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Wild Macrofungi: Diversity, Nutritional Value, Medicinal Potential and Toxicological Concerns

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Abstract

Despite the current interest in wild mushrooms, relatively limited research has been carried out on their diversity and potential applications. Numerous species of wild mushrooms exist in nature, many of which remain undiscovered or insufficiently studied. The identification of new species, investigation of their bioactive compounds, and documentation through scientific literature represent promising areas for future research. Such studies can greatly enhance our understanding of the diversity and functional properties of wild mushrooms. Moreover, wild mushrooms may serve as valuable sources of pharmacologically active compounds, nutraceuticals, and cosmeceuticals with potential applications in medicine and healthcare, especially in areas requiring precise pharmacogenetic profiling. Therefore, the present review aims to compile information on wild mushrooms reported by scientists and researchers from various regions and to highlight their medicinal and nutraceutical significance. This review is expected to provide accurate data and useful guidance for future research endeavors.

Keywords: Mushrooms, Nutraceuticals, Diversity, Bioactive Compounds, Medicinal

Introduction

Macrofungi (Mushroom) with their natural fineness have always held a unique place in this biological world. From the tropics to the poles, from the top of the mountains to the depths of the ocean, the expansion of the wild mushroom is ubiquitous. They can colonize, multiply, and survive in a wide range of habitats, including water, air, soil, foam, dung, litter, hair, paints, textiles, and others. It is notable that mushrooms are an attractive group of organisms that play an important role in human life apart from their use in medicine, agriculture sector, textile manufacturing, food processing, bioremediation, biofertilizers, and geochemical cycles (Srivastava 2021) [73].

There are many types of varieties of mushrooms, including bracket mushrooms, fairy clubs, toadstools, puffballs, morels, truffles, stinkhorns, earthstars, agarics, hedge-hog fungi, bird's nest mushrooms, and jelly mushrooms. Mushrooms, like all fungi, are non-green creatures that lack chlorophyll. They are unable to produce their own sustenance from simple inorganic components such as water, carbon dioxide, and nitrates utilizing solar energy, as green plants do. They feed on complex organic compounds found in plant and animal tissues, both dead and alive. Saprophytic fungi are those that obtain their nutrients from decaying organic debris, such as crop residues, dead tree timber, animal faeces, and so on. Parasitic fungus is those that get their sustenance from living things while inflicting harm to their hosts. The fungi can also live inside the nests of termites or around the roots of grasses or trees, such as pines, as part of a special type of partnership in which the member of the fungus enjoys the benefits of the other member. Additionally, certain fungi share a close physiological relationship with the plants and animals that serve as their hosts (e.g. those which live inside the nests of termites or mushrooms living in association with the roots of some grasses or trees like pines). These are known as mutualistic symbiotic fungi (Ao *et al.* 2016; Ukwuru *et al*. 2018) [6, 61].

Mushrooms are important in forest ecology because they aid in the decomposition of dead plants and animals, such as dead trees, branches, leaves, fruits, seeds, and animal droppings. 90% of dead plants in organic soil are made up of wood with cellulose and lignin, which means they decompose slowly. During the natural forest growth cycle, mushrooms produce an enzyme that breaks down these substances more quickly and creates nutrients for plants and microorganisms.

Approximately 130 million years ago, fossil evidence indicates mushrooms existed during the lower Cretaceous period (Bilal 2010). Anthropological observations show that hunters and food gatherers used mushrooms as a source of food or medication. Around 4600 years ago, the ancient Egyptians called mushrooms "the plant of immortality" because they were a delectable food that the kings and queens loved. Theophrastus, a Greek philosopher who lived between 372-287 BC, recorded the first account of its use as a royal meal (Reddy 2015) [74].

According to "Rig Veda," mushrooms were used in various religious rituals by Aryans throughout the Indus civilization for their hallucinogenic properties. During ancient times, poisonous mushrooms were called "soma", which were harvested by tribes in the Indus valley (Heinrich 2002). Ancient people and primitive tribes have used mushrooms in religious ceremonies for centuries. It is believed that mushrooms had properties that could grant supernatural meanders, can assist in locating lost items, and can be able to covey the soul to the gods, according to the Romans (Grube *et al.* 2001) [75].

The mushrooms are eukaryotic, aerobic, non-photosynthetic macrofungi that produce distinctive fruiting bodies. All mushrooms, which are members of the Fifth Kingdom, are heterotrophic, meaning that they break down complex organic polymers like celluloses into simple molecules that they then absorb as nourishment. According to taxonomy, mushrooms can be divided into two groups: Ascomycetes and Basidiomycetes, which together make up most of the recognized genera (Gogoi and Parkash 2015) [28]. There are over 0.14 million different species of mushrooms around the globe. 14,000 of them are known, and 7,000 are thought to be edible to varying degrees. Over 2,000 species are secured and 700 have significant pharmacological activities that have been recorded (Thatoi and Singdevsachan 2014) [57].

Mushrooms have been utilized in traditional remedies for thousands of years. Some of them can produce bioactive molecules, while others are nutraceuticals. There are many health benefits to mushrooms, including wound healing, stress reduction, rheumatoid arthritis, asthma, diabetes, liver disease, diaphoretic, epilepsy, heart ailments, skin diseases, insomnia, cholesterol reduction, allergies, cholera, colds, diarrhea, dysentery, anesthesia, gall bladder illness, and vermicides (Chugh *et al.* 2022; El-Ramady *et al.* 2022) [20, 25]. These are an important source of protein found in nature, having a protein level that is higher than that of most vegetables but lower than that of most meats and milk.

Mushrooms as a Food

There are over 200 genera of wild mushrooms and some species are useful to humans, primarily due to their edible characteristics. Rural communities in numerous nations treasure wild fungi with medicinal characteristics; however, this is of secondary importance. There are two main groups of edible wild fungi: those with widely consumed species (e.g. *Boletus* and *Cantharellus*) that are often exported in significant quantities, and those whose species are commonly consumed (usually in little amounts) but seldom traded beyond national borders. Edible mushrooms have a high nutritional content, which is why they are eaten for their nutritional and therapeutic properties.

There is increasing interest in edible mushrooms as the need for novel types of food varieties is increasing day by day and the demand for alternative sources of income is increasing in rural communities as well (Pilz and Molina 2002) [46]. More individuals than ever are "foraging" mushrooms in Asia, Europe, and North America, restoring mushroom traditions that have been diluted by urbanization and posing new challenges for long-term production.

Harvesting commercially important wild species such as matsutake (*Tricholoma spp*. morels (*Morchella spp*.), truffles (*Tuber spp*.), *Lactarius species* (e.g., *L. deliciosus*) and, boletes (*Boletus spp*.) is a lucrative industry in many nations and a vital source of earnings for collectors and his families (DeRoman and Boa 2006) [22].

