Italian Botanist 20: 77–87 (2025)
doi: 10.3897/italianbotanist.20.165144
https://italianbotanist.pensoft.net

RESEARCH ARTICLE

Italian Botanist
Published by Società Botanica Italiana

Taxonomy, habitat and distribution of medicinal mushrooms: key points for their characterization and exploitation

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Academic editor: Lorenzo Peruzzi | Received 14 July 2025 | Accepted 7 October 2025 | Published 1 December 2025

Citation: Cirlincione F, Cicero I, Balenzano G, Gargano ML (2025) Taxonomy, habitat and distribution of medicinal mushrooms: key points for their characterization and exploitation. Italian Botanist 20: 77–87. https://doi.org/10.3897/italianbotanist.20.165144

Abstract

A first attempt to provide correct information on taxonomy, habitat, and distribution of 15 taxa considered as "medicinal mushrooms" and widely used in Italy for food, medicine and commercial purposes is here presented. For each taxon, notes on hosts and ecological categories are also provided. Eight taxa are widely distributed throughout Italy, one is endemic to Sicilia, while 5 taxa follow the distribution in Italy of their respective host plants. The study can also ensure appropriate labeling of mushroom-based products on the market being the basis of a proper made-in-Italy supply chain.

Keywords

Distribution, habitat, medicinal mushrooms, mushroom-based products, taxonomy

Introduction

Many species of Dikarya (Tedersoo et al. 2018) belong to a category of fungi commonly referred to as 'medicinal mushrooms,' which are used for the prevention, alleviation, or treatment of diseases, and/or for their nutritional benefits (Lindequist et

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al. 2014). Due to the high content of bioactive compounds they are used as dietary supplements or functional food (Wasser 2002; Gargano et al. 2017; Venturella et al. 2021; Łysakowska et al. 2023). Currently, most fungal extracts and dried medicinal mushroom powders come from large-scale cultivation carried out mainly in Asia, where most production facilities lack internationally recognized Good Manufacturing Practices (GMP). In addition, powders and extracts on the market are often derived from mushrooms lacking certificate of origin and sometimes of doubtful taxonomic identification, failing to meet the quality requirements of current European regulations (Risoli et al. 2023). Although the literature is rich in studies on the effects of medicinal fungi on various human and animal diseases, including both in vitro and in vivo assays (Gargano et al. 2017), very little is known about the growth habitats and proper taxonomic identification. Data on the taxonomy, morphological description, and distribution of some medicinal fungi such as *Auricularia auricula-judae* (Bull.) Quél., *Tremella fuciformis* Berk., *T. mesenterica* Retz., *Ganoderma lucidum* (Curtis) P.Karst., *Pleurotus ostreatus* (Jacq.) P.Kumm., *P. pulmonarius* (Fr.) Quél., and *Lentinula edodes* (Berk.) Pegler were provided by some authors (Wasser et al. 1999; Guzmán et al. 2000). Characteristics of habitats of *Grifola frondosa* (Dicks.) Gray collected in Northern temperate regions in North America, Europe, Japan, and China were subsequently reported (Chen et al. 2000). Other authors (Nanagulyan et al. 2002; Zmitrovich et al. 2010) investigated the biodiversity and ecology of the medicinal mushrooms of Armenia and the taxonomy of the members of the family Polyporaceae. A morphological characterization of *Ganoderma oerstedii* (Fr.) Murrill from Mexico, combined with a phylogenetic study based in rDNA sequences, was provided by Mendoza et al. (2011). Taxonomic relationships of *Pleurotus opuntiae* (Durieu & Lév.) Sacc. with *P. djamor* (Rumph. ex Fr.) Boedijn, *P. agaves* Dennis, *Lentinus levis* (Berk. & M.A.Curtis) Murrill [sub. *P. levis* (Berk. & M.A.Curtis) Singer], and *P. yuccae* Maire were evaluated by Camacho et al. (2012). Such studies have been taken up in more recent times by Zervakis et al. (2019) highlighting how the use of the binomial *Pleurotus opuntiae* should be restricted to fungi from the Mediterranean area only. Following the widespread use of molecular techniques, the binomials of fungal species are often changing. This has led to numerous changes in the nomenclature of medically important species, such as yeasts. A major concern is that physicians may use species names that could negatively impact diagnoses. Clarification of nomenclatural ambiguity in the case of medicinal mushrooms is a very important issue as also demonstrated with the studies on *Psilocybe* (Fr.) P.Kumm. species from Japan (Guzmán et al. 2013). Similar studies have been carried out by Gargano et al. (2024) on the uncertain taxonomy of *Pleurotus nebrodensis* (Inzenga) Quél. in the case of commercial products reporting this scientific binomial in Asian countries. Results demonstrated that all "*P. nebrodensis*" material examined from Asia corresponded to another taxon named *P. eryngii* subsp. *tuoliensis*. Another study tending to clarify some unclear aspects in the use of commercial products under the name of *Tremella fuciformis* Berk. was carried out by Deng et al. (2016). Zmitrovich and Wasser (2016) analyzed the critical scientific name of "*Pleurotus sajor-caju*" reaching the conclusion that the mushroom represents a tropical ecotype of *P. pulmonarius*

