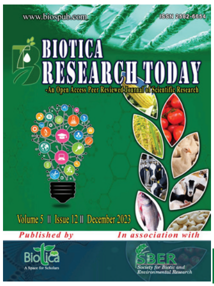

Bio. Res. Today 2023, 5(12):820-822

Biotica Research Today

e-ISSN: 2582-6654

December, 2023

Article ID: RT1521 Popular Article

Endophytic Fungi: Potential Role in Sustainable Agriculture

Abhinandana, K.R.[*] and Krishna Naik, L.

Dept. of Agricultural Microbiology, University of Agricultural Sciences, GKVK, Bangalore, Karnataka (560 065), India

Open Access

Corresponding Author

Abhinandana, K.R.

: krabhinandana18@gmail.com

Conflict of interests: The author has declared that no conflict of interest exists.

How to cite this article?

Abhinandana and Krishna, 2023. Endophytic Fungi: Potential Role in Sustainable Agriculture. *Biotica Research Today* 5(12), 820-822.

Abstract

Fungal endophytes are considered as the crucial component of plant micro-ecosystem; reside within plant tissues without displaying any apparent noticeable symptoms in the host. Endophytic fungi exert significant effects on host plants by promoting growth, improving fitness and enhancing resistance to pests and diseases. Moreover, as a symbiotic partnership between the fungal endophytes - host plant, the latter produces an abundance of bioactive substances that are expressed as defensive mechanisms to shield the former from multitude of stressful condition. In addition, endophytic fungi enhance the plant's ability to tolerate heavy metal toxicity or stress *via* secretion of numerous secondary metabolites and helps in phyto-remediation. Hence, harnessing the prospective of endophytic fungi, equipped with a range of beneficial traits, holds promise as a valuable tool in achieving the objectives of a secure and sustainable agricultural system.

Keywords: Abiotic stress, Biocontrol, Endophytic fungi, Phytoremediation

Introduction

Plants maintain an inherent association with a diverse array of microbial communities in the rhizosphere, phyllosphere, and within plant tissues, known as the endosphere. These microorganisms, endophytes ("endo" meaning within, "phyte" meaning plant) characterized by their asymptomatic presence within host plants, contribute to enhanced growth, improved nutrient absorption/ uptake, reduced disease severity and increased tolerance to numerous environmental stresses. Endophytes, particularly endophytic fungi, represent a rich source of bioactive plant secondary metabolites, showcasing remarkable diversity. Virtually every plant in existence hosts one or more endophytic fungi, constituting a significant portion of the endophytic population residing exclusively within plant tissues. Plants lacking an association with endophytic fungi are susceptible to the detrimental effects of extreme temperatures, drought and pathogenic attacks. Given the current environmental challenges associated with synthetic chemical usage and pollution, there is a pressing need to explore the natural capabilities of these fungal endophytes and their compounds for crop protection and production. This exploration is crucial in light of the adverse impacts of synthetic chemicals on the environment. Over the past few decades, studies have highlighted their diverse and multifaceted contributions to plant health, growth and environmental resilience.

Enhanced Nutrient Uptake and Plant Growth Promotion

The production of growth regulators and protectants is generally regarded as characteristic of endophytic fungi that promotes plant growth in natural and stressful conditions by producing phyto-hormones such as indole-3-acetic acid, gibberellins, auxins and cytokinins. Among them, gibberellic acid is a significant phytohormone. The phytohormone GA, which is a diterpenoid complex, regulates crop growth and facilitates seed germination, stem elongation, flowering and ripening. Fungal endophytes *viz*., *Sebacina vermifera*, *Tricoderma* sp. *Penicillium* sp. and *Piriformospora indica* are known to improve crop growth and productivity under stressful conditions because of their potential to synthesize enzymes and specific bioactive defence metabolities (Hamilton and Bauerle, 2012). Literature survey additionally revealed that PGPFs (plant growth-promoting fungi) sustain plant growth by producing number of significant enzymes such as ACCD, urease, catalase and others. Further, endophytic fungi also help the plant in nutrient absorption. Plethoras of researchers have documented the ability of endophytes to solubilize minerals (Phosphorus) and facilitate the absorption of essential nutrients [Figure 1(a)]. This

Article History

RECEIVED on 07th December 2023 RECEIVED in revised form 14th December 2023 ACCEPTED in final form 15th December 2023

process enhances the accessibility of this essential nutrient, which is often limiting in soils, promoting crop growth. Thereby, fungal endophytes can assist plants in coping with suboptimal mineral conditions. Furthermore, endophytic fungi exhibit siderophore production, contributing to the synthesis of iron-chelating compounds within the host plant [Figure 1(b)]. This aspect is particularly relevant for sustainable agriculture, offering a natural and eco-friendly alternative to chemical fertilizers.

