**Innovative Role of Endophytes in Management of Economically Important Diseases of Different Crops**

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**Introduction**

Fungi and other plant infections are the most apparent concerns to the production of sustainable food. Fungicide efficacy is declining, and there are dangers related to fungicide residues on leaves and fruit. These factors have brought attention to the need for more efficient and secure alternative management methods. Endophytes have drawn more attention recently as a potential complement to or substitute for chemical control. A practical alternative to host-plant resistance and pesticide-based pest and disease control is the strategic use of naturally occurring organisms to reduce pest populations and raise agricultural output. According to Wagenaar and Clardy (2001), one of the most chemically promising groups of microorganisms in terms of diversity and pharmacological potential are endophytic bacteria, which develop in the intercellular spaces of higher plants.Fungi and bacteria that invade internal tissues of plants without inflicting their hosts any obvious harm make up the majority of beneficial endophytic microbes (Petrini, 1991). Furthermore, because they are connected to living tissues and may in some way benefit the health of the plant, endophytic microbes are not regarded as saprophytes. Endophytes can be found in a variety of plant tissue types and can colonize the plant systemically with bacterial colonies and biofilms while latently existing in intercellular spaces, inside vascular tissue, or within cells (Ulrich et al., 2008). Endophytic microbes, which live in the tissues of living plants, are understudied yet have the potential to yield new natural compounds that could be used in agriculture.According to this theory, the microbe receives nutrients from the plant while the microbe itself may create substances that defend the host plant from pests including animals, insects, and other microorganisms (Yang et al., 1994). Since these fungi and bacteria have been researched for biological control and manufacture of chemicals with pharmacological qualities, studies on microbes from plant species are now more common. They are distinct from epiphytic microorganisms, which reside on the surface of plant organs and tissues, and they differ from phytopathogenic microorganisms in that they are not harmful, do not infect plants, and do not cause illness (Hallmann et al., 1997). In the host plant, endophytic bacteria can infiltrate and spread throughout the entire organism, aggressively colonizing the apoplast, conducting vessels, and occasionally intracellular regions (Quadt-Hallmann et al., 1997a, 1997b). These endophytic bacteria can therefore function as biological control agents against pathogens since this colonization creates an ecological niche that is comparable to that inhabited by plant pathogens (Hallmann et al., 1997). In this regard, endophytic microbes' ability to control plant diseases has been shown in a number of pathosystems (Narisawa et al., 1998).This suppression may be regulated by a number of ways, including antibiosis (Sturze et al., 1996), competition for nutrients (Puentea et al., 2009), stimulation of plant defense response (M'Piga et al., 1997), and indirect regulation by the pathogen itself (Sturze et al., 1996). Additionally, more recently, their potential for accelerating the degradation of a number of contaminants has been looked into (Doty, 2008). Numerous studies have shown that endophytic microbes are capable of producing a wide range of bioactive substances (Huang et al., 2001). Molecular markers also offer enormous data sources that can help researchers create tools to track the genetic and environmental fate of these agents. Examples of relationships between endophytic bacteria and plants, particularly those that lead to the control of diseases, will be the main emphasis of the current review.This review aims to offer more insight into the fact that there are endophytes in nature, the products they produce, and how some of these organisms are starting to exhibit some promise for the management of plant pests and diseases.

