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ENDOPHYTIC FUNGI: A KEY PLAYER IN PLANT-MICROBE INTERACTIONS AND ECOSYSTEM FUNCTIONING

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ABSTRACT

This article discusses the importance of endophytic fungi in the microbial communities associated with plants. Endophytes are microorganisms that live within plant tissues without causing harm to the host plant and can produce bioactive compounds, including plant growth hormones and enzymes, with significant implications.

Introduction. The vast and intricate diversity of microorganisms associated with plants form structured microbial communities that create complex interconnections. These networks are crucial for plant health and ecosystem functioning. It is essential to comprehend the composition of these microbial communities and their core functions to unravel their networking strategies and potential impact on plant performance. The growth and health of plants can be significantly influenced by various types of microorganisms with distinct functions (1).

Endophytes are defined as microbes that live asymptomatically in the tissues of plants, without causing harm to the host plants, and can be isolated from surface-sterilized explants. The word "endophytes" means "within the plant" (from Greek "endon" = within, "phyton" = plant), and endophytes mostly originate from the rhizosphere and phyllosphere.

Endophytes are known to produce a diverse range of bioactive compounds, including plant growth hormones and various biological substances like enzymes, alkaloids, and vitamins, that can have significant implications in biotechnology. Endophytes have been reported to produce compounds with the ability to inhibit bacterial and fungal pathogens, which could help protect plants against phytopathogens. These observations demonstrate that endophytes are present within plant tissues and subsist as reservoirs of bioactive metabolites (2).

Biodiversity of fungal endophytes. Endophytes are classified into archaea, bacteria, and fungi. Among fungi, members of different phyla, such as Ascomycota, Basidiomycota, Mucoromycota, and Oomycota, have been identified as endophytic from various crops. A review of various studies on the biodiversity of endophytic fungi from different crops has revealed that the dominant genera include *Aspergillus*, *Fusarium*, *Penicillium*, and *Piriformospora*.

Isolation and characterization of fungal endophytes. The colonization of plant tissues by fungi is largely influenced by the environmental conditions surrounding the host plants, such as soil type and pH, soil alkalinity, and climate. Endophytic fungi may develop in small amounts and occasionally in confined locations inside plants, making it difficult to determine their specific relationship with their host plant. To isolate the fungi, plant samples should be collected in a sterile polythene bag under aseptic conditions and transferred to the laboratory (3).

Both morphological and molecular techniques should be used for the identification and characterization of fungal endophytes (4). Morphological techniques involve examining the physical characteristics of the fungi, such as their growth patterns, color, and shape, which can help to identify them. However, relying solely on morphological features can be limiting, as some fungi may have similar characteristics and can be difficult to distinguish. Molecular techniques, on the other hand, can provide more accurate identification and characterization (5). By combining both techniques, researchers can obtain a more comprehensive understanding of fungal endophytes and their role in plant-microbe interactions. Additionally, the use of both techniques can help to confirm the identity of the endophytic fungi and ensure that they are accurately classified.

Biotechnological applications of endophytic fungi. The main function of plant roots is to explore the soil and acquire nutrients to support the growth and development of the plant. The plant root system is in close contact with soil microbial populations; therefore, the root system functions under the direct influence of microbial interactions. Over recent decades, researchers have made significant advances in understanding how these microorganisms interact with host plants. It has been found that endophytic fungi may increase crop yields, remove impurities, and constrain pathogens while producing novel substances. It is well known that endophytes stimulate plant growth by synthesizing phytohormones, such as indole acetic acid (IAA) and cytokinins. The use of microbial plant growth promoters is an alternative to conventional agronomic technologies. Endophytic fungi can influence the development of plants directly or indirectly by mediating the uptake of specific nutrients from the atmosphere and indirectly by decreasing or inhibiting the harmful consequences of one or more phytopathogenic organisms as well (6).

Endophytic fungi: key players in soil nutrient cycling. Endophytic microbes colonize the healthy tissues of plants inter- or intracellularly (7). Endophytic fungi are known to be important in the degradation of plant debris in a variety of ecosystems. Endophytes are able to produce various types of enzymes, such as cellulose, lipase, protease, phenoloxidase, and pectinase. After plants have died and fallen to the ground, fungal endophytes utilize glucose, oligosaccharides, cellulose, lignin, keratin, pectin, lipids, and other components of plant residues to decompose them rapidly (8).

Conclusion and future prospects. In recent decades, the use of chemical substances such as fertilizers, fungicides, bactericides, and pesticides has increased in order to enhance crop yields, but this has had negative impacts on the Earth's atmosphere and led to pollution of air and groundwater. To address this issue, new methods are being developed in agriculture to improve nutrient supply, including the use of fungal endophytes to promote plant growth. Endophytes that produce bioactive compounds from their host plants have

garnered more attention, and can be utilized as biocontrol agents and biofertilizers to promote sustainable agriculture. Additionally, fungal endophytes that produce enzymes are known to be significant in remediating environmental pollutants. These developments may have significant implications for both living organisms and human health.

Despite the significant biotechnological potential of endophytic microbes, their capacity as a valuable source of bioactive metabolites has been underexplored. To fully understand the role of endophytes in plant-microbe interactions, future research should focus on developing genomic and metabolomic tools that can shed light on their life inside plants.

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