(Fr.) Quél. named *P. pulmonarius* var. *stechangii*. Zmitrovich et al. (2017) contributed to stabilize the nomenclature of *Trametes ochracea* (Pers.) Gilb. & Ryvarden [under the name *T. multicolor* (Schaeff.) Jülich]. Due to the presence of numerous taxa with morphological characters similar to *Ganoderma lucidum*, pharmacological research has been greatly affected in the proper evaluation of results. For these reasons, Papp et al. (2017) highlighted the correct nomenclature and taxonomy of the group *G. lucidum* by distinguishing a *G. lucidum* aggregate and the taxon *G. sichuanense* J.D.Zhao & X.Q.Zhang, originally described as *G. lingzhi* Sheng H.Wu, Y.Cao & Y.C.Dai. The importance of a morphological identification combined with a molecular approach is the basis of a study conducted by Cesaroni et al. (2019) on the *Hericium* clade which includes the *H. erinaceus* group and the *H. alpestre*/*H. coralloides* group.

In the studies of medicinal mushrooms, there is little use of the International Code of Nomenclature for Algae, Fungi and Plants (Turland et al. 2025) and references are often linked to old scientific binomials reported in the literature (Hawksworth 2005). The analysis of fungal distribution data is fundamental in Mycology, especially for identifying biodiversity hotspots and predicting responses to habitat changes caused by human activities and climate changes. Furthermore, to understand the ecology and biodiversity levels, it is necessary to evaluate environmental factors, such as climate, habitat, and host species.

In this paper we provide the correct nomenclature of the main medicinal mushrooms collected and studied in Italy, together with indication on their distribution and habitat data.

Critical points in the study and exploitation of medicinal mushrooms in Italy

The worldwide crisis of taxonomy and the slow decline of taxonomic specialists has national consequences on all fields of study in Mycology. This decline is coupled with the dramatic problem of biodiversity loss, the causes of which are mainly due to fragmentation of natural habitats, pollution, global climate change, unsustainable management of natural resources, and advancement of alien fungal species as a result of the introduction of alien (Löbl et al. 2023). Besides, to be able to better understand the distribution and/or rarity of a medicinal fungi species and activate conservation strategies, it is necessary to have a number of metadata on host specificity and biogeography (Lofgren and Stajich 2021). This is possible through an integrated approach that combines traditional taxonomic knowledge and data derived from modern techniques including omics, a collective term referring to disciplines that study sets of biomolecules to obtain a comprehensive view of an organism or biological system. Also of paramount importance is the combination of data derived from the study of fungal species identified with molecular approaches and data on functional and ecological diversity.

In the case of medicinal mushrooms, many species are also critically misunderstood. Assigning an incorrect scientific name to a medicinal mushroom not only invalidates scientific publications but more importantly makes applications in the medical field futile (Sasek 2015). Several fungal species of medical importance have recently undergone nomenclatural changes based on molecular approaches (Borman and Johnson 2023).

This generates considerable clinical confusion and mislabeling of mushroom-based products. Recent scientific papers reports similar cases for *Candida* Berkhout and allied yeast genera, *Cryptococcus* Vuill., *Trichosporon* Behrend, *Trichomonascus* H.S.Jacks., *Rhodotorula* F.C.Harrison, dermatophytes and their relatives, dimorphic fungal pathogens of humans and animals in the family Ajellomycetaceae, cryptic species in *Aspergillus* P.Micheli, *Cladosporium* Link, *Fusarium* Link, *Trichophyton* Malmsten, and a number of human pathogenic filamentous fungi (Borman and Johnson 2023). Commercial mushroom products are also often mislabeled, which can lead to misinterpretations and wrong application. It has been recently demonstrated that the Italian market for mushroom-based products is characterized by species of doubtful origin (Risoli et al. 2023). For example, mushroom-based products labeled in the commercial product as *G. lucidum* showed sequences exhibiting 100% and 99% homology with *G. resinaceum* Boud. and *G. sichuanense*, respectively.