**Fungal Endophytes**

Endophytic fungi are different in terms of taxonomy and biology, yet they all have the same characteristic of invading internal plant tissues without clearly harming their host (Wilson, 1995). Members of the Clavicipitaceae (Ascomycota), which are endophytes of several temperate grasses, are the best understood of these. Typically, in these systems, each host is colonized by a single endophytic fungal species, and these fungi appear to have undergone significant coevolution with their hosts. According to Clay and Schardl (2002) and Saikkonenet al. (2004), these fungi are typically transferred vertically (from mother to children by seeds). According to Herre et al. (1999), this transmission pattern is expected to encourage positive interactions with the host plant. However, endophyte relationships in grasses can have a variety of outcomes, from parasitic (such as choke disease) to highly mutualistic (Clay and Schardl, 2002). Beneficial effects for hosts consist of elevated tolerance to drought (Arechavaleta et al., 1989), inhibition of herbivorous insects (Breen, 1994; Rowan and Latch, 1994), defense against parasites such as (Pedersen et al., 1988; West et al., 1988; Kimmons et al., 1990), and resistance towards pathogenic fungi (Gwinn and Gavin, 1992; Bonos et al., 2005; Clarke et al., 2006). Endophytes, which are found in some tropical grasses, also fit this description (Kelemuet al., 2001). Endophytes have been found to mediate anti-pathogen defense in nongramineous hosts as well. For instance, endophytic fungi have been found to protect beans and barley (Boyle et al., 2001) from fungal diseases, as well as tomatoes (Hallman and Sikora, 1995), bananas (Pocasangreet al., 2001; Sikoraet al., 2008), from nematodes. Even though there is growing evidence that endophytic fungus can lessen pathogen damage to grasses and other host plants, it is unclear how broadly these fungi play this role in natural systems or whether they can be used as a biocontrol method to safeguard crops (Bhat *et al*., 2009).

**How fungal endophytes can affect plant disease**

There is growing evidence in recent years that endophytes play a part in how plant-pathogen interactions result in disease. They may prevent the growth of pathogens through a variety of methods, which have been seen. For instance, some endophytic species may stimulate plant defense mechanisms that fend off pathogen attack; others produce antibiotic substances that inhibit pathogen growth; resident endophytes may compete with incoming pathogens for space and resources; and finally, certain parasites of plant pathogenic organisms are known to exhibit endophytic behavior.

