

Biological properties of Endophytic Fungi

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ABSTRACT

The endophytic fungus is have rich source of secondary metabolites which act as biological active agent in the higher plants. The fungal derivatives play vital part in human life and their compounds are the source of drug for cancer, microbial and viral diseases. The natural compounds from the endophytes acts as growth inhibitor of plant pathogenic organism. Endophytes are rich sources of natural products which are used in agriculture (plant growth and insecticidal), pharmaceutical industries and also used for phytoremediation.

Key words: Endophytic fungi, secondary metabolites, anticancer, Phytoremediation, Pest management

INTRODUCTION

The term 'endophytes' (Greek: endon-within; phyton- plant) was first coined by de Bary (1886). Endophytes relationship with plant varies from symbiotic to pathogenic. Endophytes benefit host plant by preventing pathogenic organism from colonizing. It has been categorized into two main groups (Clavicipitaceous and non-clavicipitaceous) based on differences in evolution, taxonomy, plants host and ecological functions. Clavicipitaceous are able to infect only some species of grasses and non-clavicipitaceous are found in the asymptomatic tissues of other higher plants (Rodriguez et al. 2008). It stimulates plants growth, increase disease resistance, improve the plants ability to withstand environmental stresses and recycle nutrients (Sturz et al. 2000). Endophytes are rich source of

secondary metabolites with multifold importance (Strobel and Daisy 2003). Compare to other endophytic microorganisms, fungal endophytes produce large number of secondary activities (Zhang et al. 2006). Endophytes isolated from medicinal plants possess strong fungicidal, bactericidal and cytotoxic metabolites (Wang et al. 2007). It produce enzymes which are used for various application like degradation and biotransformation of organic compound (Firáková et al. 2007; Pimentel et al. 2011). The endophytes derivatives are used in biotechnological applications (Tomita 2003). It has a wide significance in pharmaceutical science because of its antimicrobial, anticancer and antiviral activities. (Selim et al. 2012).

Anticancer activity

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Taxol is a highly functionalized diterpenoid which is widely used as anticancer drug (Wani et al. 1971). It was first isolated from the bark of western yew, *Taxus brevifolia*. During the cell division, taxol prevent the depolymerization of tubulin. Production of taxol from different genus of endophytes by fermentation is a cheaper method (Page et al. 1999). The anticancer drug, taxol has been found in many genera of endophytic fungi (*Alternaria*, *Fusarium*, *Monochaetia*, *Pestalotia*, *Pestalotiopsis*, *Pithomyces* and *Taxomyces*) (Strobel et al. 1996). More than 15 fungi genera were produced paclitaxel and its analogues (Zhao et al. 2010).

Pandi et al. (2011) reported that taxol isolated from *Lasiodiplodia theobromae* showed activity against breast cancer cell line. Alternariol 9-methyl ether is a major mycotoxin produced by fungi of the genus *Alternaria*. It can induce mitochondrial apoptosis in human colon carcinoma cells, and induce DNA strand breaks, micronuclei and gene mutations in various cultured mammalian cells (Meng et al. 2012). Giridharan et al. (2012) reported that sclerotiorin isolated from *Cephalotheca faveolata* showed anti-proliferative activity against cancer cells and also it induces apoptosis in colon cancer cells. Extracts from endophytes, *Fusarium* sp., and *Aspergillus fumigatus* exhibited inhibitory activity against HeLa cervix cancer cell lines (Ruma et al. 2013). The endophytic fungi, *A. terreus* showed cytotoxic effect against HepG2 cancer cell line (Suja et al. 2014). Polyketide compounds produced by *Phoma* sp., had high inhibitory activity against murine leukemia cells (Santiago et al. 2014). The anticancer activity was noticed in ethyl acetate extract of *Alternaria alternata* against human breast cancer cell lines and it also showed good cytotoxicity (Arivudainambi et al. 2014). Chen et al (2015) reported that cytochalasins from endophytic fungi, *Phoma mutirostrata* exhibited moderate anticancer activity against SMMC-7721 (hepatocellular carcinoma cell line), SK-BR-3 (breast cancer cell line), PANC-1 (pancreatic cancer cell line), HL-60 (human myeloid leukemia cell line) and A-549 (lung cancer cell line).