Additional critical points in the decline of fungal taxonomy are poor funding, scientific publication metrics, and the decline in interest in scientific collections.

Materials and methods

Periodic observations, weekly or fortnightly (monthly during summer), in different forest ecosystems, in urban areas, in public and private gardens, and in botanical gardens has been carried out during the last 5 years (2021–2025). In particular we investigated several regions of the Italian territory (Puglia, Calabria, Emilia-Romagna, Sardegna, Sicilia, and Toscana) and we collected fresh basidiomata in meadows, pastures, living and dead plants identifying them using the methods described below. We also refer to data arising from literature (Bernicchia 2005; Venturella et al. 2015; Cesaroni et al. 2019; Zervakis et al. 2019). In addition, we selected 15 taxa of medicinal mushrooms, that are the subject of applied research in Italy and most of which are marketed in the form of mushroom-based products. For the selection of the 15 taxa with medicinal properties (Table 1) reported in our study, we analyze the Checklist of Basidiomycota by Onofri et al. (2005), which includes 4198 taxa growing in Italy.

For each species, the fresh basidiomata were collected and then identified according to their macroscopic (pileus, flesh, lamellae, stipe, type of occurrence: solitary, grouped, clustered, cespitose, color of spore prints, etc.) and microscopic characters (spores, basidia, asci, cystidia, pileipellis, element of the stipe surface, etc.). Microscopic features were analyzed under distilled water, immersion oil, and chemical reagents such as Melzer's reagent, KOH, Ammoniated Congo Red, and Cotton blue-lactic acid. Analytical keys were used for each different genera, i.e. Bernicchia (2005), Breitenbach and Kranzlin (1984), Venturella et al. (2015).

The abbreviation of type of habitat reported in Table 1 are according to EUNIS terrestrial habitat classification review 2017 (https://www.eea.europa.eu/data-and-maps/data/eunis-habitat-classification/eunis-habitat-classification-review-2017) and derived from the database of The Network for the Study of Fungal Diversity (NMD) by the Italian Institute for Environmental Protection and Research (ISPRA).

Table 1. Taxa distribution, hosts and type of habitat. *Data are referred to the Habitats according to EUNIS nomenclature classification manual for Italy (2004).

Taxon	Habitat/Host	Habitat EUNIS *
Agaricus bisporus	meadows and pastures	E1.3; E2.1
Auricularia auricula-judae	branches and stumps of broad-leaved trees	B1.7; E5.21; E5.22; G1; G1.2; G1.3; G1.6; G1.7; G1.7C; G1.7D; G1.8; G1.9; G1:A; G1.A1; G1A3; G1.C; G1.D; G2; G3; G3.5; G3.7; G3.72; G3.73; G3.74; G3:F; G5; I.2
Ganoderma lucidum	stumps of *Quercus ilex* L., *Castanea sativa* Mill., *Olea europaea* L.	G.1; G1.7; G1.8; G1.A; G2; I.2
Grifola frondosa	stumps of *Quercus ilex* L., *Castanea sativa* Mill.	G.1; G1.7; G1.8; G1.A; G2
Hericium erinaceus	on dead and living trees of *Quercus petraea* (Matt.) Liebl.	G.1; G1.7; G1.8
Inonotus obliquus	Trunks of living trees of *Betula pendula* Roth	G1.9
Laetiporus sulphureus	Trunks and roots of living trees of *Ceratonia siliqua* L., *Quercus pubescens* Willd., *Eucalyptus camaldulensis* Dehnh.	G1.7C; G1.8; G2.81
Pleurotus eryngii var. *eryngii*	rotting roots of *Eryngium campestre* L. and *E. maritimum* L.	E1.3; E2.1
P. eryngii var. *elaeoselini*	rotting roots of *Elaeoselinum asclepium* (L.) Bertol.	E1-3, E2
P. eryngii var. *ferulae*	Rotting roots of *Ferula communis* L.	E1.3; E2.1
P. eryngii var. *thapsiae*	Rotting roots of *Thapsia garganica* L.	E1.3; E2.1
P. nebrodensis	Rotting roots of *Prangos ferulacea* (L.) Lindl.	E2.1
P. ostreatus	Stumps, dead and living trunks of broad-leaved trees	G1; G1.2; G1.3; G1.6; G1.7; G1.7C; G1.7D; G1.8; G1.A; G1.C; G1.D; G2; G3; I.2
Schizophyllum commune	Stumps, dead and living trunks of broad-leaved and conifer trees	B1.7; E5.21; E5.22; G1; G1.2; G1.3; G1.6; G1.7; G1.7C; G1.7D; G1.8; G1.9; G1:A; G1.A1; G1A3; G1.C; G1.D; G2; G3; G3.5; G3.7; G3.72; G3.73; G3.74; G3:F; G5; I.2
Trametes versicolor	Stumps, dead and living trunks of broad-leaved and conifer trees	B1.7; E5.21; E5.22; G1; G1.2; G1.3; G1.6; G1.7; G1.7C; G1.7D; G1.8; G1.9; G1:A; G1.A1; G1A3; G1.C; G1.D; G2; G3; G3.5; G3.7; G3.72; G3.73; G3.74; G3:F; G5; I.2