**Interactions with plant pathogenic fungi**

The production of antibiotics is widespread among endophytic species (Strobel, 2002; Schulz and Boyle, 2005; Wang et al., 2007). Several species of plant pathogenic fungi have been noticed to be restricted in their growth by liquid extracts from endophyte cultures (Liu et al., 2001; Park et al., 2005; Inácio et al., 2006; Kim et al., 2007). Such chemicals might serve as a defense tactic against fungal diseases if they were created by endophytes in plants. Observations of plant defense against pathogenic fungi following the application of endophytic culture filtrates and endophyte inoculation experiments imply that the endophyte may produce an antifungal substance or a substance that triggers the plant's defense mechanisms.The same protective effect was seen when only endophytic culture filtrates were applied to the plants (Dingle and McGee, 2003; Istifadah and McGee, 2006). This is the case with Chaetomium and Phomaendophytes of wheat. When these types of fungi were previously inoculated in plants, reduced severity of foliar disease caused by Puccinia and Pyrenophoraspp. was observed. The effects of culture filtrates on plant pathogens were not examined in these investigations.The severity of a leaf disease brought on by a Phytophthorasp. was greatly diminished in endophyte-inoculated leaves when a mixture of six species of endophytes regularly isolated from cacao (Theobroma cacao L.) trees were used for inoculation in leaves of endophyte-free seedlings of this particular species of plant.Because differences in disease severity were seen across endophyte-inoculated and non-inoculated leaves of the same plant, a mechanism of induced plant resistance did not appear to be at play. According to Arnold et al. (2003), the defense against a pathogen in this instance may be the result of direct competition between endophytes already present in the leaves and the pathogen. For example, the majority of the tissue that is susceptible to infection may already be infected, or endophytes may create zones of inhibition that prevent the entry of other fungi.Plant biochemistry may change as a result of endophyte infection, inducing defensive mechanisms against pathogens. The root endophyte *Piriformospora indica* has a diverse range of hosts, including *Arabidopsis* and a number of cereal species. In addition to an increase in production and tolerance to salt stress, barley plants injected with this endophyte have demonstrated resistance to a vascular [Fusariumculmorum(W.G. Sm.) Sacc.] and a leaf pathogen [Blumeriagraminis(DC.) Speer] (Najar *et al*., 2011, Waller et al., 2005). The defense against the leaf pathogen appears to be given via a process of induced resistance because the defense response in the pathogen-inoculated plants causes the death of host cells. Some endophytes may harbor mycoparasites. In recent years, it has been demonstrated that the endophyte *Acremonium strictum* is a mycoparasite of the potato disease *Helminthosporiumsolani*which has been isolated frequently from *Dactylis glomerata*L. and other grasses (Sánchez Márqueze et al., 2007). *Festuca rubra*L. cultivars infected by *Epichlofestucae*have shown a considerable improvement in resistance to the *Sclerotiniahomoeocarpa*causing dollar spot disease (Clarke et al., 2006). Several turfgrass species have cultivars with Epichlo and Neotyphodium endophytes that are currently available on the market. These endophytes' ability to spread vertically has made it possible to produce infected seed on a large scale. The application of such symbiotic cultivars can lead to a reduction in the usage of pesticides and fungicides in lawns since cultivars infected with Neotyphodium and Epichlo have demonstrated enhanced defense against herbivores, plant diseases, and various situations of abiotic stress (Brilman, 2005). Other endophyte species may in the future use similar uses. The research mentioned above imply that the endophytic mycobiotaconnected to a host plant may play a role in how some pathogen attacks turn out. In light of this, the endophytic assemblage of a particular species may serve as a source of organisms with potential applications for disease prevention in that plant species. Only a small portion of the many species that can enter and infect a plant, the pathogens, are capable of causing illness. This demonstrates that endophyte pathogens participate in a portion of the plant disease cycle. It appears that the majority of fungi linked with plants behave as endophytes, although fungi can function as pathogens once they enter a plant as well. Plant pathologists might benefit from knowing the distinction between pathogen- and endophyte-caused infection processes.Some research aimed at addressing this issue mentions both fungal and host properties. For instance, a pathogen like *Colletotrichum magna* can become a mutualistic endophyte by undergoing a single locus mutation (Freeman and Rodriguez, 1993). However, some isolates of the aforementioned species may act as an endophyte in some species of other plant families or as a pathogen in cucurbits (Redman et al., 2001).

**Interactions with nematodes**

Grass infected by Neotyphodium endophytes exhibits inhibitory effects against a few species of migratory and sedentary endoparasites (West et al., 1988; Kimmonset al., 1990). Unlike roots, aerial tissues are infected by neotyphodium species. As a result, it was assumed that the inhibitory effects seen in infected plants were caused by the translocation of fungal alkaloids to roots. This was confirmed by the discovery that some naturally occurring Neotyphodium strains with low levels of ergot alkaloids do not exhibit the same level of protection against Pratylenchus sp. as strains that produce ergot alkaloids (Timper et al., 2005, Anwar *et al*., 2021).In contrast, other studies revealed that there is very little ergot alkaloid translocation to roots, and research with mutant Neotyphodiums that had their pathway for ergot alkaloid synthesis disrupted suggested that ergot alkaloids are not the ones that control nematode populations in endophyte-infected plants (Panaccione et al., 2006). However, Neotyphodium species do produce various types of alkaloids with antiherbivore activity, and roots infected with Neotyphodium do undergo chemical modifications like the synthesis of phenolic compounds (Malinowski and Belesky, 2000). In conclusion, host plants are protected against a variety of nematode species by Neotyphodiumendophytes, but the exact mechanism by which this protection occurs is still a mystery.Another category of endophytes known to be involved in antinematode activity is non-pathogenic strains of Fusarium oxysporum isolated from plant roots. Meloidogyne incognita is inhibited by F. oxysporum culture filtrates, suggesting that fungal toxins may be the underlying cause of interaction (Hallmann and Sikora, 1996). The suppression of nematodes by Fusarium, however, seems to involve a process that is more intricate than a toxin-operated system. Banana plants were grown in a divided root system as part of an experiment, and the plants showed resistance to Radopholussimilis Cobb, Thorne in the root half that had not been injected with a Fusarium endophyte. The mechanism of resilience to the nematode pathogen in this case seemed to be a phenomena of systemic plant resistance brought on by the endophyte (Vu et al., 2006). Nematophagous fungi, which can live in plant roots as endophytes, may also play a role in endophytic fungal-mediated plant protection (Bordallo et al., 2002). A few entomophagous fungus species, such as Beauveria bassiana (Bals.-Criv.) Vuill., Torrubiellaconfragosa Mains, and Metarhiziumanisopliae (Metschn.) Sorokin, have been isolated from a variety of host plants, and it appears that endophytic activity can be a feature of their life cycle (Bills, 1996). To sum up, it is quite likely that fungal endophytes influence how nematode infections in plants turn out, and some endophytes may be useful for nematode protection in agricultural settings.