Mushrooms as Medicinal Uses

Medicinal mushrooms, like medicinal plants, are macroscopic fungi, primarily higher Basidiomycetes are used as extracts or powders to treat, prevent, or cure disease as well as complete nourishment. Dried fruit bodies are "herbal drugs," while mycelia or spores are "mushroom drugs" or "fungal drugs." Medicinal mushroom preparations should be classified as "mushroom pharmaceuticals" or "mushroom preparations" in the same way as "phytopharmaceuticals" or "herbal preparations" are classified. Humankind has long regarded mushrooms as both edible and medicinal.

It is well known the use of medicinal mushrooms in traditional medicine dates back many centuries. Much of the ancient information has been confirmed and proven by modern studies. In the last three decades, the interdisciplinary field of science that investigates medicinal mushrooms has grown and demonstrated increasingly effective and distinctive capabilities of chemicals derived from a variety of mushroom species. Mushroom-derived medications are used in modern therapeutic practise in Japan, People's Republic of China, Republic of Korea, Russian Federation, and a number of other nations (Wasser 2010a) [71].

Mushrooms have a very long time used in Chinese conventional remedies and in Eastern countries. The interest in studies on their effects on human health, however, has just recently emerged, particularly in Europe. Furthermore, consumers' focus is gradually shifting to the function that including mushrooms in one's diet can play in enhancing wellness and lowering the risk of getting sick (Grundemann *et al*. 2020) [31]. Historically, mushrooms have been used in both food and medicine in Asian countries because of their benefits to physical well-being and their ability to prevent and cure various diseases, including cancer, hypertension, cardiovascular diseases, neuropathies, etc.

Studies in Asia and fellow Europe in recent years suggest that the chemicals found in mushrooms have many beneficial effects on humans and animals. According to (Fernades *et al*. 2015) Dietary fibre from mushrooms helps reduce diabetes, cardiovascular disease, haemorrhoids, colon diseases, and constipation as well as enhancing digestive tract efficiency and insulin and cholesterol metabolism. It also contains anti-tumor properties and improves the immune system. However, the bioactive compounds found in mushrooms, as well as their potential applications, are vast and varied.

Biological response modifiers (BRMs), antitumor mushroom medications, These drugs are used to reduce the side effects of cancer in patients undergoing radiotherapy or chemotherapy so as to improve the lives of patients suffering from these diseases (Cateni *et al*. 2021) [14].

Wild Mushroom extracts contain polysaccharides, *Lentinan,* isolated from *Lentinula edodes* (Berk.) Pegler, Ganoderan from *Ganoderma lucidum* (Curtis) P. Karst., Schizopyllan (Sonifilan, Sizofiran, or SPG) from *Schizophyllum commune* Fr Krestin (PSK), and PSP (polysaccharide peptide) from *Trametes versicolor* (L.) Lloyd, Befungin from *Inonotus obliquus* (Fr.) Pila´t, and Imunoglukan P4H (pleuran) from *Pleurotus ostreatus* (Jacq.) P. Kumm, Grifolan from *Grifola frondosa* (Dicks.) Gray (Wasser 2014) [70]. The consumption of medicinal mushrooms on a daily basis as part of a balanced diet has also been shown to be advantageous. Mushroom is available in the market in the form of many different food supplements like powders form, liquid form, tablets form, and dried form which are used to strengthen the body's immune system. Bonanno *et al.* 2019 found that the inclusion of wild mushrooms in the diet of Sheep increased its milk quantity and improved its quality. According to Bederskaojewska *et al*. 2017 feeding edible Basidiomycetes to broiler chickens and laying hens enhances their productivity and physiological performance.

Mushroom Poisoning

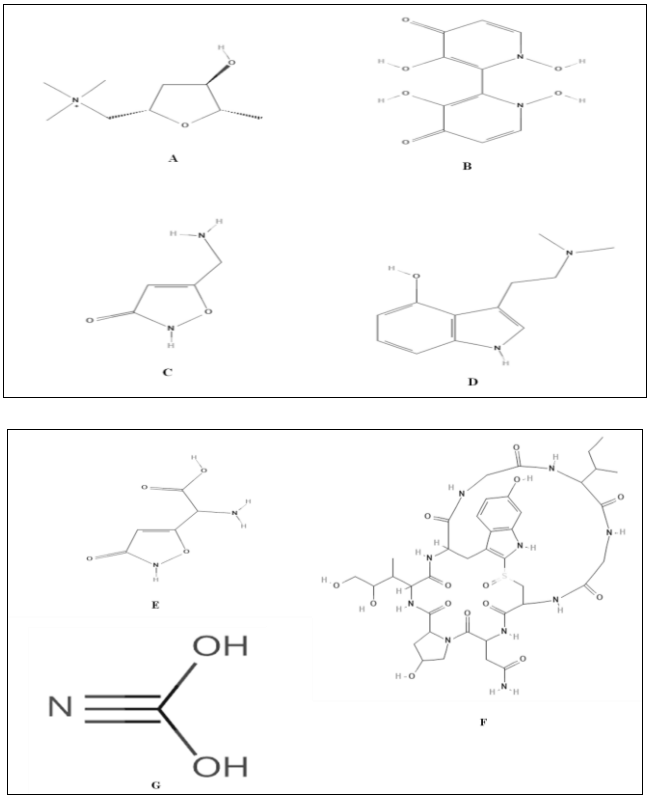
It is not possible to tell whether a mushroom is edible or not until it is properly identified. Less than 1% of all known mushrooms are poisonous, making them a potentially harmful and even fatal species. Therefore, before being consumed, mushrooms should be identified by certified mycological experts. As a result, before consuming a mushroom, one must be completely certain that it is edible. Several mushroom poisoning cases have been reported in recent years. There is no proof that the number of these data has considerably grown on a global scale, despite the fact that social media and the internet make it easier to share information, there is no doubt that fears about eating wild mushrooms have spiked due to the ease of sharing.

