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"Role of Plant Growth Promoting Rhizobacteria (PGPR) in Crop Production"

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INTRODUCTION

Agriculture today stands at a turning point, facing the double dilemma of raising food outputs to meet the needs of an exploding world population and maintaining the natural resource base and ecological health. During the last few decades, agricultural intensification has depended excessively upon chemical inputs in the form of fertilizers and pesticides. While these inputs have hugely increased crop yields, excessive and indiscriminate use has led to a number of negative consequences, including soil degradation, loss of microbial diversity, groundwater contamination, and the development of resistant pest and disease strains.

As the world moves toward more sustainable agricultural practices, there is an urgent need to explore alternative approaches that can enhance crop productivity without compromising environmental health. In this context, Plant Growth Promoting Rhizobacteria (PGPR) have emerged as a promising and eco-friendly solution. PGPR are a group of beneficial soil bacteria that colonize the rhizosphere—the region of soil surrounding plant roots—and establish symbiotic relationships with host plants.

These microbes promote plant growth and development by several mechanisms, including nitrogen fixation, solubilization of phosphate, synthesis of phytohormones (auxins, cytokinins, gibberellins), activation of systemic resistance against plant pathogens, and mitigation of abiotic stresses like drought, salinity, and heavy metal toxicity. In addition, PGPR inhibit the growth of pathogenic microorganisms by producing antibiotics, siderophores, and cell wall-degrading enzymes.

The incorporation of PGPR into agriculture systems has several benefits: enhanced nutrient use efficiency, decreased reliance on chemical pesticides and fertilizers, improved soil health, and sustainable yield increase. This not only mitigates environmental degradation but also supports the objectives of climate-resilient and resource-saving agriculture.

2. What are PGPR?

Plant Growth Promoting Rhizobacteria (PGPR) are a diverse group of free-living, soil-borne bacteria that inhabit the rhizosphere the narrow region of soil directly influenced by root secretions and associated microbial activity. These bacteria establish beneficial interactions with plant roots and significantly contribute to plant health and development.

As opposed to symbiotic bacteria that occur in plant tissue, PGPR are mostly non-symbiotic or associative, growing independently in soil but closely interacting with plant roots. In addition to promoting enhanced nutrient acquisition, they enable the plant to resist a wide range of environmental stresses.

Among the best-described genera of PGPR are:

- **Pseudomonas** – for their ability to produce antibiotics and inhibit plant pathogens.
- **Bacillus** – spores and production of a range of growth-promoting compounds.
- **Azospirillum** – nitrogen fixation and hormone production.
- **Azotobacter** – non-symbiotic nitrogen-fixers that also produce vitamins and growth regulators.
- **Rhizobium** – while mostly symbiotic, certain strains have the ability to function as PGPR in non-legumes.

These bacteria provide a green alternative to chemical inputs and are being more and more incorporated into contemporary agricultural systems.

3. Mechanisms of Plant Growth Promotion by PGPR

PGPR promote plant growth and yield by two main types of mechanisms: direct and indirect. The direct mechanisms include nutrient acquisition facilitation and hormone regulation, which affect the growth and metabolism of the plant directly.

A. Direct Mechanisms

Biological Nitrogen Fixation

Some PGPR, like Azospirillum and Rhizobium, are nitrogenase-positive, meaning they have the nitrogenase enzyme that enables them to fix atmospheric nitrogen (N_2) in the form of ammonia (NH_3), which is plant-usable. It's especially vital for increasing nitrogen supply in low-nitrogen soils.

Phosphate Solubilization

Phosphorus often occurs in insoluble forms in many soils, which cannot be easily taken up by plants. PGPR such as Bacillus and Pseudomonas produce organic acids (for example, gluconic, citric acids) that dissolve bound phosphate, hence enhancing its bioavailability.

Production of Phytohormones

PGPR produce a number of plant hormones such as:

- **Indole-3-acetic acid (IAA):** Induces elongation of roots and development of lateral roots.
- **Gibberellins:** Induce stem elongation, seed germination, and flowering.
- **Cytokinins:** Induce cell division and retard leaf senescence.

Siderophore Production

Siderophores are iron-binding compounds that PGPR excrete, which chelate ferric iron (Fe^{3+}) in soil and make it more accessible to plants. It not only increases nutrition in plants but also restricts iron availability to disease-causing microbes.

