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REVIEW ARTICLE

Plant growth promoting rhizobacteria role in agriculture biotechnology

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ABSTRACT
Rhizosphere is highly nutrient rich region that surrounds the root of plant act as a favorable habitat for microbes. Plant growth promoting rhizobacteria (PGPR) present in rhizosphere act as plant growth enhancer as they colonize with the root of the plant to increase the crop yield and productivity. They play an essential role in maintaining the fertility of the land and reduce the dependence on chemical based fertilizers, pesticides and other supplements that are required for productivity. Various studies have suggested the substantial effect of PGPR on plants. This review focus on the effect and impact of PGPR and their application in agriculture biotechnology.
Keywords: *PGPR, rhizosphere, Agriculture biotechnology.*

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INTRODUCTION

Plants play a vital role in our life and in environment. But many biotic and abiotic factors influence their growth and development. Plant root surfaces harbors many microbes as they are highly nutrient rich. These microbes can either be beneficial, neutral or harmful for the plant. Organic compounds such as sugars, organic acids, amino acids, enzymes, growth factors along with ions, oxygen and water are released as root exudates in the rhizosphere.[1] This Rhizosphere provides a suitable niche for growth of microorganisms. Rhizobacteria are the bacteria found in the rhizosphere and they colonize plant roots. Some of these bacteria are beneficial to the plants as they promote the growth of the plant by various mechanisms. Kloepper and Scroth carried out experiments on potato, sugar beet and radish plants with *Pseudomonas fluorescens-putida* and found out that these bacteria rapidly colonized in these plants and enhanced the plant growth. They termed these bacteria as plant growth promoting bacteria (PGPR) [2] Rhizosphere has high bacteria count 100-1000 times more than bulk soil i.e. the soil which is not in contact with the roots.[1]

PGPR has a direct and indirect mechanism for enhancing growth of plant. The direct mechanism includes nitrogen fixation, solubilization of phosphate and potassium, siderophore and phytohormone production whereas the indirect mechanism includes induced systemic resistance, production of antibiotics, hydrolytic enzyme and exopolysaccharide production.[3]

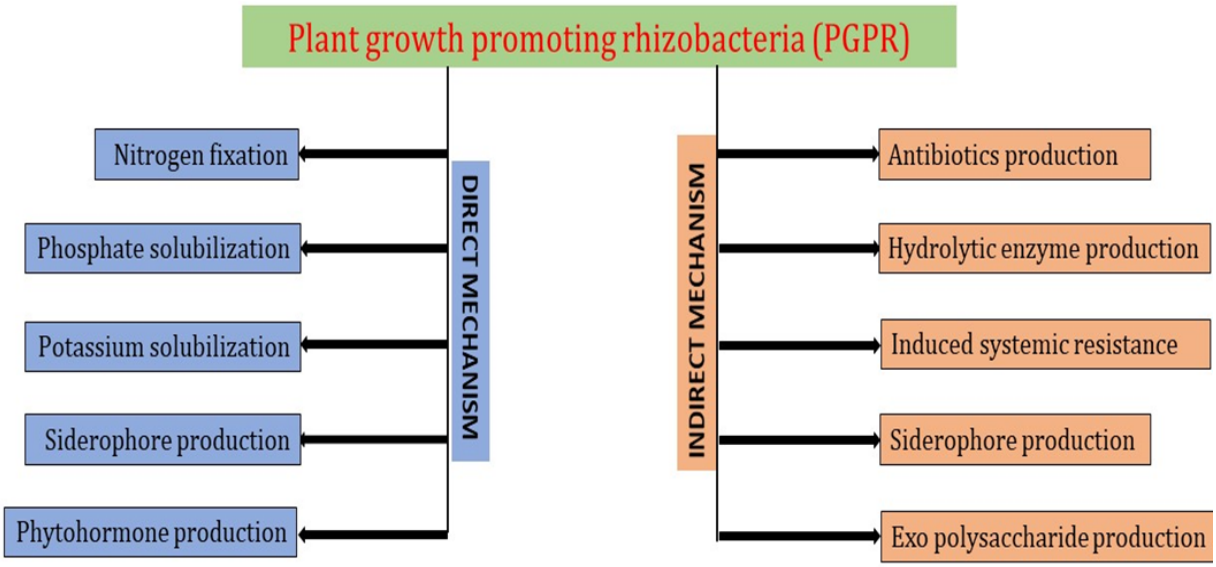

Fig 1. Schematic diagram showing direct and indirect mechanism by which PGPR affect plant growth