Table 1: List of poisonous mushrooms based on toxins and clinical symptoms **(**El-Ramady *et al*. 2022) [25]

Poisonous Mushrooms species	Toxins	Clinical symptoms	sites of poisoning
Clitocybe cerussata	Muscarin (neurotoxic)	Respiratory failure, lacrimation, diarrhea, vomiting	Nervous system
Amanita muscaria, Amanita pantherina, Amanita gemmate, Amanita virosa	Ibotenic acid (neuro toxic)	▪ Neurotoxicity, The nervous system becomes overexcited and depressed (coma, delirium, daze, anxiety, perturbation, delusion, and seizures)	▪ CNS
Psilocybe caerulescens, Psilocybe cubensis, Psilocybe Mexicana, Psilocybe semilanceata, Panaeolus cinctulus, Conocybe cyanopus	Psilocin (Neurotoxic)	Hallucinogenic, Euphoria, increase blood pressure, mydriasi (Dilated Pupils), and shivers	CNS
Amanita muscaria, Amanita pantherina	Muscimol (Neurotoxic)	Hallucinogenic, fever	CNS
Tricholoma pardalotum, Cortinarius orellanus, Chlorophyllum molybdites, Chrysina macropus, Amanita pseudoporphyria	Orellanine (Cytotoxic)	Gastroenteritis, Fibrosis of the intestinal cells and oedema, nephrotoxic	GIT & Kidney
Amanita smithiana, Russula subnigricans	Russuphelins (Myotoxic)	Renal failure	Kidney
Rubroboletus satanas, Rubroboletus legaliae	Bolesatine (Myotoxic)	vomiting, nausea, gastrointestinal irritation	Kidney, GIT
Amanita exitialis, Amanita phalloides, Amanita verna,	α-amanitin (Cytotoxic)	Nephrotoxic and Hepatotoxic consequences	Kidney & Liver
Paralepistopsis amoenolens, Clitocybe acromelalga	Acromelic acid	Syndrome resembling erythromelalgia characterised by burning, edoema, and redness in the extremities	Peripheral nerves & skin
Pleurotus eringii	Hydro-Cyanic Acid	Chronic renal failure, comma	Kidney

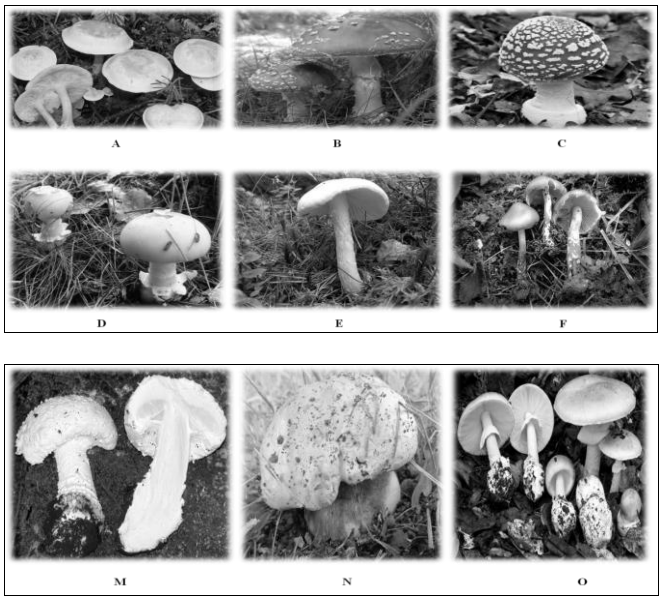
*CNS = Central nervous system, GIT = Gastrointestinal tract

Each year, between 200 and 250 people are poisoned by mushrooms, according to (Govorushko *et al*. 2019) [30]. Furthermore, according to Chen *et al*. 2014, 1,954 poisoning cases and 409 deaths in China were documented between 2000 and 2014. In addition to peer-reviewed papers, field guides, newsletters of mycological and nature societies, and formal publications, articles on both edible and lethal mushrooms are frequently seen in a multitude of journals. There are numerous websites that offer advice on which mushrooms to eat and which to avoid, but the information is sometimes inconsistent and contradictory. Those who have a long history of consuming wild mushrooms are frequently more daring in their choice of species. Fewer wild species are ingested where this tradition is weak or missing, and there is a greater inclination to categorize species as dubious, inedible, or avoidable. Field guides are an excellent storehouse of knowledge for naturalists and forest dwellers as they cover a wide geographical area, and integrate accurate information about edible or poisonous mushrooms (Wang *et al*. 2004) [69]. Ethnomycology studies provide extensive field knowledge for wild mushrooms found in particular regions.



Sources: Pubchem

Fig 1: Chemical structures of wild mushrooms toxins: A- Muscarin; B- Orellanine; C-Muscimol; D-Psilocin; E-Ibotenic acid; F-α-amanitin; G- Hydro-Cyanic Acid



Sources: www.first-nature.com, MushroomExpert.Com, www. http //commons.wikimedia.org, http://www.mykoweb.com, https:// www.iNaturalist

Fig 2: List of some poisonous wild Macrofungi: A- Clitocybe cerussata; B - Amanita muscaria; C - Amanita pantherina; D – Amanita gemmate; E -Amanita virosa; F -Psilocybe caerulescens; G - Psilocybe cubensis; H -Psilocybe Mexicana; I - Amanita muscaria; J - Cortinarius orellanus; K - Chlorophyllum molybdites; L - Amanita pseudoporphyria; M - Amanita smithiana; N - Rubroboletus satanas; O - Amanita phalloides-

An overview of diagnostic clues in mushroom poisoning

There is always the possibility of delays in diagnosis and treatment due to the lack of experience and marginal exposure to the subject during medical training. Therefore, it is important to be aware of the clinical aspects of mushroom poisoning and to have reliable sources of information on mushroom species and toxicity. Early diagnosis and treatment are essential for a positive outcome. Clinical signs of mushroom poisoning can include nausea, vomiting, diarrhea, abdominal pain, and dizziness. It is important to be aware of the signs and symptoms of mushroom poisoning in order to start treatment as soon as possible. Early treatment

can be lifesaving. The diagnosis of mushroom poisoning is based on a few pillars. Identifying the mushrooms eaten and the time interval between eating the mushroom and the onset of symptoms. and confirmation by laboratory testing, if available. The best way to make a diagnosis is to microscopically and macroscpically identify eaten or uneaten or leftover mushrooms (The description gives detailed information about the size, shape, color, texture, length, width, and strength of all parts of the fruiting body. As such some of the characteristics are recorded as follows, cap – color, shape, size, texture, details of margins, whether or not there is a presence of veil remnants, etc. gills – the color of gills, are they attached to the stem or not, the shape and size of the margins of the gills. Pores – color, shape, size, whether they are attached to the stem, whether bruising occurs and what color it becomes, whether the tubes and the pores are of different colors, etc. Stem – stem color, shape, size, texture, details of the veil remnants, presence of mycelium at the base or not. Spore print- whether there is the presence or absence of spores on the cap or stem). Spore are detected microscopically in vomit or stool from eaten mushrooms and this identification is performed by a mushroom expert. Other methods of identification include where the mushrooms were collected, what condition they were in, and how they were stored. Are many species grouped together or separately. How the mushrooms were cooked. All these points can be helpful in identification.

