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Endophytes in Pest Management

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INTRODUCTION

Ever since the discovery of insecticidal properties of DDT in 1939, the synthetic chemical pesticides dominated in pest management programmes all over the world. The indiscriminate use of pesticides has created several problems, which came to limelight with the publication of "Silent Spring" by Rachel Carson. Overdependence on chemical pesticides in pest control has brought about problems like (1) pest resistance to pesticides, (2) resurgence of pests, (3) toxic residues on food, water, air and soil, (4) elimination of natural enemies and disruption of the ecosystem and (5) minor pests assuming major status. On the other hand, use of botanicals, biopesticides and biocontrol agents (natural enemies) offer a good alternative to manage the insect pests and diseases in an eco-friendly way. Because, mostly they are (1) naturally occurring, (2) they have high specificity to target pests, (3) no or little adverse effect on beneficial insects, (4) resistance development to them is slow or less common, (5) they have no unknown environmental hazards, (6) have less residual activity and (7) are effective against insecticide resistance species of insects. Due to the above reasons the role of bilological control is considered as a potent and reliable tool in Integrated Pest Management Programme (IPM) to manage insect pests. Use of microbial endophytes which is a component of biological control is gaining greater research attention in recent years. which is also ecofriendly in nature. Hence role of endophytes in insect pest management becomes important components of biocontrol in insect pest management.

Endophytes are fungi or bacteria, which invade the tissues of living plants and cause no symptoms of disease (Wilson, 1995). The word "endophytes" derived from the two Greek words "*endon*" means within and "*phyton*" means plant. This term can be used for a wide spectrum of potential hosts inhabitants, *e.g.* bacteria (Kobayashi and Palumbo, 2000), fungi, *etc*. (Stone *et al*., 2000; Schulz *et al*., 2006).

The need of exploiting endophytes in Pest management

The use of chemical pesticides in plant protection has created several problems including the following *i.e.*,

- Indiscriminate use of chemical causing various hazards.
- Development of resistant strains in plant pathogens.
- Elimination of beneficial organisms and disruption of the ecosystem.
- Direct toxicity to the applicator.
- Accumulation of pesticide residues on food, water, air and soil

In order to cope with the above stated problems there is a need to develop ecologically sound, environmentally safe and economically viable methodologies for plant disease and pest management. Therefore, biological control has become an utmost important tool for Integrated Pest Management (IPM), where endophytes or endophytic microorganisms offer a great-untapped potential as a biological agent for plant disease management, due to their antagonistic properties.

Endophytic microbial community

Microbial community contains fungi, bacteria, actinomycetes, virus, yeast and algae. fungi and bacteria most dominantly involved in pest management, but others are rarely or not involved in pest control.

FUNGI

Fungi are the most frequently isolated endophytes. There is a tremendous diversity of endophytic fungi and their ecological roles along with the amazing chemical variety of their secondary metabolites, which display promising pharmaceutical or agro-chemical exploitable activities in various bioassays, that live for all or at least significant part of their life cycle internally and asymptomatically inside the plant. Fungal endophytes primarily ascomycetous fungi, are found in abundance, whereas basidiomycetes, deuteromycetes and oomycetes are rarely found.

Genera of entomopathogenic fungal endophytes

Beauveria spp.
Verticillium (*Lecanicillium*) spp.
Paecilomyces spp.
Cladosporium spp.
Clonostachys spp.

CLASSIFICATION OF ENDOPHYTES

1. **Based on colonization**

- **Systemic (True)**

Systemic endophytes are defined as organisms that live within plant tissues for the entirety of its life cycle and participate in a symbiotic relationship without causing disease or harm to the plant at any point. Additionally, systemic endophytes concentrations and diversity do not change in a host with changing environmental conditions.

- **Non-systemic (Transient)**

Non-systemic or transient endophytes, on the other hand, vary in number and diversity within their plant hosts under changing environmental conditions. Non-systemic endophytes have also been shown to become pathogenic to their host plants under stressful or resource-limited growing conditions.

2. **Based on host range and diversity**

- **Claviciptaceous:**

These are found to colonize on grass species of plants. endophytes typically confer benefits to their host plant by improving plant biomass, increasing drought tolerance and increasing the production of chemicals that are toxic and unappetizing to animals, thereby decreasing herbivory. These benefits can vary depending on the host and environmental conditions. Ex: *Claviceps, Balansia, Neotyphodium,* etc.

- **Nonclaviciptaceous:**

Non-clavicipitaceous endophytes represent a polyphyletic group of organisms. This group of endophytes are found to colonise on all plants other than grasses. Many non-clavicipitaceous endophytes can switch between endophytic behavior and free-living

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lifestyles. This class of non-clavicipitaceous endophytes has been the most extensively researched and has been shown to enhance the fitness benefits of their plant host as a result of habitat-specific stresses such as pH, temperature and salinity. These classes of non-clavicipitaceous endophytes have not been as extensively studied to date. Ex: *Alternaria, Cladosporium, Penicillium, etc.*

ENDOPHYTIC ASSOCIATIONS

Symbiotic and mutualistic

Endophytes and plants live in a close association for a long period of time which is termed as symbiosis. Through this symbiotic association, endophyte provides mineral nutrients to the plant where a plant gives food shelter and protection to endophytes.

