fungi. The mushroom diversity had great potential for exploration, experimentation and amelioration of the environment. It demands great interest, commitment and of course, encouragement from living fossils the systematics. There is more demand and consumer preference for various sorts of mushrooms among the people and farmers due to increased awareness of the pharmacological values and nutritional values of mushrooms. Hence, the wild mushrooms should be exploited for immediate utilization.

Compliance with ethical standards

Acknowledgments

The authors are grateful to everyone who has contributed in one way or the other to the success of this accomplishment.

Disclosure of conflict of interest

All authors declare that they do not have any conflict of interest

References

[1] Dwivedi S, Tiwari MK, Chauhan UK, Pandey AK. Int J of Pharm & Life Sci (IJPLS). 2012; 3: 1363-1367.

[2] Al-Thani RF. Survey of Macrofungi (including Truffles) in Qatar. Atlas Journal of Biology. 2010; 1: 26–29.

[3] Enow E. Diversity and distribution of macrofungi (mushrooms) in the Mount Cameroon Region. Journal of Ecology and the Natural Environment. 2013; 5: 318–334.

[4] Li S, Zhu T, Liu G, Zhu H. Diversity of macrofungal community in Bifeng Gorge : the core giant panda habitat in China. African Journal of Biotechnology. 2012; 11: 1970–1976.

[5] Okhuoya J, Akpaja E, Osemwegie O, Oghenekaro A,Ihayere C. Nigerian mushrooms: underutilized non-wood forest resources. Journal of Applied Sciences and Environmental Management. 2010; 14: 43–54.

[6] Kinge TR, Tabi EM, Mih AM, Enow EA, Njouonkou L, Nji TM. Ethnomycological studies of edible and medicinal mushrooms in the mount Cameroon region (Cameroon, Africa). International Journal of Medicinal Mushrooms. 2011; 13: 299–305.

[7] Yongabi K, Agho M, Carrera M. Ethnomycological studies on wild mushrooms in Cameroon, Central Africa. Journal of Mycology. 2004; 16: 34–36.

[8] Manoharachary C, Sridhar K, Singh R, Adholeya A. Fungal biodiversity, distribution, conservation and prospecting of fungi from India. Curr Sci. 2005; 89: 58-71.

[9] Senthilarasu G, Kumaresan V. Diversity of agaric mycota of Western Ghats of Karnataka, India. Current Research in Environmental & Applied Mycology. 2016; 6: 75-101.

[10] Hsieh HM, Lin CR, Fang MJ, Rogers JD, Foumier J, Lechat C,Ju YM. Phylogenetic status of Xylaria subgenus Pseudoxylaria among taxa of the subfamily Xylarioideae (Xylariaceae) and phylogeny of the taxa involved in the subfamily. Molecular Phylogenetics and Evolution. 2010; 54: 957- 969.

[11] Acharya K. Antioxidant and nitric oxide syntheses activation properties of *Ganoderma applanatum*. Indian Journal of experimental Biology. 2010; 43: 923-929.

[12] Suryanarayanan TS, Ravishankar JP, Venkatesan G, Murali TS. Characterization of the melanin pigment of a cosmopolitan fungal endophyte. Mycological research. 2004; 108: 974- 978.

[13] Puttaraju NG. Antioxidant activity of indigenous edible mushrooms. Journal of Agricultural and Food Chemistry. 2006; 54: 9764–9772.

[14] Guedegbe HJ, Miambi E, Pando A, Houngnandan P. Molecular diversity and host specificity of termite-associated Xylaria. Mycologia. 2009; 101: 686-689.

[15] Dutta AK, Acharya K. Traditional and ethno-medicinal knowledge of mushrooms in West Bengal, India. Asian Journal of Pharmaceutical and Clinical Research. 2014; 7: 36–41.

[16] Lakhanpal TN. Mushroom biodiversity in India: Prospects and potential. In: Proceedings of the 8th International Conference on Mushroom Biology and Mushroom Products (ICMBMP8), pp.7-16.

[17] Kumar TKA,Manimohan P. The genus Lepiota (Agaricales, Basidiomycota) in Kerala State, India. Mycotaxon. 2009; 107, 105-138.

[18] Kirk PM, Cannon PF, David JC, Stalpers J. Ainsworth and Bisby's Dictionary of the Fungi. 9th ed. CAB International, Wallingford, UK. 2001.

[19] Dwivedi S, Singh S, Chauhan UK, Tiwari MK. Biodiversity studies on macro fungi with special reference to order agaricales: Indian scenario. Journal of Bacteriology & Mycology. 2017; 5: 420-423.

[20] Singer R. The Agaricales in Modern Taxonomy, (4th ed.). Bishen Singh Mahendra Pal Singh, Dehradun. 1986; 981.

[21] Butler EJ,Bisby GR. The Fungi of India. Imp Counc of Agri Res India, Sci Mono 1, XVIII. Calcutta. 1931; 237.

[22] Berkeley MJ. Decades XXXIX, XL. Sikkim and Khassya Fungi. J Bot. 1852; 4: 130-142.

[23] Lakhanpal TN. Survey and studies on mushrooms and toadstools of N. W. Himalayas, Final Progress Report DST Project, H.P. University, Shimla. 1986.

[24] Watling R, Gregory NM. Nova Hedw. 1980; 32: 493-564.

[25] Rashid SN, Aminuzzaman FM, Islam MR, Rahaman M, Rumainul MI. Biodiversity and distribution of wild mushrooms in the southern region of Bangladesh. Journal of Advances in Biology & Biotechnology. 2016; 9: 1-25.

[26] Yadav MK, Chandra R, Dhakad PK. Biodiversity of edible mushrooms in Vindhya forest of northern India. Indian Journal of Agricultural Sciences. 2016; 86: 1070–1075.

[27] Lodge DJ, Laessoe T, Aime MC, Henkel TW. Montane and cloud forest specialists among neotropical Xylaria species. North American Fungi. 2008; 3: 193–213.

[28] Talley SM, Coley PD, Kursar TA. The effects of weather on fungal abundance and richness among 25 communities in the Intermountain West. BMC Ecology. 2002; 2: 7.

[29] Egli S, Ayer F, Peter M, Eilmann B, Rigling A. Is forest mushroom productivity driven by tree growth? Results from a thinning experiment. Annals of Forest Science. 2010; 67: 509–519.

[30] Zhang Y, Zhou DQ, Zhao Q, Zhou TX, Hyde KD. Diversity and ecological distribution of macrofungi in the Laojun Mountain region, southwestern China. Biodiversity and Conservation. 2010; 19: 3545–3563.