Table 2: Information sheets that assist in identification and diagnosis (Wennig *et al.* 2020) [72]

Important information for identification wild mushrooms
Location of specimen examined ……
Possible Species Name ……..
Date of collection ……..
Collection Number …….
Elevation range ……..
Latitude and *Longitude* ……
Habitat…… Soil, wood, decaying matter, leaf litter etc……...
Basidiocarp or Ascocarp / Pileus/ Cap…….Diameter, shape, size (young/mature/convex/depressed/uplifted/papillate), colour, colour change (any changes cut or bruised), hygrophanous, margin (smooth/ rough/striate), texture (hairy, dry, smooth, moist, fibrous)……
Stipe/ stem…… Length, width, texture, shape, size, colour, colour change (any changes cut or bruised)
Volva……. …….Presence or Absence, color, texture …….
Lamellae/gills /pores…… Presence or Absence, color, texture, margin (smooth/spiked / undulated /scalloped), attachment (decurrent/adnate/ ripply /sinuate), spacing (close/crowded/distant)……..
Odour…….. apricot, pleasant, unpleasant smell, strong, mild, earthy smell, easty, fruity, metallic, bready, etc……..
Spore print……colour……..
Important information for diagnosis after eating poisonous mushrooms
Patient name ……
Unique Identifier Number……
Age ……
Sex……..
Contact No……..
Sample collection time and date ……
Method of transportation and storage of mushroom ……..
Macroscopic identification- mushroom color, gills, stem, cap, pore size etc……..
Microscopic identification- spore deduction in vomit, and stool sample…….
The nature of the place from where the mushrooms were collected (deciduous forest, Mixed forest, coniferous forest, meadow) ……..
How were the mushrooms cooked (mushroom cooked well or not)……..
Sign and Symptoms (headache, salivation, perspiration, nausea, diarrhea, vomiting, blurred vision, abdominal pain, difficulty in breathing)……

Diversity of mushrooms (Macrofungi) in India

It was the collections made by foreign visitors in the nineteenth century of fungi from different parts of India that led to the study and collection of Indian fungi. It sent the collected samples to several European laboratories for character analysis and identification. Hooker and Thompson were the forerunners in doing a more thorough and systematic study of Indian fungus. They gathered a large number of fungus in India. They had a huge number of *Agarics* from the Eastern Himalayas in their collection, which Berkeley reported subsequently. Cunningham (1875-97) deserves special note since he was the first to investigate Indian fungi in India, the fungus thus collected by him was sent abroad to be identified and studies. Butler and Bisby's 1931 scientific monograph, 'Fungus of India,' contains a list of Indian fungi as well as a host index of harmful fungi. Bose focused his research activities on the fleshy fungus and Polyporaceae of Bengal, and has worked on the geographical distribution of Bengal polypores, their history, and the occurrence of their high altitudes. Bose was one of the first researchers to look for antibiotics in higher fungus.

In India, the prehistoric medical treatise Charaka Samhita (3000–500 B.C.) mentions the use of mushrooms as food and medicine (Tripathi *et al*. 2017) [60].

India has a rich biodiversity of wild mushrooms which has proved to be a boon to the people in the form of medicine, unemployment, and food due to various medicinal and nutritional properties (Bilal 2010). There are 357 genera of Basidiomycetes worldwide, but 232 have been reported in India. It is estimated that in India about 1,200 kinds of mushrooms have been documented, of which 300 to 315 species are edible category (Dixit and Ekka 2021) [23]. There are numerous mushroom species in India, making it one of the top ten mega diversity sites. It is due to India's diverse

climate that mushrooms are a rich and diverse source of nontimber forest resources. Some wild mushroom species have been commercialized as food or medicine in Indian markets and are sold in traditional markets (Singha *et al.* 2020) [54].

Upadhyay *et al.* 2007 reported 28 new wild species of macrofungi from the North-Western Himalayas of India, distributed in 18 genera of 10 families of the order Agaricales. Some medicinally significant mushrooms were harvested and examined in the Garhwal region (Vishwakarma *et al.* 2011) [66]. In India and other parts of the world, they're used for therapeutic purposes. These species are *Agaricus campestris, Ganodermaleucidum, Morchella esculenta, Coprinus comatus, Cantharellus cibarius* and *Hydnum repandum*. In the Garhwal Himalayan districts of Pauri, Tehri, Chamoli, and Rudraprayag, Vishwakarma *et al.* 2012 identified 40 taxa belonging to 11 macrofungi families from distinct moist temperate forests. Local people and Tibetan residents in Dehradun, Uttarakhand, reported collecting edible mushrooms such as *T. heimii, R. lepida, T. eurrhizus, A. hygrometricus,* and *T. microcarpus* from sal (*Shorea robusta*) woodlands (Semwal *et al.* 2014) [52].

A total of 365 macrofungal specimens were gathered in the Adwani Forest in the Garhwal Himalaya, and 24 species, 12 genera, and 6 families were recognized (Bhatt *et al.* 2014). Singh *et al.* 2016 identified 15 species belonging to 12 genera and 8 families viz., *Amanita hemibapha, Boletus edulis, Strobilomyces floccopus, Cantharellus cibarius, Cantharellus minor, Craterellus cornucopioides, Hydnum repandum, Marasmius oreades, Grifola frondosa, Morchella esculenta, Lactarius deliciosus, Lactarius subindigo, Lactifluus hygrophoroides, Russula brevipes, Russula virescens.* Singh *et al.* 2017 collected many macrofungi like *Agaricus augustus, Chlorophyllum rachodes, Coprinus comatus, Macrolepiota procera, Cantharellus lateritius, Ramaria botrytis, Ramaria sanguine, Helvella crispa, Hericium coralloides, Hericium erinaceus, Pleurotus ostreatus, Laetiporus sulphureus, Psathyrella candolleana, Aleuria aurantia, Lactifluus volemus, Lactifluus corrugis, Russula cyanoxantha, Stropharia rugosoannulata, Stropharia rugosoannulata, Stropharia rugosoannulata, Tremella mesenterica* from Garhwal Himalayan region Uttarakhand.