We also provide data on habitats because environmental factors contribute to determining the distribution and abundance of the investigated mushrooms. In accordance with the database of The Network for the Study of Fungal Diversity (NMD) by ISPRA, and the Habitats code adopted in the EUNIS nomenclature classification manual for Italy (2004) we selected the following habitat: E1.3 - Mediterranean xeric grasslands; E2.1 - Permanent mesophilic pastures and meadows grazed by livestock; B1.7 - Coastal dune forests; E5.21 - Margins of xerophilic forests; E5.22 - Margins of mesophilic forests; G1 - Deciduous broadleaf woods and forests; G1.2 - Riparian woods and forests of *Fraxinus - Alnus* sp. or *Quercus - Ulmus – Fraxinus* sp.; G1.3 - Mediterranean riparian woods and forests of *Populus* sp., *Fraxinus* sp., *Ulmus* sp. and related species; G1.6 – *Fagus* sp. woods and forests; G1.7 – Thermophilic broadleaf woods and forests; G1.7C – Mixed

thermophilic woods; G1.7D – *Castanea sativa* woods and forests (including fruit crops; that have now become naturalized); G1.8 – Acidophilic woodlands and forests dominated by *Quercus* sp.; G1.9 – Non-riparian woodlands and forests of *Betula* sp., *Populus tremula*, *Sorbus aucuparia* or *Corylus* sp.; G1.A - Forests and woodlands of *Quercus* sp., *Carpinus* sp., *Fraxinus* sp., *Acer* sp., *Tilia*; sp., *Ulmus* sp. and related genera, on mesotrophic or eutrophic soils; G1.A2 - Non-riparian forests of *Fraxinus* sp.; G1.A3 - Forests of *Carpinus betulus*; G1.C - Highly artificial afforestation and plantations of deciduous broadleaved trees; G1.D - Fruit plantations; G2 - Evergreen broadleaved woods and forests; G2.81 - Plantations of *Eucalyptus* sp.; G3 – Coniferous woods and forests; G3.5 - *Pinus nigra* and related species forests; G3.7 - *Pinus* sp. forests (excluding *Pinus nigra*) of the Mediterranean area; G3.72 - Supra- or sub-Mediterranean forests of *Pinus pinaster* subsp. *atlantica*; G3.73 - Forests of *Pinus pinea*; G3.74 - Forests of *Pinus halepensis*; G3.F - Highly artificial afforestation and plantations of conifers; G5 - Hedges, rows, artificial tree lines, afforestation and coppice or degraded woods; I2 - Cultivated parks and gardens.

