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Bioactive Endophytic Fungi from Forest Trees: A Review

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ABSTRACT

The microscopic creatures known as endophytic fungi live inside the plant without contaminating it or harming it in any way. These may have an impact on the host plants' distribution, ecology, physiology, and biochemistry. Several scientists studied about the endophytic fungi, their sources, categorisation, biological properties, industrial importance, & therapeutic value. Endophytic fungi are considered as "gold mine" for bioactive compounds having antimicrobial, anti-diabetic, anticancer, antioxidant, and many more medical, industrial & biotechnological applications. They are well studied for their synthesis of secondary metabolites from different sources, these are not only useful for agriculture instead used in the food industry and many of them have therapeutic potential.

Keywords: Endophytic fungi; Secondary metabolite; Forest trees; Bioactive compounds; Antimicrobial; Anticancer

1. INTRODUCTION

Microorganisms like fungi are useful for the growth and development of plants in different sectors like forestry, agriculture, horticulture, etc[1]. Fungi are an essential part of the microbial world, they have a mass of branched, tubular filaments enclosed in stiff cell walls and perform a variety of activities, including transporting nutrients in various environments, decomposing, and recycling. By improving and altering the root surface, fungi play a crucial function in enabling plants to better absorb nutrients & quickly mobilise minerals[2]. Many fungi live in the soil or water for free, while others interact with plants and animals in parasitic or symbiotic ways. According to estimates of fungi, our plant is home to about 1 million different fungal species[3]. Endophytic fungi are fungal species that live within plants without causing illness or harm to the host[4]. Fungal endophytes reside in the different organs of the host like leaves, stems, barks, roots, fruits, flowers, and seeds & they form a mutual relationship with the plant in which the plant gives shelter & harm to the endophytes whereas endophytes produce bioactive substitutes which increase the resistance & benefit the plant growth[5]. Several researchers studied endophytic fungi for their sources, taxonomic categorisation, biological & metabolic activity, and their industrial importance. Endophytes have recently been identified as a major source of several new biologically active secondary metabolites that could be employed in human treatment and a report from a recent research has indicated that 51 % of bioactive secondary metabolites and substances isolated from endophytes[6].

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1.1 Ecology and Distribution

Endophytes can be found in a wide range of plants, including lichens[7], large trees[8], palms[9]. Nearly every organ of a specific host contains endophytes, some of which are seed-borne. Endophytes have been found in plants that thrive in tropical, temperate, and boreal forests, as well as in herbaceous plants that have been found in severe arctic, alpine, xeric, and mesic *temperate* and tropical forests. The majority of the research was done on endophytic fungi from tropical and subtropical regions of forest.

1.2 Isolation and Identification Methods

Plant samples are collected from the field and placed in plastic bags for transfer to the lab. Surface sterilisation protocol is followed after the transportation which includes disinfection of the sample with 70 % alcohol for 3 mins and after that dilute sodium hypochlorite is used for 3 mins followed by ethanol. Then the plant sample was cut into pieces with a sterilised knife and placed into different prepared mediums supplemented with antibiotics. Purify the endophytes from amixed culture with the help of various methods. Polymerase chain reaction and DNA sequencing are the most promising approaches for identifying endophytic fungi[10].

2. SECONDARY METABOLITES/ BIOACTIVE COMPOUNDS ASSOCIATED WITH ENDOPHYTIC FUNGI FROM FOREST TREES

Plant endophytes are a "gold mine" for bioactive compounds having potential applications, i.e., agriculture, medical, and food industry. These microbial compounds are enforced with antimicrobial, insecticidal, cytotoxic, and anticancer properties. Endophytes reside within host tissue and don't harm, in fact produce or mimic similar

metabolites as the host plant does. This makes them more important as far as healthcare medical products are concerned[11]. Biocontrol agents from endophytes are an encouraging way to suppress pathogenic fungi by reducing the pathogenic activity as well as disease[12]. Endophytes also evoke the installation of defense mechanisms against root-knot nematode[13]. Phosphate solubilising fungi have been reported from various regions & involved in further growth of different groups of plants[14]. Endophytes are rich sources of Terpenes, flavonoids, phenolic, nitrogen & sulfur-containing compounds. These secondary metabolites are not only useful for agricultural applications but also used as a colouring agent, flavouring agent, or texturizing agent, and in food industries. Many of them have therapeutic potential. Additionally, a strain of *P. microspora* that produces severalchemicals with antifungal action was recovered from the threatened *Torreya taxifolia* tree. All of the isolated benzopyranones exhibited acetylcholinesterase inhibitory, antibacterial, antifungal, and antinematodal properties. That was the first publication on palmariol's bioactivity[15]. These are the novel reports regarding the endophytes content. Secondary metabolites with their activity associated with endophytic fungi are listed in Table 1.

