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# Role of Plant Growth Promoting Rhizobacteria in Sustainable Agriculture

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***Abstract*: Research directed towards the development of approaches for sustainable growth is the need of the hour. A key point of focus should be the beneficial interactions between plants and microbes in order to facilitate sustainable agricultural practices. Biotechnology has opened new avenues for the application of beneficial soil-bacteria for the promotion of plant growth and the biological control of phytopathogens. Plant growth promoting rhizobacteria (PGPR) are plant-friendly bacteria that reside in the root-zone of plants and affect it in many direct and indirect ways. PGPR have attracted the attention of scientists throughout the world for their role in improving plant growth and health and the results to date are very promising. Use of PGPR as soil-inoculants for many crops has shown significant improvement in their growth and yield through increased seedling germination, plant vigor, shoot height and weight, chlorophyll content and increased nodulation in legumes. They employ a variety of mechanisms to affect the overall health and growth of plant. The use of PGPR is steadily increasing in agriculture and offers an attractive way to replace chemical fertilizers, pesticides, and supplements.**

**Key words: Sustainable agriculture; Plant growth promoting rhizobacteria; biological control; Soil-inoculants**

## I. INTRODUCTION

Food demand is growing tremendously across the globe and to combat this ever increasing demand, innovative agricultural tools and methodologies are required. Though remarkable improvement in crop production has been achieved in the last few decades, however at the same time the dependency on agrochemicals like chemical pesticides and fertilizers has also increased manifolds. Chemical based products are generally toxic and non-biodegradable in nature and also exert harmful effects on human, animal and environmental health. Moreover, their continuous use results in generation of resistant strains of pests and pathogens [1]. Unwarranted use of such chemical tools to enhance the crop yield and control plant diseases, has resulted in severe problems like accumulation of chemicals in plant products and thus their entry into the food chain, depletion of soil quality and fertility, contamination of water resources and reduction in population of naturally occurring beneficial organisms [2]. Of late, consumers have shown their concern for soaring usage of agrochemicals in relation to food quality and safety as well as for the effects of modern farming methods on environment.

Key challenge, thus, is to attain twin goals of agricultural growth along with the maintenance and enhancement of environmental quality. This idea of replenishment of natural resources while maintaining economic viability of agricultural system is termed as sustainable agriculture. Sustainable agricultural practices are thus the answers to these multifaceted problems and the concept is even more important for developing countries like India.

Use of microbial agents to improve agricultural production and plant health offers an attractive option, to practice and develop sustainable agricultural practices. Agriculturally important microorganisms have thus been the focus of research during the last few decades and gained much attention as the tools for developing sustainable agriculture.

Plant growth promoting rhizobacteria (PGPR) are the bacteria which reside in the rhizosphere of plant and affect it in a favourable manner. They enjoy a close association with the plant and hence are the most suitable candidates to be developed as tools for sustainable agriculture. They have been shown to play a pivotal role in improving plant growth and health. Huge volume of literature supports their potential to improve plant health and growth. Thus it is very important to understand various aspects of PGPR related to agriculture.

## II. PLANT GROWTH PROMOTING RHIZOBACTERIA

Bacteria that provide benefit to the plant can be either symbiotic or free living in soil, but are found in abundance near roots. Plant growth-promoting rhizobacteria (PGPR) are plant-friendly bacteria that reside in the rhizosphere and enhance plant growth by a wide variety of mechanisms. The term PGPR was coined by Joe Kloepper in late 1970s and was defined by Kloepper and Schroth [3] as "the soil bacteria that colonize the roots of plants by following inoculation on to seed and that enhance plant growth". PGPR may benefit the host by causing plant growth promotion or biological disease control. The same strain of PGPR may cause both growth promotion and biological control [4]. When Kloepper and Schroth coined the term Plant Growth-Promoting *Rhizobacteria* (PGPR), it was originally used to describe the biocontrol group.

A wide range of bacteria has been identified as belonging to this category including *Pseudomonas, Bacillus*, *Azospirillum, Azotobacter, Klebsiella, Enterobacter, Alcaligenes, Arthrobacter, Flavobacterium, Burkholderia, Mesorhizobium, Serratia* etc. [5] [6] [7]. However, most promising reports for the improvement of plant growth and health have been obtained for two bacterial species in this group i.e. *Pseudomonas* and *Bacillus*.

## III. CATEGORIZATION OF PLANT GROWTH PROMOTING RHIZOBACTERIA

Broadly, PGPR may be divided into two categories depending on their effect on plant. First group includes 'biocontrol agents' that inhibit the growth of various phytopathogens through a variety of mechanism thus controlling plant diseases. Second group includes 'biofertilizers' that improve the availability and uptake of nutrients by the plant resulting in enhanced plant growth. PGPR also enhance the tolerance capacity of the plant to a variety of environmental stresses through production of phytohormones [8] and ACC deaminase [9]. Same strain of PGPR may cause plant growth promotion and disease suppression in many cases [4].

## 1V. Mechanisms of plant growth promotion

Depending on their category, PGPR may improve plant growth through various direct and indirect mechanisms. A broad overview of these mechanisms is discussed in the following paragraphs.

