



## PGPR – PLANT GROWTH PROMOTING RHIZOBACTERIA

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### Abstract

Plant Growth-Promoting Rhizobacteria (PGPR) are a diverse group of beneficial soil bacteria that colonize plant roots and enhance plant growth through various direct and indirect mechanisms. These microorganisms play a crucial role in sustainable agriculture by improving nutrient uptake, producing phytohormones such as auxins and gibberellins, and facilitating nitrogen fixation and phosphate solubilization. Additionally, PGPR contribute to plant health by inducing systemic resistance against pathogens and mitigating abiotic stresses like salinity, drought, and heavy metal toxicity. The integration of PGPR into crop management practices reduces dependence on chemical fertilizers and pesticides, thus promoting environmentally friendly and cost-effective agriculture. Ongoing research focuses on strain selection, formulation development, and understanding the molecular interactions between PGPR and plants to maximize their effectiveness in diverse agro-ecological conditions. This review highlights the multifaceted roles of PGPR and their potential in enhancing crop productivity, soil fertility, and sustainable agricultural practices.

### Keywords:

*Plant Growth-Promoting Rhizobacteria, rhizosphere bacteria, sustainable agriculture,*

*nitrogen fixation, phosphate solubilization, Phytohormone production, Soil fertility*

### Introduction

PGPR is a beneficial soil bacterium that assists plants in converting unavailable nutrient forms into accessible ones through the process of fixation. These PGPR bacteria colonize plant roots, promoting root elongation and facilitating nutrient uptake. Furthermore, PGPR stimulates growth in the root zone while simultaneously reducing nutrient uptake, which enhances crop productivity and diminishes reliance on chemical fertilizers, thereby increasing plant resilience to sustainable environmental stress. PGPRs represent a category of free-living bacteria that inhabit the rhizosphere—the specific soil area directly affected by root secretions and associated microorganisms. Additionally, they can reside within plant tissues (as endophytes) or on the root surface (as epiphytes).

### Why is it important for agriculture?

These beneficial bacteria reside in the soil, primarily around the roots of plants. They are completely harmless; in fact, they enhance plant growth in various ways. In recent years, scientists and farmers have increasingly focused on studying PGPR because they can assist in crop production while reducing the

reliance on chemical fertilizers and pesticides. Utilizing PGPR can lead to cost savings, as farmers will not need to purchase as much fertilizer or pesticide. Additionally, it is more advantageous for the soil and the environment. Given that PGPR are natural and safe, they represent an excellent choice for individuals seeking to cultivate food in a more environmentally friendly manner. PGPR can assist plants in several ways:

- They aid in nitrogen acquisition – Certain bacteria, such as *Rhizobium*, can extract nitrogen from the atmosphere and convert it into a form that plants can utilize. This is particularly beneficial for crops like beans and peas.
- They facilitate phosphorus accessibility – A significant amount of phosphorus present in the soil is not readily available for plant uptake. PGPR such as *Bacillus* and *Pseudomonas* produce acids that release phosphorus, allowing plants to absorb it.
- They generate plant hormones – Some PGPR synthesize natural hormones like IAA (Indole-3-acetic acid), which promotes stronger and deeper root growth.
- They provide disease protection – PGPR can combat harmful microbes by producing antibiotics or activating the plant's immune system to defend itself.
- They assist in adverse conditions – In situations of drought or high salinity, certain PGPR help plants better cope with stress.

### **Recent Innovations in PGPR: Transforming Stress Resilience in Crops**

As the interest in sustainable agriculture increases, recent advancements in

Plant Growth Promoting Rhizobacteria (PGPR) research are providing innovative solutions to support crop resilience in stressful conditions. These advanced PGPR applications not only promote plant growth but also prepare them to endure environmental challenges such as drought, salinity, and climate-related CO<sub>2</sub> fluctuations. Below are some significant developments:

1. **Enhancing Drought Resistance in Rice**  
Researchers have identified promising PGPR strains *Bacillus megaterium* CACC109 and CACC119 that markedly enhance drought resistance in rice (*Oryza sativa* L.). These strains function by modulating the expression of antioxidant and drought-responsive genes within the plant. This genetic adjustment enables rice plants to manage water scarcity more effectively, showing considerable potential for agriculture in arid areas.
2. **Biofilm-Forming PGPR for Maize Resilience**  
Two robust PGPR strains, MJ1 and SRJ4, have demonstrated remarkable potential in assisting maize to endure drought stress. These microorganisms not only create protective biofilms around the roots but also promote plant growth by solubilizing phosphate, producing the plant hormone IAA, and degrading the stress-related compound ACC. Healthier plants with enhanced drought resistance and improved root systems.
3. **Nanotechnology and PGPR for Groundnut Growth**  
An innovative approach has integrated zinc oxide (ZnO) nanoparticles with PGPR to foster growth in groundnut (*Arachis hypogaea* L.). This combination enhances plant growth-promoting characteristics, such as nutrient absorption and hormone synthesis, resulting in increased productivity. It represents an exciting advancement towards more precise,

efficient, and environmentally friendly agricultural practices.

4. Boosting Medicinal Plants Under Elevated CO<sub>2</sub> PGPR is not limited to staple crops it is also proving beneficial for medicinal plants. In species like *Pseudostellaria heterophylla*, PGPR enhances both growth and the synthesis of essential bioactive compounds under elevated CO<sub>2</sub> conditions.

### Emerging Trends in PGPR Innovation

**Co-application with Biochar:** The combination of PGPR and biochar has been investigated to enhance soil characteristics and promote plant growth in stressful conditions. This integrated strategy seeks to utilize the advantages of both PGPR and biochar for sustainable agricultural methods.

