Feature Article

Endophytic Fungal Species in Tropical Trees: A Review

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Abstract

Pathogenic fungi are common in forest ecosystems which cause diseases and sometimes death of plants, while some fungi live inside trees harmlessly without causing issues. Sometimes, plants benefit from the presence of those endophytic fungi, such as gaining resistance to environmental stresses, protection from harmful pathogens etc. Numerous studies have been conducted on such relationships between endophytic fungi and short-term agricultural crops. However, such studies are rare in the literature on tropical tree species which bear timber and non-timber values. This study illustrates the studies conducted on endophytic fungi in tropical trees and explores the potential use of such fungi for obtaining benefits.

Keywords: Endophytic fungi, interactions, tropical trees, abundance

1. Introduction

Fungi are essential components in every ecosystem, intimately associated with crucial processes like the decomposition, recycling, and transportation of nutrients in different environments. Endophytic fungi are a group that colonize living, internal tissues of plants without causing immediate or overt adverse effects (Bacon and White, 2000). However, they may be pathogenic during host senescence (Rodriguez and Redman, 2008). They are a taxonomically and ecologically heterogeneous group of organisms; mainly belonging to Ascomycota, coelomycetes, and hyphomycetes (Rajagopal et al., 2012). Most endophytes are horizontally transmitted to their host plants through airborne spores. In contrast, some endophytes can vertically transmit to the next plant generations via seeds (Hartley and Gange, 2009). Though endophytic fungi were known for over one hundred years, they did not receive much attention until the recent recognition of their pharmaceutical and ecological significance (Gunatilaka, 2006).

Various relationships exist between fungal endophytes and their host plants, ranging from mutualistic or symbiotic to slightly pathogenic (Schulz and Boyle, 2005). Symbiotic associations between fungi and photosynthetic organisms are both ancient and ubiquitous. The relationship of endophytes with hosts is described in different terms of host specificity, host recurrence, host selectivity etc. Host specificity is the relationship where a fungus is restricted to a single plant species or a group of related species and not found in other unrelated plants in the same habitat (Ananda and Sridhar, 2002). Host recurrence is the predominant occurrence of endophytic fungus on a particular host or a range of plant hosts. Still, the fungus can also occur infrequently on other host plants in the same habitat. If a single fungal endophyte form relationship with two related plant hosts, but demonstrate more likely to one host, it is described as host selectivity (Cohen, 2006).

Endophytic fungi commonly demonstrate host specificity at the plant species level, but environmental conditions can influence this specificity (Cohen, 2004). At the same time, differences in endophytic fungal assemblage have been found in different tissues of the same plant species and even in other tissues of a single plant. This phenomenon reflects the tissues specificity (Ganley and Newcome, 2006).

2. Positive and Negative Interactions between Endophytic Fungi and Trees

Beneficial interactions between fungi and relevant hosts could be presented in different aspects. Endophytic fungi produce many substances inside the host plants that have potential use in modern medicine, agriculture and industry such as antibiotics, anticancer compounds (Michell et al., 2008). Some endophytic fungi could produce different plant hormones to enhance the growth of their host plants (Waqas et al., 2012). For example, the growth of wheat (*Triticumaestivum* L.) could be enhanced by *Azospirillum sp.* under drought stresses (Dingle and McGee, 2003). Some produce different bioactive compounds, such as alkaloids, diterpenes, flavonoids, and isoflavonoids to increase their host plants' resistance to biotic and abiotic stresses (Rodriguez et al., 2009). Certain endophytic fungal species could also promote the accumulation of secondary metabolites (including important medicinal components or drugs) originally produced by plants. According to the references, these metabolites may be produced by both host plants and/or endophytic fungi (Shwab and Keller, 2008).