The indication of ecological categories in fungi is relevant for understanding their role as decomposers, pathogens, or symbionts. They are also useful in providing information on ecosystem stability, biodiversity, biotechnological potential, and conservation status. The abbreviation of ecological categories reported in Table 2 corresponds to Terricolous saprotrophs (St), Parasites (P) and Saprotrophs on wood (Sw). The abbreviation of the regions reported in Table 2 matches to Abruzzo (A), Basilicata (B), Calabria (C), Campania (Ca), Emilia-Romagna (E), Friuli Venezia Giulia (F), Lazio (L), Liguria (Li), Lombardia (Lo), Marche (M), Molise (Mo), Piemonte (P), Puglia (Pu), Sardegna (S), Sicilia (Si), Toscana (T), Trentino-Alto Adige (Tr), Umbria (U), Valle d'Aosta (Va), and Veneto (V). The data reported for Puglia, Calabria, Emilia-Romagna, Sardegna, Sicilia e Toscana were obtained from recent field surveys conducted between 2021 and 2025, while those relating to other regions were obtained from studies conducted by Onofri et al. in 2005.

Table 2. Ecological categories and distribution in Italy.

Taxon	Ecological category	Distribution
Agaricus bisporus	St	In all Italian regions
Auricularia auricula-judae	Sw	In all Italian regions
Ganoderma lucidum	P/Sw	In all Italian regions
Grifola frondosa	Sw	B, C, Ca, E, L, Li, Lo, P, S, Si, T, Tr, U, V
Hericium erinaceus	P/Sw	B, C, E, L, Lo, P, S, Si, T, V, Tr
Inonotus obliquus	P/Sw	E, Lo, P, Si, Tr, Va
Laetiporus sulphureus	P/Sw	In all Italian regions
Pleurotus eryngii var. *eryngii*	St	In all Italian regions
P. eryngii var. *elaeoselini*	St	A, B, C, Ca, L, M, Mo, Pu, Si, U
P- eryngii var. *ferulae*	St	A, B, C, Ca, E, L, Li, Lo, M, Mo, Pu, S, Si, T, U, V
P. eryngii var. *thapsiae*	St	B, C, Ca, L, Pu, S, Si, T
P. nebrodensis	St	Si
P. ostreatus	Sw	In all Italian regions
Schizophyllum commune	Sw	In all Italian regions
Trametes versicolor	Sw	In all Italian regions

The dried specimens were obtained in an universal dryer 475Watt stainless steel structure and kept in the Fungarium of the Herbarium SAF of the Department of Agricultural, Food and Forest Sciences of the University of Palermo. The Fungarium codes of each taxa are SAFMM01 (*Agaricus bisporus*), SAFMM02 (*Auricularia auricula-judae*), SAFMM03 (*Ganoderma lucidum*), SAFMM04 (*Grifola frondosa*), SAFMM05 (*Hericium erinaceus*), SAFMM06 (*Inonotus obliquus*), SAFMM07 (*Laetiporus sulphureus*), SAFMM08 (*Pleurotus eryngii* var. *eryngii*), SAFMM09 (*P. eryngii* var. *elaeoselini*), SAFMM10 (*P. eryngii* var. *ferulae*), SAFMM11 (*P. eryngii* var. *thapsiae*), SAFMM12 (*P. nebrodensis*), SAFMM13 (*P. ostreatus*), SAFMM14 (*Schizophyllum commune*), and SAFMM15 (*Trametes versicolor*),

The nomenclature follows Index Fungorum (https://www.indexfungorum.org) for fungi and Plants of World Online (POWO, https://powo.science.kew.org/) for vascular plants (date of consultation July 2025).

Results

The distribution and type of habitat of 15 medicinal mushroom taxa, i.e. *Agaricus bisporus* (J.E.Lange) Imbach, *Auricularia auricula-judae* (Bull.) Quél., *Ganoderma lucidum* (Fr.) Ryvarden, *Hericium erinaceus* (Bull.) Pers., *Inonotus obliquus* (Fr.) Pilát, *Laetiporus sulphureus* (Bull.) Murrill, *Grifola frondosa* (Dicks.) Gray, *Pleurotus ostreatus* (Jacq.) P.Kumm., *Pleurotus eryngii* (DC.) Quél. var. *eryngii*, *P. eryngii* var. *elaeoselini* Venturella, Zervakis & La Rocca, *P. eryngii* var. *ferulae* (Lanzi) Sacc., *P. eryngii* var. *thapsiae* Venturella, Zervakis & Saitta, *P. nebrodensis* (Inzenga) Quèl, *Schizophyllum commune* Fr., and *Trametes versicolor* (L.) Lloyd are reported in Table 1 while the ecological categories and distribution of each taxon in Italy are included in Table 2.