**Interactions with bacteria and viruses**

There haven't been as many studies done on how endophytes affect bacterial and viral infections as there have been with other plant pathogens. Endophyte culture extracts have been shown to have bactericidal effects, and these effects do not appear to be different from those seen for fungi or nematodes (Wang et al., 2007). In terms of viruses, Lolium pratense infected by Neotyphodium had a lower incidence of Barley Yellow Dwarf Virus (BYDV) than endophyte-free plants. Toxic fungal alkaloids may be the cause of this effect as BYDV is spread by aphid vectors; in fact, aphid reproduction was lower in endophyte-infected plants than in endophyte-free plants (Lehtonen et al., 2006).Endophytes and viruses have a different link that is highly intriguing. It was discovered that a Curvularia endophyte of the plant Dichanteliumlanuginosum (Elliott) Gould gave the plant resistance to high soil temperatures. Further investigation of this system revealed that a virus affecting the endophyte was a significant contributor to the plants' apparent heat tolerance. Furthermore, tomato plants could benefit from the virus-infected endophyte's ability to tolerate heat (Márqueze et al., 2007). Another virus known as EpichloFestucae Virus 1 (EfV1) infects the grass endophyte EpichloFestucae asymptomatically; however, in this instance, it is unknown if the virus' presence in the endophyte impacts the plant host (Romo et al., 2007).

**Bacteria Endophytes**

Endophytic bacteria have the ability to enter the host plant and spread throughout it, actively populating the apoplast, conducting vessels, and occasionally intracellular regions (Quadt-Hallmann et al., 1997a, 1997b). Endophytic bacteria inhabit an ecological niche that is comparable to plant pathogens, particularly vascular wilt pathogens, which may favor them as potential biocontrol agents. Additionally, recent results from intense research on rhizosphere biocontrol agents have demonstrated that the presence of six rhizobacteria caused cucumbers to develop systemic resistance and displayed both exterior and internal root colonization (Kloepper et al., 1992b). Since the control agent might circumvent adverse circumstances in one habitat by fleeing into the other habitat, using an additional microbial habitat for biocontrol objectives may improve overall disease management and enhance control consistency.