Endophytes and plants often engage in mutualism, where endophytes primarily aid in the health and survival of the host plant with issues such as pathogens and disease, water stress, heat stress, nutrient availability and poor soil quality, salinity, and herbivory. In exchange, the endophyte receives carbon for energy from the plant host.

Endophytes may benefit host plants by preventing other pathogenic or parasitic organisms from colonizing them. Endophytes can extensively colonize plant tissues and competitively exclude other potential pathogens. Some fungal and bacterial endophytes have proven to increase plant growth and improve overall plant hardiness.

Studies have shown that endophytic fungi grow in a very intimate interaction with their host plant cells. Fungal hyphae have been seen growing either flattened or wedged against plant cells. This growth pattern indicates that fungal hyphae are substantially attached to the plant host's cell wall, but do not invade plant cells. Endophytic fungal hyphae appear to grow at the same rate as their host leaves, within the intercellular spaces of the plant tissue.

The presence of certain fungal endophytes in host meristems, leaves and reproductive structures has been shown to dramatically enhance the survival of their hosts. This enhanced survivability is largely attributed to endophytic production of secondary metabolites which protect against herbivory as well as increased uptake of nutrients. There is evidence that plants and endophytes engage in communication with each other that can aid symbiosis.

Mechanisms of pests/disease control by endophytes.

1) DIRECT

Directly by antibiosis and competition for space and nutrients also by way of hyper parasitism, Competition and lytic enzyme production.

2) IN-DIRECT

Indirectly by induction of plant defense response or ISR (Induced Systemic Resistance). Some endophytic microorganisms indirectly protect plants from pathogens by inducing resistance in plants. Systemic acquired resistance (SAR) and induced systemic resistance (ISR) are two forms of induced resistances. SAR, induced by the pathogen infection, is mediated by salicylic acid and associated with the accumulation of pathogenesis-related (PR) proteins. ISR, induced by some non-pathogenic rhizobacteria, is mediated by jasmonic acid or ethylene and is not associated with the accumulation of PR proteins

ROLE AND APPLICATION

Endophytes are an increasingly important area of research in many fields because of their chemical diversity and their ability to produce many novel secondary metabolites that can be utilized for fuel, medicine, restoration and agriculture. It is their chemical diversity that sparks profound interest in these organisms.

Agriculture

Webber (1981) was the first to report endophytic fungus, *Phomopsis oblonga* (Desm) which protected elm trees against the elm bark beetle, it was also responsible for reducing the spread of the Dutch elm disease.

Further, a report on mortality of adult *Cosmopolites sordidus* (Germar) and reduced larval damage was attributed to the successful establishment of endophytic *B. bassiana* in banana by Akello *et al.* (2008). Shortly after that Pampapathy *et al.* (2010) found cotton leaves colonized by *Lecanicillium lecanii* (Zimmerman) or *Baeuveria bassiana* and wheat leaves colonized by *B. bassiana* which brought about a significant reduction in the reproduction of *Aphis gossypii* Glover. Among the many promising applications of endophytic microbes those intended to increase agricultural use of endophytes to produce crops that grow faster and are more resistant and hardier than crops lacking endophytes. *Epichloë* endophytes are being widely used commercially in turf grasses to enhance the performance of the turf and its resistance to biotic and abiotic stresses. *Piriformospora indica* (Sav verma) is an interesting endophytic fungus of the order Sebacinales, the fungus is capable of colonizing roots and forming a symbiotic relationship with many plants.

There are several endophytes that have been discovered to exhibit insecticidal properties. One such endophyte comes from the *Nodulisporium sp.* which was first harvested from the plant *Bontia daphnoides* (C.F.Gaertn.). Indole diterpenes, known as nodulisporic acids, have been harvested from this endophyte which has effective insecticidal properties against the blowfly larvae.

There are many obstacles to successfully implementing the use of endophytes in agriculture. Despite many known benefits that endophytes may confer to their plant hosts, conventional agricultural practices continue to take priority. Current agriculture relies heavily on fungicides and high levels of chemical fertilizers. The use of fungicides has a negative effect on endophytic fungi and fertilizers reduce a plant's dependence on its endophytic symbiont. Despite this, the interest and use of bio-insecticides and using endophytes to aid in plant growth is increasing as organic and sustainable agriculture is considered more important. As humans become more aware of the damage that synthetic insecticides cause to the environment and beneficial insects such as bees and butterflies' biological insecticides may become more important to the agricultural industry.

Drug discovery and pharmaceutical industry

Endophytes produce a wide variety of compounds that might be used as lead compounds in drug discovery. Certain endophytic mediated secondary metabolites have anti-fungal, anti-microbial, anti-viral, anti-oxidant, and anti-cancer properties; examples of this include taxol, torreyanic acid, exopolysaccharides and solamargine. Manipulations of a plant's endosymbionts can also affect plant development, growth and ultimately the quality and quantity of compounds harvested from the plant.