The selected taxa belongs to the ecological categories of terricolous saprotrophs (St, 6 taxa) and saprotrophs on wood (Sw,5 taxa), 4 taxa are parasites and they act also as saprothrophs after the host is dead, 8 taxa (*A. bisporus*, *A. auricula-judae*, *G. lucidum*, *L. sulphureus*, *P. eryngii* var. *eryngii*, *P. ostreatus*, *S. commune*, and *T. versicolor*) are very frequent along the Italian territory.

Discussion

The results obtained in our research correspond to what is reported in the Checklist of Onofri et al. (2005) as regards the distribution of the selected medicinal mushroom taxa, with the exception of the *Pleurotus* taxa growing on the dead roots of the Apiaceae which have been well characterized from the taxonomic and nomenclatural point of view in the publication by Venturella et al. (2015). *Agaricus bisporus*, *Auricularia auricula-judae*, *G. lucidum*, *S. commune*, and *T. versicolor* are very common along the Italian territory. The presence of *G. frondosa* is currently excluded for Abruzzo, Friuli Venezia Giulia, Marche, Molise, Puglia, and Valle

d'Aosta (Onofri et al. 2005). In addition to the classic brown or grayish color of the sporophores of *G. frondosa*, an albino form has recently been identified in the Madonie Mountains (northern Sicilia) on a different host (*Q. ilex*). It is very rare and also has interesting nutritional and medicinal properties, according to Gargano et al. (2020).

Hericium erinaceus, somewhat rare and with sporadic reports, has been reported so far in 11 Italian regions, while the rare and endangered *P. nebrodensis* is endemic to Sicilia. Other *Pleurotus* taxa, growing as saprotrophs on Apiaceae dead root plants, such as *P. eryngii* var. *eryngii*, *P. eryngii* var. *elaeoselini*, *P. eryngii* var. *ferulae*, and *P. eryngii* var. *thapsiae*, follow the distribution in Italy of their respective host plants, namely *Eryngium campestre* L., *E. maritimum* L., *Elaeoselinum asclepium* (L.) Bertol., *Ferula communis* L., and *Thapsia garganica* L.

The same is true for *I. obliquus*, whose distribution is restricted to Emilia-Romagna, Lombardia, Piemonte, Sicilia, Trentino-Alto Adige, and Valle d'Aosta, as a specific host of *Betula pendula* Roth and *B. aetnensis* Raf. ex J.Presl & C.Presl.

As shown in Table 1, habitat types are highly variable ranging from arid and dry environments like sandy beaches and Mediterranean xeric grassland to montane and subalpine woodlands. The host plants ranging from trees and shrubs to herbaceous plants. The most common habitat is oak, beech, and chestnut woods and Mediterranean maquis. Some species such as *P. ostreatus*, *S. commune*, and *T. versicolor* are also common in low- and high-elevation riparian forests. Plants used in reafforestation and also as ornamental in urban areas, hosted some species of food and medicinal interest like *A. auricula-judae*, *L. sulphureus*, and *P. ostreatus*. Some others species mainly *L. sulphureus* and *S. commune* are frequently found in fruit trees like *Ceratonia siliqua* L., *Citrus* × *limon* (L.) Osbeck, *C.* × *sinensis* (L.) Osbeck, and *Prunus domestica* L.

Conclusion

The research conducted on the most widely used species of medicinal interest in Italy is by far the first that provides precise insights into their distribution and ecological features. By understanding the natural habitat of medicinal mushrooms, we also aimed to provide useful guidance to individual mushroom hunters who make dietary use of certain species that combine excellent organoleptic characteristics with medicinal properties. This survey also takes its cue from the need for a certified, made-in-Italy supply chain of new mushroom-based products that would allow Italian companies to avoid turning for the purchase of medicinal mushrooms and their extracts to third countries that do not guarantee either correct species identification or good manufacturing practices. Correct information on the taxonomy and habitat of medicinal fungi is crucial for a correct approach to the study of these species whose derived products are intended for integrated medicines and the treatment of various diseases in humans and animals.

Acknowledgments

Project funded under the National Recovery and Resilience Plan (NRRP), Mission 4, Component 2 Investment 1.4—Call for tender No. 3138 of 16 December 2021, rectified by Decree n.3175 of 18 December 2021 of Italian Ministry of University and Research funded by the European Union—NextGenerationEU. Project code CN_00000033, Concession Decree No. 1034 of 17 June 2022 adopted by the Italian Ministry of University and Research, CUP B73C22000790001, Project title "National Biodiversity Future Center—NBFC".

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