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Mini Review Paper

Plant Growth Promoting Rhizobacteria (PGPR): An Alternative of Chemical Fertilizer for Sustainable, Environment Friendly Agriculture

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Abstract

In developing countries like India, demand of chemical fertilizers for crop production has increased tremendously due to the release of several high yielding and nutrient demanding varieties of crop plants. The use of chemical fertilizers has resulted not only in the deterioration of soil health but also has led to some major environmental problems, such as soil and water pollution and other health related problems, besides increasing the input cost for crop production especially on the marginal farmers. So, there is an urgent need to recycle available organics and manipulate rhizospheric microflora in a more efficient way and improve and expand their usage. Search for ecologically adaptable Plant Growth Promotory Rhizobacteria with enhanced plant growth promotory properties and their use to enhance crop productivity can improve the socio-economic status of poor farmers. The present review highlights the Plant growth promoting rhizobacteria as an alternative of chemical fertilizer for sustainable, environment friendly agriculture.

Keywords: Biofertilizers, PGPR, sustainable agriculture.

Introduction

Rhizospheric bacteria, which play an important role in plant growth promotion are termed as PGPR's. They not only promote plant growth but also help in sustainable agricultural development and protecting the environment. Concept of rhizosphere was first given by Hiltner to depict the zone of soil surrounding the roots where microbial populations are accelerated by root activities[1] and PGPR term was coined for the first time by Kloepper and Schroth to describe this microbial population in the rhizosphere which is beneficial, colonize the roots of plants and shows plant growth promotion activity[2]. Plant rhizospheric region is a dynamic and versatile environment of acute plant microbe interactions for tackling essential macro and micro nutrients from a confined nutrient pool. Multiple types of biological interactions between microorganisms and plants takes place in the soil. Numerous microorganisms such as algae, bacteria, protozoa and fungi coexist in the rhizospheric region, but bacteria are the super abundant among them. Plants only prefer those bacteria contributing virtually to their fittingness by releasing sugars, amino acids, organic acids, vitamins, enzymes and organic or inorganic ions through roots exudates producing a very scoop environment where diversity is low[3-5]. PGPR exhibits both direct and indirect mechanisms as biofertilizers and biopesticides.

Plant Growth Promoting Rhizobacteria as Biofertilizer

Plant growth promoting rhizobacteria are beneficial soil bacteria that colonize plant roots and enhance plant growth promotion activity by different mechanisms in various ways (figure 1).

Bioavailable phosphorous for plant uptake: Phosphorus is necessary for plant growth and is taken by the plants from soil as phosphate anions. Even so, phosphate anions are highly reactive and may be trapped via precipitation with cations such as Mg^{2+}, Ca^{2+}, Al^{3+} and Fe^{3+} depending on the quality of the soil. Phosphorus is extremely insoluble and unavailable to plants in these forms. As a result, the amount available to plants is usually a small proportion of this total. Many scientists have reported the ability of different bacterial species to solubilize insoluble inorganic phosphate compounds such as dicalcium phosphate, tricalcium phosphate, rock phosphate and hydroxyapatite. These bacteria solubilize phosphate through the production of acids, and by some other mechanism and are termed as phosphate solubilizing bacteria (PSB) [6-10]. Several researchers consequently have isolated PSB from various soils and prove that inoculations of these bacteria increase the plant growth and yield [11-12]. The bacterial genera with phosphate solubilising capacity are *Alcaligenes, Acinetobacter, Arthrobacter, Azospirillum, Burkholderia, Bacillus, Enterobacter, Erwinia, Flavobacterium, Pseudomonas, Rhizobium and Serratia.*

Nitrogen fixation for plant use: Nitrogen is an essential elements for all forms of life; a basic requisite for synthesizing nucleic acids, proteins and other organic nitrogenous compounds. Regrettably no plant species is capable for fixing atmospheric dinitrogen into ammonia and expend it directly for its growth. Thus the plants depend on biological nitrogen fixation (BNF). BNF imparts 180 $X10^6$ metric tons per year globally, out of which symbiotic Nitogen fixation contributes 80% and the remaining comes from free living Nitrogen fixation[13]. *Rhizobium*, is an example of symbiotic nitrogen fixing forms, while Azospirillum*, Cyanobacteria, Azoarcus, Azotobacter, Acetobacter diazotrophicus* etc. are the examples of while free-living N_2-fixing forms.

Symbiotic nitrogen fixation: Symbiotic nitrogen fixation is a mutualistic relationship between a microbe and the plant. The microbe first enters the root and later on form nodules in which N_2 fixation occurs. Rhizobia have the ability to lay symbiotic interactions by the colonization and formation of root nodules with leguminous plants, where nitrogen is fixed to ammonia and make it available for the plant. So the amount of nitrogen fixed is high.

Free-living nitrogen fixing: Numerous nitrogen fixing microbes does not exhibit symbiotic interaction. These microbes are free living and survive on either plant residues or photosynthesise themselves. So, the amount of nitrogen fixed is comparatively small.