ACC Deaminase Activity

Plants tend to grow high levels of ethylene, a hormone that can repress root growth, under stressful conditions. Certain PGPR synthesize the enzyme 1-aminocyclopropane-1-carboxylate (ACC) deaminase, which breaks down the precursor to ethylene, ACC, reducing ethylene concentration and enhancing root growth even under stress.

This article examines the multifaceted roles and processes of PGPR in enhancing plant health, their use in different cropping systems, and their future potential to reshape modern agriculture towards a more biologically integrated and sustainable future.

3. Mechanisms of Plant Growth Promotion by PGPR (continued)

B. Indirect Mechanisms

Besides directly promoting plant growth, PGPR also promote plant health and resistance by several indirect mechanisms, especially functioning as biocontrol agents and enhancing plant defense mechanisms. These mechanisms lower disease incidence and enhance overall crop performance:

Biocontrol of Pathogens

PGPR inhibit soil-borne pathogens by synthesizing a variety of antimicrobial metabolites, including:

- Antibiotics (e.g., 2,4-diacetylphloroglucinol, pyoluteorin)
- Hydrogen cyanide (HCN) – toxic to a broad spectrum of microbial pathogens.
- Lytic enzymes like chitinases, glucanases, and proteases that break down fungal cell walls.

This biologic antagonism reduces the incidence of diseases and minimizes chemical fungicide use.

Induced Systemic Resistance (ISR)

Some PGPR can "prime" plant immune systems by inducing ISR, a defense response similar to immunization. ISR makes the plant more capable of resisting a wide range of pathogens and pests without doing anything to the invaders directly. Unlike systemic acquired resistance (SAR), ISR does not require the buildup of pathogenesis-related proteins, thus constituting a low-energy cost defense strategy.

Competition for Nutrients and Niche

PGPR has the ability to compete against deleterious microorganisms for essential nutrients such as iron, carbon, and root exudates in the rhizosphere. Through the occupation of ecological niches and better utilization of root exudates, PGPR inhibits the establishment and growth of pathogens, promoting a better microbial population surrounding plant roots.

4. Advantages of PGPR in Crop Production

The application of PGPR in crop production has various agronomic, economic, and environmental advantages:

Improved Nutrient Uptake

By fixing atmospheric nitrogen and solubilizing nutrients, PGPR enhance nutrient uptake, particularly of nitrogen, phosphorus, and micronutrients. This minimizes the reliance on chemical synthetic fertilizers.

Enhanced Root Architecture

Phytohormone production by PGPR results in improved root development, such as enhanced root length, branching, and surface area. This enhances the efficient uptake of water and nutrients from the soil.

Stress Tolerance

PGPR increase plant resistance to abiotic stresses like drought, salinity, temperature, and heavy metal toxicity through the regulation of stress-related hormones and antioxidants.

Increased Crop Yield and Quality

Enhanced nutrient efficiency, disease resistance, and stress tolerance result in elevated biomass production, improved grain or fruit quality, and greater overall yields.

Environmental Safety and Sustainability

PGPR decrease dependence on chemical inputs, hence reducing the environmental pollution risk and enhancing soil health. Their application is consistent with sustainable and environmentally friendly agricultural practices, helping develop long-term agricultural resilience.

5. Utilization of PGPR in Agriculture

The utilitarian application of PGPR in agriculture can be done in different ways depending on the crop, environmental factors, and cultivation practices:

Seed Inoculation

Seeds are treated or preconditioned with PGPR-formulation before planting. This promotes early colonisation of the rhizosphere and quick growth gains.

Soil Application

PGPR may be blended with compost, biofertilizers, or carrier materials (e.g., peat, vermiculite) and applied to the field soil directly. This approach is applied mainly to field crops and horticultural crops.

Foliar Sprays

Foliar spraying of PGPR suspensions enables colonization of the phyllosphere and leads to systemic resistance in the plant. It is especially beneficial for foliar disease management.

Integrated Nutrient Management (INM)

PGPR can be integrated with organic manures and inorganic fertilizers to maximize the availability of nutrients and reduce chemical input. This method is conducive to balanced nutrition and sustainable soil fertility.