Antimicrobial activity

World health problems caused by drug resistant bacteria and fungi are increasing. Many pathogenic microorganisms have developed resistance due to the misuse or long-term usage of the same class of antibiotics. Intensive search for newer and more effective antibiotics to deal with these problems is now underway. The isolation of novel secondary

metabolites from the endophytes is a progressive research field (Huang et al. 2008). Fungal endophytes such as *Phaeosphaeria avenaria*, *Leptosphaeria* sp., *Fusarium* sp., *P. chrysanthemicola*, *Cladosporium* sp., *Cylindrocarpon* sp., *Saussurea involucreta*, *Fusarium solani*, *Cordyceps memorabilis*, *P. longicolla* and *Dothideomycete* sp., are found to have antimicrobial activity against human pathogenic bacteria and fungi such as *Micrococcus luteus*, *Enterococcus shirae*, *Escherichia coli*, *Klebsiella pneumonia*, *Bacillus subtilis*, *Staphylococcus aureus*, *Shigella flexneri*, *S. epidermidis*, *Candida tropicalis*, *C. albicans*, *Cryptococcus neoformans*, *A. fumigatus* and *Salmonella typhi* (Lv et al. 2010; Tayung et al. 2011; Rhoden et al. 2012). The *Phomopsis* sp., exhibited antimicrobial activity against *E. coli*, *K. pneumoniae*, *B. subtilis*, *M. luteus* and *C. albicans* (Jayanthi et al. 2011). Silva et al. (2011) reported that secondary metabolites of *A. niger*, *Curvularia pallescens*, *Guignardia bidwelii*, *Paecilomyces variotii* and *Mycelia sterilia* showed antibacterial activity against *S. aureus*, *B. subtilis*, *Enterococcus faecalis*, *M. luteus*, *E. coli* and *Pseudomonas aeruginosa*. *Gibberella* sp., exhibited the antimicrobial activity against *S. aureus* and *C. neoformans* (Liang et al. 2012). The extracts from *Colletotrichum gloeosporioides* and *Chaetomium globosum* exhibited antimicrobial activity against *Mycobacterium tuberculosis*, *Gordonia terrae*, *S. aureus* and *E. coli* (Bungihan et al. 2013). The extracts isolated from *C. gloeosporioides* showed antimicrobial activity against *Streptococcus pyogenes* and *Enterococcus faecalis* (Nath et al. 2014). The extract from *Diaporthe arengae* showed antimicrobial activity against *S. aureus* and *B. subtilis* (Patil et al. 2014). The earlier research clearly shows that Endophytic fungi derived compounds are being used in the development of antimicrobial drug.

Insecticidal activity

Endophytic fungi can protect their host plants from pathogens and pests (Arnold et al. 2003). The foliar endophytes can reduce herbivory by producing alkaloids which are toxic to insects and vertebrates (Scharl 2001). Webber (1981) who was the first researcher to endophytic fungi, *P. oblonga* to protect elm trees against the beetle *Physocnemus brevilineum*. The endophytic fungi (*Acremonium coenophialum*) exhibited insecticidal activity against aphids (*Rhopalosiphum padi*, *Schizaphis*

graminum) and milkweed bug (*Oncopeltus fasciatus*) (Johnson et al. 1985). *Cladosporium herbarum*, *A. alternata*, *Rhodotorula rubra*, *Epicoccum nigrum*, *Cryptococcus* sp., *Penicillium* sp., *Fusarium graminearum* were act as protectants to plants from herbivores (Larran et al. 2002; dos santos et al. 2003). The different genera of entomopathogenic fungus of *Acremonium*, *Beauveria*, *Cladosporium*, *Clonostachys* and *Paecilomyces*; were isolated from the coffee plants, among them *B. bassiana* and *Clonostachys rosea* were pathogenic to coffee berry borer (Vega et al. 2008). *B. bassiana* was found to control the borer insects in coffee seedlings (Posada and Vega 2006). Baskar et al. (2012) stated that *B. bassiana* isolated from Pulemy exhibited larvicidal and growth inhibitory activities against *Spodoptera litura*. The endophytic fungi *Claviceps purpurea* possess a significant insecticidal activity against *A. gossypii* Glover (Hemiptera:Aphididae) (Shi et al. 2013). Senthilkumar et al (2014) reported that phytochemicals such as Dodecanoic acid, ethylester, Phthalic acid, octyl 2- pentyl ester isolated from *Phomopsis* sp. are used as insecticide. The *Cladosporium oxysporum* showed insecticidal activity against *A. fabae* (Bensaci et al. 2015). The extracts from *Emericella nidulans*, *A. oryzae*, *A. tamaritii* and *A. versicolor* were applied topically on *S. litura* larvae and found that all the fungus showed insecticidal activity; notably *A. versicolor* showed maximum insecticidal activity (Abraham et al. 2015).