Endophytic fungi can protect their host plants from pathogens and pests (Arnold et al., 2003). The foliar endophytes can reduce herbivory by producing alkaloids that are toxic to insects and vertebrates (Schardl, 2001). The endophytic fungus *Acremonium coenophialum* exhibited insecticidal activity against aphids (*Rhopalosiphum padi*, *Schizaphis graminum*) and milkweed bugs. *Cladosporium herbarum*, *A. alternata*, *Rhodotorula rubra*, *Epicoccum nigrum*, *Cryptococcus* sp., *Penicillium* sp. and *Fusarium graminearum* act as protectants to plants from herbivores (Larran et al., 2002). Senthilkumar et al., (2014) reported that phytochemicals such as dodecanoic acid, ethyl ester, phthalic acid, octyl 2-pentyl ester isolated from *Phomopsis* sp. can be used as an insecticide. Further, *Cladosporium oxysporum* showed insecticidal activity against *Aphis fabae* (Bensaci et al., 2015). Extracts of *Emericella nidulans, A. oryzae, A. tamarii* and *A. versicolor* showed the insecticidal ability on *Spodoptera litura* larvae with the maximum activity of *A. versicolor* (Abraham et al., 2015).

Endophytes can actively or passively promote plant growth through different mechanisms. Endophytic metabolites provide a variety of fitness to host plants enhanced by increasing plant resistance to biotic and abiotic stresses, as well as enhancing plant growth. Many endophytes are capable of solubilization of phosphate, enhance uptake of phosphorus, nitrogen fixation and plant hormones such as auxin, abscisic, ethylene, gibberellins, and indole acetic acid (e.g., *Fusarium tricinctum alternate*), which are important for plant growth regulation (Khan et al., 2015; Sandhiya et al., 2005). Fungal endophytes the form mycorrhizal associations assists to distribute nutrients within the surrounding plants (Franklin et al., 2014). The mechanisms of certain endophytic fungi induced resistance related to the nutritional status of the host, and thereby to increasing the fitness of plants by enhancing their tolerance to abiotic stress (Lu et al., 2000). Symbiotic fungi play an important role in the ecological community by decreasing the spoilage of land and water caused by excessive toxic organic insecticide, environmental degradation, industrial sewage, poisonous gases and loss of biodiversity (Guo et al., 2008).

Due to the potential of microorganisms for bioaccumulation of heavy metals and other pollutants from the environment, it can enhance and increase plant growth (Ma et al., 2011). Due to that, endophytes may also play a direct or indirect role in the phytoremediation process and degradation of environmental toxins, indirectly through enhancing plant growth having the ability of phytoremediation and this accelerate phytoremediation process, or directly through degradation and/or accumulating pollutants (Oses et al., 2008). For example, *Penicillium funiculosum* acts against the copper stress and enhances the plant growth. Therefore, it can be used in bioremediation of pollution in the cultivated area by stress mediating endophytes (Khan and Lee, 2013).

3. Potential for the Use of Positive Impacts

Endophytes generated an interest among the scientists of microbial chemistry due to their potential to contribute to the discovery of new bioactive compounds. It has been suggested that the close biological association between endophytes and their plant hosts results in the production of a large number and diversity of biologically active molecules compared to epiphytes or soil-related microbes (Strobel, 2003). Moreover, the symbiotic nature of this relationship indicates that endophytic bioactive compounds are less toxic to the animal cells, as these chemicals do not kill the eukaryotic host system. This is particularly important to the researchers in the medical field as potential drugs may not adversely affect human cells (Alvin et al., 2014).

4. The Abundance of Fungi in Tropical Trees

Endophytic fungi have been found in all plant species examined to date, including algae, mosses, conifers, angiosperms, palms and a variety of dicotyledonous shrubs and trees. Studies conducted on the presence of endophytic fungi in commercially valuable tropical timber trees such as *Dipterocarpus tuberculatus, Guarea guidonia, Hevea brasiliensis, Khaya anthotheca,* and *Tectona grandis.* In addition, similar studies were conducted on commercially valuable non-timber species in food and confectionary (*Mangifera indica, Musa acuminate, Theobroma cacao*), medicine, (*Azadirachta Indica, Camptotheca acuminate, Crocus sativus, Ginkgo biloba, Mesua ferrea, Samanea saman, Terminalia sp., Vitex negundo*) and enzyme production (*Calophyllum inophyllum*). Several authors have suggested that endophytes are especially diverse in tropical forests (Table 01).