3. ENDOPHYTIC FUNGI ASSOCIATED WITH FOREST TREES

According to certain reports, temperate forest zones have a higher diversity of endophytic fungi. Diaporthales species frequently predominate in the endophyte community of angiosperms, whereas Helotiales species predominate in the endophyte community of gymnosperms[28]. Endophytes are found in other different aerial and underground parts of the forest trees like leaves, bark, stems, roots, flowers, etc. A complete collection of endophytic fungi connected with various forest tree sections has been presented in Table 2.

Table 1. Secondary metabolites/ bioactive compounds with their activity associated with endophytic fungi

Secondary metabolite/ Bioactive compound	Endophytic fungi	Plant	Reference	Activity
Paclitaxol	*Nigrosporasp*	*Taxus globosa*	[16]	Anti-cancer
Xylarenone Sesquiterpenes	*Xylaria sp.*	*Torreyajackii*	[17]	Antitumor, Antimicrobial
Tauranin (Sesquiterpenes)	*Phyllostictaspinarum*	*Platycladusorientalis*	[17]	Anti-cancer
Trichothecolone (Sesquiterpenes)	KLAR 5	*knemalaurina*	[17]	Anti-cancer
Trichodermol (Sesquiterpenes)	KLAR 5	*knemalaurina*	[17]	Anti-cancer
Hypericin	*Chaetomium globosum*	*Hypericum perforatum*	[18]	Antifungal & Antibacterial
Emodin	*Chaetomium globosum*	*Hypericum perforatum*	[18]	Antifungal & Antibacterial
Bisphenylpropanoid amides	*Peniciliumbrasilianum*	*Melia asedarach*	[19]	Antibacterial
Benzopyranones	*Hyalodendriella sp.*	*Populus deltoids*	[15]	Antibacterial, Antifungal, Antinematodal
Brefeldin Antimicrobial Hydroxymonocerin	*Phomamedicaginis*	*Stemona sp.*	[20]	Antimicrobial
1-tetradecene	*Fusarium solani*	*Taxus baccata*	[20]	Antimicrobial
4-hydroxymellein	*Phoma sp.*	*Cinnamomum mollissimum*	[21]	Antileukemic
Chaetoglobosin	*Chaetomium globosum*	*Imperata cylindrical*	[22]	Cytotoxic
Daldinone C	*Hypoxylontruncatum*	*Artemisia annua*	[23]	Cytotoxicity
Leptosphaerone C	*Penicillium sp.*	*Aegicerascorniculatum*	[24]	Antifungal, Antibacterial, Anticancer, Antiviral, Nematicidal
Spirobisnaphthalenes	*Mycelia sterilia*	*Knightia excels*	[25]	Antibacterial, Antifungal
Colletotriolid	*Colletotrichum sp*	*Pandanus amaryllifolius*	[26]	Antitumor, Antiplasmodial, Antitubercular, Antioxidant
Leptusphaerone	*Penicillium sp*	*Aegicerascorniculatum*	[27]	Antimicrobial

4. BIOLOGICAL PROPERTIES OF ENDOPHYTIC FUNGI

Endophytic fungi are an abundant source of secondary metabolites with antifungal, antibacterial, and anticancer properties and many more bioactivity with important pharmaceutical and biotechnological applications[42-43]. Endophytes are a good source of physiologically active metabolites having anticancer, and antimicrobial properties due to the production of cytotoxic metabolites, antibiotics, and antioxidant compounds. A good record has also been noticed regardingthe biodegradation of toxic contents of pollutants, Biosolubilisation of minerals, and indirect involvement of the phytoremediation process[44]. Many endophytic fungi are known for anti-diabetic, antioxidant & immunosuppressive compounds and so very helpful as healthcare agents[45-46].

