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Basic Characteristics of Fungal Endophytes: A mini review

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ABSTRACT

This review article signifies the basic features of the endophytes(fungi) in order to acknowledge the prominence and behaviour of them in nature. Fungal endophytes play the pivotal character in encouraging the plant performances by promoting the habitat adaptations along with the fortification of plants against various stresses including both abiotic and biotic. Endophytic fungi along with the protection of plants against pathogens and pests, also provokes the removal of various toxicities in various temperate grasses in order to produce tolerant plants for the wide range of abiotic and biotic stresses.

Key words : *Anti-insect compounds, Anti-microbial compounds, Endophyte, Novel compounds, Secondary metabolites.*

Introduction

Endophytes are microorganisms that live in mutual association with the plants,resides in the internal living plant tissue without causing any visible manifestation of disease, for at least a part of their life cycle (Bacon and White, 2000). The word 'endophyte' (Gr. endon, within; phyton, plant) was first coined by De Bary, (1866). All types of microorganisms (fungi, bacteria, and actinomycetes) have been discovered as endophytes. The recurrent appearance of endophytes are fungi (Staniek *et al.,* 2008). It has been known since the end of nineteenth century that in asymptomatic plants there exists the fungi which remain intimated to the tissue of the plants (Guerin, 1898). Various evidences have revealed about the plant –microorganisms association, that has been found in the petrified tissues of the stems and the leaves, and indicates that endophytic plant association may have arisen during the first appearance of the higher plants on the earth (Redecker *et al.,* 2000). Inside the plants endophytes act as the chemical synthesizers (Owen and Hundley, 2004). Production of secondary metabolites from the associated endophytes of the medicinal plants can be subjugated as an antidote to various ailments (Tejesvi *et al.,* 2007). The numerous natural products produced by endophytic fungi possess unique structures and bioactivities, and act as an emerging resource which possess a massive potential for the utilization in various sects of agricultural and industrial field (Tan and Zou, 2001). Isolation of the endophytic fungus *Taxomyces andreanae* fromthe bark of the pacific yew plant (*Taxus brevifolia*) which produces the million dollar drug Taxol (1) (C47H51NO14).Taxol, a secondary metabolite which is diterpenoid in nature and holds the anti- cancerous potency has been a landmark in the study of endophytic fungi, which are now considered as a source of anticancer compounds (Stierle and Strobel, 1993).

Aim of Review

The prior purpose of this review is to acknowledge the important features of the fungal endophytes that

can be used efficiently for provoking growth, improving fitness of the plant, attribute various adaptation to stress condition in some plants and invoking the secondary metabolites of host plant.

Appearance

Endophytic fungi mostly belongs to ascomycetes, and has been recuperated from plants which are found in the extreme environmental conditions including the cold alpine regions, hot deserts, grasslands and savannahs, mangroves, arctictundra, temperate and tropical forests and from croplands (Arnold, 2007; Arnold and Lutzoni, 2007; Arnold, 2008). Hardoim *et al.*, (2015) study divulges that in plants there is a presence of varied microbial communities of fungi, archae, bacteria and protists. Blackwell, (2011) revised the assessment of the scale of the variability of the fungal exists on the earth which comprises of 1.5 million species. According to the Hawksworth, (2001) to the new-fangled estimation of 5.1 million through the scientific sequencing analytic methods, besides the demonstration about the discovery, identification and the classification of the fungi. Strobel and Daisy, 2003; Ganley *et al*., 2004 reveals the estimation of fungal endophytic species are at least 1 million, this amount signifies magnificence of endophytic fungi as a critical ingredient of fungal biodiversity. Endophytic fungi are present in the major lineages of land plants and are commonly found in non-vascular plants like mosses and ferns along with other seedless plants, conifers and flowering plants (Arnold, 2007). The innovation of biodiversity of endophytic fungi across innumerable geographical areas are still unknown however there is a sharp declination stretching from the tropics to the north boreal forests plants stretching from the tropics to northern boreal forests (Arnold, 2007; Arnold and Lutzoni, 2007). The peculiar feature of endophytic fungi are their extraordinary diversity both at global level and at individual level extending from parts of plants like leaves, stems, and rhizome , plants, and various locations (Arnold, 2008). In addition the higher latitude plants are colonized by fewer number of endophytic fungal as compare to tropical regions where endophytes are dominated by various classes featured comprising wide range of diversity of endophytes (Arnold and Lutzoni, 2007; Arnold *et al*., 2000). The dimensional approach of fungi inside the plants shows the variation along the space and functionality. One such example is of *Medicagosativa,* the leaves, stems, and roots of which are inhabited by the varied number of endophytic fungi which leads to the formation of the diverse ranges of secondary compounds(Weber and Anke, 2006; Porras-Alfaro and Bayman, 2011).