**Fungal Disease Suppression by endophytes**

**Wilt diseases**

Studies on wilt diseases of various commercial and food crops are the focus of studies involving endophytic microbes as agents of biocontrol. Endophytic bacteria isolated from potato tubers demonstrated in vitro antibiosis against *F. avenaciarum, F. sambucinum* and *F. oxysporum*. The antimicrobial activity of the isolates reduced significantly with depth of their site of isolation from the tuber surface. In an effort to fight against pathogenic onslaught, it's possible that plants embraced bacteria (Sturze et al., 1999). According to Brooks et al. (1994), endophytic bacteria isolated from live oak stems exhibited in vitro antagonistic activity against the pathogen that causes oak wilt, *C. fagacearum*. Crown loss was dramatically decreased after a pre-inoculation with the endophytic isolates *P. putida* and *P. denitrificans*. Spanish oak stems were given injections of Bacillus species, which allowed *Pseudomonas* species to colonize the plants more successfully(Brooks *et al*., 1994). The prevalence and severity of *V. dahliaeand F. oxysporum*f. sp*. lycopersici* diseases in these crops were reduced by over seventy-five percent as a result of endophytic bacteria derived from rape and tomato plants, while the plant height and shoot dry weight were raised (Nejad and Johnson, 2000). In addition to hydrogen cyanide, these strains also create additional volatile compounds. According to Hall *et al.* (1986), *Bacillus* spp. found in xylem channels decreased the percentage of silver maple stem colonization by *V. dahlia*.

**Rots and Damping-off Diseases**

When used as a seed treatment, endophytic bacteria isolated from rice seeds colonized the stellar region of the root and displayed potent anti-fungal action against *R. solani*, *Pythium myrotylum, Guamanomycesgraminis,* and *Heterobasidiumannosum* (Mukhopadhyay *et al.,* 1996). In addition, from the 170 endophytic bacterial strains isolated from cotton, 40 strains protected cotton plants from *R. solani* infection (Chen et al., 1995). Two endophytic bacterial strains isolated from cotton that were antagonistic to *R. solani* in vitro diminished infection of cotton plants from *R. solani* infection by 60% (Qui et al., 1990). *Phytophthora infestans* was inhibited by endophytic bacteria found in potato tubers (Sturze*et al*., 1999). The antagonistic potential of endophytic *Bacillus* and *Pseudomonas* spp. isolated from plants and seeds of several crops was examined (Pleban *et al.,* 1995). These pathogenic fungi included *P. ultimum, R. solani,* and *S. rolfsii*. When *B. cereus* strain 65 was put to cotton, radioactive labeling revealed that it remained there for 16 days. Up to 72 days after being introduced into the root and stem, the bacteria were still present at concentrations of 2.8 x 105 and 5 x l04 CFU g-1 fresh weight of root and stem tissue, respectively. When injected into the plant during the seed germination stage, *B. cereus* strain 65 and other endophytic bacterial strains examined showed greater than 50% protection against *R. solani* and *S. rolfsii* infection in cotton and bean seedlings.The crude production of extracellular proteins dramatically reduced the spore germination of *F. oxysporum*f.sp.*meloni*, and strain 65 developed a 36 kDachitinolytic enzyme known as chitobiosidase (Pleban et al., 1997). *P. fluorescens* successfully colonized the root tips of beans after being isolated from the interior tissues of apple plantlets that had been micropropagated. The chiA gene, which codes for Serratia marcescens' main chitinase, was cloned into this strain, and the recombinant strain, when administered to bean seedlings, effectively protected them from *R. solani*. This indicates that internal colonization by P. fluorescens was crucial for disease control (Downing and Thomson, 2000). The addition of this bacteria to soil did not give protection.

**Galls and Abnormal Growth**

From the woody tissues of lemon and sour orange, Lima *et al*. (1994) identified 160 bacterial strains, of which 55 were hostile to *Phomatracheiphila*, the causative agent of citrus malsecco disease. By injecting them into the stem of sour orange seedlings 15 days prior to pathogen inoculation, nine of the most potent antagonistic strains were examined for disease control. Significantly reducing disease symptoms and maintaining higher populations in the interior tissues of the host plant were achieved by three isolates of *B. subtilis* and one isolate of *P. fluorescens* (Lima *et al.,* 1994).

