Endophytes and their role in Enhancing Horticultural productivity

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Abstract

Horticulture, encompassing fruits, vegetables, nuts, seeds, herbs, sprouts, mushrooms, algae, flowers, seaweeds, and non-food crops such as grass and ornamental trees and plants, plays a pivotal role in enhancing global food security, nutritional quality, and the economic well-being of farmers. In India, where agriculture is the backbone of the economy with nearly 80% population dependent on this industry, increasing horticultural productivity is imperative. One of the emerging and promising strategies to achieve this goal is the application of endophytes.

Understanding Endophytes

Endophytes are an endosymbiotic group of microorganisms predominantly bacteria and fungi, that colonize plant's inter- and/or intracellular spaces without causing any apparent harm to the host.Numerous studies on plant species have revealed that almost all of them have one or more endophytes, which shield host plants from harmful environmental factors and pathogen invasion.They establish a symbiotic relationship with their host plants, often providing various benefits such as enhanced growth, improved resistance to diseases, and increased tolerance to abiotic stresses like drought and salinity. The potential of endophytes in boosting horticultural productivity lies in their multifaceted roles in plant health and development. Endophytic microorganisms, such as *Bacillus*, *Burkholderia*, *Enterobacter*, *Pseudomonas*, *Streptomyces*, etc., are used as microbial formulations against various phytopathogens. Endophytes are able to create metabolites with a wide range of biological activity, including terpenoids, polypeptides, alkaloids, and polyketides. Due to their potential applications as natural antioxidants, antibiotics, insecticidal agents, anticancer agents, antidiabetic medicines, and more, these metabolites have garnered a lot of interest and research. On the basis of their life history, characteristics and evolutionary relatedness, endophytic fungi have generally been classified into two major groups. One group is the clavicipitaceous endophytes colonizing inside certain grasses. They are reported to enhance the host plant resistance towards insect feeding. Examples are *Epichloe, Neotyphodium coenophialum, Balansia,* etc. The other type isthe non-clavicipitaceous endophytes from asymptomatic tissues of nonvascular plants, conifers, ferns, and angiosperms. It has been demonstrated that a number of NC-endophytes form mutualistic relationships with plants, offering fitness advantages like resistance to biotic and abiotic stresses, uptake of nutrients, and enhanced growth and yields.

Bacterial endophytes have been found in every plant studied till date with a few rare exceptions. Bacteria showing endophytic properties belong to diverse groups of species. They range from gram-positive to gram-negative bacteria. Also known as plant growth promoting rhizobacteria (PGPR), endophytic bacteria are a subgroup of Rhizospheric bacteriai.e., inhabiting roots of plants inside the soil. Actually, these are a unique class of rhizobacteria that have developed the capacity to infiltrate their plant host. Examples of widely studied endophytic bacteria are *Proteobacteria*, *Firmicutes*, *Bacillus*, *Pseudomonas*, *Agrobacterium*, etc.

The Role of Endophytes in Plant Growth Promotion

Nutrient Acquisition

Endophytes enhance nutrient availability to plants. The soil-plant-microbe continuum is created by endophytic microorganisms, which facilitate nutrient solubilization and further transport these nutrients to the plant roots through interactions with rhizospheric microbes and plants. Additionally, during the rhizophagy cycle, plant roots internalize microorganisms and oxidatively absorb nutrients from them. Certain endophytic bacteria can fix atmospheric nitrogen, converting it into a form that plants can absorb and utilize. Others solubilize phosphates and make them available to the plants. This biological nutrient acquisition reduces the dependency on chemical fertilizers, promoting sustainable agricultural practices.

Phytohormone Production

Endophytes are known to produce phytohormones such as auxins, cytokinins, and gibberellins. These hormones play a crucial role in regulating plant growth and development. For instance, auxins stimulate root growth, leading to better water and nutrient uptake. Cytokinins promote cell division and shoot formation, while gibberellins enhance stem elongation and seed germination.

Enhanced Stress Tolerance

Plants often face various abiotic stresses such as drought, salinity, and extreme temperatures. Endophytes help plants cope with these stresses by inducing the production of stress-related proteins and enzymes. They also enhance the antioxidant capacity of plants, protecting them from oxidative damage caused by environmental stresses.

Disease Resistance

Endophytes act as biocontrol agents against plant pathogens. They produce antimicrobial compounds that inhibit the growth of pathogenic bacteria and fungi and are environment friendly. Moreover, endophytes can induce systemic resistance in plants, making them more resilient to diseases. Metabolites synthesized by endophytes are part of plant disease management, and the application of endophyte metabolites to induce plant resistance is very promising.This reduces the reliance on chemical pesticides, fostering a healthier and more sustainable environment. For example, the pathogenic fungus causing rice blast disease *Pyricularia oryzae* can be managed by endophyte application.The first reported endophyte used for biocontrol of plant diseases is *Epichloe typhina* isolated from Timothy-grass. The fungal endophyte *Populus alba* increased the host plant tolerance towards *Venturia tremulae* infestation. Recently many microorganisms have been manipulated for application in agricultural biocontrol programs like *Bacillus, Enterobacter, Pantoea, Pseudomonas, Streptomyces,* etc.