Over the years various kinds of bacteria have been recognized as PGPR, some of which are *Flavobacterium, Acetobacter, Pseudomonas, Azospirillum, Azotobacter, Arthrobacter, Micrococcus, Chromobacterium, Agrobacterium, Bacillus, Burkholderia, Erwinia, Hypomycrobium, Xanthomonas, Klebsiella*.[4]

The use of chemical fertilizer has increased in agriculture because fertilizers provide indispensable plant nutrients. Plants can only take a small portion of the applied nutrient due to the low use efficiency of chemical fertilizer. This leads to leaching of groundwater and contamination of runoff water. Overuse of fertilizers can cause hazardous environmental impacts.[5] In present scenario the use of biological approach for improving crop yield is increasing. PGPR increase soil health and promote plant growth by developing sustainable system in crop production. The classification of PGPR can be done by the beneficial effect it shows in the plant. For example, Biofertilizers help in nitrogen fixation which improves plant growth as nitrogen is an essential element required by plant. Similarly, hormone production is achieved by Phytosimulators which enhance plant growth.[6]

PGPR also helps plant cope up with abiotic stress like drought, salinity and nutrient deficiency.[7] They also increase crop productivity by managing plant diseases. *Fluorescent pseudomonas* and *Bacillus* species produce antibiotics which suppress growth of plant pathogens.[8]

Iron is an essential element required by plant. The insoluble form of iron is converted into soluble form by microbial siderophores. Siderophores also remove toxic metals from polluted soil and provide defense against pathogen.[9]

Results suggest that biofilm and exopolysaccharide production by PGPR increased salinity tolerance of faba bean (*Viciafaba L.*) Microorganisms having Biofilm protects the plant from external stress and provides tolerance to antimicrobial agents.[10]

Many researchers have shown that PGPR enhanced plant growth in commercial crops like Rice [11], wheat [12], tomato [13], cucumber [14], apple [15], soybean [16], banana [17], and maize [18]. In this review we have focused mainly on effect and impact of PGPR and their application in agriculture biotechnology.

FUNCTION OF PLANT GROWTH PROMOTING RHIZOBACTERIA: -

Plant Growth Promoting Rhizobacteria (PGPR) affects growth of plant in many ways either directly or indirectly. In the direct way, PGPRs effect the growth of plant by the conversion of elements present in the environment. PGPR plays very important role in fixing atmospheric nitrogen, solubilizing insoluble phosphates, secreting hormones such as IAA, GAs, and Kinetins. In the indirect way, PGPR hinders the harmful effects of one or more phytopathogenic organism by the production of antagonist substance or by inducing resistance from pathogen to the plant.