**Leaf spots and leaf blights**

There have been few attempts to use endophytic microbes as biocontrol agents for the diseases leaf spot and leaf blight. In an in vitro bioassay, Bacillus subtilis, which was isolated from the xylem fluid of chestnut trees, inhibited the growth of the chestnut blight pathogen Cryphonectriaparasitica and decreased the lesion areas on stems (Wilhelm et al., 1998). Additionally, according to Wilhelm et al. (1998), B. subtilis caused the synthesis of acidic chitinase and -1,3-glucanase in chestnut. According to Krishna Murthy and Gnanamanickam (1997), Pseudomonas species caused systemic resistance in rice against R. solani-associated sheath blight illnesses. This bacterium wasn't present on the plant's exterior, but its presence inside the stem prevented illness from spreading.8 bacteria and 24 fungi were identified to be antagonistic to P. infestans in the tomato phyllosphere, rhizosphere, and endosphere during a survey of antagonistic microorganisms (Garita et al., 1988), indicating the endophytic nature of antagonistic organisms. One of the most thoroughly developed systems for biological control employing rhizosphere isolates is utilized to treat crown gall produced by Agrobacterium tumefaciens (Kerr, 1980). For their antagonistic action against a variety of tumerogenic*A. tumefaciens*biovar 3 strains, endophytic bacteria isolated from the xylem sap of grapevine plants were tested (Bell et al., 1995).

Despite variation with regard to in vitro antibiosis, 24 of the 851 strains had a strong inhibitory effect on the grapevine gall-producing *A. vitis*. These microorganisms were identified as *Pseudomonas* spp., *Rahnellaaquatilis*, and E. agglomerans. The number of colonies of Agrobacterium strains in situ were significantly reduced by an isolate of P. corrugata, Further tests with the chardonnay grape variety, where galled vine incidence was moderate, revealed that three endophytic bacterial strains significantly reduced disease susceptibility. However, these strains proved useless in defending vines where gall incidence was high (Bell et al., 1995). These results also imply that the host genotype has a significant role in how well endophytic bacteria function as biocontrol agents.

**Nematode diseases**

Since nematode wounds encourage the establishment of bacterial colonies of the root surface and their entrance into the root tissue, endophytic microorganisms have an extra benefit over nematodes (Bookbinder et al., 1982; Khan, 1993). The density and variety of the total endophytic bacteria increased after Meloidogyne incognita was injected into cotton and cucumber plants. A model system involving the interaction of Meloidogyne with the endophytic bacterium E. asburiae Strain JM22 was employed to make the determination (Hallman et al., 1998). JM22 was found in abundance on the surface of nematode galls, particularly where the root epidermis had been damaged by gall expansion.

Electron microphotographs of the area around galls revealed a buildup of bacterial cells near necrotic plant cells (Hallman et al., 1998). Chitin (1% w/w) soil amendment shielded cotton from plant-parasitic nematode infection (Hallman et al., 1999).When the bacterial and endophytic microbial populations in soils with and without chitin amendments were contrasted.The *B. cepacia* populations were determined to be the identical in both soils, but only the soil that had been modified with chitin did it successfully colonize the internal tissues of cotton (Hallman et al., 1999). After being isolated from cotton and cucumber plants, the seven endophytic bacteria *Aerococcusviridans*, *B. megaterium*, *B. subtilis*, *P. chlororaphis*, *P. vesicularis*, *S. marcescens*, and *Sphingomonaspaucimobilis* significantly shielded cucumber seedlings from M. incognata infection (Hallman et al., 1995).