Tripathi and his students started a major effort on macrofungi variety in Uttar Pradesh's northeastern region. They conducted a thorough survey of the area to learn more about the macrofungal diversity and assess its nutritional and medicinal value (Jha *et al*. 2011; Jha and Tripathi 2012 a,b,c; Chandrawati *et al.* 2014; Vishwakarma 2015) [32, 33, 34, 35, 15, 67]. *Ganoderma applanatum, G. lucidum, Hygrophorus eburnes, Laetiporus sulphureus, Lentineullus cochleatu, Lepiota organensis, Oudemansiella redicata and Schizophyllum commune, Cantharellus umbonatus, Clitocybe flaccida, Collybia butyracea, Coriolus versicolor, Galerina unicolor, Daldinia concentrica, Lycoperedon pyriforme, Scleroderma citrinum, and Agaricus campestris* were among the 17 macrofungi collected by (Chandulal *et al.* 2013) [16]. *Russula aurea, Russula atropurpurea, Suillus variegates, Boletus rhodoxanthus* macrofungi are recorded (Dar *et al.* 2010) [21].

Kumar *et al.* 2011 found wild fruiting bodies in North West Himalaya region of Jammu and Kashmir namely *Agaricus arvensis, Geopora arenicola, Boletus luridus, Morchella sp., Gyromitra sp., Pleurotus spp., Rhizopogon sp., Sepultaria sumneriana, Termitomyces sp., Sparassis sp., Boletus edulis, B. granulatus, Ramaria sp., Helvella sp., Clavulina sp., Coprinus comatusClavaria vermicularis, Ramaria sp., Macrolepiota procera.*

Five new species of macrofungi have been collected by Anand and Chowdhary 2013 namely *Scleroderma citrinum, Psilocybe subtropicalis, Ganoderma applanatum, Cyptotrama asprata,* and *Entoloma serrulatum.* Anand *et al.* 2014 gathered 120 mushroom samples in Jammu and Kashmir's Rajouri district. Lakhanpal contributed significantly to the study of Himachal Pradesh's macrofungi (Bhatt and Lakhanpal 1988 a,b; Sagar and Lakhanpal 1989) [8, 9, 51]. In the North West Himalayan region, (Lakhanpal 1995) [39] collected and identified 190 species of Agaricales. Chauhan *et al*. 2014 were reported 12 edible wild mushrooms, including *Agaricus campestris, Morchella conica, Helvella compressa Morchella deliciosa, Morchella esculenta, Ramaria botrytis, Rhizopogon vulgaris, Gyromitra sp., Sparassis crispa, Lycoperdon sp., Hygrophorus sp.,* and *Lactarius deliciosus.*

Chaudhary *et al.* 2016 were collected 54 sample from forests of Mandi, Kangra, Solan, Kullu,and Lahul Spiti districts from Himachal Pradesh, including *Tricholoma vaccinum, Tubaria furfuracea, Trametes sp., Pleurotus sp., Hygrocybe flavescens, Coprinus silvaticus, Macrolepiota procera, Agaricus sp., Panaeolus acuminatus, Aariscalpium sp., Bovista sp., Agrocybe sp., Pholiota populnea, Psathyrella multipedata, Panaeolus acuminatus, Pluteus aurantiorugosus, Clitocybe squamulosa, Agaricus sp., Coprinus sp., Gymnopilus sp., Tubaria furfuracea, Camarophyllus lacmus, Trametes sp., Chlorophyllum molybdites, Volvariella sp., Coprinellus sp., Pluteus salicinus, Boletus sp., Boletus sp., Tricholoma album, Coprinus neveus, Collybia confluens., Cantharellus cinereusTrametes sp., Ganoderma carnosum, Phellinus, inocybe geophylla, Gloeophyllum sp., Russula sp., Boletinus sp., Marasmium sp., Marasmium sp., Amanita battarae, Psilocybin sp., Lepiota sp., Trametes sp., Boletus sp., Gymnopus acervatus, Inonotus sp., Russula californiensis, Conocybe tenera* and *Ganoderma adspersum.*

Since the 1950s, Exploration of higher fungus has been largely emphasized in the northwest Himalaya. Paracer and Chahal were the first to report an edible *Agaricus* species*, Kbasianulosus,* from Punjab in the North-West Himalaya (1962). Rattan 1977 were collected 198 species of resupinate aphyllophoroid taxa from NorthWest Himalaya using the data from Thind and his colleagues on the Polyporaceae of India. Karwa and Rai 2010 were previously gathered 153 mushroom species from Central India (Maharashtra). Borkar *et al*. 2014 had collected *Agaricus trisulphuratus, Agaricus arvensis, Agaricus placomyces, Macrolepiota procera,* and *Leucocoprinus brinbaumii* of the Agaricaceae family from several locations in Konkan, Maharashtra. Many macrofungi were collected by Tagade and Kawale 2014 from Maharashtra's Koka and Chandpur forests, including *Daldinia concentrica, Coprinus comatus, Polyporus lucidus, Xylaria polymorpha, Marasmius delectans, Mycena sp., Dictyophora duplicata, Schizophyllum commune, Claveria stricta, Cantharellus infundibuliformis, Geaster fimbriatus, Lepiota americana, Clathrus cancellatus, Mutinus ravenelii.*

Dwivedi *et al*. 2012 gathered 50 macrofungi samples in Madhya Pradesh. Vyas *et al.* 2014 were collected 18

macrofungi from Patharia forest, Madhya Pradesh, belonging to 12 families viz., *Lycoperdon pyriform, Vacellum pretense, Clitocybe geotrapa, Microglossum virde, Coniophora puteana, Panaeolus sphinctrinus, Fomes fomentarius, Ganogerma tsugae, Tyomyces lacteus, Pleurotus cornucopiae, Hypholoma butyracea, Omphalina ericetorum,* and *Lenzites Betulina*. Macrofungi, including *Macrocybe lobayensis, Laccaria laccata, Lentinus sajor-caju Pleurotuseous, P. ostreatus, Russula adusta, Schizophyllum commune, Macrolepiota procera Agaricus bisporus* and *Boletellus ananas,* were collected in central India (Verma *et al.* 2017b; Verma and Verma 2017b; Verma and Pandro 2018a) [63, 64, 65].

Pradeep *et al.* 1998 were the first to explore the genus *Volvariella* from Kerala, India. Pradeep *et al.*1998 describe and illustrate for the first time *Volvariella taylori, Volvariella nigrodisca, Volvariella gandiformis* and *Volvariella apalotricha,* from Kerala, out of ten *Volvariella* species. According to Natarajan 1995 [42], of the southern Indian states that do not include Kerala, there are 230 types of agaric and bolete species. South India has contributed a large amount of work, such as Kerala, Karnataka, Tamil Nadu, and Andhra Pradesh. Swapna *et al.* 2008 were collected 778 species of macrofungi from Karnataka; they belonged to 101 genera and 43 families. *Ganoderma lucidum, Pleurotus florida, Pleurotus pulmonarius* and *Phellinus rimosus* are therapeutic mushrooms obtained from South India, according to (Ajith and Janardhanan 2007) [1].