Table 01. Fungal species identified in tropical tree species

Tree species	**No. of fungal species**	**Dominant species**	**Location and abundance**						**Reference**
			B	**L**	**S**	**T**	**F**	**R**	
Aegle marmelos	10	*Alternaria* sp.	L	-	-	-	-	-	Gond et al., 2007
		Aspergillus sp.	H	-	-	-	-	-	
		Bipolaris crotonis	L	-	-	-	-	-	
		Cladosporium sp.	H	-	-	-	-	-	
		Colletotrichum sp.	H	-	-	-	-	-	
		Curvularia sp.	L	-	-	-	-	-	
		Daldinia sp.	H	-	-	-	-	-	
		Fusarium sp.	L	-	-	-	-	-	
		Nigrospora sp.	L	-	-	-	-	-	
		Phomopsis sp.	L	-	-	-	-	-	
		Schizophyllum sp.	L	-	-	-	-	-	
		Trichoderma sp.	L	-	-	-	-	-	
		Xylaria sp.	L	-	-	-	-	-	
Artocarpus heterophyllus	1	*Colletotrichum* sp.	-	H	-	-	-	-	Sunkar et al., 2017
Azadirachta Indica	29	*Alternaria* sp.	-	H	-	-	H	H	Chutulo et al., 2018
		Aspergillus sp.	L	L	L	-	L	L	
		Colletotrichum sp.	-	L	-	-	L	-	
		Diaporthe sp.	H	H	H	-	-	-	
		Fusarium sp.	L	L	L	-	L	L	
		Penicillium sp.	-	-	-	-	L	L	
		Trichoderma sp.	H	H	H	-	H	H	
		Xylaria sp.	-	-	H	-	-	-	
Calophyllum inophyllum	8	*Cladosporium* sp.	-	H	-	-	-	-	Hedge et al., 2011
		Discosia sp.	-	H	-	-	-	-	

		Fusarium sp.	-	H	-	-	-	-	
		Isaria sp.	-	H	-	-	-	-	
		Penicillium sp.	-	H	-	-	-	-	
		Pestalotiopsis sp.	-	L	-	-	-	-	
		Xylaria sp.	-	L	-	-	-	-	
Camptotheca acuminata	>5	*Alternaria* sp.	H	-	-	H	-	H	Lin et al., 2007
		Fusarium sp.	-	-	-	-	L	-	
		Paecilomyces sp.	-	-	-	-	L	-	
		Phomopsis sp.	-	-	-	H	-	H	
		Rhizoctonia sp.	-	-	-	T	-	-	
Coffea arabica	1	*Glomerella cingulata*	-	H	-	H	-	-	Sette et al., 2006
Coffea robusta	2	*Glomerella cingulate*	-	-	-	L	-	-	Sette et al., 2006
		Phomopsis sp.	H	-	-	-	-	-	
Crocus sativus	12	*Alternaria* sp.	-	-	L	-	-	-	Raj et al., 2013
		Fusarium sp.	-	-	H	-	-	-	
		Penicillium sp.	-	-	L	-	-	-	
		Phytophthora sp.	-	-	H	-	-	-	
		Rhizoctonia sp.	-	-	H	-	-	-	
		Trichoderma sp.	-	-	L	-	-	-	
Dillenia indica	25	*Alternaria* sp.	-	L	-	-	-	-	Prasher and Kumar, 2021
		Aspergillus sp.	-	H	-	-	-	-	
		Bipolaris crotonis	-	H	-	-	-	-	
		Cladosporium sp.	-	H	-	-	-	-	
		Colletotrichum sp.	-	H	-	-	-	-	
		Daldinia sp.	-	L	-	-	-	-	
		Fusarium sp.	-	L	-	-	-	-	
		Nigrospora sp.	-	L	-	-	-	-	
		Phomopsis sp.	-	H	-	-	-	-	
		Schizophyllum sp.	-	L	-	-	-	-	
		Trichoderma sp.	-	L	-	-	-	-	
		Xylaria sp.	-	L	-	-	-	-	
Diospyros celebica	7	*Aspergillus* sp.	L	H	L	-	-	L	Mukrimin et al., 2021
		Fusarium sp.	L	L	L	-	-	L	
		Gliocladium sp.	L	L	-	-	-	-	
		Penicillium sp.	L	-	H	-	L	L	
		Phytophthora sp.	L	-	-	-	-	-	
		Trichoderma sp.	L	-	L	-	-	L	
Diospyros crassiflora	7	*Clypeosphaeria* sp.	-	L	-	-	L	-	Douanla-Meli and Langer, 2012
		Colletotrichum sp.	-	L	-	-	-	-	
		Penicillium sp.	-	-	-	-	L	-	
		Phomopsis sp.	-	H	-	-	-	-	
		Phyllosticta sp.	-	H	-	-	-	-	
		Xylaria sp.	-	H	-	-	-	-	
Dipterocarpus tuberculatus	9	*Daldinia* sp.	-	L	-	-	-	-	Sutjaritvorakul et al., 2011
		Fusarium sp.	-	L	-	-	-	-	
		Penicillium sp.	-	L	-	-	-	-	
		Pestalotiopsis sp.	-	L	-	-	-	-	
		Phomopsis sp.	-	L	-	-	-	-	
		Phyllosticta sp.	-	L	-	-	-	-	
		Xylaria sp.	-	L	-	-	-	-	