The following are the different functions performed by the PGPR's: -

1. **Free atmospheric nitrogen fixing PGPRs: -** The nitrogen available in the atmosphere is fixed by the PGPRs present in the association with the roots of the plant. The fixed nitrogen is further utilized by the root and helps in formation of protein in plants. Some bacteria that are associated in nitrogen fixation process are Enterobacter*, Klebsiella, Burkholderia,* and *Stenotrophomonas* [19].
2. **Mineral Phosphate Solubilization: -** Many living microorganisms associated with the soil have been reported in solubilizing the insoluble phosphate compounds in the useful form which can be used by the plants. The phosphorus is available in many soil samples in the range of 1 µmol per liter, while the plant needs 30 µmol per liter to give their maximum result in production. Different bacteria such as *Achromobacter, Agrobacterium, Bacillus, Enterobacter, Erwinia, Escherichia, Flavobacterium, Mycobacterium, Pseudomonas* and *Serratia* are highly efficient and effective in solubilizing the unavailable complex phosphate intoavailable inorganic phosphate ion that can be utilized by the plant [19]
3. **PGPRs in Potassium Solubilization: -** Potassium is the third most viable and important element that are being utilized by the plants in adequate amount. The potassium available in the soil has very low concentration and above 90% of potassium present in the soil exists in the form of silicate minerals and insoluble rocks. PGPRs available in the soil also solubilize the potassium rock by the production and secretion of organic acids which gets utilized by the plant for further development. Bacteria which are related in Potassium Solubilization are *Acidothiobacillus ferrooxidans*, *Bacillus edaphicus*, *Bacillus mucilaginosus*, *Burkholderia*, *Paenibacillus*sp. and *Pseudomonas* [3].
4. **Siderophores production: -** Siderophores are the low molecular weight, ferric ion chelating agents produced by bacteria and fungi growing under low iron stress. Iron is the most essential micronutrients and the fourth most abundant element present in earth. In soil, Siderophores are the whole and sole source of iron for the plants which enhance the chlorophyll level in the leaf of the plant. The bacteria that are useful in siderophore production and viability are *Aeromonas*, *Azadirachta*, *Azotobacter*, *Bacillus*, *Burkholderia*, *Pseudomonas*, *Rhizobium*, *Serratia* and *Streptomyces* sp [20].
5. **Phytohormone production: -** Many PGPRs with the ability of producing phytohormone like Indole acetic acid (IAA), gibberellic acid, cytokinins and ethylene.
    - **Indole Acetic acid (IAA)** is a positive regulator of plant growth which has been proved by some sort of evidences. It has been observed that up to 80% of Rhizobacteria are capable of producing Indole acetic acid in soil surface for increased uptake of nutrients for the host plant [21].
    - **Gibberellic acid and cytokinins** can be produced by several plant growth promoting rhizobacteria like *Azotobacter*sp., *Rhizobium* sp., *Pantoeaagglomerans*, *Rhodospirillum rubrum*, *Pseudomonas fluorescens, and Bacillus subtilis*and *Paenibacillu spolymyxa* [22].
    - **Ethylene**
6. **PGPRs as Biofertilizer: -** Fertilizers are the substance that are used to increase the yielding capacity of the soil or land. Biofertilizer are the organic substance where living organisms or their remaining are being used to increase the crop productivity and fertility of the soil. They enhance the crop ability to with stand against stress condition. *Allorhizobium, Azorhizobium, Bradyrhizobium, Mesorhizobium, Rhizobium* and *Sinorhizobium* are some PGPRs that are commonly used as biofetilizer.
7. **PGPRs in Plant Growth stimulation and Seed germination: -** Apart from the above functions performed by PGPRs, they also enhance the plant growth, seed emergence, seed germination and overall yield of crops in various systems [23]. PGPRs work as a combined factor reducing the stress environment and providing a favorable condition for the plant growth. Some of the examples of the PGPRs that work in association with fungi or each other to increase the plant growth are *Azotobacter chroococcum, Acaulospora and Azospirillum*[25].
8. **Antagonistic nature of PGPR's: -** Sometimes Rhizobacteria decrease the growth of the host plant by competing for the nutrients available, space and limiting resources of Iron, phosphorus, ammonia etc producing lytic enzymes and antibiosis [24]. Among various types of PGPRs, fluorescent pseudomonades are commonly and exclusively reported as the antagonist for their wide range antagonist activity against number of different kinds of phytopathogens [25]. Use of *Pseudomonas aeroginosa* in association with some common medicinal plant *Launaeanudicaulis* also gives good result for effective control of root infecting fungi of mungbean [26].
9. **PGPRs as Biocontrol Agents: -**Competition for available nutrients, niche exclusion, induced systemic resistance against the enemic factors and production of anti-fungal metabolites known as AFMs, is basically responsible for biocontrol activity of PGPRs. PGPR like Azotobacter sp., Azospirillum sp., and Pseudomonas fluorescence and AM fungi like *Glomus fasciculatum, G. mossae* and *Gigaspora margarita* are observed as the commonly used microbes to decrease the wilt disease of brinjal [27].

