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The Silent Partners: Role of Endophytes in Enhancing Growth, Yield and Quality of Horticultural Crops

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Horticulture is the branch of agriculture dealing with the cultivation of fruit, vegetables, ornamentals and spice crops which are vital not only for global food security but also for economic and nutritional sustainability. The population is increasing at an alarming rate worldwide due to which there is need for improvement in the crop yields to sustain the ever-increasing population with the reducing cultivable farmlands. This need for increasing productivity has led to the enormous use of chemical fertilizers and pesticides which on other side degrades the environment, causes pollution and also severely impacts the health of living beings.

Seeing all the consequences of continuous use of chemical fertilizers, there is need to opt for an alternative which provides more sustainability, productivity and quality produce. The use of endophytes has emerged as alternative area in terms of increasing demand of healthy food supply, long-term sustainability, and concerns regarding environmental pollution. They influences the overall health of plants by enhancing nutrient intake, protecting plants from phytopathogens and promoting resistance to various abiotic stresses such as poor soil fertility, drought or presence of heavy metal content in soil. Efficient endophytes used as biofertilizers and biological control agents are promising substitutes for minimizing the application of synthetic agrochemicals in crop production.

What are Endophytes?

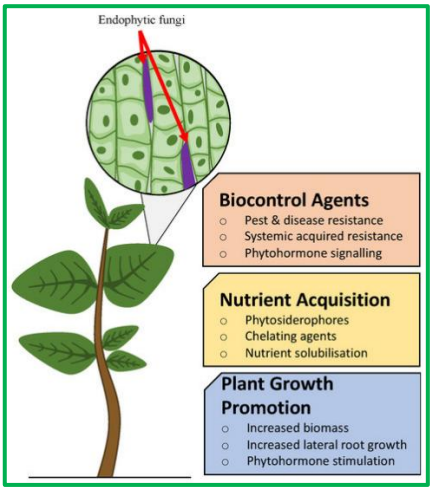
Rhizosphere is home of vast and diverse microbes. The endophytic microorganisms are those which colonize inside the plant tissues without causing any external symptoms of disease or any negatives effects on the plant. No single plants species on this earth is devoid of these endophytes which are present in every part of the plant viz roots, stem, branches or leaves.
The endophytic microbes have been isolated from number of plants species by different researchers. Although the precise role of these endophtes is not known yet but their close association with the plant metabolic processes, origin from the internal biome and the high colonization ability in the internal tissues of the plant has made them the potential candidates for use in the agriculture.

These endophytes are found in all plants and form mutualistic relationships with host plants and offer numerous benefits, including enhanced growth, improved nutrient acquisition, stress tolerance and product quality.

Endophytes are widely utilized to enhance microbial processes that improve the availability of nutrients in forms readily assimilated by plants, thereby promoting their growth. These microbes improve soil fertility by fixing the atmospheric nitrogen, produce plant growth promoting substances in the soil and solubilizing insoluble nutrients e.g. potassium and phosphates. These microbes have been encouraged to reap the naturally available biological system of nutrient mobilization which enormously increases soil fertility and crop yield. They may be bacterial endophytes (e.g. *Azospirillum, Bacillus, Pseudomonas*) or fungal endophytes (e.g. *Trichoderma, Aspergillus, Penicillium*).

These organisms can colonize roots (rhizosphere endophytes), stems (caulosphere) or leaves (phyllosphere) and play different roles depending on the host plant species, environment and endophyte strain.

A particular endophytic microbe (bacteria/ fungi) affects the plant growth and development using one or more mechanisms cites above which depends and varies with the compatibility with host plant, their interaction and stage of the life cycle of plant.



Overview of desirable endophytic impacts upon host plants

Role in Plant Growth and Development

1. Phytohormone Production

Many endophytes produce growth-regulating hormones like gibberellins which stimulate stem elongation, seed germination and flowering; cytokinins that enhance shoot growth and delay leaf senescence. Phytohormones such as auxin, gibberllins, cytokinin, ethylene regulate various functions and metabolic processes of plants. These are synthesized endogenously but microbial synthesis of phytohormones through abiotic or biotic processes is well known from long time.

