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Role of plant growth promoting rhizobacteria (PGPR) in growth and disease suppression

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Plant Growth Promoting Rhizobacteria (PGPR) is root-colonizing bacteria that are found to form symbiotic relationships with many plants. Microorganisms colonized more intensively to the rhizosphere and rhizoplane than the other regions of the soil. These microorganisms get benefited from the nutrients secreted by the plant and also in return positively influence the plants for their growth and health (Mutualism). These rhizobacteria are often referred as plant growth promoting rhizobacteria (PGPR). The term PGPRs was first used by Joseph W. Kloepper and Milton N. Schroth. The colonization process may be as that it has the ability to survive inoculation onto seed, to multiply in the spermosphere (region surrounding the seed) in response to seed exudates, to attach to the root surface, and to colonize the developing root system. The PGPR inoculants currently commercialized that seem to promote growth through at least one mechanism; suppression of plant disease (termed Bioprotectants), improved nutrient acquisition (termed Biofertilizers), or phytohormone production (termed Biostimulants). Genera of PGPR include *Azotobacter*, *Azospirillum*, *Pseudomonas*, *Acetobacter*, *Burkholderia*, *Bacillus*, *Paenibacillus*, and some are members of the Enterobacteriaceae. These beneficial, free-living bacteria enhance emergence, colonize roots, stimulate growth, help in disease suppression and enhance yield. The beneficial effects of these rhizobacteria have been variously attributed to their ability to produce various compounds including phytohormones, organic acids, siderophores, and fixation of atmospheric nitrogen, phosphate solubilization, antibiotics, HCN production and some other unidentified mechanisms. PGPR are beneficial for plant growth and also referred as yield increasing bacteria (YIB) due to its ability to increase yield.

Agrios' definition of plant health – the ability of a plant to 'carry out its physiological functions to the best of its genetic potential'– is an example of a positive plant health definition. It does not refer to disease or injury and does not carry any elements of negation. Again Soil health can be defined as the continued capacity of soil to function as a vital living system, by recognizing that it contains biological elements that are key to ecosystem function within land-use boundaries. The term soil health is used to assess the ability of a soil to: Sustain plant and animal productivity and diversity; Maintain or enhance water and air quality and Support human health and habitation.

PGPR and mechanism of biocontrol : Phytopathogenic microorganisms have a great impact on crop yields and can significantly reduce plant performance and crop quality. The usual strategy for the control of phytopathogens is to apply certain chemical pesticides, but this strategy has led to increased concerns over environmental contamination and has resulted in the resistance development to individual chemical controls over time. In this context, rhizobacteria that can provide biocontrol of disease or insect pests (biopesticides) are considered an alternative to chemical pesticides. A large number of mechanisms are involved in biocontrol and can involve-

– Direct antagonism via production of antibiotics, siderophores, HCN and some hydrolytic enzymes as chitinases, proteases, lipases etc.

– Indirect mechanisms where the biocontrol organisms act as a probiotic by competing with the pathogen for infection and nutrient sites.

Biocontrol can also be mediated by activation of the acquired systemic resistance (SAR), induced systemic resistance (ISR) responses in plants, and by modification of hormonal levels in the plant tissues. ISR is enhancement of the plants defensive capacity against a broad spectrum of pathogens and pests that is acquired after appropriate stimulation. Different defense enzymes associated with ISR include phenylalanine ammonia lyase (PAL), chitinase, b-1,3-glucanase, peroxidase (PO), polyphenol oxidase (PPO), superoxide dismutase (SOD), catalase (CAT), lipoxygenase (LOX), ascorate peroxidase (APX) and proteinase inhibitors. SA is a key regulator of pathogen-induced systemic acquired resistance (SAR) whereas JA and ET are required for rhizobacteria-mediated induced systemic resistance (ISR).

Antibiotic-producing rhizobacteria: The ability to produce antibiotics is considered one of the most powerful biocontrol mechanisms for suppression of plant pathogens. Antibiotics are heterogeneous group of low molecular weight chemical organic compounds that are produced by the PGPR are as butyrolactones, kanosamine, oomycin A, phenazine-1-carboxylic acid, pyrrolnitrin, xanthobaccin, and 2,4-diacetyl phloroglucinol (2,4- DAPG). The 2,4-DAPG is one of the most efficient antibiotics in the management of plant pathogens and can be produced by various strains of *Pseudomonas*.