Mode of Transmission

The mode of transmission is determined in many endophytic fungi and the transmission is either horizontally or vertically. However there are certain examples where transmission can be enrooted by both ways providing that the ascospores are able to retain in the host plant e. g *Epichloe* species. In vertical, transmission takes place via seed and this type accounts for the asexual mode of *Epichloe* species.As these fungi are impotent to produce viable reproductive structure on their related host plants and hence are naturally disseminated through developing seed along the growing embryo and subsequently hyphae colonize the young seedling as the seed germinates (Philipson and Christey, 1986). In the laboratories certain type of manipulation can be done in approach of vertical transmission of various endophytes from one plant to another in *Epichloe* species (Latch and Christensen, 1985) for commercialization purposes through the artificial inoculation of endophytes in grasses, result in desirable grass-endophyte combinations (Johnson *et al.*, 2013a). Vertical transmission also can permit via the seed coating and are present in the Class 2 endophytes (Rodriguez *et al*., 2009). In this category the classic example is of *Curvularia protuberata* endophyte that induces the tolerance in host tropical grass plant which are found in the geothermal habitat against the soil temperature (Redman *et al*., 2002).

In contrast, dissemination through the horizontal transmission occurs through the specified procreative structures such as spores of the respective endophytes which are spread by the vector from plant to plant, or can be dispersed by the wind or the rain.It can happen through the soil, by the vectors like insects or via the air movements. In case of Class 2 and 3, colonization in the plants takes place through the hyphal penetration in the plant tissue and can also occur through the infection structures such as appresoria (Ernst *et al*., 2003; Gao and Mendgen, 2006). Documentation regarding the horizontal transmission in the sexual species of *Epichloe* through the means of as cospores (reviewed in Schardl *et al*., 2004) and in comparison to the sexual species of Epichloe , the sexual species display vis-

ible indications and results in the formation of external reproductive fruiting structures as stromata on flowering parts, tillers and also inhibits the development of flowering structures as well as the production of seed (choke diseases).

Role in Ecosystem

Fungal endophytes also plays a pivotal role in maintaining the ecosystem by providing the plants against biotic and abiotic stresses, also influence on the capability to resilience, and helps the plant in adaption to the new habitat (Strobel and Daisy, 2003; Schulz, 2006; Rodriguez *et al*., 2008; Aly *et al*., 2011).Endophytes promotes protection against various biotic stresses consists of various plants pathogens, nematodes and insects. While in abiotic stresses it comprises drought, salination, nutrient limitation, temperature and extreme pH values.In response to this, plants offer protection, spatial structure, and propagation to the next generation of hosts (Schulz, 2006; Aly *et al*., 2011).