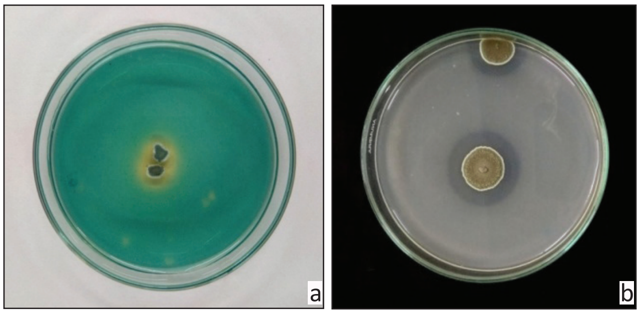

Figure 1: (a) Siderophore production and (b) phosphate solubilization by endophytic fungi, *Penicillium* sp.

Enhanced Abiotic Stress Tolerance

Endophytic fungi contribute to the resilience of plants in the face of various environmental stresses, including salinity, drought, high or low temperature and heavy metal contamination. Reactive oxygen species (ROS) production rises dramatically under all of these stress conditions and can even exceed the osmolytes' metabolic capacity. Stress-induced accumulation of ROS has the potential to cause significant harm to cellular constituents like proteins, DNA and RNA, even leading to cell death. However, plants combat/ withstand the accumulation through upregulation of antioxidants such as proline, glycine betaine, peroxidases (POD), superoxide dismutase (SOD) and catalase (CAT). Compelling evidences from the studies identified that presence of endophytes significantly enhances the synthesis of osmolytes and antioxidants in plant tissues, improving the plant's capacity to metabolize ROS (Hereme *et al.*, 2020). In addition, endophytic colonization has been linked to the induction of stress-responsive genes, production of stress-mitigating secondary metabolites, improved water retention, biochemical and physiological parameters, collectively enhancing the adaptability of crops to challenging growing conditions. They can influence plant hormone levels, such as abscisic acid (ABA), which exhibits an immense part in the plant's response to drought stress. The modulation of hormone levels can contribute to improved water use efficiency and stress tolerance. In heavy metal stress condition, endophytic fungi have metal sequestration or chelation that improve their host resistance to metal toxicity by boosting the antioxidative system, alters the distribution/ uptake of metals in plant and finally detoxifies them through their metabolic capacity. This helps the hosts to survive in contaminated soil. This mutualistic interaction contributes to the overall fitness of both the fungus and the host, creating a harmonious relationship that benefits both parties.

Biocontrol and Disease Suppression

Endophytic fungi have demonstrated biocontrol potential against various plant pathogens and pests (Table 1). Through the antifungal metabolites secretion and activation of plant defense mechanisms, they contribute to disease suppression in crops. This biocontrol aspect aligns with the principles of sustainable agriculture by reducing the reliance on synthetic pesticides. Numerous pieces of evidence have been reported regarding the role of endophytic fungi in mitigating various destructive plant diseases through diverse biocontrol mechanisms, such as competing with pathogens for ecological niches or substrate, antibiosis and induction of systemic resistance. Fungal endophytes can produce signaling molecules that act as elicitors. These compounds trigger the plant's defense mechanisms, such as the production of phytoalexins, pathogenesis-related (PR) proteins and reactive oxygen species. The mechanism by which endophytes inhibits insect attack and damage is by production of antiherbivory compounds/ bioactive compounds or complicated interactions between the fungus's and the plant's post-infection metabolic processes. These defensive/ protective substances can discourage feeding (antixenosis) or lowers the insect performance (antibiosis). Endophytic fungi generate the specific biologically active compounds/ secondary metabolites without any apparent harm to their host plant. Defensive compounds involved in biocontrol can be distinguished into several functional groups: alkaloids, flavonoids, isocoumarin derivatives, terpenoids, chlorinated metabolites, phenols, quinones and phenolic acids, *etc.* (Latz *et al.*, 2018).