Table 1 : Classification of plant growth promoting bacteria based on their mechanism

Category of PGPR	Definition	Mechanisms
Biopesticide	Microorganisms (bacteria) that promote plant growth through the control of phytopathogenic agents, mainly for the production of antibiotics and antifungal metabolites.	- Production of antibiotics, siderophores, HCN, antifungal metabolites, enzymes - Acquired systemic resistance and Induced systemic resistance - biocontrol organisms act as a probiotic by competing with the pathogen for a niche
Biofertilizer	A substance which contains live microorganisms which, when applied on the seed, plant surface or the soil, colonizes the rhizosphere or the interior of the plant and Promotes growth through increased supply or availability of primary nutrients for the host plant.	- Biological nitrogen fixation - Utilization of insoluble forms of phosphorus - Availability of micronutrient
Phytostimulator	Microorganism with the ability to produce or change the concentration of growth regulators such as indole acetic acid, gibberellic acid, cytokinins and ethylene	- Production of phytohormones (auxins, cytokinins and gibberelins) - Regulating plant ethylene level

Hydrogen cyanide (HCN) producing rhizobacteria: HCN is a volatile, secondary metabolite that suppresses the development of microorganisms. But in excess amount it also negatively affects the growth and development of plants. Schippers *et al.*, 1990 reported that about 50% of pseudomonads isolated from potato and wheat rhizosphere are able to produce HCN *in vitro*. Again suppression of “root-knot” and “black rot” in tomato and tobacco root caused by the nematodes *Meloidogyne javanica* and *Thielaviopsis basicota*, respectively was also found.

Siderophore-producing rhizobacteria : Siderophores are low molecular weight compounds that are produced and utilized by bacteria and fungi as iron (Fe) chelating agents. Iron is essential for cellular growth and metabolism, so other harmful microorganisms become deprive of iron and as a result growth suppressed or gets killed. Different siderophore producing bacteria belonging to the *Bradyrhizobium*, *Pseudomonas*, Rhizobium, *Serratia* and *Streptomyces* genera were isolated from the rhizosphere.

PGPR as biofertilizer-mechanism of plant and soil health enhancement: PGPR are also play very important role in enhancing and make availability of different nutrients including N, P and micronutrients for plant and soil health enhancement. For example, *Rhizobium* spp., in symbiosis with their legume host plant, and free living *Azotobacter*, *Azospirillum* in non-symbiotic association with their host plant, can fix atmospheric N_2 and make available to plant system. Different PGPR like *Bacillus* spp. *Pseudomonas fluorescence* and *P. putida* are able to enhance P availability, by production of organic acids and phosphatase enzymes. Siderophores producing PGPR can also increase Fe solubility and uptake by plant.

Production of phytohormones and regulation of ethylene levels in plant: Phytohormones are signal molecules acting as chemical messengers and play a fundamental role in regulating growth and development in the plants. These are organic compounds that in extremely low concentrations influence biochemical, physiological and morphological processes in plant.

Indole acetic acid (IAA) producing rhizobacteria: The IAA is responsible for the division, expansion and differentiation of plant cells and tissues and also stimulates root elongation. Rhizobacteria like *Azospirillum, Azotobacter, Bacillus, Pseudomonas, Rhizobium etc.*synthesize IAA from tryptophan by different pathways, although it can also be synthesized via tryptophan-independent pathways.

Regulating plant ethylene levels by rhizobacteria: In response to different types of environmental stress, such as cold, draught, flooding, infections with pathogens, presence of heavy metals plants synthesized 1-aminocyclopropane-1-carboxylate (ACC), which is the precursor for ethylene. Some of the ACC is secreted into the rhizosphere and is readsorbed by the roots, where it is converted into ethylene and as result of accumulation of ethylene leads a diminished ability of plants to acquire water and nutrients due to poor root growth. The PGPR have the ability to degrade ACC in the rhizosphere can help to reduce production of ethylene.

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