Diversity of different types of wild mushrooms vicinity of Bangalore was studied by Pushpa and Purushothama 2012, who categorized 90 species in 48 genera belonging to 19 families in 5 orders. Xylaria was collected by Ramesh *et al.* 2012, and about 23 macrofungi were identified by Thiribhuvanamala *et al.* 2013 in the Western Ghat region of Tamil Nadu. In Kerala, twelve species of Russula were discovered, including some edible ones (*R. congoana*) (Mohanan 2014) [40]. By Akash *et al.* 2017 some wild macrofungi found in Biligiri rangana hills of Karnataka viz., *Termitomyces sp., Auricularia delicate, Termitomyces microcarpus, Podoscypha petalodes, Calvatiaholo thurioides, Gymnopilus crociphyllus, Coprinus comatus, Gyrodontium sacchari, Clitocybeaff fellea.*

The edible mushrooms *Agaricus sp., Pleurotus sp.,* and *Coprinus sp.* were found in Rajasthan, (Singh 1977) [53]. 12 genera and 43 species of mushroom were found in Nag *et al.*1991 Jaipur district. In 1997 Doshi and Sharma enumerated 173 species from 95 different genera of macro-fungi in Rajasthan, including *Agricales, Aphyllophorales, Gastromycetes*, and *Dacrymycetales.* Gehlot *et al.* 2014 were reported many wild mushrooms in Thar desert, Rajasthan, viz., *Hygrophoropsis aurantiaca, Volvariella earlei, Volvariella pusilla, Pluteus subcervinus, Termitomyces eurhizus, Termitomyces tyleranus, Clitocybe dealbata, Marasmius confetus, Hemimycena pithya, Macrolepiota exocortiata, Agaricus augustus, Agaricus silvicola, Lepiota mericana, Coprinus extinctorius, Coprinus sterquilinus, Pholiota squarrosa, Stropharia semiglobata, Crepidotus quitensis*.

Meghalaya has been reported to have edible wild mushrooms such as *Boletus edulis, Clavaria aurea, Clavaria Cinerea, Lentinus edodes, Clavaria spp.,* and *Cantharllus floccosus,* consumed by the local inhabitants since ancient times. In the wild forests of the Khasi Hills in Meghalaya, *Cantharellus cibarius, Agaricus biosporus, Clavaria flava, Lactarious volemus, Gomphus floccossus,* and *Ramaria boyryt* have been recorded with local names (Das *et al.* 2014). Eleven edible wild fruit body were gathered and identified from the Meghalaya realm by Kalita *et al.* 2016 like *Suillus bovinus, Armillaria mellea, Laccaria laccata, Lactarius deliciosus, Lactarius indigo, Gomphus floccosus, Russula parvovirescens, Ramaria formosa, Boletus edulis, Lactarius rubidus* and *Lentinus edodes* that belong to 7 families.

Locals sell edible species such as *Lentinus conatus, Termitomyces eurrhizus, Tricholoma giganteum, Schizophyllum commune,* and *Pleurotus* at the marketplaces of Nagaland's Kohima region (Tanti *et al.* 2011). *Lentinula edodes, L. sajor-caju, Lentinus squarrosulus, Lactarius volemus, L. tigrinus, T. heimii, T. microcarpus, T.eurhizus, A. auricula-judae, S. commune, A. polytricha, P. pulmonarius, Pleurotus ostreatus*, etc are some of the most commonly sold edible wild mushrooms in Nagaland every year (Toshinungla *et al*. 2016) [59]. In Nagaland, Ao and Deb 2019 studied ten different varieties of wild mushrooms isolated and determine their antioxidant and nutritional properties.

In Nagaland, 87 different kinds of wild mushrooms were gathered and documented by Toshinungla *et al.* 2016 [59]. Out of the collected macrofungi, 37 species were found to be edible, 21 species for medical purposes, 5 poisonous, and 37 others inedible or unclassified.

Gogoi and Sarma 2012 have found 12 species of macrofungi in the Dhemaji area of Assam. The authors Saharia and Sarma, 2012 reported 50 morphotypes of macrofungi responsible for post-harvest bamboo decay in Assam, including *Cyathus striatus, Clavaria cristata,* and *Rhizopogon lutiolus.* Gogoi and Vipin 2015 found 22 gasteroid fungi in the Hollongapar Gibbon Wildlife Sanctuary, Jorhat, Assam, they belong to 9 genera, 4 families, 4 orders, viz., *Phallus indusiatus, Phallus duplicatu, Phallus merulinus, Mutinus bambusinus, Clathrus delicates, Scleroderma cepa, Calvatia cyathiformi, Bovista longispora, Bovista dermoxantha,* etc. Gogoi and Parkash 2015 compiled a list of the gilled mushrooms found in the Hollongapar Gibbon Wildlife Sanctuary. Devi and Shrivastava 2016 investigated the macrofungal diversity in Kamrup district, Assam's Jalukbari Reserve Forest. Researchers Parveen *et al.* 2017 studied the biodiversity of macrofungi in Assam and their habitat characteristic. From Nagaon's Kaliabar sub-division, Assam, Nath and Sarma 2018 reported several edible macrofungi. Paul *et al.* 2019 recorded 82 macrofungi species belonging to 51 genera, 34 families, and 12 orders in some districts of Assam. Datta *et al*. 2025 found a new species *Hericium indicum* in Bageshwar Uttarakhand.

Table 4: List of some species of macrofungi recorded in different regions of India

