

# Fungi over fungi, endophytic fungi associated with mushroom fruiting bodies and lichens

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## Abstract

Mushrooms are macrofungi that are famous for their nutritional and pharmaceutical values. On the other hand, lichens are the form of symbiosis representing the complex relation between fungi and algae. Understanding the ability of fungi to grow over anything, this review is focusing on endophytic fungi capable of growing in association with mushrooms and lichens, respectively. Although reports describing these association are rare, it is important to highlight such relation, and encourage for conducting more studies in order to understand the consequences of growth of endophytes on mushroom, status of lichen endophytes, and to investigate the diversity of endophytic fungi within lichen thalli.

**Keywords:** endophytic fungi; mushrooms; lichens; endolichenic; biological activities

## Introduction

Fungal endophytes constitute a major part of the unexplored fungal diversity. Endophytic fungi are an important source for novel, potential and active metabolites. Bioactive compounds produced by endophytes main function are helping the host plants to resist external biotic and abiotic stress, which benefit the host survival in return. These organisms mainly consist of members of the Ascomycota, Basidiomycota, Zygomycota and Oomycota. Endophytes are productive ground for drug discovery. Endophytic fungi are considered as the hidden members of the microbial world and represent an underutilized resource for new therapeutics and compounds. Endophytes are rich source of natural products displaying broad spectrum of biological activities like anticancer, antibacterial, antiviral, immunomodulatory, antidiabetic, antioxidant, anti-arthritis and anti-inflammatory [1-4].

Discovery and development of new antibiotics is still very important because of the continuous appearance of drug-resistant pathogenic bacteria, endophytes play that role and also endophytes play important role in the growth and development of the host [5, 6]. They can participate in the metabolic processes of the host, produce biological macromolecules with growth-promoting or antibacterial activities, and affect the yield and quality of the host [7, 8]. However, the study of endophytes is mostly focused on plants and animals, and reports on endophytic flora are moderately rare [9-11]. Many large mushrooms have a complex life history and demanding environmental requirements. Studying the community structure of organisms in mushrooms may be significant for their cultivation.

## Endophytic fungi associated with mushrooms

Fruit-body production of mushrooms is not well understood to date as many factors interact with mushroom growth in nature. Weather conditions play a key role, but they do not completely explain the growth and productivity of wild mushrooms. Mycorrhizal fungi depend on photosynthetically fixed carbon produced by their associated trees, and the physiological state of host trees may well drive the growth of these fungi. We raise the question of whether mycorrhizal fungi can be used as indicators for tree health [12]. The study of endophytes is mostly focused on plants and animals, and reports on microorganisms associated with fungus are relatively rare [13]. The soil surrounding mushrooms mycelia contains varied microbial communities that may affect the growth of mushrooms mycelium and the formation of fruiting body [14].

*Tricholoma matsutake* fruiting bodies are rare and commercially valuable. Polysaccharides and terpenoids extracted from the fruiting body have anti-tumor and antioxidant properties [15-18]. Li *et al.*, [13], studied the endophytic microorganisms associated with twelve samples of *Tricholoma matsutake* fruiting bodies in three locations in Sichuan, China, and reported that *Tricholoma matsutake* fruiting bodies have 13 fungus, 15 yeast and 14 bacterial strains. The most abundant cultivable fungus, yeast and bacteria isolates were assigned as *Fusarium solani*, *Cryptococcus* sp. and *Pseudomonas* sp., respectively. Beta and gamma-proteobacteria, Acidobacteria, Bacteroidetes and Sphingobacterium were found in samples from all collecting sites. Among these bacteria, we may find some strains that can promote the growth of *Tricholoma matsutake* [19, 20].

## Mushrooms on mushrooms

On other hand mushrooms can grow on mushrooms but not as endophytic fungi but as parasitic fungi. *Asterophora* species this mushrooms

belonging to Basidiomycetes, family: Lyophyllaceae can grow as a parasite on other mushrooms in complete form [21]. This fascinating mushroom is a parasite on other mushrooms like *Russula densifolia*. It pops right out of the top of its victim, usually when the *Russula* has blackened and begun to decay. Also there are other mushrooms that parasitize russulas and are superficially similar, including species of *Collybia* and another species of *Asterophora*, *Asterophora parasitica*. Among these parasites, *Asterophora lycoperdoides* is unique in having a

cap surface that soon becomes covered with brown powder [21]. *Asterophora parasitica* (basidiomycete) is a mushroom that grows on mushrooms. *Hypomyces lactifluorum* (ascomycete) is a parasite of fleshy mushrooms (basidiomycetes). The parasitized mushrooms are edible and are sold as “lobster mushrooms”. This is one of the strangest mushrooms on Earth, it were a gilled mushrooms that parasitizes other mushrooms, which already makes it a rarity [21], (Figure, 1).



Figure (1). *Asterophora* different species.

(Cited in: <https://www.forestfloornarrative.com/blog20191115the-fungal-parasite-asterophora-lycoperdoides> and <https://www.first-nature.com/fungi/asterophora-lycoperdoide>).

