Endophytes: Prospects and Applications for the Plant Disease Management

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Plant diseases, caused by agricultural pests and pathogens, commonly result in crop losses and are a significant threat to food security. Agrochemicals are efficient in plant disease management (Xia et al., 2022). However, the intensive application of chemical fertilizers and pesticides has negative effects on the ecosystem and human beings, causing environmental pollution, pathogen resistance, and ecological imbalance1. Biocontrol, unlike chemical methods, are environmentally friendly through the action of natural control agents, such as beneficial microorganisms and their products, metabolites [Vianle et al., 2008].

Endophytes and their bioactive metabolites have received considerable attention due to their potential as biological control agents (BCAs) [Dutta et al., 2014; Rabiey et al., 2019]. Endophytes, including endophytic fungi, endophytic bacteria, and endophytic actinomycetes, exist in various organs, tissues, and intercellular spaces of plants without causing immediate signs of diseases [Wison, 1995; Jia et al., 2016]. They have established a mutually beneficial relationship with host plants during long-term coevolution. Plants provide nutrients for endophytes, while endophytes contribute to maintaining the health of plants [Khare et al., 2018; Yan et al., 2019]. The mechanisms proposed for disease prevention include competition with pathogens for niche and nutrition, induction of plant resistance, secretion of bioactive metabolites, and promotion of plant growth, usually working in concert [Dubey et al., 2020; Martínez-Arias et al., 2020].

Endophytic microorganisms, such as *Bacillus*, *Burkholderia*, *Enterobacter*, *Pseudomonas*, *Streptomyces*, etc., are used as microbial formulations against various phytopathogens [Jacob et al., 2020]. Endophytes can produce metabolites with a variety of biological activities, such as alkaloids, polypeptides, polyketides, terpenoids, etc., which are of great significance and value in different fields, especially in agriculture and the pharmaceutical industry [Dubey et al., 2020]. In plant health protection, the major function of these bioactive metabolites is to directly or indirectly help the host plants resist biotic and abiotic stresses. For example, some antimicrobial compounds produced by endophytes are well known for strongly inhibiting pathogens, hydrolases secreted by endophytic bacteria can decompose the cell wall of pathogens, and phytohormones released by endophytes play a vital role in plant development and stress response [Singh et al., 2017].

The major members of endophytic fungi include Ascomycota, Zygomycota, and Basidiomycota. In general, endophytic fungi have been recognized as two broad groups according to the life history traits and evolutionary relatedness, namely, (1) the clavicipitaceous endophytes colonizing within some grasses and (2) the non-clavicipitaceous endophytes from asymptomatic tissues of nonvascular plants, conifers, ferns, and angiosperms. Whereas endophytic bacteria belong to a diverse group of species, ranging from gram-positive to gram-negative bacteria, such as Bacillus, Agrobacterium, Brevibacterium, Pseudomonas, etc. [(Xia et al., 2022).

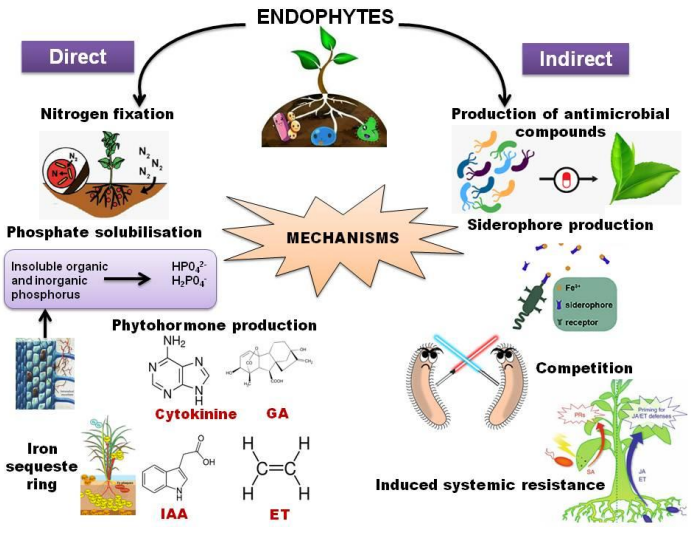

Fig. 1: Outline of various mechanisms adapted by endophytes to promote plant growth

Endophytes secrete various metabolites that directly or indirectly enhance the tolerance of the host to different stresses, thus making them beneficial to the plants, and they potentially serve as promising biological agents in controlling plant diseases. the key mechanisms of endophytes are (1) competing with pathogens for niche and nutrition, (2) producing antimicrobial compounds, (3) secreting lytic enzymes, (4) inducing systemic resistance in host plants, and (5) producing plant hormones and plant growth promoting regulators. There are still more problems to be solved. An overview of the main functions, future prospects, and challenges in using endophytes and their metabolites in plant disease management is shown in Figure 1.

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