Garcinia indica	6	*Aspergillus* sp. *Fusarium* sp. *Trichoderma* sp.	L H H	- - -	- - -	L H H	- - -	- - -	Tejesvi et al., 2006
Ginkgo biloba	1	*Muscodor albus*	-	-	H	-	-	-	Banerjee et al., 2010
Guarea guidonia	14	*Colhotrichum* sp. *Phomopsis* sp. *Rhizoctonia* sp. *Trichoderma* sp. *Xylaria* sp.	- - - - -	- - - - -	- - - - -	H L H L L	- - - - -	- - - - -	Gamboa and Bayman, 2001
Hevea brasiliensis	58	*Colletotrichum* sp. *Fusarium* sp. *Penicillium* sp. *Trichoderma* sp. *Xylaria* sp.	- - - - -	H L L L L	H L L H H	- - - - -	- - - - -	- - - - -	Gazis and Chaverri, 2010
Khaya anthotheca	10	*Colletotrichum* sp. *Fusarium* sp. *Phomopsis* sp. *Xylaria* sp.	- - - -	H L L H	- - - -	- - - -	- - - -	- - - -	Linnakoski et al., 2012
Mangifera indica	7	*Aspergillus flavus* *Aspergillus niger* *Candida* sp. *Cladosporium* sp. *Penicillium* sp. *Moniliella* sp. *Trichoderma* sp.	H L H H L - L	H L H H L H L	- - - - - - -	- - - - - - -	- - - - - - -	H L H H L - L	Nayak, 2015
Mesua ferrea	1	*Phomopsis* sp.	-	L	L	-	-	-	Jayanthi et al., 2011
Musa acuminata	6	*Colletotrichum* sp. *Cordana musae* *Dactylaria* sp. *Deightoniella* sp. *Guignardia* sp. *Pyriculariopsis* sp.	- - - - - -	H H H H H H	- - - - - -	- - - - - -	- - - - - -	- - - - - -	Photita et al., 2001
Pinus attenuate	5	*Leploslrotnn* sp. *Naemacyclus* sp.	- -	H H	- -	- -	- -	- -	Carroll and Carroll, 1978
Pinus contoria	5	*Cladosporium* sp. *Leploslrotnn* sp. *Naemacyclus* sp.	- - -	H H H	- - -	- - -	- - -	- - -	Carroll and Carroll, 1978
Pinus monticola	2	*Leploslrotnn* sp.	-	H	-	-	-	-	Carroll and Carroll, 1978
Samanea saman	4	*Colletotrichum* sp. *Nigrospora* sp. *Penicillium* sp. *Phomopsis* sp.	- - - -	H L L L	- - - -	- - - -	- - - -	- - - -	Chareprasert et al, 2006
Tectona grandis	7	*Alternaria* sp. *Colletotrichum* sp. *Fusarium* sp. *Nigrospora* sp. *Penicillium* sp. *Phomopsis* sp. *Schizophyllum* sp.	- - - - - - -	H H L L L L L	- - - - - - -	- - - - - - -	- - - - - - -	- - - - - - -	Chareprasert et al., 2006

