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Endophytes As Potential Biocontrol Agent

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Abstract

Endophytes are microbes that live in host tissues without causing visible disease symptoms. They have been found to participate in balanced interactions with plants and provide benefits such as growth promotion and disease resistance. Endophytes can be used as a potential biocontrol agent because biocontrol becomes the most appropriate disease control strategy due to their own health and environment. The mutual interaction of endophytes involves different mechanisms, because it can trigger certain genes associated with induced systemic resistance (ISR), which can trigger a defence mechanism against pathogen attacks or through the formation of secondary metabolites and other chemical compounds that are directly toxic to pathogens.

Introduction

"Endophytes colonize the internal tissues of the host without causing symptoms, but it is possible that endophytes can cause disease after the end of the latency period" (Petrini, 1991). The word endophytes literally mean "within plants" (Greek; endo and phytophytes). The endophyte colonizes plant tissues internally (Carroll, 1986) without causing visible disease symptoms. They live in a symbiotic relationship with plants. And they also have differences in symbiotic interactions ranging from facultative saprobic to parasitic and mutualistic. However, like all endophytic interactions, they provide nutritional benefits and protection against environmental and microbial stress (Schulz and Boyle, 2005). Endophytes can be isolated from external plant tissues cleaned with a disinfectant or isolated from internal parts of plants without damaging them (Hallmann *et al*., 1997). Endophytes include both commensal microbes that do not affect their host plants and mutualistic symbionts that are useful in biological control.

Endophytic Diversity

- Endophytes show greater diversity and abundance in plant systems than plant pathogens (Ganley *et al*., 2004).

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- Endophytes mostly belong to the phyla Basidiomycota and Ascomycota and may originate from the orders Hypocreales and *Xylariales* of *Sordariomycetes* or *Loculoascomycetes* (Unterseher *et al*., 2011).
- Arbuscular mycorrhizal fungi are part of the mutualistic rhizosphere and they are microsymbionts involved in improving plant nutrient assimilation and providing protection against various stresses (Smith and Read, 1997).
- Arbuscular mycorrhizal fungi include biotrophic Glomeromycota associated with various plant species (Van der Heijden *et al*., 2015).
- Grasses/ Herbs mostly contain endophytic fungi belonging to the family Clavicipitaceae, family Balansiae. The tribe has five genera and about 30 species (Luttrell and Bacon, 1977).
- Zinniel *et al*. (2002) reported that five taxa of endophytic bacteria were identified as *Microbacterium*, *Pseudomonas*, *Clavibacter*, *Curtobacterium*, *Cellulomonas* using molecular methods such as gene sequencing and fatty acid analysis.
- According to Dobereine (1993) *Rhizobacteria* also belong to bacterial endophytes and play an important role in the survival of host plants.

Mode of Action

- Endophytes can also minimize plant defense mechanisms, allowing other pathogens to cause disease (Houterman *et al*., 2008).
- Induction of host defense mechanism: For example, a fungi *Colletotrichum tropicale* has stimulated hundreds of genes and their expression caused greater plant immunity in *Theobroma cocao* (Mejia *et al*., 2014).
- Suppressing effects of endophytes due to competition or endophytic metabolites (Martin *et al*., 2015). For example, *Ampelomyces* spp. Suppress the powdery mildew sporulation.
- "Induced resistance" is a term used for resistance induced by chemical or biological agents that help plants fight future attacks by pathogens (Kuc, 1982).
- According to Lugtenberg & Kamilova (2009) ISR is only initiated when endophytes colonize the root system of host plants.
- An endophytic fungus *Phomopsis* spp. produced number of secondary metabolites including antimicrobial and antifungal compounds (Erbert *et al*., 2012).

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- Biofilm formation: It is essential for root formation in *Bacillus subtilis*, host cell wall polysaccharides stimulate matrix production by triggering bacterial genes (Beauregard *et al*., 2013).
- *Trichoderma* spp. forms around plant roots where it forms an appressorium-like structure, which is an important feature of the pathogenic fungus (Mukherjee *et al*., 2013).
- When *Pseudomonas*, *Bacillus* and *Trichoderma* strains are located around plant roots, they use auxin to form large numbers of lateral roots that help improve nutrient uptake and protect against pathogens.
- Akinsanya *et al*. (2015) reported that, endophytes were found to be responsible for the production of bioactive compounds that contribute to their biocontrol activity.
- 3-Methyl-2-aryl benzofurans obtained from the fermentation products of endophytic fungi *Phomopsis* showed anti-TMV activity.

Why needs of Biocontrol?