Plant growth stimulants

Endophytes can actively or passively promote the plant growth through a variety of mechanisms, as endophytic metabolites provide a variety of fitness to host plants enhanced by increasing plant resistance to biotic and abiotic stresses, as well as enhance plant growth. Many endophytes are capable of solubilization of phosphate, enhance uptake of phosphorus (P), nitrogen fixation, production of siderophores, and plant hormones such as auxin, abscisins, ethylene, gibberellins, and indole acetic acid (IAA), which are important for plant growth regulations (Goodman et al. 1986; Barraquio et al. 1997; Malinowski et al. 1999; Zou et al. 1999; Malinowski and Belesky 2000; Boddey et al. 2003; Loiret et al. 2004, Sandhiya et al. 2005, Firáková et al. 2007). Gibberellic acid (GA) is a potent phytohormone, that regulates plant growth. Fungal endophyte, *Cladosporium sphaerospermum* from the plant, Glycine max (L) Merr. produce

GA3, GA4 and GA7. It induced plant growth in rice and soybean (Hamayun et al. 2009). A pestalotin analogue isolated from the *Pestalotiopsis microspora* exhibited significant gibberellin activity against *Distylium chinense* seeds and increase germination rate (85.56%) (Li et al. 2015). The *Fusarium tricinctum* and *A. alternata* derivatives of indole acetic acid enhanced the plant growth (Khan et al. 2015).

Crop protection

Endophytic fungi are also capable of inducing resistance to diseases, and many mechanisms have been proposed for this resistance. The mechanisms of endophyte induced resistance are related to the nutritional status of the host, and to increase the fitness of plants by enhancing their tolerance to abiotic stress (Aguilar and Barea 1996). Endophytic fungi *Cryptosporiopsis cf. quercina* and *Colletotrichum* sp., are found effective against phytopathogens such as *Rhizoctonia cerealis*, *Phytophthora capsici*, *Pyricularia oryzae*, *Gaeumannomyces graminis* (Li et al. 2000; Lu et al. 2000).

Phytoremediation

It found to play an important role in the ecological community, with the aim of decreasing the spoilage of land and water caused by excessive toxic organic insecticide, environmental degradation, industrial sewage, poisonous gases and loss of biodiversity. Biological control using endophytes as a new efficient method is being widely used for environmental remediation, and killing insects or pathogens (Guo et al. 2008).

A novel application of endophytes in the area of phytoremediation (plant assisted removal of xenobiotics and heavy metals from the soil) (Ma et al. 2011). However, the success of phytoremediation depends upon microbes and plant ability to tolerate and accumulate high concentrations of pollutant, while yielding a large biomass. Due to the potential of microorganisms for bioaccumulation of heavy metals and other pollutants from environment or its enhancing plant growth and pollutant uptake from soil by plant through mobilization/immobilization of pollutant (Ma et al. 2011). Plants, *Festuca arundinacea* schreb. and *F. pratensis* Huds. are infected with endophytic fungi *Neotyphodium coenophialum* and *N. uncinatum* and uninfected plants are grown on petroleum contaminated soil. The endophyte infected plants had more shoot and root biomass

when compare to the uninfected plants (Soleimani et al. 2010a). It proves that the endophytes play a major role in phytoremediation.

Endophytes may play indirect or direct role in phytoremediation process and degradation of environmental toxins, indirectly through enhancing plant growth having ability of phytoremediation and this accelerate phytoremediation process, or directly through degradation and/or accumulating pollutants by itself. Endophytes have a cryptic existence and one of their main role in the ecosystem are decomposers, as they are among the primary colonizers of dead plant tissues (Kumaresan and Suryanarayanan 2002; Oses et al. 2008). The *Neotyphodium* endophytes enhance the Cadmium tolerance activity in two plant species of *Festuca arundinacea* and *F. pratensis* when compared to non endophyte infected plants (Soleimani et al. 2010b). The fungal endophyte *Penicillium funiculosum* acts against the copper stress and enhances the plant growth; it can be used in bioremediation of pollution in cultivated area by stress mediating endophytes (Khan and Lee 2013).

CONCLUSION

Endophytic fungi have wide application in different fields. It has the potential to produce many bioactive compounds. The secondary metabolites produced by the endophytic fungi have the ability to act as biocontrol agent. Endophytic fungi isolated from the medicinal plants would be a promising source for many pharmaceutical ingredients. Plants are the major preliminary source for pharmaceutical drug products. Isolating a compound from the plants and large scale production of a product is expensive and time consuming. But endophytic fungi originated from medicinal plants have the capability to produce valuable compounds and can be easily cultured and large scale production is possible through fermentation process. In future the products from the endophytic fungi will be a cheap source for medical, agriculture and other industries. It is sure that the research on endophytic fungi will lead to isolate more novel compounds.

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