4.1 Antimicrobial Activity

These days, bacteria and fungi are the pathogens most frequently responsible for health issues. In-depth research is currently being done to find new, efficient antibiotics to treat illnesses. Numerous endophytic fungi also have antibacterial and antifungal properties.Antimicrobial activity of *Phomopsis sp.,* showed against *E. coli, K. pneumoniae, B. subtilis, M. luteus, and C. albicans*[47]. The extracts from *Colletotrichum gloeosporioides*and *Chaetomium globosum*exhibited antimicrobial activity. This study gives us an idea about how endophytic fungi are used as antimicrobial drugs.

4.2 Crop Protection

Additionally, crops are protected by endophytic fungi. Endophytes create induced resistance that is related to nutrition and help plants grow more quickly by increasing their ability to withstand abiotic stress [48].

4.3 Phytoremediation

According to research by Sudha, *et al.*, endophytic fungi have been revealed to play an important function in the ecological community with the goal of minimising land and water contamination caused by the excessive use of dangerous organic pesticides, environmental degradation, industrial effluent, dangerous fumes, and biodiversity loss. Endophytes are a new and effective biological control technique that is frequently employed for pathogen or insect eradication and environmental cleanup. Due to the ability of microorganisms to mobilise or immobilise contaminants to either increase plant development or the uptake of pollutants from the soil by plants[44]. Endophytic fungi are used in many different industries. A viable source for many pharmacological compounds would be endophytic fungi isolated from medicinal plants.

4.4 Antioxidant Activity

Pestalotiopsis microspora, shows antioxidant activity with antimicrobial activity having two important compounds pestacin and isopestacin. Isopestacin shares structural similarities with flavonoids that have antioxidant properties as well as the chemical pestacin, which has strong antioxidant properties[45] Pesticin's purported antioxidant activity is thought to have originated from the breakage of a highly reactive CH bond, with OH abstraction playing a smaller role.

Table 2. Endophytic fungi found in leaf, bark, stem, root sample

Endophytic fungi	Plant genus	Part of plant	References
Absidia sp.	*Meyna spinosa*	Leaf	[29]
Gloeosporidiella sp.	*abies alba*	Leaf	[28]
Clypeosphaeria sp.	*Diospyros crassiflora*	Leaf	[30]
Venturia orni	*Fraxinus ornus*	Leaf	[31]
Biscogniauxia sp.	*Quercus ilex*	Bark	[32]
Biscogniauxiaformosana	*Cinnamomum sp*	Bark	[33]
Cryptosporiopsisquercina	*Cryptosporiopsisquercina, Tripterygium wilfordii*	Bark	[34]
Cecropia sciadophylla	*Saracaasoca*	Bark	[35]
Colletotrichum cariniferi	*D.cariniferum*	Stem	[36]
Drechsleraellisii	*A. marmelos, Nyctanthes arbor-tristis*	Stem	[37]
Epicoccumsorghinum,	*Dendrobium officinale*	Stem	[38]
Hypocrea lutea	*Saracaasoca*	Stem	[36]
Phialocephala europaea	*Piceaabies*	Root	[39]
Penicillium brevistipitatum	*Phragmites australis*	Root	[40]
Pestalotiopsisaustralasiae	*Vellozia gigantean*	Root	[41]

4.5 Anti-diabetic Activity

Aspergillus sp. and *Phoma sp.* are fungal endophytes that contains some antidiabetic drugs lower the blood glucose level of the body[56], *Pseudomassaria sp.,* an endophytic fungus identified in the African jungle near Kinshasa, Democratic Republic of the Congo is where L-783 was first discovered. Unlike insulin, which is eliminated in the digestive system, this substance mimics the effects of insulin. L-783, 281 significantly lowered blood glucose levels after being given orally to two diabetes-prone mice models. These intriguing findings might result in brand-new diabetes treatments[50].

4.6 Immunosuppressive Activity

Subglutinols A and B, which were isolated from the endophyte *Fusarium subglutinans*, have immunosuppressive properties. According to their research, subglutinols A and B are more effective than the immunosuppressant medication cyclosporine in thymocyte proliferation assays. They recommend that it be investigated in greater detail because subglutinols A and B don't seem to be hazardous.

5. CONCLUSION

Endophytic fungi are highly diverse in various parts of forest trees and this review gives strategies for bioactive substances and secondary metabolites present in endophytic fungi. Understanding the diversity, bioactive compounds, significance that influence the interaction between the microorganism and environment and also develops the study of mycological research.

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