Chapter-24

Plant Growth Promoting Rhizobacteria (PGPR): Mechanisms, Applications, and Role in Plant Disease Management

Varala Krishnaveni[1], Sathish Kota[2], Rama Krishna V[3], Thudumu Ramakrishna[4]

[1]Teaching Associate, Sri Konda Laxman Telangana Horticuyltural University, Rajendranagar, Hyderabad

[2]Teaching Associate, Professor Jayashankar Telangana Agricultural University, Rajendranagar, Hyderabad

[3]Research Scholar, Professor Jayashankar Telangana Agricultural University, Rajendranagar, Hyderabad

[4]Teaching Associate, Sri Konda Laxman Telangana Horticuyltural University, Rajendranagar, Hyderabad

Email: varalakrishnaveni4444@gmail.com

Abstract

Plant Growth Promoting Rhizobacteria (PGPR) are beneficial bacteria that inhabit the rhizosphere—the narrow zone of soil surrounding plant roots—and enhance plant growth and health through diverse direct and indirect mechanisms. PGPR facilitate nutrient acquisition, including nitrogen fixation, phosphate solubilization, and iron chelation, and produce phytohormones that stimulate root and shoot development. Indirectly, they suppress plant pathogens through antibiosis, competition, induction of systemic resistance, and production of lytic enzymes, making them effective agents in biocontrol of soil-borne and foliar diseases. Common PGPR genera include *Bacillus*, *Pseudomonas*, *Azospirillum*, *Rhizobium*, *Enterobacter*, *Paenibacillus*, and *Serratia*, which can be isolated from rhizosphere soil, root surfaces, and plant tissues. Application methods include seed coating, soil amendment, and root dipping, often combined with organic fertilizers to enhance colonization and efficacy. PGPR offer an eco-friendly, sustainable alternative to chemical fertilizers and pesticides, improving crop productivity, reducing environmental impacts, and enhancing soil health. This chapter provides a comprehensive overview of PGPR, including definition, classification, mechanisms of plant growth promotion, colonization, application methods, role in plant pathology, and future prospects in sustainable agriculture.

Keywords: Biocontrol, Induced Systemic Resistance, Nutrient Solubilization, PGPR, Rhizosphere

Introduction

Plant Growth Promoting Rhizobacteria (PGPR) are a diverse group of beneficial bacteria that colonize plant roots and enhance growth and health by direct and indirect mechanisms. The rhizosphere, a narrow zone of soil surrounding plant roots, provides a nutrient-rich environment due to root exudates, attracting beneficial microorganisms. PGPR improve nutrient availability, stimulate root and shoot growth, produce phytohormones, and protect plants from biotic and abiotic stresses. Their application in agriculture is critical for sustainable crop production, as they reduce reliance on chemical fertilizers and pesticides while improving yield, quality, and resilience to diseases and stress. The dual functionality of PGPR—enhancing growth and suppressing pathogens—positions them as vital components of integrated crop and soil management systems.

Definition and Scope of PGPR

Plant Growth Promoting Rhizobacteria (PGPR) are defined as root-colonizing bacteria that actively enhance plant growth and productivity either directly through nutrient facilitation or indirectly by suppressing plant pathogens. Their scope includes improving nutrient availability (such as nitrogen, phosphorus, and iron), producing phytohormones to stimulate plant growth, alleviating abiotic stresses like salinity and drought, controlling soil-borne and foliar pathogens, and enhancing soil health and structure. PGPR thus offer multifunctional benefits, combining growth promotion and disease suppression in a sustainable and eco-friendly manner.

Classification of PGPR

PGPR can be broadly classified based on their association with plants. Free-living PGPR survive independently in the rhizosphere and include species like *Pseudomonas fluorescens* and *Bacillus subtilis*. Associative PGPR colonize root surfaces or intercellular spaces, such as *Azospirillum brasilense*, while symbiotic PGPR form mutualistic associations with legumes, including *Rhizobium* species. Each group contributes uniquely to nutrient acquisition, growth promotion, and disease suppression.

Microorganisms Identified as PGPR

PGPR Genus	Examples	Key Functions
Bacillus	*B. subtilis*, *B. amyloliquefaciens*	Phosphate solubilization, antibiotic production, ISR
Pseudomonas	*P. fluorescens*, *P. putida*	Siderophore production, antibiosis, disease suppression
Azospirillum	*A. brasilense*	Nitrogen fixation, root development
Rhizobium	*R. leguminosarum*, *R. etli*	Nitrogen fixation in legumes
Paenibacillus	*P. polymyxa*	Antibiotic production, phosphate solubilization
Enterobacter	*E. cloacae*	Phytohormone production, nutrient mobilization
Serratia	*S. marcescens*	Antifungal compounds, siderophores

Colonization of PGPR

Effective colonization is crucial for PGPR activity. The process begins with bacterial attachment to root hairs and epidermis, followed by biofilm formation, which provides stability and protection in the rhizosphere. Chemotaxis allows bacteria to move toward root exudates, which contain sugars, amino acids, and organic acids. Successful colonization depends on environmental factors, soil type, plant species, and competition with native microflora.