Applications of Endophytes in Horticulture

Fruit Crops

The application of endophytes in fruit crops like mango, banana, and citrus has shown promising results. For example, endophytic bacteria in mango trees have been found to enhance flowering and fruit set, leading to increased yields. In bananas, endophytes have been used to control the Panama disease caused by Fusarium wilt.A study conducted in the mango orchards of Maharashtra revealed that the application of endophytic bacteria significantly increased the fruit yield. The bacteria enhanced nutrient uptake and induced systemic resistance against common mango diseases, resulting in healthier and more productive trees.

Vegetable Crops

Endophytes have been successfully used in vegetable crops such as tomatoes, cucumbers, and peppers. In tomatoes, endophytic fungi have been reported to improve growth and yield under both normal and stress conditions. Similarly, endophytes in cucumbers have enhanced resistance to powdery mildew, a common fungal disease.Researchers in Karnataka experimented with endophytic fungi in tomato plants. *Ampelomyces* sp. and *Penicillium* sp. endophytes proved effective in conferring positive benefits to tomatoes placed under stress as well as under normal growing conditions. *Ampelomyces* sp. conferred tolerance to tomatoes placed under drought stress in addition to enhancing overall plant growth and fruit yield in comparison to non-symbiotic plants under drought stress. *Penicillium* sp. conferred tolerance to tomatoes placed under 300 mM salinity stress in addition to enhancing root biomass in comparison to non-symbiotic plants. The treated plants exhibited improved growth, higher fruit yield, and better tolerance to drought conditions. The endophytes also reduced the incidence of root-knot nematodes, a common pest in tomato cultivation. The compound ZhiNengCong (ZNC) extracted from endophytic fungus *Paecilomyces Variotii* SJ1 has been reported to induce immunity with ultra-high activity in tobacco. Similarly, *Streptomyces* sp. ZX01triggered immune responses in tobacco through glycoproteinGP-1 production. Endophytic bacteria, *Bacillus amyloliquefaciens*SQR9, commonly found in the rhizosphere of cucumber plant, can elicit systemic resistance in *Arabidopsis*.

Floriculture

In ornamental plants, endophytes have been employed to improve growth and stress tolerance. For instance, endophytic bacteria in roses have increased the number of flowers and extended their shelf life. In orchids, endophytes have been shown to promote seed germination and enhance plant vigor.Tamil Nadu has the largest area under floriculture in India. and endophytes have been successfully used to enhance the quality and longevity of cut flowers in this industry. Endophytic bacteria isolated from local plants were applied to roses and chrysanthemums, resulting in increased flower production and extended vase life. Some *Pseudomonas* species are used for biocontrol of fusarium wilt in carnation by competing for nutrients and resources with the pathogen. Through salicylic acid (SA) and jasmonic acid (JA)signaling networks, the fungal endophytes *Penicillium citrinum* LWL4 and *Aspergillus terreus* of the sunflower family (Helianthus annuus L.) notably increased host resistance to stem rot brought on by *Sclerotium rolfsii*.

Medicinal plants

Endophytes are an essential component of the microecology of medicinal plants. They can increase the growth of medicinal plants, increase the hosts'

ability to withstand stress, and encourage the build-up of active components within the hosts. The generation of bioactive secondary metabolites such as phenols, quinols, peptides, polyketones, alkaloids, steroids, and terpenoids which are ccrucial for the medicinal propertiesis largely dependent on the internal microbiome of medicinal plants.The growth and yield of several medicinal plants have been reported to be enhanced by many endophytes, especially by gene expression modulation regulated in important secondary metabolites' biosynthesis. Native endophytes of *Coleus forskohlii* (*Phialemoniopsis cornearis* (SF1), *Macrophomina pseudophaseolina* (SF2), and *Fusarium redolens* (RF1), isolated from stem and root parts have been reported for plant growth and secondary metabolite enhancement in medicinal plant *Andrographis paniculata*, and aromatic plants *Pelargonium graveolens* and *Artemisia pallens*. Also, endophytic fungi associated with *Monarda citriodora,* an aromatic and medicinal plant popular for its antifungal properties has been reported to show tremendous biocontrol potential against some fungal pathogens like *Fusarium oxysporum*.

Challenges

While the application of endophytes in horticulture holds immense potential, there are challenges that need to be addressed. The variability in the effectiveness of endophytes due to environmental conditions, host plant specificity, and the complex interactions between endophytes and plants are some of the major hurdles. Additionally, the commercialization of endophytic products requires rigorous testing and validation to ensure their efficacy and safety.To overcome these challenges, interdisciplinary research involving microbiologists, horticulturists, and agronomists is essential. Advances in genomics, proteomics, and metabolomics can provide deeper insights into the mechanisms of endophyte-plant interactions. Developing formulations and delivery systems that ensure the survival and colonization of endophytes in the field is also crucial. Furthermore, the integration of endophytes into conventional horticultural practices requires awareness and training programs for farmers. Demonstration trials and field studies can showcase the benefits of endophytes, encouraging their adoption at the grassroots level.

Conclusion

Endophytes represent a promising frontier in enhancing horticultural productivity. Their ability to promote plant growth, enhance stress tolerance, and protect against diseases makes them valuable allies in sustainable agriculture. As research progresses and challenges are addressed, the widespread application of endophytes can revolutionize horticulture in India, contributing to food security, environmental sustainability, and the economic well-being of farmers.Embracing this natural and eco-friendly approach to crop management can pave the way for a greener and more resilient agricultural future, ensuring that India's horticultural sector continues to flourish and thrive.

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