**Microbial Consortia Development:** The creation of microbial consortia, which include various PGPR strains, is receiving increased focus due to its potential to deliver synergistic benefits for plant growth and stress resilience, thus providing a comprehensive strategy for crop enhancement.

**Omics Technologies in PGPR Research:** Progress in omics technologies, including genomics, transcriptomics, and metabolomics, is being utilized to comprehend the intricate interactions between PGPR and plants, facilitating the creation of customized PGPR formulations.

### Harnessing Microbial Consortia for Effective Wastewater Bioremediation

Water pollution continues to be a significant global issue, exacerbated by rising industrialization, urban expansion, and agricultural activities. Although traditional

wastewater treatment methods are available, they frequently face challenges in addressing the complex and hazardous nature of contemporary pollutants. Consequently, the scientific community is increasingly exploring nature-inspired solutions, with microbial consortia emerging as one of the most promising options. These are organized groups of microorganisms that collaborate, enhancing one another's abilities and providing an environmentally friendly, effective, and robust method for bioremediation.

Microbial consortia are notably effective due to the synergistic interactions among various microbial species. In contrast to single strains or monocultures, these communities have a wider array of metabolic functions, enabling them to more efficiently decompose complex mixtures of pollutants. Whether addressing heavy metals, dyes, hydrocarbons, or pharmaceuticals, microbial consortia demonstrate improved stability and adaptability in various environmental conditions. This characteristic renders them particularly suitable for the treatment of highly variable and toxic wastewater streams.

The mechanisms through which microbial consortia accomplish bioremediation are both varied and complex. Processes such as biosorption, bioaccumulation, and enzymatic transformation facilitate the conversion of hazardous substances into less toxic or non-toxic forms. Enzymes such as oxidoreductases, peroxidases, and laccases are crucial in the degradation of persistent organic pollutants. These biochemical transformations are frequently supported by a diverse range of microbial species, including bacteria (such as *Pseudomonas* and *Bacillus*), fungi (like

*Trichoderma* and *Aspergillus*), as well as algae and yeasts.

In practical scenarios, microbial consortia have demonstrated significant success in eliminating contaminants from industrial effluents, agricultural runoff, and municipal sewage. They can effectively degrade organic pollutants like phenols and hydrocarbons, detoxify heavy metals such as lead and cadmium, and treat wastewaters that contain synthetic dyes or pharmaceutical compounds. Their extensive metabolic capabilities and cooperative interactions make them formidable tools for the restoration of water quality.

Despite their potential, treatments based on microbial consortia face several challenges. Creating stable and effective consortia necessitates meticulous selection and equilibrium among microbial members. Additionally, there exists the possibility of community imbalance, where a dominant species may inhibit the functions of others. To address these challenges, advancements in genomics, synthetic biology, and bioinformatics are being investigated to create customized consortia with enhanced pollutant-degrading capabilities.

Looking forward, microbial consortia signify a new frontier in sustainable biotechnology. They possess the potential to transform wastewater treatment, making it more environmentally friendly, economically viable, and resilient. With continuous research and the integration of technology, these living systems could become fundamental to global strategies for managing water pollution.

#### **PGPR: Why Should Farmers Be Concerned?**

Farmers today encounter increasing challenges escalating input costs,

environmental concerns, and the demand for reliable yields. This is where PGPR (Plant Growth-Promoting Rhizobacteria) can truly impact. These naturally occurring soil bacteria establish close associations with plant roots, working diligently to promote healthier and more robust crops.

#### **Why should farmers be concerned?**

Firstly, PGPRs function as nature's biofertilizers by unlocking essential nutrients. Numerous strains are phosphate-solubilizing or nitrogen-fixing this indicates that they release phosphorus and convert atmospheric nitrogen into forms that are beneficial for plants. In addition to nourishing plants, certain PGPR strains generate phytohormones such as auxins and gibberellins that encourage vigorous root and shoot development. This fosters stronger plants that are more capable of enduring stresses from drought or subpar soil. Crucially, PGPR also enhance natural disease resistance. They safeguard crops by:

- Competing with detrimental microbes for space and resources,
- Producing antibiotic substances or enzymes that are harmful to pathogens,
- Initiating Induced Systemic Resistance (ISR) a type of immune "priming" within the plant

This threefold action—nutrient delivery, growth enhancement, and disease protection renders PGPR powerful partners in establishing resilient, low-input agricultural systems. For instance, it's a commercial PGPR product that employs patented *Bacillus firmus* to solubilize phosphorus, release root-stimulating phytohormones, and generate iron-chelating siderophores a benefit for nutrient absorption and crop vitality.

**How might a farmer utilize PGPR?**

Common methods of application consist of:

- Seed coatings or inoculants,
- In-furrow applications at the time of planting,
- soil drenches during the growing season

These options are easy to integrate whether you're sowing wheat or peas and aim to support crop performance right from the start.

**Conclusion**

Plant Growth-Promoting Rhizobacteria (PGPR) serve as a valuable resource for increasing crop yield, enhancing soil quality, and fostering sustainable agricultural methods. By employing various mechanisms such as nutrient solubilization, hormone synthesis, disease control, and stress mitigation, PGPR play a crucial role in promoting plant growth and resilience. Their capacity to lessen reliance on chemical inputs positions them as an environmentally friendly option in contemporary farming practices. Ongoing research and practical applications in the field are vital to maximize their efficacy across various crops and agro-climatic regions. With appropriate incorporation into farming practices, PGPR can significantly contribute to achieving food security and environmental sustainability. The success of PGPR is contingent upon selecting the appropriate strain for your specific region, soil characteristics, and crop type. Although laboratory results are frequently encouraging, challenges such as formulation stability, field conditions, and long-term reliability persist.