Another way through which the Endophytes may play the crucial role in the ecosystem functioning by felicitating plant growth by having antagonistic activity of fungal-fungal interaction. A classical example is the interaction of endophyte *Fusarium verticillioides*, and the pathogen *Ustilago maydis* under their shared host plant maize(*zea mays*), in this interaction endophytes are in position of reducing the rate of pathogenic growth by the secretion of secondary metabolites which can break down certain plant compounds capable of limiting the growth of *Ustilago maydis* (Rodriguez Estrada *et al.*, 2012). Strobel and Daisy, (2003); Zhang *et al*. (2006); Vega *et al*. (2010); Aly*et al*., (2011); Boberg *et al.* (2011) study reveals the ecosystem is the promotion of biodegradation of the dead or dying host plant. According to Vázquez de Aldana *et al*., (2013) survey, demonstrates that the dominating endophyte present in the taxa of grasses, also act as the airborne fungi. They hypnotized, for some species in order to complete their life cycle, and in order to transforms to saprobe from an endophyte there is a requirement of sporulation after the host senescence. Endophytes while residing in the host plant tissue utilize the plant nutrients available during their senescence (Rodriguez *et al*., 2008; Aly *et al*., 2011).

Plants harbouring endophytes

Scientific expedition to the rainy forests of the amazon forests has led to the discovery of various fungal endophytes that are capable of producing secondary metabolites (Strobel and Strobel, 2007). Organisms possess certain microbial metabolites are the residual of specific biotopes, anchoring specific environment and taxonomic status (Schulz, 2001).According to this study organisms of unique biotope habitat are interrupted with the constant metabolic and environmental interaction that results in the production of secondary compounds compare to those plants which resides in the normal one (Schulz, 2001). Hence, organisms that occupy unique dwelling biotopes could be the primary centres for novel secondary metabolites.

Production of Secondary Metabolites by fungal endophytes

Bioactive natural products

Endophytic fungi besides playing various roles while staying in plant interactions, also delivers equal opportunity of gathering some natural chemical constituents with unique chemical structures. Reputed and advanced screening technologies along with other renowned scientific techniques have clearly demonstrated the prospective of endophytic fungi in generating some innovative biologically active compounds which can contribute in medicinal and agriculture efficiently (Zhang *et al.,* 2006; Aly *et al*., 2011; Wu *et al*., 2015a). These molecules helps plants in adaptation to different habitats and environmental changes, also promotes plant protection, and in communication between organisms. Strobel and Daisy, (2003) study revealed that the endophytic fungi producing secondary compounds are promoting tremendous opportunities in controlling the pests and pathogenic growth. In nutshell there is a worth need to understand the potentialities of endophytes producing bioactive compounds, some of whom are found to be innovative as an antibiotic, biofuels, antioxidant, as well as anticancer agent respectively (Strobel, 2015).

In below sections, we have described about the plants that harbour various microbes which are having the capacity of producing bioactive compounds.

Anti-microbial Secondary Metabolites

Illustrations of endophytic fungi producing secondary metabolites that we are using or have promising use in future against the various pathogens and pests present in the agricultural plants.It accounts number of endophytic fungi which produce auspi-

cious but unrevealed compounds which demonstrate anti-microbial secondary metabolites. According to Gunatilika, (2006) study, an estimation of about 230 plant metabolites in association of microbial strains including the fungal endophytes had been produced. A number of these compounds have been cited by (Strobel and Daisy, 2003).Endophytic fungi producing some novel and well characterized secondary metabolites which are anti- microbial in function, and areillustrated below:

Extraction of the Ambuic acid from the *Pestalotiopsis microspora,* anendophytic fungi, which can been in the rain forests all around the world. It is also antagonistic to *Pythiumultimum and* actively against *Fusarium* (Li *et al*., 2001). From medicinal plant *Artemisiaannua*, an endophytic fungi *Colletotrichum* sp., has been isolated from which a compound Colletonoic acid has been obtained (Bills *et al*., 2002). Colletonoic acid shows antagonistic property against certain bacterial strains, fungus and some algal growth (Hussain *et al*., 2014). Another metabolite Colletotric acid obtained from *Artemisia mongolica*, endophytic fungi namely *Colletotrichum gloeosporioides* (Zou *et al*., 2000*)* study reveals that colletotric acid displays antimicrobial characteristics against the fungus *Helminthos porium sativum* as well as bacteria. Varughese *et al*., 2012 study demonstrate Cordycepsidone A obtained from *Cordyceps dipterigena* possess biological activities against plant pathogenic fungus *Gibberellafujikuroi*.*Cryptosporiopsisquercina*, an endophytic fungi delivers a source of Cryptocandin metabolite which is lipo- peptide in nature, and is usually associated with the hardwood species in Europe. Strobel *et al*., 1999 reveals Cryptocandin is antagonistic to *Sclerotinias clerotiorum* and *Botrytis cinerea,* both of them are plant pathogenic fungi. In *Terminalia morobensis,* there resides an endophytic fungi *Pestalotiopsis microspora* which produces secondary metabolites Pestacin and isopestacin and are anti-oxidant in nature (Strobel *et al*., 2002; Harper *et al*., 2003). Also showsan anti-microbial activity (Strobel and Daisy, 2003). Horn *et al*.,1995 study reveals that the secondary compound Phomopsichalasin isolated from endophytic fungi *Phomopsis* sp. shows antagonistic activity against bacteria namely Salmonella enterica, *Bacillus subtilis* and S.aureus. Jesterone is manufactured by *Pestalotiopsis* which has been isolated from Papua New Guinea, an area having the moist conditionsand was isolated from an area with moist conditions, and possess the potent activity against plant pathogens, especially oomycetes (Li and Strobel, 2001).

It is incredible to know that none of the bacteria have produce any anti-microbial compound as produced by the endophytic fungi which could kill or control plant diseases caused by various microbes. (Haas and Défago, 2005; Lugtenberg and Kamilova, 2009; Pliego *et al*., 2011).

Anti-insect secondary metabolites

The negative impact of synthetic pesticides on the various ecological aspects, led to a demand of immediate research in order to discover the strong, special and safe derivatives (Strobel and Daisy, 2003). Although the Biopesticides acquires a small position in the pesticide market, but they convoyed the incremental influence. A number of the endophytes has been discovered which possess the anti-insectproperties. Some among them can be discussed as below:

Demain, 2000 study discloses the discovery of the Nodulisporic acids which areindole derivative, diterpenes in nature and possess anti-insect characteristic towards the larvae of blowfly by promoting insect chloride glumate gated channels. The assessment of the *Nodulisporium* sp. endophyte obtained from *Bontiadaphnoides* plant leads to isolation of the first nodulisporiccompounds. After this discovery more focus has been given in searching for more discoveries and isolation of the *Nodulisporium* spp and the respective analogues of the nodulisporic acid carrying more potency of insecticidal properties. A single volatile compound naphtalene has been found in fungal endophyte *Muscodorvitigenus,* sequestered from the lianas of the Peruvain Amazon rain forest. And naphtalene functions as anti-insect against the wheat stem sawfly, the common mothballs .It also act as active repellent against the adult phase of sawfly *Cephuscintus* of the wheat stem. For the production of naphtalene presence of starch in the growth media is critical. (Daisy *et al*., 2002). Gallagher *et al*., (1984) study confronts the production of Lolitrem B from the Epichloeendophytes, and is alkaloid derivative Indole-diterpenes in characteristic, shows the toxicity against the ryegrass staggers. Lolitrem B also leads to reductive growth of ASW larvae (Prestidge and Gallagher, 1985). Another class of indolediterpene namely epoxyjanthitrems obtained from epichloesps. known to have some pesticidal properties, as were made in

the presence of wide spectrum insect confrontation of the strain AR37 (Finch *et al.*, 2012).

Conclusion

There is a prerequisite to review and demonstrate the previous achievements, present going investigation and latest developments along their application in research associated with endophytic microorganisms.

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