Many of these novel compounds produced by endophytes have been shown to have important medical applications such as antimicrobial, antiparasitic,cytotoxic, neuro protective, antioxidant, insulin mimetic and immunosuppressant properties. A well-known example of the discovery of chemicals derived from endophytic fungi is from the fungus *Taxomyces andreanae* isolated from the Pacific yew *Taxus brevifolia*. *Taxomyces andreanae* produces Paclitaxel also known as Taxol. This drug is important for the treatment of cancer. Endophytic fungi produce many secondary compounds such as alkaloids, triterpenes and steroids which have been shown to have anti-tumor effects.

An endophytic fungus from the species *pseudomassaria* has been found in the rainforest of the Democratic Republic of the Congo. This fungus yields a fungal metabolite that shows potential as an antidiabetic medicine, also known as an insulin mimetic. This compound acts like insulin and has been shown to significantly lower blood glucose levels in mouse model experiments.

Environmental remediation

In restoration ecology, endophytes can assist native species in outcompeting non-native invasive species and, colonizing barren land in secondary ecological succession, and restoring ecosystems degraded by pollutants. As in biofuel production, in phytoremediation, high productivity species are often used. Plants can contain, store, potentially break down, and stimulate microorganisms in the soil to break down certain pollutants. With phytoremediation, the main challenge is the growth of plants in soil contaminated with organic pollutants and inorganic pollutants such as heavy metals. In this endophyte assist plants in converting pollutants into less biologically harmful forms.

The roots of plant communities to varying degrees help to hold the soil together by creating a network of roots that trap soil within. This, in turn, helps to prevent soil erosion, stabilizes slopes and prevent landslides, prevent desertification in vulnerable areas, and controls pollution into waterways by acting as part of riparian buffers.

Source of bioactive and novel compound

Endophytes provide a broad variety of bioactive secondary metabolites against insect pests which includes, Alkaloids, Terpenoids, Sterols, Phenols, Quinones, Flavonoids, Benzopyranones, Steroids, Tetralones and Xanthones and others.

Mode of action endophytic fungi

Entomopathogenic fungi have great potential as control agents. These fungi begin their infective process when spores are retained on the integument surface, where the formation of the germinative tube initiates, the fungi starting to excrete enzymes such as proteases, chitinases, quitobiases, upases and lipoxygenases. These enzymes degrade the insect's cuticle and help in the process of penetration by mechanical pressure that is initiated by the appressorium, a specialized structure formed in the germinative tube. Once inside the insect, the fungi develop as hyphal bodies that disseminate through the haemocoel and invade diverse muscle tissues, fatty bodies, malpighian tubes, mitochondria and haemocytes, leading to the death of the insect 3 to 14 days after infection.

Entomopathogenic endophytes	Toxins	Remarks	References
Beauveria spp.	Beauvericin, Bassianolide, Beauveriolide, Bassiacridin and Tenellin	Beauvericin ruptures midgut epithelium & dissolves ribosomes in *Culex pipens*, *Aedes aegypti* and *Caliphora erithrocephala*	Zizka and Weiser (1993)
Hirsutella thompsonii	Phomalactone and Hirsutellin -A	They have ribonuclease activity and toxic to citrus rust mite	Mazet *et al.* (1995)
Oospora destructor	Destruxins	Toxic to onion bulb fly, *Dalia antiqua*	Paprawski *et al.* (1985)
Lecanicillium lecanii	Bassionalide		Suzuki *et al.* (1997)
Isaria spp.	Isariin		Briggs *et al.* (1966)
Metarhizium spp.	Destruxins and Cytochalasins		Roberts (1981)
Paecelomyces tenuipes	Tenuipesine		Kikuchi *et al.* (2004)

ADVANTAGES OF USING ENDOPHYTES

- Harmless to other forms of life
- High degree of specificity
- Compatible with many chemical insecticides
- Resistance to microbes is less likely to develop
- Self-sustaining so economical Easy application Aesthetically acceptable
- Effective against cryptic feeders
- Resistant to biotic and abiotic stress
- Little inoculums is required
- No need for frequent application
- Development of virulence is less
- Development of mutation is nil

DISADVANTAGES OF USING ENDOPHYTES

- Totally dependent on environment, so uncertainty is always there
- Not quick results, as establishment takes time
- Specificity is disadvantageous as in some cases only
- Makes plants unpalatable by toxin production
- Some toxins are harmful

CONCLUSION

Application of different innovative strain of endophytes will help in the strengthening the understanding of plant-endophytes interactions, producing new bioactive compounds, perk up the growth in plants, improve biocontrol activity, avoid the attack of insect pests and disease and reducing the indiscriminate use of a chemical which is otherwise harm full to the ecosystem. Considering all these, endophytes have proved to be a boon and have left a good impact on plants, environment and human being in several possible ways.