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# ACTINOBACTERIA IN SUSTAINABLE AGRICULTURE: ENHANCING PLANT GROWTH AND SOIL FERTILITY

**Jegan K P[1], Shanmugabhavatharani R[2], Shalini R[3], Hari Prasanth T[1], Manimaran G[4] and Yuvasri E A[5]**

*[1]Department of Fruit Science, Tamil Nadu Agricultural University, Coimbatore – 641003, Tamil Nadu, India*

*[2]Department of Vegetable Science, Tamil Nadu Agricultural University, Coimbatore – 641003, Tamil Nadu, India*

*[3]Department of Agricultural Extension Education, College of Agriculture, Kerala Agricultural University, Vellayani - 695522, Kerala*

*[4]Department of Soil Science and Agricultural Chemistry, Tamil Nadu Agricultural University, Coimbatore – 641003, Tamil Nadu, India.*

*[5]Department of Agricultural Microbiology, Tamil Nadu Agricultural University, Coimbatore – 641003, Tamil Nadu, India*

**Corresponding Author Mail ID: jeganragul2@gmail.com*

## Introduction

Several kinds of bacteria proliferate in, on, or near plant tissue and rhizosphere soil, promoting plant growth through various mechanisms. These bacteria are collectively referred to as plant growth-promoting rhizobacteria (PGPR). Given the detrimental impact of chemical fertilizers and pesticides on human health, it is imperative to prioritize the exploration of alternatives like PGPR. Recent research indicates that the application of PGPR to soil significantly enhances growth metrics, including plant height, root length, and dry matter production of both shoots and roots. The investigation into the mechanism of action of PGPR is advancing swiftly for commercial application as biofertilizers.

PGPR has been commercialized as a novel inoculum for the enhancement of plant growth through both direct and indirect methods. Plant development can be enhanced through direct methods, including chemical synthesis or nutrient uptake. Nitrogen fixation, enhanced nutrient availability in the rhizosphere, and the synthesis of phytohormones, including auxins, cytokinins, and gibberellins, all facilitate direct growth-promoting mechanisms. The synthesis of antimicrobial compounds to mitigate the adverse effects of phytopathogens on plants and to enhance the host's innate resistance exemplifies indirect mechanisms of plant growth promotion. Biocontrol agents indirectly enhance plant growth through mechanisms such as root competition, pathogen displacement, induced resistance, and stress tolerance.

## Plant Growth Promotion Mechanisms

### Phytohormone Production

Through a variety of processes, including the synthesis of phytohormones such as auxins, cytokinins, gibberellins, ethylene, and abscisic acid, plant growth-promoting rhizobacteria (PGPR) promote plant growth. One important auxin that regulates plant development is indole-3-acetic acid (IAA), which affects organogenesis, cell division, and expansion.

Many soil microorganisms, including bacteria, fungi, and algae, produce IAA, which also stimulates spore germination and mycelial elongation in *Streptomyces* species.

*Streptomyces* species, such as *S. olivaceoviridis*, *S. rimosus*, and *S. rochei*, have demonstrated the ability to produce IAA, promoting seed germination and root growth. These Phytohormones such as gibberellins, cytokinins, and IAA are produced by actinobacteria and are known to promote plant growth. Additionally, the secretion of IAA by *Streptomyces* species has been observed in significant quantities, indicating their potential in agricultural applications to improve plant growth and development.

**Solubilization of Minerals**

Phosphorus is crucial for the growth and development of living organisms, playing a significant role in essential biological molecules and processes. Actinobacteria are particularly effective at solubilizing phosphate, making it available for plant uptake by producing organic acids. These bacteria are also known for their resilience in extreme environments and their ability to enhance plant growth. The solubilization of phosphate by Actinobacteria plays a crucial role in improving phosphorus availability in soils.

**Siderophores Production**

The role of siderophores, which are low-molecular-weight compounds secreted by bacteria to chelate iron in iron-deficient environments. Siderophores play a crucial role, especially in marine environments, where iron availability limits production. Actinobacteria are capable of producing siderophores, particularly amphiphilic ferrioxamine types, which help in marine and terrestrial environments.

Siderophores can be classified into catecholate, hydroxamate, and carboxylate types, with some bacteria producing mixed types. They are synthesized through non-ribosomal peptide synthetase (NRPS) or NRPS-independent pathways and can be generated either intracellularly or extracellularly. The production of siderophores by one type of actinobacteria, such as *Streptomyces griseus*, can stimulate the development of other actinobacteria, like *Streptomyces tanashiensis*.

In soil and water ecosystems, siderophores help maintain productivity by making iron more available. Some plants, like sorghum, oats, peanut, and cotton, can use microbial siderophores to access iron, which enhances plant growth. This phenomenon also indirectly protects plants from pathogens by limiting the availability of iron to harmful microbes in the rhizosphere.