6. Challenges and Limitations

As much as there has been increased interest and demonstrated advantages of Plant Growth Promoting Rhizobacteria (PGPR), many challenges limit their successful use and reliable performance in the field:

Variability in Field Performance

One of the most significant limitations is the variable efficacy of PGPR between agro-climatic regions. Soil type, pH, temperature, water content, and crop genotype may all impact the viability and efficacy of PGPR strains. What proves effective in one area could be ineffective in another.

Survivability and Shelf-Life

Sustaining healthy populations of PGPR during storage, transit, and post-application in the field is a current technological bottleneck. Several PGPR strains are desiccation, UV light, and temperature-sensitive, thus impacting their survival and ability to colonize.

Formulation and Delivery Constraints

Formulation of cost-effective, stable, and user-friendly formulations is essential to make PGPR viable for practical use. Insufficiency of effective carrier materials, standardized methods, and site-specific delivery systems restricts their commercial appeal, particularly among small and marginal farmers.

7. Future Directions

To alleviate current limitations and unlock the full potential of PGPR in sustainable agriculture, a number of innovative and multi-disciplinary strategies are being pursued:

Strain Improvement

Improvements in genomics, transcriptomics, proteomics, and synthetic biology provide novel tools for improving PGPR characteristics like stress resistance, root colonization efficiency, and metabolite synthesis. Genetic improvement and selection approaches may be used for generating second-generation bioinoculants that display enhanced field efficacy.

Consortium Formulations

Rather than depending on single-strain inoculants, microbial consortia with mixtures of PGPR, mycorrhizae, and other compatible elements are being engineered. These products utilize synergistic effects to offer multi-functional benefits such as nutrient mobilization, suppression of pathogens, and stress resistance.

Applications of Nano-biotechnology

The convergence of nanotechnology in PGPR formulations (nano-encapsulation, for instance) can improve stability, shelf life, and site-specific delivery to root systems. Nanocarriers can shield bacteria from environmental stresses and facilitate controlled release for extended activity.

Policy Support and Farmer Awareness

Government support in terms of incentives, subsidies, and policy guidelines, coupled with farmer capacity-building programs and extension worker training, is crucial. Extension demonstrations, training, and coverage under national agricultural missions can help hasten grassroots adoption.

8. CONCLUSION

Plant Growth Promoting Rhizobacteria (PGPR) provide a green and environmentally friendly approach to satisfy the increasing food requirements without compromising environmental integrity. Their positive effects on nutrient uptake, synthesis of plant hormones, inhibition of plant pathogens, and tolerance to abiotic stress make them valuable partners in present-day agriculture.

However, their successful deployment in real-world farming systems requires overcoming technological, biological, and socio-economic barriers. With continued research, strategic policy interventions, and widespread awareness, PGPR can play a transformative role in building a resilient, productive, and environmentally sustainable agricultural system.

REFERENCES

Mehmood, U., Inam-ul-Haq, M., Saeed, M., Altaf, A., Azam, F., & Hayat, S. (2018). A brief review on plant growth promoting rhizobacteria (PGPR): a key role in plant growth promotion. Plant protection, 2(2), 77-82.

Nadeem, S. M., Ahmad, M., Zahir, Z. A., Javaid, A., & Ashraf, M. (2014). The role of mycorrhizae and plant growth promoting rhizobacteria (PGPR) in improving crop productivity under stressful environments. Biotechnology advances, 32(2), 429-448.

Sun, W., Shahrajabian, M. H., & Soleymani, A. (2024). The roles of plant-growth-promoting rhizobacteria (PGPR)-based biostimulants for agricultural production systems. *Plants*, *13*(5), 613.

Swarnalakshmi, K., Yadav, V., Tyagi, D., Dhar, D. W., Kannepalli, A., & Kumar, S. (2020). Significance of plant growth promoting rhizobacteria in grain legumes: Growth promotion and crop production. *Plants*, *9*(11), 1596.

Vejan, P., Abdullah, R., Khadiran, T., Ismail, S., & Nasrulhaq Boyce, A. (2016). Role of plant growth promoting rhizobacteria in agricultural sustainability—a review. *Molecules*, *21*(5), 573.

Vocciante, M., Grifoni, M., Fusini, D., Petruzzelli, G., & Franchi, E. (2022). The role of plant growth-promoting rhizobacteria (PGPR) in mitigating plant's environmental stresses. *Applied sciences*, *12*(3), 1231.