- ✓ Chemical compounds used to control plant diseases are not safe for environment, therefore biological agents are used as an acceptable strategy to manage the plant diseases (Mejia *et al*., 2008).
- ✓ Due to excessive use of chemicals, pathogens have developed resistant strains.
- ✓ For example, genus *viz*., *Pythium*, *Phytophthora*, *Penicillium*, *Botrytis*, *Cercospora*, *Colletotrichum*, *Fusarium*, *Aspergillus*, *Mycosphaerella*, Sphaerotheca, *Verticillium* and *Alternaria* are among the fungal pathogens that have developed resistant strains against fungi (Agrios, 2005).

Endophytes as a biocontrol agent against plant diseases

Sr. No.	Endophytic fungi	Plants	Pathogens	References
A. Fungi target				
1.	*Alternaria alternata*	*Cornus officinalis*	*Alternaria arborescens*	Zhao *et al*. (2020)
2.	*Fusarium solani*	*Vitis labrusca*	*Botrytis* sp.	Brum *et al*. (2008)
3.	*Fusarium oxysporum*	*Solanum lycopersicum*	*Phytophthora infestanse*, *P. capsici*	Kim *et al*. (2007)

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4.	*Gliocladium catenulatum*	*Theobroma cacao*	*Crinipellis perniciosa*	Rubini *et al.* (2005)
5.	*Colletotrichum gloeosporioides*	*Theobroma cacao*	*Phythophthora* sp.	Mejía *et al.* (2008)
6.	*Aspergillus* sp., *Penicillium* sp. and *Trichoderma* sp.	*Eucalyptus benthamii*	*Botrytis cinerea*	Sbravatti *et al.* (2013)
7.	*Trichoderma viride*	-	*Rhizoctonia solani*	Mathivanan *et al.* (2005)
B. Bacteria target				
1.	*Xylariales* sp.	*Distylium chinense*	*Clavibacter michiganensis*, *Xanthomonas citri* pv. *phaseoli* var. fuscans and *Pseudomonas syringae* pv. *lachymans*	Zhang *et al.* (2020)
1.	*Paecilomyces variotii*	*Nicotiana benthamiana* and *N. tabacum*	*Potato Virus X* (PVX) and *Tobacco mosaic virus* (TMV)	Peng *et al.* (2020)

Conclusion

Understanding the endophyte-plant interaction and its important role as a potential biopesticide, it can be used as a better and rational integrated disease management strategy and can play a key role in promoting low-cost and sustainable agricultural applications. The availability of complete genome sequences of endophytes, which have previously shown their potential, allows the identification of genes that influence the establishment and biocontrol properties of endophytic plants. Eventually, we can move towards gaining our goals of sustainable agriculture.

Reference

Agrios, G. N. (2005). Plant Pathology (5th ed.). Academic Press, London.

Akinsanya, M. A., Goh, J. K., Lim, S. P. and Ting, A. S. Y. (2015). Diversity, antimicrobial and antioxidant activities of culturable bacterial endophyte communities in Aloe vera. *FEMS Microbiology Letters*, 362(23).

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Beauregard, P. B., Chai, Y. R., Vlamakis, H., Losick, R. and Kolter, R. (2013). *Bacillus subtilis* biofilm induction by plant polysaccharides. *Proceedings of the National Academy of Sciences*. 110: E1621-30.

Brum, M. C. P. (2008). Fungos endofíticos de Vitis labrusca L. var. Niagara Rosada e o seu potencial biotecnológico. PhD Thesis, Universidade de Mogi das Cruzes: Mogi das Cruzes.

Carroll, G. C. (1986). The biology of endophytism in plants with particular reference to woody perennials. In N. J. Fokkema, and J. van den Heuvel (Eds.). *Microbiology of phyllosphere*. pp. 205-222.

Döbereiner, J. (1993). Recent changes in concepts of plant bacteria interactions: Endophytic N2 fixing bacteria. *Cienc Cult*. 44: 310-313.

Erbert, C., Lopes, A. A., Yokoya, N. S., Furtado, N., Conti, R. and Pupo, M. T. (2012). Antibacterial compound from the endophytic fungus *Phomopsis longicolla* isolated from the tropical red seaweed *Bostrychia radicans*. *Botanica Marina*. 55: 435-440.

Ganley, R., Brunsfeld, S. and Newcombe, G. (2004). A community of unknown, endophytic fungi in western white pine. *Proceedings of the National Academy of Sciences USA*. 101: 10107-10112.

Hallmann, J., Quadt-Hallmann, A., Mahaffee, W. F. and Kloepper, J. W. (1997). Bacterial endophytes in agricultural crops. *Canadian Journal of Microbiology*. 43: 895-914.

Houterman, P. M., Cornelissen, B. J. C. and Rep, M. (2008). Suppression of plant resistance gene-based immunity by a fungal effector. *PLoS Pathology*. 4: e1000061.

Kim, H. Y., Choi, G. J., Lee, H. B., Lee, S. W., Lim, H. K., Jang, K. S., Son, S. W., Lee, S. O., Cho, K. Y. Sung, N.D. *et al*. (2007). Some fungal endophytes from vegetable crops and their anti-oomycete activities against tomato late blight. *Letters in Applied Microbiology*. 44: 332–337.