Examples of some actinobacteria that produce siderophores include:

- *Streptomyces griseus* (Desferrioxamine)
- *Streptomyces coelicolor* (Coelichelin)
- *Streptomyces pilosus* (Desferrioxamine)

These siderophores are essential in promoting both microbial and plant growth, showing a positive interaction between actinobacteria and plants.

**Enhancers of Soil Fertility**

The microbial breakdown of complex organic matter into nutrient-rich humus, supports plant growth and soil productivity. Actinobacteria are essential to this process by secreting enzymes such as lignin peroxidases, which aid in the conversion of lignin into humic acid, thereby promoting composting. The composition of Actinobacteria varies throughout the stages of composting, with mesophilic and thermotolerant species exhibiting activity at different phases. These bacteria also produce a range of enzymes that mineralize complex organic materials, enhancing soil fertility and making them valuable for natural fertilizers.

**Stress Tolerance**

Biotic stress in plants is caused by various pathogens, including fungi, bacteria, viruses, and insects, leading to significant damage. Among these, fungi are a major cause of abiotic stress as well. Actinobacteria have shown potential in managing biotic stress due to their antifungal properties, with studies demonstrating the effectiveness of *Streptomyces*

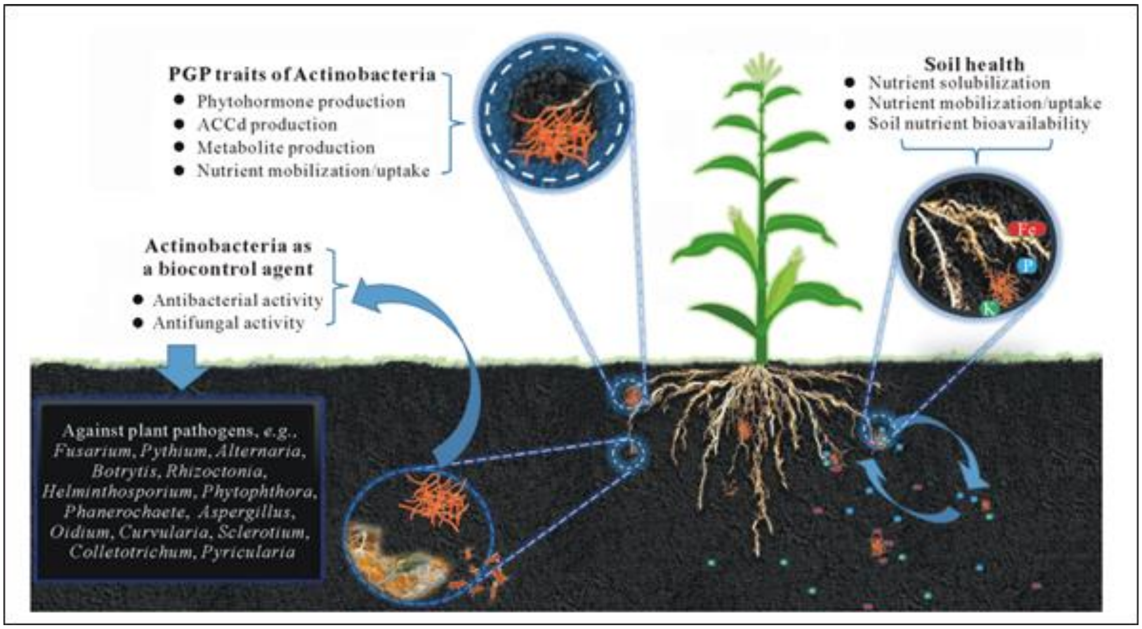


**Fig 1. Positive effects and interactions of Actinobacteria with plants and the rhizosphere. PGP denotes plant growth-promoting (1-aminocyclopropane-1-carboxylate deaminase).**

species against soil-borne fungal pathogens. Actinobacteria can be used for biotic stress management through strategies involving colonization of plant systems, production of anti-phytopathogenic compounds, and promotion of plant growth. Additionally, they help manage abiotic stress, such as drought and salinity, by producing compounds like cytokinin and ACC deaminases that reduce stress ethylene in plants.

## Conclusion

Plant growth-promoting rhizobacteria (PGPR) provide a sustainable and effective substitute for chemical fertilizers and pesticides. They promote plant growth through various mechanisms, such as the production of phytohormones, the solubilization of essential minerals, and the synthesis of siderophores. Furthermore, PGPR enhances soil fertility through the decomposition of organic matter and assists plants in managing both biotic and abiotic stresses. Actinobacteria, including Streptomyces species, are integral to these processes, enhancing plant health and productivity. The incorporation of PGPR into agricultural practices enhances sustainable and resilient crop management, under environmental and economic objectives.

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