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Role of Helpful Soil Microbes (PGPMS) in Better Farming: A Review

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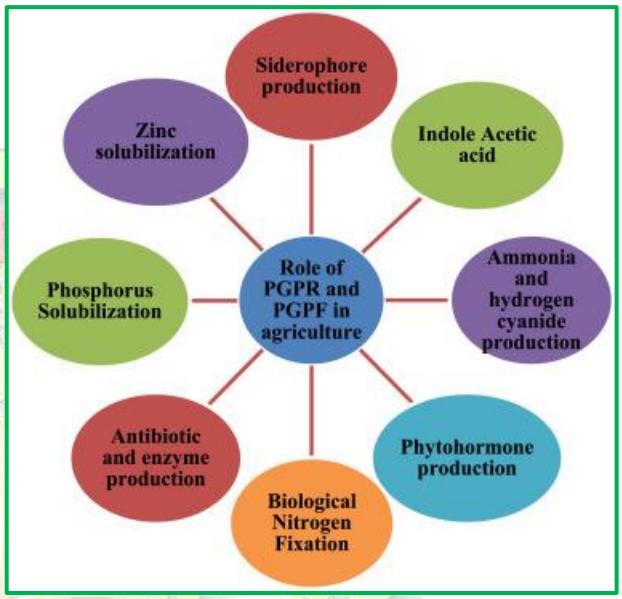
Farmers seek high yields, healthy crops, and reduced dependence on costly chemical fertilizers and pesticides. Plant Growth-Promoting Microbes (PGPMs)—beneficial soil microorganisms that live around the plant root zone—offer a natural, cost-effective alternative. These microbes enhance nutrient availability, improve root growth, boost plant immunity, and enrich soil structure. Their application through seeds, soil, or irrigation results in stronger, faster-growing plants while lowering chemical inputs. This review simplifies the role and mechanisms of PGPMs for easy understanding and highlights their potential to transform modern farming into a more sustainable, eco-friendly system.



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Introduction

Healthy farming begins with healthy soil. Beneath the surface, millions of microscopic organisms work silently to support plant growth. These beneficial organisms—Plant Growth-Promoting Microbes (PGPMs)—play a crucial role in nutrient cycling, soil structure improvement, and natural disease control. With rising fertilizer costs, declining soil fertility, and increasing environmental concerns, PGPMs offer farmers an effective and sustainable solution. Their use not only strengthens crop performance but also contributes to long-term soil conservation and eco-friendly agriculture.

Mechanisms of PGPMs

PGPMs promote plant growth through a combination of direct and indirect mechanisms (Kumar et al., 2022; Koskey, 2021).

A. Direct Mechanisms

These involve nutrient production, transformation, or mobilization by microbes.

1. Biological Nitrogen Fixation (BNF)

Nitrogen-fixing bacteria convert atmospheric nitrogen into ammonia, making it available to plants.

- **Non-symbiotic fixers:** Bacillus, Corynebacterium, Pseudomonas, Xanthobacter.

- **Symbiotic fixers:** Rhizobium in legumes**.** Application of Azospirillum spp. Has shown significant improvements in crop yields (Ansabayeva et al., 2025).

2. Phosphate Solubilization

Phosphorus, though abundant in soil, is often unavailable in insoluble forms. PGPMs release organic acids to solubilize these forms into plant-available phosphates (Jeane et al., 2021).

Key phosphate-solubilizing microbes include: Bacillus, Pseudomonas, Rhizobium, Burkholderia, Aspergillus, and Penicillium.

3. Phytohormone Production

PGPMs synthesize plant growth regulators that influence root and shoot growth**..**

- **Auxins**: promote root development and cell elongation**.**
- **Gibberellins**: stimulate stem growth, delay senescence, and enhance fruit production**.**
- **Cytokinins**: regulate cell division and bud formation**.**
- **Abscisic Acid (ABA):** enhances drought tolerance**.**
- **Ethylene**: regulates ripening and senescence (Jalal et al., 2022)

B. Indirect Mechanisms

These mechanisms protect plants from diseases and improve resilience.

1. **Biocontrol of Pathogens**

Beneficial microbes suppress harmful pathogens through antibiotics, antimicrobial metabolites, and competitive exclusion (Abdala et al., 2021).

2. **Antibiosis**

PGPMs produce low-molecular-weight antibiotics that disrupt pathogen membranes, inhibit spore formation, and suppress fungal and bacterial growth.

3. **Competition in the Rhizosphere**

Beneficial microbes compete with pathogens for space, nutrients, and root exudates—similar to outnumbering harmful organisms in a crowded marketplace (Ansabayeva et al., 2025).

4. **Siderophore Production**

Siderophores are iron-chelating compounds that deprive pathogens of iron while improving iron uptake by plants (Lopes et al., 2021). They indirectly boost plant health and inhibit pest and weed activity.

Benefits in Crop Production

1. Enhanced Crop Yield

Numerous studies report significant yield improvements in cereals, fruits, and vegetables after PGPM inoculation (Wang & Ding, 2024).

Bacillus strains have been shown to improve raspberry yield and fruit quality (Orhan et al., 2006).

2. Improved Nutritional Quality

PGPMs enhance nutrient uptake, leading to higher mineral content—such as zinc, iron, and magnesium—in edible plant parts (Ruiz et al., 2025).

3. Soil Health Restoration

These microbes improve soil structure, organic matter content, and long-term fertility—critical for sustainable farming.

Challenges

Modern agriculture faces constraints including:

- Declining soil fertility
- Climate variability
- Increased pest and disease pressure
- Inconsistent field performance of microbial products

Promoting eco-friendly practices—biofertilizers, biopesticides, and recycling of crop residues—is essential for sustainable agricultural production (Gopalakrishnan et al., 2014).

Advancements and Future Prospects

Future research should focus on:

- Identifying multifunctional, stress-tolerant, and ecologically adaptable PGPM strains.
- Enhancing inoculation technology for better survival and colonization.
- Integrating PGPMs into plant tissue culture systems.
- Promoting green technologies (biofertilizers, biopesticides) for sustainable production (Soumare et al., 2021).
- Encouraging responsible resource use, reduced chemical dependency, and recycling of agricultural waste (Kumar et al., 2022)

PGPM-based formulations are expected to play a major role in climate-smart and resource-efficient agriculture.

Conclusion

Plant Growth-Promoting Microbes (PGPMs) are vital allies in sustainable agriculture. They improve soil fertility, mobilize nutrients, synthesize natural hormones, and protect crops from biotic and abiotic stresses. By reducing dependence on chemical fertilizers and pesticides, PGPMs support healthier crops and enhance farm profitability. Although variability in field performance remains a challenge, ongoing advancements in microbial biotechnology promise effective and reliable applications. With proper adoption, PGPMs can significantly contribute to resilient, eco-friendly, and high-yield farming systems, especially in the face of climate change.