S. No	Name of the species	Region	Reference / investigator
1	*Amanita albocreata*	Uttarakhand	(Bhatt *et al.*1999)
2	*Amanita concentric*	Uttarakhand	(Bhatt *et al.*2003)
3	*Russula compacta*	Uttarakhand	(Das and Sharma 2004)
4	*Amanita avellaneosquamoso*	Uttarakhand	(Semwal *et al.* 2006)
5	*Lactarius mukteswaricus*	Uttarakhand	(Das *et al.* 2004)
6	*Inonotus ryvardenii*	Uttarakhand	(Sharma *et al.* 2013)
7	*Cortinarius cf. distans*	Uttarakhand	(Semwal *et al.* 2018)
8	*Amanita cokeri*	Uttarakhand	(Bhatt and Bhatt 1996)
9	*Amanita grisofolia*	Uttarakhand	(Bhatt *et al.* 2017)
10	Agaricus basianulosus	Panjab	(Pracer and Chahal 1962)
11	*Fomes lignosus & Polyporus zonalis*	Uttarakhand	(Bakshi *et al.*1963)
12	*Auricularia, Lepiota, Phellorina*	Rajasthan	(Sharma *et al.*1992)
13	*Macrolepiota procera, M. rhacodes*	Uttar Pradesh	(Ghosh and Pathak 1965)
14	*Coprinus comatus*	Uttar Pradesh	(Jha *et al.* 2011) [32]
15	*Ganoderma Appalantum*	Uttar Pradesh	(Jha *et al.* 2011) [32]
16	*Coprinus, Morchella, Pleurotus*,etc.	Jammu and Kashmir	(Kaul and Kachroo 1974)
17	*Agaricus arvensis & Boletus crocatus*	Gujarat	(Moses 1948)
18	*Cantharellus aurantiacus*	Bengal	(Bose and Bose 1940)
19	*Boletus edulis*	Himachal Pradesh	(Bhatt and Lakhanpal 1988a) [8]
20	*Coprinus comatus*	Bengal	(Bose and Bose 1940)
21	*Lactarius hygrophoroides*	Himachal Pradesh	(Bhatt and Lakhanpal 1988b) [9]
22	*Russula crustosa*	Himachal Pradesh	(Bhatt and Lakhanpal 1988c)
23	*Amanita fulvaurantia*	Himachal Pradesh	(Kumar *et al.* 1990)
24	*Amanita konkanensis*	Maharashtra	(Kulkarni 1992)
25	*Amanita magniverrucata*	Kerala	(Pradeep and Vrinda 2010)
26	*Amanita ovalispora*	Odisha	(Das and Sinha 1990)
27	*Amanita phalloides*	Kerala	(Vrinda *et al.* 2005b)
27	*Amanita pilosella*	Himachal Pradesh	(Singh and Kaur 2016b)
29	*Amanita pseudovaginata*	Uttarakhand	(Bhatt *et al.* 2003)
30	*Amanita sampajensis*	Karnataka	(Sathe *et al.*1980)
31	*Amanita solitaria*	Kerala	(Bhavanidevi and Nair 1983)
32	*Amanita subvaginata*	Odisha	(Dhancholia 1989)
33	*Calvatia and Lycoperdon*	West Bengal	(Gupta *et al.*1974)
34	*Cantharellus luteocomus*	Kerala	(Joseph *et al.* 2015)
35	*Morchella conica*	Madhya Pradesh	(Rai *et al.* 1999)
36	*Agaric species*	Kerala	(Vrinda *et al.* 2001)
37	*Pleurotus tuber-regium*	Kerala	(Geetha *et al.* 2002)
38	*Holtermania dimorphobasidiae*	Maharashtra	(Mahamulkar *et al.* 2002)
39	*Sebacioa microbasidiae*	Maharashtra	(Mahamulkar *et al.* 2002)
40	*Termitomyces umkowaanii*	Kerala	(Vrinda *et al.* 2002)
41	*Amanita caesarea*	Kerala	(Vrinda *et al.* 2005)
42	*Sinotermitomyces zang*	Punjab	(Atri and Kaur 2003)
43	*Agrocybe putaminum*	NWH	(Upadhyay and Kaur 2003)
44	*Collybia butyracea*	NWH	(Upadhyay and Kaur 2003)
45	*Russula compacta*	Uttarakhand	(Das and Sharma 2004)
46	*Leucocoprinus biornatu*	Kerala	(Vrinda *et al.* 2003)
47	*Leucocoprinus venezuelanus*	Kerala	(Vrinda *et al.* 2003)
48	*Leucocoprinus croceovelutinus*	Kerala	(Deepa *et al.* 2006a)
49	*Leucocoprinus jubilaei*	Kerala	(Deepa *et al.* 2006a)
50	*Leucocoprinus lilacinogranulosus*	Kerala	(Deepa *et al.* 2006a)
51	*Amanita avellaneosquamoso*	Uttarakhand	(Semwal *et al.* 2006)
52	*Fomes fomentarius*	Jammu and Kashmir	(Kumar and Sharma 2008)
53	*Pseudocolus grandis*	Puducherry	(Kumaresan *et al.* 2008)
54	*Morchella esculenta*	Kerala	(Kaviyarasan *et al.* 2006)
55	*Macrocybe lobayensis*	Kerala	(Vrinda and Pradeep 2006)
56	*Favolaschia tonkinensis*	Kerala	(Pradeep *et al.* 2008)
57	*Bovista aestivalis*	Karnataka	(Syed *et al.* 2008)
58	*Calvatia craniiformis*	Karnataka	(Syed *et al.* 2008)
59	*Psathyrella velutina*	Kerala	(Vrinda *et al.* 2008)
60	*Conocybe brachypodii*	Punjab	(Atri *et al.* 2009)
61	*Bolbitius titubans*	Punjab	(Atri *et al.* 2009)
62	*Agaricus, Russula, Boletus, Tuber, Volvariella*	Chattisgarh	(Thakur and Chandravanshi 2009)
63	*Podaxis pistillaris*	Central India	(Sharma *et al.* 2009a)
64	*Leucocoprinus birnbaumii*	West Bengal	(Dutta *et al.* 2011)
65	*Agaricus campestris*	Uttarakhand	(Vishwakarma *et al.* 2011) [66]
66	*Cantharellus cibarius*	Uttarakhand	(Vishwakarma *et al.* 2011) [66]
67	*Boletus rhodoxanthus*	Kashmir	(Dar *et al.* 2010) [21]