Auxin is synthesized by various microbes isolated from rhizosphere and plant tissue (roots, leaves etc.) as secondary metabolites. Indole acetic acid (IAA) plays vital role in cell division, cell differentiation, stimulates seed germination, increased root development and xylem differentiation, apical dominance etc. Similarly, the production of IAA in bacteria relaxes the cell walls and increases the release of exudates and also provides extra nutrients to support the growth of other helping bacteria of rhizosphere. Thus, endophytic bacterial IAA is identified as an effector molecule in plant– microbe interactions, both in pathogenesis and phytostimulation.

Ethylene, another plant hormone which regulate fruit ripening process in plants. The abiotic and biotic stress conditions result in the increased levels of ethylene hormone in the plant which counteract by supressing growth, defoliation, premature fruit drop. These actions of ethylene severely affect the crop productivity. Some bacterial strains (*Agrobacterium, Azospirillum, Bacillus*) exhibiting ACC deaminase activity are identified. These endophytic bacteria inhibit the endogenous production of ethylene by trapping the ethylene precursor ACC and binding it with enzyme ACC deaminase.

2. Nutrient Acquisition and Solubilization

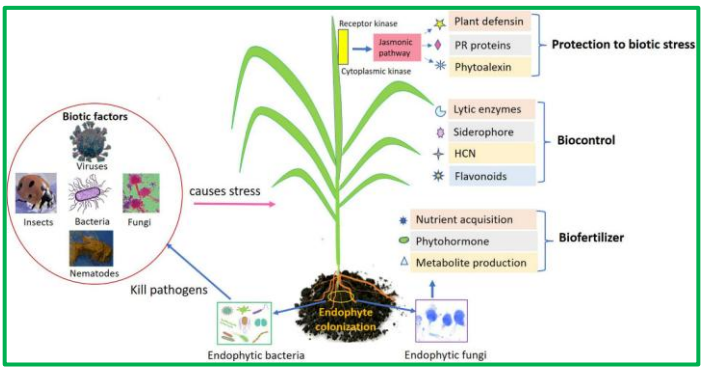
A wide range of endophytic bacteria (*Pseudomonas, Burkholderia, Paenibacillus, Bacillus, Azatobator, Azospirillum*) possesses nutrient solubilization trait. These endophytes solubilize the inorganic form of nutrients into plant available form through different mechanisms as nitrogen fixation, production of siderophores, organic acids, chelation, ion exchange and make them readily available to plants.

3. Role in Enhancing Yield

Endophytes directly and indirectly influence flowering, fruit set and yield through:

a. Induced Systemic Resistance (ISR)

The endophytes can "prime" the plant's immune system against pathogens and pest infestation by activating induces systemic resistance mechanism. ISR is induced by non-pathogenic rhizobacteria which is



Role of endophytes as biofertilizers, biocontrol and biotic stress management in horticultural crops.

mediated by jasmonic acid. Plants colonized with endophytic bacteria have the capability to induce defence mechanism more rapidly than the non- colonized one.

b. Pest and Disease Suppression

Endophytic bacteria posses the ability to control the pathogenic activity inside the plants. The defense mechanism includes production of antibiotics, lytic enzymes or indirect effects to enhance plant resistance by making some morphological and biochemical changes in the plant system, production or secondary metabolites.

4. Impact on Quality of Produce

Quality in horticultural crops is defined by taste, appearance, nutritional value, aroma, shelf-life and safety. Endophytes contribute to these parameters in various ways:

a. Enhanced Nutritional Composition

Endophytes boost levels of:

- Phenolics and flavonoids (antioxidants)
- Ascorbic acid (Vitamin C)
- Carotenoids and anthocyanins

b. Improved Taste and Aroma

Some endophytes modulate sugar-acid balance, aroma compound production and ripening enzymes.

Endophytes in strawberries can increase soluble sugar and volatile esters, enhancing fruit aroma.

c. Reduction of Nitrates and Residues

In leafy vegetables, endophytes reduce nitrate accumulation and residual toxicity, making them safer for consumption.