Terminalia arjuna	6	*Colletotrichum* sp.	-	L	-	-	-	-	Kouipou and Boyom, 2019
		Phomopsis sp.	H	H	-	-	-	-	
		Trichoderma sp.	H	H	-	-	-	-	
		Tubercularia sp.	H	-	-	H	-	-	
Terminalia catappa	7	*Colletotrichum* sp.	-	H	-	-	-	-	Kouipou and d Boyom, 2019
		Diaporthe sp.	-	-	L	-	-	-	
		Trichoderma sp.	L	-	-	-	-	-	
		Xylaria sp.	L	-	-	-	-	-	
Terminalia chebula	4	*Colletotrichum* sp.	-	L	-	-	-	-	Kouipou and Boyom, 2019
		Penicillium sp.	-	-	H	L	-	-	
		Xylaria sp.	-	-	L	L	-	-	
Terminalia crenulate	4	*Colletotrichum* sp.	-	L	-	-	-	-	Kouipou and Boyom, 2019
Terminalia mantaly	6	*Colletotrichum* sp.	-	L	-	-	-	-	Kouipou and Boyom, 2019
		Diaporthe sp.	L	L	L	-	-	-	
		Fusarium sp.	-	-	-	-	-	-	
Theoborma cacao	3	*Colletotrichum* sp.	-	H	-	-	-	-	Arnold et al., 2003
		Fusarium sp.	-	L	-	-	-	-	
		Xylaria sp.	-	L	-	-	-	-	
Vitex negundo	9	*Alternaria* sp.	-	-	-	H	-	-	Sunayana et al., 2014
		Aspergillus flavus	-	L	-	L	-	-	
		Colletotrichum sp.	-	-	-	L	-	L	
		Discosia sp.	L	L	-	L	-	-	
		Fusarium solani	L	L	-	L	-	-	
		Lasiodiplodia sp.	-	-	-	-	-	-	

Location of the tree: B=bark, F=fruit, L=leaf, R=root, S=stem, T=twig
Abundance of fungal species: H=high, L=low

4. Conclusion

The impacts of endophytic fungi can effectively be used for the efficient production of agriculturally, industrially and economically important plants and plant products. The rational application of endophytes to manipulate the microbiota, intimately associated with plants, can help in the enhancement of production of the agricultural product, increased production of key metabolites in medicinal and aromatic plants, as well as adaption to new bio-geographic regions through tolerance to various biotic and abiotic conditions (Wani et al., 2015).

References

Abraham, S., Basukriadi, A., Pawiroharsono, S. and Sjamsuridzal, W., 2015. Insecticidal activity of ethyl acetate extracts from culture filtrates of mangrove fungal endophytes. *Mycobiol*, 43:137-149.

Alvin, A., Miller, K.I. and Neilan, B.A., 2014. Exploring the potential of endophytes from medicinal plants as sources of antimycobacterial compounds. *Microbiol*, 169:483-495.

Ananda, K. and Sridhar, K.R., 2002. Diversity of endophytic fungi in the roots of mangrove species on the west coast of India. *Canadian Journal of Microbiology*, 48:871-878.

Arnold, A.E., Mejía, L.C., Kyllo, D., Rojas, E.I., Maynard, Z., Robbins, N. and Herre, E.A., 2003. Fungal endophytes limit pathogen damage in a tropical tree. Proceedings of the National Academy of Sciences, 100:15649-15654.

Arnold, A.E., Maynard, Z. and Gilbert, G.S., 2001. Fungal endophytes in dicotyledonous neotropical trees: patterns of abundance and diversity. *Mycological research*, 105:1502-1507.

Arnold, A.E. and Lutzoni, F., 2007. Diversity and host range of foliar fungal endophytes: are tropical leaves biodiversity hotspots. *Ecology*, 88:541-549.

Bacon, C.W. and White, J.F., 2000. Microbial endophytes. Dekker, New York, pp 341–388

Banerjee, D., 2011. Endophytic fungal diversity in tropical and subtropical plants. *Res J Microbiol*, 54-62.

