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PLANT GROWTH PROMOTING RHIZOBACTERIA: APPLICATION IN AGRICULTURE

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The use of plentiful chemical fertilizers with higher nutrient content has no doubt increased the crop yield by many folds in recent years which substantially reduced global hunger. However; the half-century-long application of these chemical fertilizers has raised the issue of sustainability and consequence on ecology, human and animal health. As a result, alternative methods are the need of the hour; be it a single strategy or as an integrated approach. In modern days use of beneficial microbes in agriculture is not a new phenomenon rather gaining momentum as a cost-effective, environment-friendly, and sustainable approach to meet the plant demand as well as maintaining ecological symphony. PGPRs are a group of soil bacteria that are free-living in nature which tends to colonize the root zone (Rhizosphere) and promote plant growth.

In this regard, the rhizosphere is particularly important than other soils in agricultural land due to the thoroughly researched fact that the number of beneficial bacteria in the zone is generally 10-1000 times higher than the bulk soil of other facts. This is due to the complex nature of the rhizosphere owing to the secretion of multiple organic compounds including organic acid and sugar from the plant root, higher moisture activity, and higher pH buffering capacity. However; all the microbes which reside in the rhizosphere are neither equally competent nor desired. As a result, selective preference should be given to the most beneficial one. The selective preference is a two-way mechanism where either metabolite can be altered or the strains. However; the real challenge which is faced in this scenario is that lab-grown strains are not highly competitive as compared to the native ones with very high adaptation rate evolution capacity. This is the prime reason why the PGPR amendment does not work promisingly in well-watered, well compost amended soils rather works great in a scarce scenario where the growth of inherent microbes is already compromised due to extreme environmental conditions.

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Function and Mechanism of PGPR

The growth-promoting function of PGPR is dependent upon the secretion of metabolites by PGPR. The process is not a standalone one; rather a combination of several actions including secretion of indole acetic acid (IAA), gibberellins, cytokinin, nitrogen fixation, solubilization of phosphate, and other minerals.

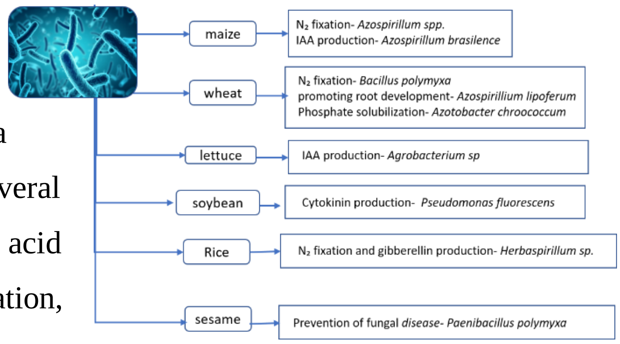

Fig1: PGPR bacterial strains and their host plant with potential functions

PGPR are classified into two groups based on their association with the plant roots which are iPGPR or extracellular ePGPR and PGPR or intracellular PGPR. ePGPR infests the zone of the rhizosphere, rhizoplane, and intercellular spaces between cells of the root cortex while the iPGPR infests inside the nodule structure of the root. The ePGPR category includes bacterial genera such as *Agrobacterium, Arthrobacter, Azotobacter, Azospirillum, Bacillus, Burkholderia, Erwinia, Flavobacterium, Micrococcus, Pseudomonas, and Serratia.* Apart from fixing nitrogen and solubilizing phosphorus and other nutrients, several PGPR has proven their function against phytopathogenic microbes by producing siderophores, synthesizing new antibiotics, enzymes and also competing with their valuable resources. PGPR has attracted more attention in the case of cereal crops, like legumes, in general, can have a significant amount of symbiotic association with nitrogen-fixing bacteria. On the other hand, cereals do not have such association ata significant level hence require external manipulation of the rhizosphere to enhance yield and quality. The yield was always a prime focus and numerous research finding has indicated that combination of multiple PGPR strains is more beneficial than a single strain. For example, a combination of *B. megaterium, A. chlorophenolicus, and Enterobacter*is more effective to increase plant height and yield in wheat.