Mechanisms of Plant Growth Promotion

PGPR promote plant growth through direct and indirect mechanisms. Direct mechanisms include nitrogen fixation by *Azospirillum* and *Rhizobium*, phosphate solubilization by *Bacillus* and *Pseudomonas*, production of phytohormones such as auxins and gibberellins, siderophore production to sequester iron, and ACC deaminase activity to alleviate ethylene stress and promote root elongation. Indirect mechanisms, which are central to plant disease management, involve antibiosis through production of antibiotics, competition for nutrients and colonization sites, induction of systemic resistance in the host plant, and secretion of lytic enzymes like chitinases and glucanases that degrade pathogen cell walls. These mechanisms allow PGPR to suppress a wide range of soil-borne pathogens, including *Fusarium*, *Rhizoctonia*, *Pythium*, *Phytophthora*, *Macrophomina*, and nematodes such as *Meloidogyne* species.

Applications of PGPR

PGPR can be applied in multiple ways, including seed treatment, soil amendment, and root dipping, often in combination with organic fertilizers to improve survival and colonization. Seed coating protects emerging seedlings from pathogens, while soil amendment ensures long-term colonization of the rhizosphere. Root dipping in PGPR suspensions before transplantation enhances early growth and disease resistance. Combined application with compost or vermicompost further improves bacterial efficacy. These practices lead to enhanced nutrient uptake, improved plant growth, reduced disease incidence, increased crop yield and quality, and reduced reliance on chemical inputs.

Advantages of PGPR

PGPR offer several advantages over conventional methods. They are eco-friendly, reduce chemical use, have broad-spectrum antagonism against pathogens, enhance plant growth and nutrient uptake, and improve soil health. They are compatible with integrated pest and disease management strategies and contribute to sustainable agriculture by improving crop productivity and resilience to environmental stresses.

Challenges and Limitations

Despite their benefits, PGPR face challenges in field applications. Environmental variability, soil type, and plant genotype affect efficacy. Competition with native microflora may limit colonization, and storage and shelf-life of bioformulations are often limiting factors. Environmental conditions such as pH, temperature, and moisture can significantly influence PGPR survival and performance.

Future Perspectives

Future research aims to enhance PGPR effectiveness through nano-formulations for improved shelf-life and delivery, integration with omics technologies to understand plant-microbe-pathogen interactions, and use of precision agriculture tools for optimized application timing. Breeding crops compatible with PGPR colonization and developing eco-friendly, sustainable biocontrol strategies will expand their role in modern agriculture.

Conclusion

Plant Growth Promoting Rhizobacteria (PGPR) are vital for sustainable agriculture, providing both growth promotion and disease suppression. Through mechanisms like nutrient mobilization, phytohormone production, antibiosis, competition, and induction of systemic resistance, PGPR enhance plant health, improve soil quality, and reduce chemical dependency. Their integration into agricultural systems contributes to higher yields, better crop quality, and environmental sustainability. Continued research and technological innovations will further enhance their potential as a cornerstone of modern integrated crop management.

References

1. Glick, B. R. (2012). Plant growth-promoting bacteria: Mechanisms and applications. *Scientifica*, 2012, 963401.
2. Kloepper, J. W., Leong, J., Teintze, M., & Schroth, M. N. (1980). Enhanced plant growth by siderophores produced by plant growth-promoting rhizobacteria. *Nature*, 286, 885–886.
3. Lugtenberg, B., & Kamilova, F. (2009). Plant-growth-promoting rhizobacteria. *Annual Review of Microbiology*, 63, 541–556.
4. Vessey, J. K. (2003). Plant growth promoting rhizobacteria as biofertilizers. *Plant and Soil*, 255, 571–586.
5. Glick, B. R., & Bashan, Y. (2010). *Genetic Engineering of PGPR for Agriculture.* Springer.
6. Glick, B. R., Cheng, Z., Czarny, J., & Duan, J. (2007). Promotion of plant growth by bacterial ACC deaminase. *Critical Reviews in Plant Sciences*, 26, 227–242.
7. Lucy, M., Reed, E., & Glick, B. R. (2004). Applications of free-living plant growth-promoting rhizobacteria. *Antonie van Leeuwenhoek*, 86, 1–25.