Banerjee, D., Strobel, G., Geary, B., Sears, J., Ezra, D., Liarzi, O. and Coombs, J., 2010. *Muscodor albus* strain GBA, an endophytic fungus of Ginkgo biloba from United States of America, produces volatile antimicrobials. *Mycology*, 1:179-186.

Bensaci, O.A., Daoud, H., Lombarkia, N. and Rouabah, K., 2015. Formulation of the endophytic fungus *Cladosporium oxysporum* Berk and MA Curtis, isolated from Euphorbia bupleuroides subsp. luteola, as a new biocontrol tool against the black bean aphid (Aphis fabae Scop.). *Journal of Plant Protection Research*, 55.

Carroll, G.C. and Carroll, F.E., 1978. Studies on the incidence of coniferous needle endophytes in the Pacific Northwest. *Canadian Journal of Botany*, 56:3034-3043.

Chareprasert, S., Piapukiew, J., Thienhirun, S., Whalley, A.J. and Sihanonth, P., 2006. Endophytic fungi of teak leaves *Tectona grandis* L. and rain tree leaves *Samanea saman* Merr. *World Journal of Microbiology and Biotechnology*, 22:481-486.

Chutulo, E.C. and Chalannavar, R.K., 2018. Endophytic mycoflora and their bioactive compounds from Azadiracta indica: a comprehensive review. *Journal of Fungi*, 4:42.

Cohen, S.D., 2004. Endophytic-host selectivity of Discula umbrinella on Quercus alba and Quercus rubra characterized by infection, pathogenicity and mycelial compatibility. *European Journal of Plant Pathology*, 110:713-721.

Cohen, S.D., 2006. Host selectivity and genetic variation of Discula umbrinella isolates from two oak species: analyses of intergenic spacer region sequences of ribosomal DNA. *Microbial ecology*, 52:463-469.

Dingle, J. and Mcgee, P.A., 2003. Some endophytic fungi reduce the density of pustules of Puccinia recondita f. sp. tritici in wheat. *Mycological Research*, 107:310-316.

Douanla-Meli, C. and Langer, E., 2012. Diversity and molecular phylogeny of fungal endophytes associated with Diospyros crassiflora. *Mycology*, 3:175-187.

Dreyfuss, M.M. and Chapela, I.H., 1994. Potential of fungi in the discovery of novel, low-molecular weight pharmaceuticals. *Discovery of novel natural products with therapeutic potential*, 49-80.

Faeth, S.H. and Hammon, K.E., 1997. Fungal endophytes in oak trees: long-term patterns of abundance and associations with leafminers. *Ecology*, 78:810-819.

Franco F.V., Moreno R.S. and Ghneim H.T., 2021. Are endophytic bacteria an option for increasing heavy metal tolerance of plants? A meta-analysis of the effect size. *Frontiers in Environmental Science*, 294.

Gamboa, M.A. and Bayman, P., 2001. Communities of endophytic fungi in leaves of a tropical timber tree (Guarea guidonia: Meliaceae). *Biotropica*, 33:352-360.

Ganley, R.J. and Newcombe, G., 2006. Fungal endophytes in seeds and needles of Pinus monticola. *Mycological research*, 110:318-327.

Gazis, R. and Chaverri, P., 2010. Diversity of fungal endophytes in leaves and stems of wild rubber trees (Hevea brasiliensis) in Peru. *Fungal ecology*, 3:240-254.

Gond, S.K., Verma, V.C., Kumar, A., Kumar, V. and Kharwar, R.N., 2007. Study of endophytic fungal community from different parts of Aegle marmelos Correae (Rutaceae) from Varanasi (India). *World Journal of Microbiology and Biotechnology*, 23:1371-1375.

Gunatilaka, A.A.L., 2006. Natural products from plant-associated microorganisms: distribution, structural diversity, bioactivity, and implication of their occurrence. *J Nat Prod*, 69:509-526

Guo, B., Wang, Y. and Sun, X., 2008. Tang K. Bioactive Natural Products from Endophytes: A review. *Appl Biochem Microbiol*, 44:136-142

Hartley, S.E. and Gange, A.C., 2009. Impacts of plant symbiotic fungi on insect herbivores: mutualism in a multitrophic context. *Annu Rev Entomol* 54:323-342

Hegde, S.V., Ramesha, A. and Srinvas, C., 2011. Optimization of amylase production from an endophytic fungi Discosia sp. isolated from *Calophyllum inophyllum*. *Int J Agric Technol*, 7:805-813.