**Effects of endophytic microorganisms towardspathogens**

In fact, extensive research has demonstrated the ability of endophytic microbes to suppress nematodes (Hallman et al., 1998) and diseases (Duijff et al., 1997; Sturz and Matheson, 1996). Shimanuki (1987) demonstrated that timothy (*Phleumpratense*) plants infected with the choke fungus, *Epichloetyphina*, were resistant to the fungus *Cladosporiumphlei*, marking the first instance of an endophyte having an impact on a plant disease. In some circumstances, they can also hasten the emergence of seedlings, encourage plant establishment in challenging environments, and improve the growth and development of plants (Lazarovits and Nowak, 1997; Pillay and Nowak, 1997). According to studies (Hallman et al., 1997; Stoltzfuse et al., 1998), a number of bacterial endophytes have been shown to promote plant development and health. As a result, they may be significant sources of biocontrol agents. For instance, many endophytic bacteria, such as many strains of *Pseudomonas* sp., *Curtobacterium luteum*, and *Pantoeaagglomerans*, suppress *Erwinia carotovora* (Sturze et al., 1999). In addition, Wilhelm et al. (1997) showed that *Bacillus subtilis* strains isolated from the xylem sap of healthy chestnut trees have antifungal activity against the *Cryphonectriaparasitica* that causes chestnut blight. Endophytic bacteria are an appealing alternative for biological control agents because they are in close contact with the plant and have the capacity to promote growth and inhibit plant disease. For instance, according to studies performed by Sturz *et al.* (1999), 61 of 192 endophytic isolates of bacteria from potato stem tissues were successful biocontrol agents against Clavibacter*michiganensis subsp. sepedonicus.* Endophytic bacteria in oak have been found to be physiologically active against the pathogen *Ceratocystisfagacearum,* which causes oak wilt (Brooks et al., 1994).

According to Coombs and Franco (2003), Sessitsch et al. (2001), and Xaio et al. (2002), many of the physiologically active endophytes and root-colonizing microorganisms that have been isolated or found belong to the actinobacterial phylum, notably the genus Streptomyces. The first actinobacterial endophyte discovered is a nitrogen-fixing actinobacterium from the genus Frankia that associates with eight different species of angiosperms to generate actinorhizae (Provorov et al., 2002). *Streptomyces, Microbispora, Micromonospora,* and*Nocardioides* are the main genera of endophytic actinobacteria that have been previously isolated using culture-dependent techniques (Coombs and Franco, 2003). Many of these isolates, including *Rhizoctoniasolani, Pythiumspp., and Gaeumannomycesgraminis*var*tritici*, were able to reduce fungal pathogens of wheat both in vitro and in vivo, indicating their potential application as biocontrol agents (Anwar *et al*., 2008, Coombs et al., 2003).

**Mechanisms of diseases control displayed by Endophytes**

In this regard, endophytic microbes' ability to control plant diseases has been shown in a number of pathosystems (Narisawa et al., 1998). The pathogen inside the plant may be directly controlled via antibiosis and competition for resources, or indirectly by inducing a plant's response to resistance (M'Pigaet al., 1997). Endophytes vary from mycorrhizae in that they lack external hyphae, typically occurring in above-ground plant tissues but rarely in roots (for instance, dark septate endophytic fungus have been recovered from diverse plants).

Although some root endophytic fungi require plant cell death for proliferation during the development of mutualistic symbiosis with the plant (Deshmukh et al., 2006), it is universally hypothesized that endophyte-host interactions involve a balance of antagonism and exhibit great phenotypic plasticity in comparison to plant pathogens. Only a small number of texts discuss the secondary metabolism of plants that is mediated by fungi. Because there are literally millions of different biological niches (higher plants) that endophytes occupy and because they flourish in so many different odd habitats, endophytes are currently thought of as an amazing source of bioactive natural compounds. The originality and biological activity of the products linked to endophytic bacteria may thus be governed by these biotypical features, which suggest that they can play a significant role in plant selection. Following inoculation with a leaf fungal endophyte, peppermint growth and terpene production of in vitro created plants (Menthapiperita) reveal modification of the essential oil profile by fungal infection. The results of the other study demonstrated that after being inoculated with an endophytic bacterium that has a wide host range, *Euphorbia pekinensis*' weight of roots, seedlings, and terpene production increased. According to Wang et al. (2006), microbial elicitor produced from various fungal endophytes also encourages biomass and causes the development of terpenoids (artemisinin) in plant suspension cells. It appears plausible that both fungal endophytes and mycorrhizal fungi may cause a particular augmentation of the MEP pathway metabolic flux in plants.