### *1) Siderophore production*

Siderophores are low molecular weight molecules (400-1000 daltons) which have high affinity for iron (Kd = $10^{-20}$ to $10^{-5O}$) and thus bind ferric ions available in the soil [10]. Iron is not readily available to plants as it gets easily oxidized and exists predominantly in the form of sparingly soluble ferric ions which cannot be utilized directly [11]. Many PGPR strains like *Pseudomonas* [12], *Bacillus* [13] [14], *Acinetobacter* [15], *Serratia* [16] are known to produce siderophores. Thus PGPR improves the availability of iron to plants and also indirectly control the pathogens as they scavenge the rhizosphere of the limited amount of ferric ions available thus inhibiting the pathogens in their immediate vicinity due to iron limitation [17].

### *2) Phosphorus solubilization*

Phosphorous is an essential mineral for the growth and development of plants as it is crucial for many physiological activities like cell division, photosynthesis, development of root system and utilization of carbohydrates etc. Though soils are generally rich in P, the concentration of soluble/bioavailable P is usually very low in soil due to the phenomenon of chemical fixation of phosphate immobilized soon after application and becomes unavailable to plants. However many soil microorganisms are known to release phosphate (P) from the binded or absorbed (nutritionally unavailable) forms present in the soil thus improving the availability of this highly important mineral nutrient to the plants [18] in both acidic and alkaline soils [19]. Besides improving the plant growth through stipulation of optimal P concentrations, phosphate solubilizing bacteria (PSB) also exhibit antagonistic activities against deleterious organisms in the rhizosphere [20] [21].

### *3) $N_2$ - fixation*

Nitrogen is the major plant nutrient required for many key functions. Biological nitrogen fixation contributes more than 180 x $10^6$ metric tons of nitrogen per year, globally, including symbiotic as well as free-living or associative systems [22]. Symbiotic nitrogen fixing soil bacteria include *Rhizobium,* which is an obligate symbiont in leguminous plants and *Frankia* in non-leguminous plants while major groups of free-living, associative or endophytic nitrogen-fixing bacteria are cyanobacteria, *Azospirillum*, *Azotobacter*, *Acetobacter*, *Azoarcus* etc. Thus, the presence of these N-fixers improves the availability of N to plants.

*4) Control of phytopathogens*

PGPR are known to suppress plant disease by various mechanisms like increasing plant resistance to fungal [23], bacterial [24] and viral diseases [25] [26], insects [27] and nematodes [28], by production and release of metabolites that reduce the population or activities of pathogens or deleterious rhizosphere microflora [29] e. g. production of siderophores that bind Fe; making it less available to the native pathogens [17], lytic enzymes, diffusible antibiotics, volatile organic compounds (VOCs), toxins and biosurfactants [30] or competing with the pathogens for limited nutrients [31] and suitable sites in the rhizosphere [32] .

*5) Phytohormone production*

Phytohormones are the secondary metabolites that act as chemical messengers and provide the ability to the plant to respond to environment. They are also termed as growth regulators as they control (stimulate or inhibit) growth in plants. Five major groups of phytohormones are auxins, gibberellins, ethylene, cytokinins, and abscisic acid [33]. Diverse range of PGPR is known to secrete these phytohormones [34] [35]. These PGPR thus favourably influence aspects like seed germination, development of root-system and other plant growth activities.

*6) Induced Systemic Resistance (ISR)*

Induced resistance may be defined as enhancement of plant's defensive capacity against an array of pathogens wherein the plant's innate defenses are potentiated against subsequent biotic challenges via a stimulus prior to infection [36] [37]. It is plant-mediated, broad-spectrum resistance response that is activated by selected strains of saprophytic rhizosphere bacteria specifically the PGPR. Many PGPR strains have been found to induce systemic resistance in plant-pathogen combinations like *P. putida* WCS358 in *Arabidopsis thaliana* against *P. syringae* and *Fusarium oxysporum* [38], *P. putida* 89B-27 in cucumber against *Fusarium oxysporum* [39] and *P. aeruginosa* 7NSK2 against *Botrytis cinerea* in bean and tomato [40] [41]. Hence PGPR enhance the capacity of plant to resist the presence of pathogens.

**V. Conclusion**

PGPR are a diverse group of soil bacteria that colonize the root zone of plant extensively and improve the growth and yield of plant through a varied range of mechanisms. Same strain of PGPR many affect the plant in more than one way so as to protect it from deleterious organisms residing in soil and also improve the availability of essential nutrients.

In view of the fact that increased crop-yields are highly required but not at the cost of environmental and human health, eco-friendly agricultural tools are highly needed. Development of PGPR based soil-inoculants to control plant diseases and improve their growth is thus a viable option. Many such kind of bioformulations are already being used either individually or in combination with chemical products. Biocontrol agents are being successfully used as components of integrated pest management programmes. However, though the results are highly promising under *in-vivo* conditions, more detailed studies are required in order to obtain better on-field output for such bio-inoculants. In order to attain commercial competitiveness with established low-priced and effective chemical tools, these bio-inoculants must give consistent performance under actual field conditions.

Hence, it may be concluded that PGPR based organic farming is the future of sustainable agriculture and the concept is even more important in developing countries like India.

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