Huang, W.Y., Cai, Y.Z., Hyde, K.D., Croke, H. and Sun, M., 2008. Biodiversity of endophytic fungi associated with 29 traditional Chinese medicinal plants. *Fungal Diversity*, 33:61-75.

Jayanthi, G., Kamalraj, S., Karthikeyan, K. and Muthumary, J., 2011. Antimicrobial and antioxidant activity of the endophytic fungus Phomopsis sp. GJJM07 isolated from Mesua ferrea. *Int J Curr Sci*, 1:85-90.

Khan, A.L. and Lee, I.J., 2013. Endophytic *Penicillium funiculosum* LHL06 secretes gibberellin that reprograms *Glycine max* L. growth during copper stress. *BMC Plant Biol.*, 13:86.

Khan, A.R., Ullah, I., Waqas, M., Shahzad, R., Hong, S.J., Park, G.S., Jung, B.K., Lee, I.J. and Shin, J.H., 2015. Plant growth-promoting potential of endophytic fungi isolated from *Solanum nigrum* leaves. *World J Microbiol Biotechnol*, 31:1461-1466.

Kouipou, T.R.M. and Boyom, F.F., 2019. Endophytic fungi from Terminalia species: a comprehensive review. *Journal of Fungi*, 5:43.

Larran, S., Perelló, A., Simo, M.R. and Moreno, V., 2002. Isolation and analysis of endophytic microorganisms in wheat (*Triticum aestivum* L.) leaves. *World J Microbiol Biotechnol*, 18:683-686.

Lin, X., Lu, C., Huang, Y., Zheng, Z., Su, W. and Shen Y., 2007. Endophytic fungi from a pharmaceutical plant, Camptotheca acuminata: isolation, identification and bioactivity. *World Journal of Microbiology and Biotechnology*, 23:1037-1040

Linnakoski, R., Puhakka-Tarvainen, H. and Pappinen, A., 2012. Endophytic fungi isolated from Khaya anthotheca in Ghana. *Fungal ecology*, 5:298-308.

Lu, H., Xou, W.X., Meng, J.C., Hu, J. and Tan, R.X., 2000. New bioactive metabolites produced by *Colletotrichum* sp., an endophytic fungus in *Artemisia annua*. *Plant Sci.*, 151:67-73.

Ma, Y., Prasad, M.N.V., Rajkumar, M. and Freitas, H.J.B.A., 2011. Plant growth promoting rhizobacteria and endophytes accelerate phytoremediation of metalliferous soils. *Biotechnology advances*, 29:248-258.

Michell, J., 2008. Is psychometrics pathological science? *Measurement*, 6:7-24.

Mukrimin, M., Musdalifah, N., Larekeng, S.H., Sultan, S. and Christita, M., 2021, November. Fungal diversity inhabiting tissues of ebony (Diospyros celebica Bakh.) in urban forest. In IOP Conference Series: Earth and Environmental Science, 886:012-031

Nayak, B.K., 2015. Isolation and identification of phylloplane and endophytic fungi from one ornamental plant, Mangifera indica. *International Journal of TechnoChem Research*, 1:188-192.

Oses, R., Valenzuela, S., Freer, J., Sanfuentes, E. and Rodriguez, J., 2008. Fungal endophytes in xylem of healthy chilean trees and their possible role in early wood decay. *Fungal Diversity*, 33: 77–86.

Photita, W., Lumyong, S., Lumyong, P. and Hyde, K.D., 2001. Endophytic fungi of wild banana (Musa acuminata) at doi Suthep Pui National Park, Thailand. *Mycological Research*, 105:1508-1513.

Prasher, I.B. and Kumar, V., 2021. Diversity of endophytic fungi associated with Dillenia indica L., an ethnomedicinal plant. Current Research in Environmental & Applied Mycology, *Journal of Fungal Biology*, 11:532-559.

