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Role of Plant Growth Promoting Rhizobacteria in Sustainable Agriculture

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PGPR's directly solubilized and mineralize inorganic phosphorus or facilitate the mobility of organic phosphorus through microbial turnover and/or increase the root system.

Plant Growth Promoting Rhizobacteria (PGPR)

Plant growth promoting rhizobacteria (PGPR), a diverse group of soil bacteria, are key components of soil plant systems, where they are engaged in an intense network of interactions in the rhizosphere, thus affecting the plant growth and yield. Numerous species of soil bacteria which flourish in the rhizosphere of plants, but which may grow in, on, or around plant tissues, and stimulate plant growth by a plethora of mechanisms. PGPR's are the potential tools for sustainable agriculture and trend for the future; they not only ensure the availability of essential nutrients to plants but also enhance the nutrient use efficiency. The beneficial effects of PGPR involve boosting key physiological processes, including water and nutrient uptake, photosynthesis, and source-sink relationships that promote growth and development. One of the mechanisms by which bacteria are adsorbed onto soil particles is by ion exchange.

A soil is said to be naturally fertile when the soil organisms are releasing inorganic nutrients from the organic reserves at a rate sufficient to sustain rapid plant growth. The PGPR associations range in the degree of bacterial proximity to the root and intimacy of association. The three distinct characteristics of PGPR are they must be able to colonize the root, they must survive and multiply in microhabitats associated with the root surface, in competition with other microbiota, at least for the time needed to express their plant promotion/protection activities and they must promote plant growth .

Based on their relationship with the plants PGPR are classified into two groups, symbiotic bacteria and free living rhizobacteria.

On the basis of their residing sites: (*i.e.*, symbiotic bacteria), example *Rhizobia* sp. and *Frankia* sp., which live inside the plant cells, produce nodules, and are localized inside the specialized structures; and ePGPR (*i.e.*, free-living rhizobacteria), which live outside the plant cells and do not produce nodules, but still prompt plant growth.

Depending on their functional activities PGPR are categorized as (i) bio-fertilizers (increasing the availability of nutrients to plant); (ii) phyto-stimulators (plant growth promotion, generally through phyto-hormones); (iii) rhizo-remediators (degrading organic matter).

PGPR and Abiotic Stress

Any unfavorable environmental condition that may affect the functional diversity of microbes and also the physicochemical properties of soil can dictate a biotic stress. Numerous drastic conditions including heavy metal toxicity, salinity, drought, and flooding affecting the plant microbiome and the surrounding ecology are abiotic stress.

Heavy Metals

Hyper-aggregation of noxious metals like Hg, As, Cd, and Pb in soil result in plant stress, and extraordinarily diminish crop productivity. Such metal aggregations directly influence soil pH and its texture, thereby hampering crop growth by imparting negative consequences on a few biological processes. Thus, there is a decrease in the effect of pollutants on plants added by the help of these Za. Though PGPR helps in plant growth and productivity, it also improves soil properties through various mechanisms to regulate soil metal contaminants .Some peculiar binding metal peptides are associated with metal chelation or accumulation. Oxidation of Fe, or through involvement of microbial inorganic acids like H_2S, H_2CO_3 and H_3PO_4.

Salinity

Salinity conditions are detrimental for agro-economy. The primary reason for the salinity issue is attributed to the accumulating salts due the use of agrichemicals over long. There is alternation in plant homeostasis in salt-stressed region in the soil, leading to nutritional imbalance.

Drought

Drought is a leading factor that hinders worldwide agricultural productivity. It is believed to have played down the national cereal production by 9–10%. The capacity of a plant to sustain and endure during drought situation is its drought resistance. Solutions to increase abiotic stress tolerance like drought in plants enabling its growth meeting food needs under restricted accessibility of water resources need to be established. Abscisic acid (ABA) improves drought tolerance owing to a few responsible active signaling genes like DSM2, Os-NAP, and OsNAC5. These genes facilitate an increase in the yield during drought

Facilitating Shoot Growth

Decreased accessible leaf surface to restrict evaporative loss is an adoptive mechanism in plants to address drought stress which may stunt shoot growth .Treating such plants with PGPR improves shoot growth; plants inoculated with successful PGPR strains may retain close-to-average shoot growth in drought stress, resulting in enhanced crop productivity.

Relative Water Content

Perhaps a better approach to evaluate plant water status is measure its relative water content (RWC) in leaf as it is involved in tissue metabolic activity. A reduced RWC indicates turgor deficiency that restricts cellular development and diminished plant growth. Found that better RWC could be a consequence of change in the physiological activity like stomatal closure.

Flood

Reports indicate the effect of rhizobacteria on plant physiology when exposed to flooding. Studies reveal that plant roots associated with bacterial population impact in regulating ethylene. Such exchange of gas reduces during flooding, resulting in rapid accumulation of inside plant. Accumulated ethylene regulates the traits related to flood adaptation. Highlighted the role of *R. palustris* in ACC deaminase production which led to a reduction in the ethylene levels. ACC level rises during flood (low oxygen condition) attributed to the action of both ACC synthase and ACC oxidase genes.

PGPR and Biotic Stress

Biotic stress in plants is brought about by living forms, particularly bacteria, viruses, fungi, insects, and nematodes. Such stress interferes directly with host nutrients causing plant death. Both pre- and post-harvest loss occurs due to biotic stress. Although few microbes participate in the biological control of pathogens, yet PGPR is known to create protection from many diseases following various mechanisms including bacteriocin, antibiosis, volatile organic compound (VOC) production, and lysis through the extracellular enzyme.

Bacteriocin

Bacteriocins (bacterial toxins against bacteria) are peptide secretions with narrow-spectrum antimicrobial activity. Bacteriocins are produced by Gram-negative (e.g., colicin) as well as Gram-positive (e.g., nisin) bacteria. These toxins are very specific in their action and eliminate competitor bacterial species. Bacteriocins have shown promising results under *in vitro* conditions against bacterial spot disease in tomatoes

Antibiosis

Antibiotics produced by PGPR are more efficient than others due to their antimicrobial, insecticidal, antiviral, phytotoxic, cytotoxic, and anthelminthic properties. Numerous species of *Pseudomonas* produce a wide scope of antifungal antibiotics, including 2,4-diacetylphloroglucinol (2,4-DAPG), butyrolactones, rhamnolipids, N-butylbenzene sulfonamide . *Bacillus* species also excrete a large variety of antibiotics, including bacilysin, bacillaene, mycobacillin, etc. Additionally, they produce various lipopeptide biosurfactants e.g., bacillomycin with antibiotic activity.

Criteria to Select Suitable PGPR Candidate

For the development of a successful PGPR formulation, the rhizobacterial species should possess the following characteristics

- Should be enhancing plant growth
- Should be amenable for mass multiplication
- Should possess high rhizospheric competence
- Should have high competitive saprophytic ability
- Should demonstrate broader activity spectrum
- Should be environmentally safe.