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Plant growth promoting rhizobacteria, a formula for sustainable agriculture: A review

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ABSTRACT

The race for producing more crop yield by adopting more intensive agronomic practices and applying more fertilizers is thought to have had adverse effects on the soil health. Improvement in agriculture sustainability requires optimal use and management of soil fertility and soil physical properties, both of which rely on soil biological processes and soil biodiversity. In this context, the long-lasting challenges in soil microbiology are development of effective methods to know the types of microorganisms present in soil, and to determine functions which they perform in situ. It is imperative to understand the relationship of soil and plants with the diversity of associated bacteria, rhizobacteria, defining the roles of plant growth promoting bacteria (PGPR) to evolve strategies for their better exploitation. Different cropping systems are of central interest to explore for sustainable agriculture. The rhizosphere, considered to be a hot spot of bacterial diversity, harbors bacterial flora whose diversity is mainly expressed in terms of functions adapted to the root presence, and in particular to favor plant growth. This in turn is beneficial to the whole rhizosphere microbiota through the highly nutritive and energetically rhizo-depositions. Plant growth promotion and development can be facilitated both directly and indirectly. Generally, PGPR function in three different ways: synthesizing particular compounds for the plants, facilitating the uptake of certain nutrients from the soil, and preventing the plants from diseases. Some common examples of genera exhibiting plant growth promotingactivity are Azospirillum, Azotobacter, Bacillus, Burkholderia, Corynebacterium, Pseudomonas, Rhizobium, Serratia etc.

Keywords: PGPR, Rhizosphere, Rhizobacteria, Sustainable agriculture

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INTRODUCTION

The world population will cross 10 billion mark by 2050. This staggeredly increasing population is creating insurmountable pressure on the existing land area for food, fiber, fuel and raw materials. Agriculture contributes to a major share of national economy in many developing countries, while ensuring food security and employment. Utilization of improved plant varieties and technological interventions have been instrumental in meeting the demands of the growing populace in the country [1].The race for producing more crop yield by adopting more intensive agronomic practices and applying more fertilizers is thought to have had adverse effects on the soil health. Sustainable agriculture is vitally important in today's world because it offers the potential to meet our future agricultural needs, something that conventional agriculture will not be able to do. Beneficial rhizobacteria can increase plant vigor and soil fertility [2]. The application of plant growth promoting rhizobacteria (PGPR) as biofertilizers, phytostimulators and biocontrol agents would be an attractive alternative to decrease use of chemical

fertilizers which lead to environmental pollution [3].The main aim of this review is to understand the role of PGPR in sustainable agriculture.

2. RHIZOSPHERE

The rhizosphere is the narrow zone of soil specifically influenced by the root system [4]. This zone is rich in nutrients when compared with the bulk soil due the accumulation of a variety of plant exudates such as amino acids and sugars, providing a rich source of energy and nutrients for bacteria [5]. The zone of influence of the root harbors an approximately 10-to100-fold greater microbial population, suggesting fierce competition for nutrients as well as the existence of species which show a variety of functional diversity and metabolic versatility [6, 7].The rhizosphere itself can be demarcated into (a) endorhizosphere, which refers to the internal root area extending generally to cortical region which harbors large population of bacteria with varied functions, (b) rhizoplane, and (c) ectorhizosphere [8].The rhizospheric soil contains diverse types of bacterial genera called as rhizobacteria, which exhibit beneficial effects on plant growth [9].

3. FUNCTIONAL ATTRIBUTES OF PGPR

3.1 Plant-microbe interaction

PGPRs colonize the rhizosphere, the rhizoplane or the root itself [10]. A successful plant-microbe interaction is a result of effective colonization of microbes [11]. Steps of colonization include attraction, recognition, adherence, invasion (in case of endophytes and pathogens), colonization and growth. Plant roots send signals in the form of root exudates which are recognized by microbes [12]. PGPR reach root surfaces by active motility guided by chemotactic responses [13].

3.2 Mode of action

Plant associated bacteria can be classified into beneficial, deleterious and neutral groups on the basis of their effect on plant growth [4]. Beneficial free-living rhizobacteria are usually referred to as plant growth promoting rhizobacteria- PGPR [14].It is well established that only 1 to 2% of bacteria promote plant growth in the rhizosphere [15]. PGPRs are from diverse genera like *Azospirillum*, *Azotobacter*, *Bacillus*, *Burkholderia*, *Corynebacterium*, *Pseudomonas*, *Rhizobium*, *Serratia* etc, of which *Bacillus* and *Pseudomonas spp.* Are predominant. Generally, PGPR function in three different ways[16]: (a) synthesizing particular compounds for the plants[4, 17], (b) facilitating the uptake of certain nutrients from the soil[18, 19], and (c)lessening or preventing the plants from diseases[20, 21, 22].