Multitude Factors Affecting the Abundance of PGPR

The abundance and survival of PGPR are highly space and time-dependent. Although the inherent location of the land is the prime factor of PGPR diversity; the availability of different essential nutrients. Other important factors are the host plant's species and variety, biotic and abiotic stress, root exudates which determine the PGPR diversity. Other

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environmental factors and agronomic management factors also significantly alter the diversity of PGPR. An important point that has been reported by much long-term research is that in general compost amendment increases the biomass and diversity of PGPR, however; if the compost is contaminated with heavy and pollutant metals; it significantly reduces microbial diversity and biomass which ultimately hampers different nutrient cycles, soil quality and ultimately undermines the plant growth and development. Other severe geo-temporal factors including severe drought, salinity, and alkalinity disturb the diversity of PGPR; in such conditions only, the extremophiles can survive. The magnitude of change in PGPR diversity is less affected by agronomic management practices like crop rotation although little research also suggests that the diversity is enhanced by cereal-legume crop rotation.

PGPR Specific Functions

Phosphorus solubilization:

The importance of phosphorus in agriculture is only next to nitrogen, its management is one of the most critical activities in the whole nutrient management arena. The complexity is related to the fact is that, unlike nitrogen, more than 98% of the phosphorus is either fixed, immobilized or precipitated form which is beyond the reach of plants. PGPR is particularly helpful in this regard, it releases low molecular weight organic acid such as gluconic and keto gluconic acid which solubilizes the phosphorus. PGPR bacteria possess both solubilization and mineralization activity which is very helpful as a cheaper alternative to chemical means. The majority of the soils are very deficient in phosphorus due to several issues which are even more amplified by the high cost of phosphatic fertilizers. Several phosphate solubilizing bacteria such as *Bacillus, Rhizobium, and Pseudomonas* are the potent bacterial genera that are very competent to hydrolyze the inorganic phosphorus into a soluble form and makes it accessible by the plants. Interestingly, two commonly found modulating rhizobium strains of chickpea *Mesorhizobiumciceri*and*MesorhizobiumMediterranean*are also effective phosphate solubilizes.

Siderophore production:

Siderophores are specific kinds of organic molecules produced by some microorganisms under specific circumstances especially under iron deprivation conditions to improve their potential to uptake iron. Several bacterial species like *Pseudomonas sp*produces iron under iron limiting condition. This is even more useful when uptake of iron is limited due to competition from other metallic irons like cadmium or nickel which can be altered by producing ferric- siderophore complex. Siderophore is not a single chemical structure rather a group that possesses electron-rich atoms i.e., oxygen or nitrogen electron donor atom which can bind with metal ions. Recent studies also indicate microbes such as *Azotobacter vinelandii* which is a nitrogen fixer also possess the ability to help the uptake of molybdenum which is a nitrogenase cofactor. Apart from these functions, the same strains can control several diseases like *fusarium* wilt. However; the recent study is quite limited in this field and needs more exploration.

Exchange of nutrients:

Microbes residing in soil depend primarily on plan roots for their essential carbon source. This transfer of carbon can be through root exudates, or plant residue inputs. Soil microbes are the end point to several nutrient cycles such as carbon, nitrogen, phosphorus where they essentially act as decomposers. Several nutrient cycles are also entangled due to microbes which can be effectively utilized as PGPR.

Production of phytohormones:

Phytohormones canaffect the metabolic activities of the plant by inducing, enhancing, or restricting physiological functions. In general; phytohormones are auxin, cytokinin, ethylene, gibberellins, and abscisic acid while some other newer phytohormones like brassinosteroids, jasmonates, and strigolactones are added to the list which can be effectively used to control stress-related issues. Strains like *Pseudomonas*sp, are well known to produce IAA, which has a role in cell differentiation and cell division and ultimately increases plant height. Abscisic acid is another important phytohormone that is particularly essential in drought-related issues. Strains like *Bacillus amyloliquefaciens* have been found to produce ABA and help the rice to sustain drought conditions.

Conclusions

PGPR holds huge potential for sustainable agriculture in the future. It has the potential to reduce a load of chemical fertilizer on one hand and on the other, it can enhance better recycling. Apart from nutrient management; PGPR can be effectively used to enhance growth and yield under stressed conditions and pathogen suppression. However; modern studies are in their infancy and more rigorous studies are needed to explore possible identification, application, and mechanism related to PGPR.

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