Table 1. Summarizing functions of PGPR

Sl.No.	Function Of PGPR	Description	PGPR strain
1.	Nitrogen fixation	Conversion of free atmospheric nitrogen into oxide form that can be used.	*Enterobacter, Klebsiella, Burkholderia,* and *Stenotrophomonas.*
2.	Phosphate Solubilization	Conversion of insoluble phosphate into the soluble form absorbed by the plants.	*Achromobacter,Agrobacterium, Bacillus, Enterobacter, Erwinia, Escherichia, Flavobacterium, Mycobacterium, Pseudomonas* and *Serratia.*
3.	Potassium Solubilization	Conversion of potassium in the useful form.	*Acidothiobacillusferrooxidans*, *Bacillus edaphicus*, *Bacillusmucilaginosus*, *Burkholderia*, *Paenibacillus*sp. and *Pseudomonas.*
4.	Production of siderophore	Enhancing the source of iron in the soil that can be absorbed by the plants.	*Aeromonas*, *Azadirachta*, *Azotobacter*, *Bacillus*, *Burkholderia*, *Pseudomonas*, *Rhizobium*, *Serratia* and *Streptomyces* sp.
5.	Phytohormone production	Production of phytohormones such as auxin,cytokinins, gibberellic acid and ethylene.	*Azotobacter*sp., *Rhizobium* sp., *Pantoeaagglomerans, Rhodospirillum rubrum, Pseudomonas fluorescens, and Bacillus subtilis*and*Paenibacillus.*

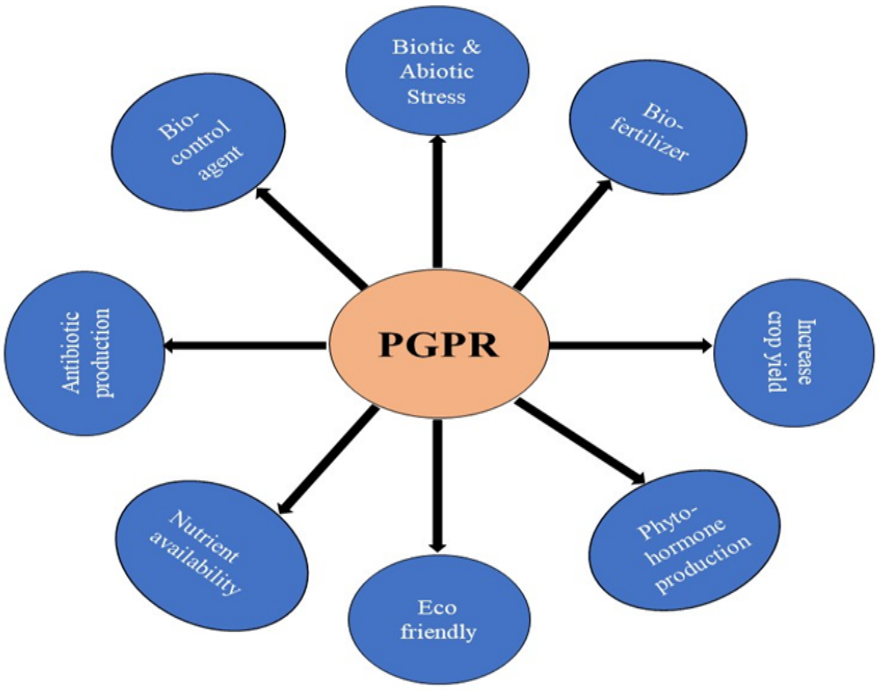

Fig 2. Schematic diagram showing PGPR and its effect in sustainable agriculture

CONCLUSION

The need of the hour is to switch to reduce the dependence on chemical fertilizers and pesticides and switch to biological means like biofertilizers and biocontrol agents. Use of PGPR will not only increase crop yield and enhance plant growth but will also provide fertility to the soil in an ecofriendly manner. In current scenario the agriculture is facing various abiotic stress like drought, waterlogging, salinity, temperature. These stress damage crop yield. PGPR serve as a great aid to farmers as: -

- They are eco friendly
- They are cost effective
- Increase crop yield
- Improve soil fertility

- Act as biocontrol agent
- Manage biotic and abiotic stress in plant
- Helps solubilization of minerals
- Produce antibiotics
- Produce phytohormone

With the help of agriculture biotechnology PGPRs have helped in overall growth and health of plant and soil and in future this will lead to sustainable and environment friendly agriculture.

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