### Endophytic fungi associated with lichens

Microbial endophytes have been found in the leaves, bark and xylem of higher plants [22-24], including grasses [25], also in lower forms like algae [26], and mosses [27]. Lichen thalli provide a mostly unexplored and uncharted ecological niche for a wide variety of microorganisms including fungi. Endolichenic fungi have an intimate association and live in the thalli of lichens that are similar to plant endophytic fungi [22]. Endolichenic fungi also reported as parasymbionts in lichens [28]. A number of fungi grow and produce fruiting bodies on the surface of lichen thalli with identical fructifications. The terms lichenicolous or endolichenic fungi are different because of their occurrence or association on surface or within tissues of internal parts [29]. Some researchers used the term endolichenic because they isolated from internal tissues [30], and others isolated endolichenic fungal strains that lived along in the lichen thallus *Pseudocephalaria* sp., *Usnea* sp. and *Parmotrema* species. Lichens are economically important as traditional medicine and food in some regions [31-33]. Endolichenic fungal strains isolated from lichen thalli *Pseudocyphellaria* sp., *Parmotrema* sp. and *Usnea* sp. also showed biological activities as antifungal activities against common plant pathogenic fungi [34].

A recovery of endolichenic fungi from tissue segments of lichen thalli showed that these fungi not found on surface sterilized lichen thalli [35]. The colonization of fungi was considered environmental contaminants. Fungi belong to soil and litter symbiosis or pathogenic also isolated from fruticose lichens which were symbionts or pathogens of higher plants and lichens inhabiting fungi [28]. Although there are several studies on endophytic microorganisms of higher plants, but very few studies were carried out on the isolation of endolichenic fungi from the lichen thallus [30, 36, 37].

Vinayaka *et al.*, [29], reported that about 300 genera and 1000 species of obligatory lichenicolous fungi known which form parasitic, saprophytic, parasymbiotic and obligatory symbiotic mode of biological relationships on lichen species. Vinayaka *et al.*, [29], have examined some lichen species for isolation of endolichenic fungi from the internal tissues of

macrolichens which commonly occur in forests of Bhadra Wildlife Sanctuary, Southern India. A total of 30 different endolichenic fungal species were recovered from 11 species of foliose and fruticose lichens. Twenty four species of isolated fungi have produced fructifications. Among the 30 isolates, 24 species were identified in that most of them were belonging to ascomycota. The fungal species associated with thalli of lichen species were *Chaetomium globosum*, *Cladosporium cladosporoides*, *Colletotrichum dematium*, *Fusarium heterosporum*, *Phoma* sp. and *Xylaria* species. A total of 389 strains of fungi belonging to 38 species were isolated from 10 lichen species of the Western Ghats, southern India. All the lichens screened, irrespective of their growth forms or location, harboured endolichenic fungi. Most of the fungi belonged to the Ascomycotina. *Chaetomium* sp., *Hypoxyton investiens*, *Nemania bipapillata*, *Nodulisporium* sp., *Paecilomyces* sp., and *Sporormiella intermedia* were the most common ones and were present in 5 or more lichen species. Of the 28 sporulating fungi, 7 belonged to Xylariales, and their total colonization frequency in all the lichens was also high [38].

Association of endolichenic fungi with eleven lichen species belongs to five families distributed in Bhadra Wildlife Sanctuary, South India were investigated during May, 2013 to January, 2014. A total of 30 endolichenic taxa from 486 segments were isolated. *Chaetomium globosum* was occurred in eight, among 11 species of lichen, it was the dominant species of endolichenic fungi in thalli of lichens screened. The *Ramalina pacifica* and *Parmotrema tinctorum* showed maximum colonization by the endolichenic fungi. Out of 30 species of fungi 24 were sporulated and they were identified up to genus/species level. *Chaetomium globosum*, *Fusarium* spp., *Xylaria* sp. were isolated from thalli of lichen species [29]. Li *et al.*, [31], reported that endophytic fungi of seven lichen species belonging to five families were investigated in Baihua mountain of Beijing. Various endophytic fungi were found among the lichens. A total of 32 taxa from 488 thallus segments were obtained, with 14 ascomycetes, 16 hyphomycetes, one ceolomycetes and one yeast. *Scopulariopsis* sp. was distributed in six out of seven lichens and was the dominant species in five lichens. *Geniculosporium serpens* was the dominant species in the lichen, *Dermatocarpon miniatum*. *Sporormiella* species only occurred in *Xanthoria manschurica*. This review represent

that abundant endophytic fungi are distributed within different lichen thalli and the endophytic fungi is different among the lichens.

## Conclusion

The study of microorganisms in mushrooms fruiting body is still comparatively rare, and many information need to answered many questions. The growth-promoting activity of associated organisms should be tested, and their role in material exchange between mushrooms host and endophytic fungi should be evaluated. On the other hand, endolichenic fungi are interesting type of lichens-fungal interactions. As the lichens composed of symbiosis relationship, these non-obligatory endolichenic fungal presence in lichen thalli attracts further study regarding lichen-fungi inter-relationship and their significance in symbiosis, parasitism. Many studies must be conducted in order to understand the status of lichen endophytes, and to investigate the diversity of endophytic fungi within lichen thalli.

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