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Mini Review

Plant Growth Promoting Rhizobacteria (PGPR) for Sustainable and Eco-Friendly Agriculture

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Abstract

Conventional agriculture is mainly dependent on chemical fertilizers and pesticides which have caused a serious threat to human health and environment. Plant Growth Promoting Rhizobacteria (PGPR), a diverse group of soil bacteria, are engaged in an intense network of interactions in the rhizosphere exerting beneficial traits on plant growth and development. In recent past, PGPR have emerged as a promising tool for eco-friendly and sustainable crop production. These beneficial soil microbes play an important role in plant growth promotion by (i) enhancing the availability and uptake of nutrients through biofixation and mobilization (ii) reducing the harmful effects of soil-borne plant pathogens by employing multiple mechanisms of action and (iii) producing plant growth regulators or other biologically active substances that alter endogenous levels of phytohormones.

Keywords: Sustainable Agriculture; PGPR, Biofertilizers; Bio-control Agents; Phytohormones

Soil is considered simply a source of nutrients to plants. In real sense it is a complex ecosystem hosting bacterium, fungi, actinomycetes, protists, and animals. Plants exhibit a diverse array of interactions with these soil organisms, which span the full range of ecological possibilities (symbiosis, competition, neutralism, commensalism, mutualism etc.). The narrow zone of soil influenced by the plant root system is known as rhizosphere [1]. This zone is rich in sugars and amino acids than the bulk thus providing a better nutritional environment for growth and proliferation of soil microorganisms [2,3]. The beneficial free-living bacteria colonizing rhizosphere are referred to as Plant Growth Promoting Rhizobacteria (PGPR). The use of PGPR for sustainable and environment friendly agriculture has increased globally during the last couple of decades on account of increasing costs of chemical fertilizers and their negative impact on environment [4,5].

PGPR as Biofertilizers

Plant Growth Promoting Rhizobacteria (PGPR) participate in soil fertilization through biofixation of atmospheric nitrogen and biosolubilization of insoluble nutrients such as phosphorus, potassium and some micronutrients. The most part of nitrogen is in gaseous form which is not accessible to plants. The biological nitrogen fixation is limited to bacteria that possess an enzymatic complex (nitrogenase) which catalyses the reduction of atmospheric nitrogen into ammonia [6,7]. Nitrogen-fixing prokaryotes include both free living rhizospheric bacteria (e.g. *Azotobacter, Azospirillum, Clostridium, Achromobacter, Acetobacter, Alcaligenes, Arthrobacter, Azomonas, Bacillus, Beijerinckia, Corynebacterium, Derxia, Enterobacter, Herbaspirillum, Klebsiella, Pseudomonas, Rhodospirillum, Rhodopseudomonas and Xanthobacter*) [8,9] and symbiotic rhizospheric bacteria(*Rhizobium, Bradyrhizobium, Sinorhizobium, Azorhizobium, Mesorhizobium and Allorhizobium*) that fix nitrogen only in association with certain plants. The latter group comprises Rhizobia associated with leguminous plants and filamentous sporulating bacteria associated with Actinorhizal plants [2,10].

Solubilization and mineralization of phosphorus by phosphate-solubilizing bacteria is an important trait that can be achieved by PGPR. Almost 95-99% of phosphorus in soil is present in insoluble, immobilized, or precipitated form, therefore, it is difficult for plants to absorb it. The low molecular weight organic acids released by various soil bacteria solubilize inorganic phosphorus [11,12]. Phosphate solubilizing PGPR are included in the genera Arthrobacter, *Bacillus, Beijerinckia, Burkholderia, Enterobacter,* Microbacterium, Pseudomonas*, Erwinia, Rhizobium, Mesorhizobium, Flavobacterium, Rhodococcus,* and *Serratia* [13-15]. The ability of PGPR to solubilize potassium rock by producing and secreting organic acids has also been widely investigated. Potassium solubilizing PGPR, such as *Acidothiobacillus* sp., *Bacillus edaphicus, Bacillus mucilaginosus, Ferrooxidans* sp., *Pseudomonas* sp., *Burkholderia* sp. and *Paenibacillus* sp. have been reported to release potassium in accessible form from potassium-bearing minerals in soils [16,17].

Siderophores are small organic molecules produced by microorganisms under iron-limiting conditions that enhance iron uptake capacity. *Pseudomonas* sp. as PGPR, utilizes the siderophores produced by other microbes present in the rhizosphere for fulfilling their iron requirements. More specifically, *Pseudomonas putida* utilize heterologous siderophores produced by other microorganisms to enhance the level of iron available in the natural habitat [18]. A potent siderophore, such as the ferric-siderophore complex, plays an important role in iron uptake by plants in the presence of other metals, such as nickel and cadmium [3].Thus, applying nutrient solubilizing PGPR as biofertilizer to improve agriculture can reduce the use of artificial fertilizers and support eco-friendly crop production [19].

PGPR as bio-control agents

Four types of main mechanisms (parasitism, antagonism, antibiosis and competition) are involved in the bio-control of soil borne pathogenic microorganisms by PGPR. The PGPR may parasitize the pathogenic microbe by secreting hydrolytic enzymes that degradation the cell wall of pathogens. e.g. *Bacillus* sp. causes hyphal lysis of *Gaeumanornyces graminis*. The chitnolytic enzymes of *Serratia marcescens* caused cell wall lysis of *Scierotium rolfsii*. The antibiotic compounds secreted by the PGPR suppress the growth of the pathogen. e.g. Phenazine-1-carboxylic acid produced by *Pseudomonas fluorescens* plays an important role in suppressing the take all disease of wheat [20]. The PGPR compete for food and essential elements with the pathogen thereby displacing and suppressing the growth of pathogen. e.g. the competition for nutrients between fluorescent siderophores (iron chelaters) such as Pseudobactinis and pyoverdins produced by *Pseudomonas fluorescons* chelates iron available in the soil, thereby depriving the pathogen of its iron requirement [21].

PGPR as plant growth regulators

Plant growth regulators are organic molecules, which at extremely low concentrations promote, inhibit, or modify growth and development of plants [22,23]. Ironically, production of these substances can also be induced by PGPR. Common groups of plant growth regulators produced by PGPR include gibberellins, auxins, cytokinins, abscisic acid and ethylene [24]. They are also called exogenous phytohormones as they can be applied exogenously as extracted substances or synthetic analogues to plants or plant tissues [25]. Microbes that induce production of phytohormones play an important role in shoot and root invigoration such as *Rhizobium leguminosarum, Pantoea agglomerans, Rhodospirillum rubrum, Pseudomonas fluorescens, P. aeruginosa, P. putida, Bacillus subtilis, Azotobacter chroococcum, Enterobacter asburiae, Paenibacillus polymyxa, Stenotrophomonas maltophilia, Mesorhizobium ciceri* and *Klebsiella oxytoca* which are regarded as PGPR [26].

Conclusion

Over-dependence on artificial fertilizers and pesticides has led to the circulation of life-threatening substances in the environment which are not only hazardous for human and animal consumption but can also disturb the ecological balance. So, there is an urgent need to manipulate and exploit rhizospheric microflora such as PGPR in an efficient way and expand their usage to serve as a key for sustainable agriculture via improving soil fertility, crop tolerance, productivity, and maintaining a balanced nutrient cycling.

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