Traditional Chinese medicine frequently treats traumatic and visceral hemorrhages with the crimson resin of Dracaena cochinchinensis. Chemical analyses have shown that several flavonoids are present in the resin (Zhenget et al., 2004).Additionally, endophytic actinomycetes may influence plant growth by improved secondary metabolite (anthocyanin) synthesis or nutrient assimilation. In addition, one key strategy for combating phytopathogens is the synthesis of antimicrobial compounds such antibiotics and HCN (Blumer and Haas, 2000). Sesquiterpenes, chokols, hydroxyl-unsaturated lipids, phenolic glycerides, and an aromatic sterol are only a few of the substances produced in the mycelial-choked heads of timothy that Koshinoet al. (1989) reported as being poisonous to some fungi. Endophytes produce a variety of volatile chemicals that efficiently inhibit and kill specific other fungus and bacteria (Strobelet al., 2001). Most of these substances have been discovered using gas chromatography-mass spectrometry, manufactured or obtained, and then combined artificially. The volatile chemicals that the fungus produced that acted as antibiotics were duplicated by this mixture. The recently described *Muscodorroseus* was twice collected from Australian Northern Territory tree species. According to Woraponget et al. (2002), this fungus is just as effective as *Muscodoralbus* at inhibiting and killing test microorganisms in a lab setting. In culture, a different endophyticstreptomycete (NRRL 30566) from the Northern Territory of Australia's Grevilleatree (*Grevilleapteridifolia*) produces brand-new antibiotics known as kakadumycins (Castillo et al., 2003). Alanine, serine, and an unidentified amino acid are all present in each of these antibiotics according to the nature of their amino acids. Colletotric acid, a metabolite of the endophytic fungus *Colletotrichumgloeosporioides* found in *Artemisia mongolica*, exhibits antibacterial efficacy both against bacteria and the fungus *Helminthsporium sativum* (Zouet et., 2000). The bioactive compounds produced by a different Colletotrichum sp., isolated from *Artemisia annua*, also demonstrated a range of antibacterial activity. According to Yueet al. (2000), some chemicals produced by cultures of the*Epichloe* and *Neotyphodium*species exhibit antifungal activity against the pathogen that causes chestnut blight, *Cryphonectriaparasitica*, and they may have a similar effect on other diseases.

The chemicals in this investigation that showed the strongest antifungal action were a sesquiterpene, a diacetamide, and the indole derivatives indole-3-acetic acid and indole-3-ethanol. According to van Weeset et al. (1999), indirect disease management is accomplished by processes that influence the plant immune response, such as the creation of systemic acquired resistance.

**Genetic and environmental modifications influencing diseases control by endophytes**

Cultivation-based techniques have been the mainstay of endophyte identification (Bell et al., 1995). Molecular methods based on the rRNA gene as a phylogenetic marker (Amannet al., 1995) offer a potent way to get beyond cultivation-related problems. In order to analyze genetic variation in endophytes and host plants and to gain insight into the connection between endophyte and host plant variation and the variability of agronomic parameters, molecular markers are used (Gamperet al., 2008). In order to better understand the molecular processes involved in the formation of plant endophytic associations, researchers have worked to date (Bailey et al., 2006). Rapid characterisation of microbial communities is made possible by methods like terminal restriction fragment length polymorphism (T-RFLP) analysis and denaturing gradient gel electrophoresis (Smalla et al., 2001). The SSR markers are useful for determining genetic variation within and between endophyte species, as shown by comparison with data from amplified fragment length polymorphism (AFLP) data. The assessment of endophyte diversity in a pool of perennial ryegrass germplasm with a global distribution is presented following the discovery of these markers for the sensitive detection of endophytes in plants. Recently, Garbevaet al. (2001) used PCR-denaturing gradient gel electrophoresis to monitor endophytic populations of potatoes. The results showed the presence of a variety of organisms belonging to many unique phylogenetic groupings. Their findings also revealed that potato had nonculturable endophytes.

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