Plant growth promotion and development can be facilitated both directly and indirectly. Direct plant growth promotion includes symbiotic as well as non-symbiotic PGPR which function via production of metabolites that enhance plant growth such as auxins, cytokinins, gibberellins, and through the solubilization of phosphate minerals [23].Indirect growth promotion occurs via the removal of pathogens by the production of secondary metabolites such as hydrogen cyanide (HCN) and siderophores[24]and/or fungal cell wall degrading enzymes, e.g., chitinase and ß-1, 3-glucanase [16, 25, 26].PGPR has also been applied in remediation of contaminated soils in association with plants [27].

3.2.1 Nitrogen fixation

Nitrogen is one of the most limiting plant nutrients for plant growth [28]. Some rhizobacteria have the ability to fix nitrogen into organic forms which can then be utilized by the plants. PGPR by forming symbiotic and non-symbiotic associations with plants fix atmospheric nitrogen converting it into usable form ammonia. In symbiotic nitrogen fixation, a mutualistic relationship between plant and microbe exits. The microbes form nodules on the root surfaces where nitrogen fixation takes place. While as in case of non-symbiotic nitrogen fixation, microbes are free living. *Rhizobium* is an example of symbiotic nitrogen fixer while as *Cyanobacteria*, *Acetobacter* fix N_2 freely. Numerous studies have shown greater nitrogen fixation activities in inoculated plants as compared to uninoculated plants [29].

3.2.2 Siderophore production

Iron is one of the bulk minerals present on the surface of earth, yet it is unavailable in the soil for plants. This is because iron is commonly present in the form of Fe^{3+} in nature which is highly insoluble [30]. To overcome this problem, PGPR secrete siderophores. Siderophores are low molecular weight iron binding proteins having binding affinity with ferric ions. These siderophores improve plant growth and development by increasing the accessibility of iron in the soil surrounding the roots [14].Plants sequester iron by utilizing siderophores secreted by PGPR[31].*Bacillus*, *Klebsiella*, and *Pseudomonas* are some of the genera that produce siderophores.

3.2.3 Phosphate solubilization

Phosphorus, which is taken by the plants from soil as phosphate anions, is necessary for plant growth. But the amount available to plants is very low because of its extreme insolubility. Various reports of many researchers have reported the ability of PGPR to solubilize insoluble inorganic phosphate compounds. These bacteria solubilize phosphate by secreting some acids or by some other means and these bacteria are collectively termed as phosphate solubilizing bacteria- PSB[32, 33, 34, 35, 36]. Several researchers have consequently proven that PSB increase plant growth and yield[37, 38]. The bacterial genera with phosphate solubilizing ability are *Azospirillum, Bacillus, Pseudomonas, Rhizobium, Serratia* and others.

3.2.4 Phytohormone production

Plant growth is also regulated by phytohormones produced by PGPR. Many researchers have reported the production of auxins and cytokinins by PGPR but production of gibberellins by rhizobacteria remains scanty. *Pseudomonas fluorescens* isolated from soybean has been reported to produce cytokinins [39]. Among the mechanisms operative in PGPR Glick has reported stimulation of plant growth through the activity of the enzyme ACC deaminase [16]. ACC deaminase activity helps plant to combat abiotic stress by hydrolyzing ACC, the precursor of ethylene, to alpha-ketobutyrate and ammonia. Use of biofertilizer containing PGPR with ACC deaminase activity may improve plant growth and development by overcoming the ill effects of salt stress ethylene [40].

3.2.5 Biocontrol agents

Indirect plant growth promotion includes the prevention of the deleterious effects of phytopathogenic organisms. PGPR have also been shown to produce various antagonistic metabolites that are involved in direct inhibition of plant pathogens [41, 42]. It includes antibiosis *i.e.* the inhibition of microbial growth by diffusible antibiotics and volatile organic compounds, toxins, and biosurfactants, and parasitism that may involve production of extracellular cell wall-degrading enzymes such as chitinases and β-1,3-glucanase [43, 44].For example, *Bacillus subtilis* strains produce a variety of powerful antifungal metabolites, e.g., zwittermicin-A, kanosamine and lipopeptides from the surfactin, iturin and fengycin families [45, 46]. More recently, *Pseudomonas* and *Bacillus* species have been implied in biocontrol due to their effective competitive interactions with bacteria, fungi, oomycetes, protozoa, nematodes[47, 48, 49].

CONCLUSION

There is a substantial proof in the literature indicating the PGPR have an unquestionable potential role in sustainable agriculture. They do not only promote the plant growth by various strategies (direct as well as indirect) and increase the soil fertility, but also are eco-friendly. A better understanding of the basic principles of the rhizosphere ecology, including the function and diversity of inhabiting microorganisms is on the way but further study is necessary to optimize soil microbial technology to benefit plant growth and development in the natural environment. There is a need of designing systematic strategies to fully utilize all the beneficial factors of PGPRs facilitating their development as reliable components in the management of sustainable agricultural systems reducing the uncountable hazardous of chemical fertilizers.

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