Kuc, J. (1982). Induced immunity to plant disease. *Bioscience*. 32: 854-60.

Lugtenberg, B. and Kamilova, F. (2009). Plant-growth-promoting rhizobacteria. *Annual Review of Microbiology*. 63: 541-56.

Luttrell, E. S. and Bacon, C. W. (1977). Classification of Myriogenospora in the Clavicipitaceae. *Canadian Journal of Botany*. 55: 2090-2097.

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Martin, J. A., Macaya-Sanz, D. and Witzell, J. (2015). Strong in vitro antagonism by elm xylem endophytes is not accompanied by temporally stable in planta protection against a vascular pathogen under field conditions. *European Journal Plant Pathology*. 142: 185-196.

Mathivanan, N., Prabavathy, V. R. and Vijayanandraj, V. R. (2005). Application of Talc Formulations of *Pseudomonas Fluorescens* Migula and *Trichoderma Viride* Pers. Ex S.F. Gray Decrease the Sheath Blight Disease and Enhance the Plant Growth and Yield in Rice. *Journal of Phytopathology*. 153: 697–701.

Mejia, L. C., Herre, E. A., Sparks, J. P., Winter, K., Garcia M. N., Van Bael, S. A., … Maximova, S. N. (2014). Pervasive effects of a dominant foliar endophytic fungus on host genetic and phenotypic expression in a tropical tree. *Front Microbiology*. 5: 479.

Mejia, L. C., Rojas, E. I., Maynard, Z., Bael, S. V., Arnold, A. E., Hebbar, P., … Herre, E. A. (2008). Endophytic fungi as biocontrol agents of *Theobroma cacao* pathogen. *Biological Control*. 46: 4-14.

Mukherjee, P. K., Horwitz, B. A. and Herrera-Estrella, A. (2013). *Trichoderma* research in the genome era. *Annual Review of Phytopathology*. 51: 105-29.

Peng, C., Zhang, A., Wang, Q., Song, Y., Zhang, M., Ding, X., Li, Y., Geng, Q. and Zhu, C. (2020). Ultrahigh-Activity Immune Inducer from Endophytic Fungi Induces Tobacco Resistance to Virus by SA Pathway and RNA Silencing. *BMC Plant Biology*. 20: 169.

Petrini, O. (1991). Fungal endophytes of tree leaves. In J. H. Andrews, & S. S. Hirano (Eds.), Microbial ecology of leaves. pp 179-197.

Rubini, M. R., Silva-Ribeiro, R. T., Pomella, A. W. V., Maki, C. S., Araújo, W. L., Dos Santos, D. R. and Azevedo, J. L. (2005). Diversity of endophytic fungal community of cacao (*Theobroma Cacao* L.) and biological control of *Crinipellis Perniciosa*, causal agent of witches' broom disease. *International Journal of Biological Sciences*. 1: 24–33.

Sbravatti Junior, J. A., Auer, C. G., Pimentel, I. C., Santos, Á. F. dos and Schultz, B. (2013). Seleção *in vitro* de Fungos Endofíticos Para o Controle Biológico de Botrytis Cinerea Em *Eucalyptus Benthamii*. 43: 145.

Schulz, B. and Boyle, C. (2005). The endophytic continuum. *Mycological Research*. 109(6): 661-686.

Smith, S. E. and Read, D. J. (1997). Mycorrhizal Symbiosis (2nd ed.). Academic Press, San Diego.

Unterseher, M., Jumpponen, A., Opik, M., Tedersoo, L., Moora, M., Dormann, C. F. and Schnittler, M. (2011). Species abundance distributions and richness estimations in fungal metagenomics—Lessons learned from community ecology. *Molecular Ecology*. 20(2): 275-85.

Van der Heijden, M. G., Martin, F. M., Selosse, M. A. and Sanders, I. R. (2015). Mycorrhizal ecology and evolution: the past, the present and the future. *New Phytologist*. 205(4): 1406-23.

Zhang, X.-Q., Qu, H.-R., Bao, S.-S., Deng, Z.-S. and Guo, Z.-Y. (2020). Secondary Metabolites from the Endophytic Fungus *Xylariales* Sp. and Their Antimicrobial Activity. *Chemistry of Natural Compounds*. 56: 530–532.

Zhao, X., Hu, Z., Hou, D., Xu, H. and Song, P. (2020). Biodiversity and Antifungal Potential of Endophytic Fungi from the Medicinal Plant *Cornus Officinalis*. *Symbiosis.*

Zinniel, D. K., Lambrecht, P. and Harris, B. N. (2002). Isolation and characterization of endophytic colonizing bacteria from agronomic crops and prairie plants. *Applied and Environmental Microbiology*. 68: 2198-2208.