Table 1: Endophytic fungi with biocontrol potential

Endophytic fungi	Source	Target pathogen	Percent inhibition
Curvularia chiangmaiensis	*Rice plants (Oryza sativa)*	*Pyricularia oryzae*	-
Eupenicillium javanicum	Agar wood (*Aquilaria sinensis*)	*Fusarium oxysporum*	43.30
Fusarium subglutinans	*Thymus* spp.	*Botrytis cinerea*	61.33
Penicillium sp.	Tomato (*Lycopersicon esculentum*)	*Fusarium oxysporum*	66.40
Trichoderma asperellum	Soybean (*Glycine max*)	*Rhizoctonia solani*	42.00
Trichoderma harzianum	Rattan (*Calamus castaneus*)	*Fusarium solani*	62.28
Trichoderma koningiospsis	Spines	*Fusarium fujikuroi*	59.94
Trichoderma longibrachiatum	Soybean (*Glycine max*)	*Rhizoctonia solani*	87.00

Phytoremediation and Environmental Sustainability

Certain fungal endophytes can accumulate and tolerate high concentrations of organic and inorganic pollutants. When associated with plants, these fungi can contribute to the process of phytoremediation, where plants absorb and accumulate pollutants from the soil, aiding in environmental cleanup (Table 2). Fungi contribute to phytoremediation through various mechanisms, including the secretion of enzymes that facilitate the breakdown of contaminants, the enhancement of plant root systems and the formation of complexes that bind and immobilize pollutants. Fungi can accumulate/ adsorb heavy metals within their biomass through processes like adsorption, absorption and complexation. This is often facilitated by the presence of specific metal-binding proteins and chelating compounds produced by the fungi. In addition, certain fungi can transform the chemical forms of heavy metals, transforming into less bioavailable or less mobile compounds. This transformation can be crucial for reducing the environmental impact of heavy metal contamination. In addition, fungal endophytes contribute to nutrient cycling in ecosystems by decomposing organic compounds and releasing nutrients in readily available or bioavailable form. The synergy between fungi and plants, coupled with the unique enzymatic capabilities of certain fungal species, opens new possibilities for sustainable and eco-friendly solutions to pollution.

Table 2: Endophytic fungi with bioremediation potential

Endophytic fungi	Host used	Bioremediation activity
Neotyphodium coenophialum	*Festucaarundinacea Schreb.*	TPH removal from petroleum contaminated soils.
Mucor sp.	*Brassica napus* L. *Brassica chinensis* L.	Bioaccumulation of Pb and Cd fromheavy-metal contaminated soil.
Peyronellae	*Zea mays*	heavy metal absorption and accumulation (Pb, Zn and Cd).
Mucor sp. CBRF59 *Fusarium* sp. CBRF14	*Brassica napus* L.	Phytoremediation of multi-metals (Cd, Pb, Zn) in contaminated soil.
Leotiomycetes fungi Pezizomycetes fungi	*Imperata cylindrical* (L.) *Beauv*.	Phytoremediation of Pb and Cd from contaminated soil.
Aspergillus sp. A31, *Lindgomycetaceae* P87 and *Westerdykella* sp.	*Aeschynomene fluminensis* Vell.	Mercury bioremediation.
Lasiodiplodia sp. MXSF31	*Portulaca oleracea* L.	High bio-aborption and bioaccumulation capacities of Cd, Pb and Zn from metal-contaminated solutions and metal extraction.

Conclusion

Fungal endophytes have an immense potential in promoting sustainable agriculture by offering safety, cost-effectiveness and the capacity to generate diverse compounds such as phytohormones, defensive agents, phosphate solubilization, extracellular enzymes, siderophore production, inhibition of phytopathogens, thereby enhancing plant growth. Recently, there has been a sharp notable rise in study of fungal endophytes, as they hold significant potential in agricultural sector. Harnessing the potency of these fungi in agriculture and ecosystem management can contribute to more sustainable and resilient systems. Understanding the beneficial relationship between plants - fungal endophytes is an active area of research with implications for agriculture, forestry and ecosystem management. Nevertheless, the precise mechanism behind the enhancement of crop growth by endophytes remains incompletely understood. Attaining a comprehensive understanding of their ecology and molecular interactions would undoubtedly aid in discovering new potential applications in agriculture

References

Hamilton, C.E., Bauerle, T.L., 2012. A new currency for mutualism? Fungal endophytes alter antioxidant activity in hosts responding to drought. *Fungal Diversity* 54, 39-49. DOI: https://doi.org/10.1007/s13225-012-0156-y.

Hereme, R., Morales-Navarro, S., Ballesteros, G., Barrera, A., Ramos, P., Gundel, P.E., Molina-Montenegro, M.A., 2020. Fungal endophytes exert positive effects on *Colobanthus quitensis* under water stress but neutral under a projected climate change scenario in Antarctica. *Frontiers in Microbiology* 11, 264. DOI: https://doi.org/10.3389/fmicb.2020.00264.

Latz, M.A.C., Jensen, B., Collinge, D.B., Jorgensen, H.J.L., 2018. Endophytic fungi as biocontrol agents: Elucidating mechanisms in disease suppression. *Plant Ecology & Diversity* 11(5-6), 555-567. DOI: https://doi.org/10.1080/17550874.2018.1534146.