68	*Russula atropurpurea*	Kashmir	(Dar *et al.* 2010) [21]
69	*Sinotermitomyces taiwanensis*	Karnataka	(Abolfazl and Janardhana. 2011)
70	*Clitocybe gibba*	Jammu and Kashmir	(Beig *et al.* 2011)
71	*Collybia subsulphurea*	Jammu and Kashmir	(Beig *et al.* 2011)
72	*Cortinarius bulliardii*	Jammu and Kashmir	(Beig *et al.* 2011)
73	*Peziza boltonii*	Jammu and Kashmir	(Beig *et al.* 2011)
74	*Amanita hemibapha*	Kerala	(Vrinda *et al.* 2005)
75	*Mycena saparna*	Kerala	(Aravindakshan and Manimohan 2012)
76	*Mycena deeptha*	Kerala	(Aravindakshan *et al.* 2012)
77	*Poronia pileiformis*	Kerala	(Deepna and Manimohan 2012)
78	*Boletus fallax*	Madhya Pradesh	(Pyasi *et al.* 2012)
79	*Bolbitius coprophilus*	Punjab	(Amandeep *et al.* 2013a)
80	*Bolbitius vitellinus*	Punjab	(Amandeep *et al.* 2013a)
81	*Agaricus nivescens*	Tamil Nadu	(Sousa *et al.* 2012)
82	*Calocybe gambosa*	Tamil Nadu	(Sousa *et al.* 2012)
83	*Panaeolus papilionaceusare*	Tamil Nadu	(Sousa *et al.* 2012)
84	*Boletus rubripes*	Sikkim	(Das 2013a)
85	*Retiboletus ornatipes*	Sikkim	(Das 2013b)
86	*Strobilomyces echinocephalus*	Jammu and Kashmir	(Kour *et al.* 2013)
87	*Strobilomyces mollis*	Jammu and Kashmir	(Kour *et al.* 2013)
88	*Russula dubdiana*	Sikkim	(Das *et al.* 2013)
89	*Russula sharmae*	Sikkim	(Das *et al.* 2013)
90	*Russula sikkimensis*	Sikkim	(Das *et al.* 2013)
91	*Lepiota truncastispora*	Himachal Pradesh	(Kumari *et al.* 2013a)
92	*Lepiota humei*	Himachal Pradesh	(Kumari *et al.* 2013a)
93	*Lepiota castaneidisca*	Himachal Pradesh	(Kumari *et al.* 2013a)
94	*Auricularia olivaceus*	Himachal Pradesh	(Kumari *et al.* 2013b)
95	*Morchella*	Rajasthan	(Paliwal *et al.* 2013)
96	*Agaricus arvensis, A. placomyces*	Maharashtra	(Borkar *et al.* 2014) [13]
97	*Conocybe albipes*	Punjab	(Amandeep *et al.* 2015)
98	*Conocybe apala*	Punjab	(Amandeep *et al.* 2015)
99	*Conocybe brachypodii*	Punjab	(Amandeep *et al.* 2015)
100	*Agaricus abruptibulbus*	Sikkim	(Das and Chakraborty 2014)
101	*Leccinum Insigne*	Sikkim	(Das and Chakraborty 2014)
102	*Leccinum scabrum*	Sikkim	(Das and Chakraborty 2014)
103	*Russula shingbaensis and R. thindii*	Sikkim	(Das *et al.* 2014)
104	*Gymnopilus pampeanus*	Punjab	(Kaur *et al.* 2015)
105	*Gymnopilus russipes*	Punjab	(Kaur *et al.* 2015)
106	*Geastrum fimbriatum*	Western Ghats	(Karun and Sridhar 2014)
107	*Panaeolus cyanoannulatus*	Punjab	(Amandeep *et al.* 2014a)
108	*Panaeolus lepus-stercus*	Punjab	(Amandeep *et al.* 2014a)
109	*Agaricus stellatuscuticus*	Punjab	(Amandeep *et al.* 2014b)
110	*Agaricus flavistipus*	Punjab	(Amandeep *et al.* 2014b)
111	*Saproamanita flavofloccosa*	Tamil Nadu	(Purushothama and Natrajan 1987)
112	*Saproamanita vittadinii*	Jammu and Kashmir	(Abraham and Kachroo 1989)
113	*Geastrum pseudostriatum*	Western Ghats	(Karun and Sridhar 2014)
114	*Geastrum lageniforme*	Western Ghats	(Karun and Sridhar 2014)
115	*Cyptotrama asprata*	Uttarakhand	(Semwal *et al.* 2018)
116	*Amanita manicata*	Uttarakhand	(Semwal *et al.* 2018)
117	*Lactarius sanjappae*	Uttarakhand	(Das *et al.* 2004)
118	*Lactarius verbekenae*	Uttarakhand	(Das *et al.* 2004)
119	*Aureoboletus nephrosporus*	Sikkim	(Chakraborty *et al.* 2017)
120	*Strobilomyces mirandus*	Sikkim	(Chakraborty *et al.* 2017)
121	*Agaricus campestris*	Uttarakhand	(Bhatt *et al.* 2018)
122	*Boletus edulis*	Uttarakhand	(Bhatt *et al.* 2018)
123	*Cordyceps militaris*	Uttarakhand	(Bhatt *et al.* 2018)
124	*Hericium erinaceus*	Uttarakhand	(Bhatt *et al.* 2018)
125	*Grifola frondosa*	Uttarakhand	(Bhatt *et al.* 2018)
126	*Schizophyllum commune*	Tripura	(Debnath *et al.* 2017)
127	*Lentinus squarrosulus*	Tripura	(Roy *et al.* 2017)
128	*Lentinus tuber-regium*	Tripura	(Roy *et al.* 2017)
129	*Amanita spissacea*	Mizoram	(Lalrinawmi *et al.* 2018)
130	*Pleurotus pulmonarius*	Arunachal Pradesh	(Deb and Singh 2013)
131	*Volvariella bombycena*	Arunachal Pradesh	(Deb and Singh 2013)
132	*Ganoderma applanatum*	Himachal Pradesh	(Pathania and Chander 2018)
133	*Calvatia Species*	Central India	(Verma *et al.* 2018) [65]
134	*Daldinia concentrica*	Gujarat	(Korat *et al.* 2013)
135	*Lycoperedon pyriforme*	Gujarat	(Korat *et al.* 2013)
136	*Scleroderma citrinum*	Gujarat	(Korat *et al.* 2013)

137	*Cantharellus umbonatus*	Gujarat	(Korat *et al.* 2013)
138	*Lactarius ambiguous*	Arunachal Pradesh	(Bera and Das 2021)
139	*Lactarius hirtipes*	Arunachal Pradesh	(Bera and Das 2021)
140	*Lactarius kesiyae*	Arunachal Pradesh	(Bera and Das 2021)
141	*Calvatia craniiformis*	Assam	(Gogoi and Kumar 2020)
142	*Hericium indicum*	Uttarakhand	(Datta *et al*. 2025) [76]

Future Prospects

Looking at the current situation, not much research work has been done on wild mushrooms so far. Many species of wild mushrooms are found in nature. Discovering new species of these hidden mushrooms, properly identifying them, exploring new compounds hidden in them, and writing new literature would be a novel research in future. In this way, the properties and diversity of wild mushrooms can be further explored.

The total number of macro-fungi discovered to date is estimated to be only 7% to 10 %. As animals and plants, fungi are endangered by human activity. They are neglected organisms that are poorly protected. Due to habitat destruction, deforestation, unorganized harvesting, climate change, urbanization trends, and population growth, many macro-fungi are becoming extinct or facing extinction threats. Therefore, ethnobotanical significance must be adequately investigated, conserved, and documented, as well as scientifically validated.

In the future, more research on wild mushrooms is needed to explore the nano-biofortification, bioactive compounds present in mushrooms, their healing properties, and the health benefits found in wild edible mushrooms that can lead to a healthier lifestyle in the future may prove useful.

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