Raj, P., Khan, S.S., Modak, M., Lone, Z.A., Rather, S.A. and Yaqoob, M., 2013. Biodiversity of endophytic fungi in saffron (Crocus sativus) and antimicrobial activity of their crude extract. *Indo Am J Pharm Res*, 3:3702-3713.

Rajagopal, K., Maheswari, S. and Kathiravan, G., 2012. Diversity of endophytic fungi in some tropical medicinal plants-A report. *Afr. J. Microbiol. Res.*, 6:2822-2827.

Rodriguez, R. and Redman, R., 2008. More than 400 million years of evolution and some plants still can't make it on their own: plant stress tolerance via fungal symbiosis. *J Exp Bot* 59:1109-1114

Rodriguez, R.J., White Jr, J.F., Arnold, A.E. and Redman, A.R.A., 2009. Fungal endophytes: diversity and functional roles. *New phytologist*, 182:314-330.

Saikkonen, K., Faeth, S. H., Helander, M. & Sullivan, T. J., 1998, Annu. Rev. Ecol. Syst. 29:319-343

Sandhiya, G.S., Sugitha, T.C., Balachandar, D. and Kumar, K., 2005. Endophytic colonization and in planta nitrogen fixation by a diazotrophic *Serratia* sp. in rice. *Indian J Exp Biol*, 43:802-807.

Schardl, C.L., 2001. *Epichloe festucae* and related mutualistic symbionts of grasses. *Fungal Genet Biol*, 33:69-82.

Senthilkumar, N., Murugesan, S., Babu, D.S. and Rajeshkannan, C., 2014. GC-MS analysis of the extract of endophytic fungus, *Phomopsis* sp. isolated from tropical tree species of India, *Tectona grandis* L. *Int J Innov Res Sci Eng Tech*, 3:10176-10179

Sette, L.D., Passarini, M.R.Z., Delarmelina, C., Salati, F. and Duarte, M.C.T., 2006. Molecular characterization and antimicrobial activity of endophytic fungi from coffee plants. *World Journal of Microbiology and Biotechnology*, 22:1185-1195.

Shwab, E.K. and Keller, N.P., 2008. Regulation of secondary metabolite production in filamentous ascomycetes. *Mycological research*, 112:225-230.

Strobel, G.A., 2003. Endophytes as sources of bioactive products. *Microbes Infect*, 5:535-544

Sunayana, N., Nalini, M.S., Sampath Kumara, K.K. and Prakash, H.S., 2014. Diversity studies on the endophytic fungi of Vitex negundo L. *Mycosphere*, 5:578-590.

Sunkar, S., Sibitha, V., Nachiyar, V., Pandurangan, P. and Renugadevi, K., 2017. Bioprospecting endophytic fungus Colletotrichum sp. isolated from Artocarpus heterophyllus for anticancer activity. *Research Journal of Biotechnology*, 12:46-56.

Sutjaritvorakul, T., Whalley, A.J.S., Sihanonth, P. and Roengsumran, S., 2011. Antimicrobial activity from endophytic fungi isolated from plant leaves in Dipterocarpous forest at Viengsa district Nan province, Thailand. *Journal of Agricultural Technology*, 7:115-121.

Tejesvi, M.V., Mahesh, B., Nalini, M.S., Prakash, H.S., Kini, K.R., Subbiah, V. and Shetty, H.S., 2006. Fungal endophyte assemblages from ethnopharmaceutically important medicinal trees. *Canadian Journal of Microbiology*, 52:427-435.

Wani, Z.A., Ashraf, N., Mohiuddin, T. and Riyaz-Ul-Hassan, S., 2015. Plant-endophyte symbiosis, an ecological perspective. *Appl. Microbiol. Biotechnol*, 99:2955-2965.

Waqas, M., Khan, A.L., Kamran, M., Hamayun, M., Kang, S.M., Kim, Y.H. and Lee, I.J., 2012. Endophytic Fungi Produce Gibberellins and Indoleacetic Acid and Promotes Host-Plant Growth during Stress. *Molecules*, 17:10754-10773.