Sequestration of Iron by Siderophores: Iron is one of the bulk mineral present in plenteous amount on earth, yet it is unavailable in the soil for the plants. This is because Fe^{3+} (ferric ion) is common form of iron found in nature and is meagerly soluble[14]. To overcome this problem, PGPR's secrete siderophores. Siderophores are iron binding protein of low molecular mass and have a high binding affinity with ferric ion. Siderophores secreted by PGPR's improves plant growth and development by increasing the accessibility of iron in the soil surrounding the roots[15]. Marschner and Romheld in 1994 described that plants utilize siderophores secreted by PGPR for sequestering iron[16]. Plants such as Oats, Sorghum, Cotton, Peanut, Sunflower and Cucumber demonstrate the ability to use microbial siderophores as sole source of iron than their own siderophores (phytosiderophores)[17-19]. Microbial siderophores are also reported to increase the chlorophyll content and plant biomass in plants of Cucumber[20].

Production of Plant Hormones: Plant growth and development is also regulated by phytohormone producing PGPR's. Phytohormones such as auxins and cytokine production by PGPR's have been reported by many researchers, but evidence regarding production of gibberellins by the plant growth promotroy rhizobacteria are scanty. Yet, it has been reported to be produced by certain rhizospheric bacteria's like *Bacillus licheniformis* and *Bacillus pumilus*[21]. Cytokinin encourages tissue expansion, cell division and cell enlargement in plant. *Pseudomonas fluorescens* isolated from the rhizosphere of soybean is reported to produce cytokinins[22]. Auxin is an important phytohormone, which promotes root cell division, root initiation, and cell enlargement[23]. Indole-3-acetic acid (IAA) produced by PGPR's are reported to increase root growth and length, modifying the plant (morphological functions) to uptake more nutrients from the soil. Gibberellins also can alter the plant morphology by the elongation of stem tissues.

Lowering Plant Ethylene Levels: Both abiotic and biotic factors affect the Agricultural crops and its yield under stress conditions. The PGPR's containing ACC deaminase activity are present in various soils and assures improvement of plant growth and development under stress conditions such as heavy metal stress, phytopathogens, flooding, drought and high salt concentration. Ethylene is a significant phytohormone, but excess secretion of ethylene will lead to root curling and shortening, even it can result in plant death under extreme conditions. ACC deaminase property/activity of PGPR helps plant combat abiotic stress by hydrolyzing ACC, the precursor of ethylene, to alpha-ketobutyrate and ammonia, and encourages plant growth under stress environment. Use of biofertilizer containing PGPR with ACC deaminase activity may improve plant growth and development by relieving harmful effects of salt stress ethylene[24]. Besides this, heavy metal stress can also be alleviated using PGPR's[25].

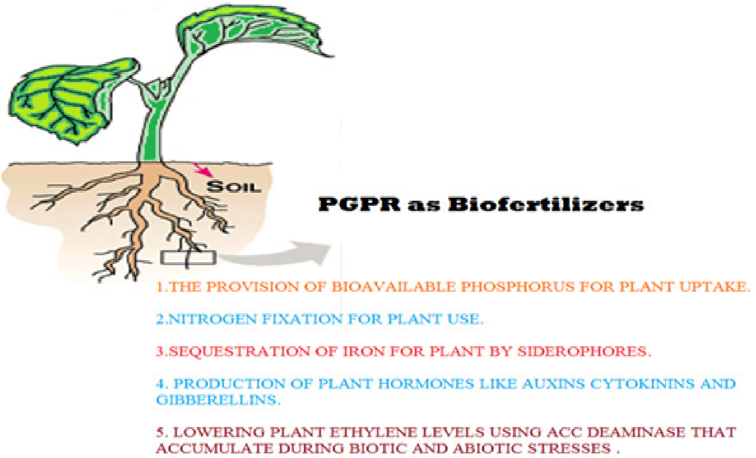

Figure-1
Mechanism depicting how PGPR's help plant growth promotion

Conclusion

There is deluging proof in the literature indicating that PGPR's can be a best alternative of chemical fertilizer for sustainable and ecofriendly agriculture. They will not only provide nutrients to the plants (direct plant growth promotion) and protect plants against the phytopathogens (indirect plant growth promotion)but also increase the soil fertility. Thus, awareness must prevail among the farmers about negative impact of chemical fertilizers and positive aspects of PGPR's as biofertilizer.

References

1. Hiltner L., Uber neuere erfahrungen und probleme auf dem gebiet der boden bakteriologie und unter besonderer berucksichtigung det grundungung und branche, *Arb. Deut. Landw. Ges*., **98,** 59-78 **(1904)**

2. Kloepper J.W. and Schroth M.N., Plant growth-promoting rhizobacteria on radishes: Proceedings of the 4th Internatational Conf. on Plant Pathogenic Bacteria, Station de Pathologie Vegetable et Phytobacteriologie, INRA, Angers, France, 879-882 **(1978)**

3. Lynch J.M., The Rhizosphere, John Wiley and Sons Ltd, Chichester, Edited by Lynch JM, 458 **(1990)**

4. Marilley L. and Aragno M., Phytogenetic diversity of bacterial communities differing in degree of proximity of Lolium perenne and Trifolium repens roots, *Applied Soil Ecol.*, **13,** 127–136 **(1999)**

5. García J.L., Probanza A., Ramos B. and Mañero F.J.G., Ecology, genetic diversity and screening strategies of plant growth promoting rhizobacteria, *J. Plant Nut. Soil Sc.*, **164**, 1–7 **(2001)**

6. Nautiyal C.S., Bhadauria S., Kumar P., Lal H., Mondal R. and Verma R., Stress induced phosphate solubilization in bacteria isolated from alkaline soils, *FEMS Microbiol. Lett*, **182**,291-296 **(2000)**

7. Yadav K.S. and Dadarwal K.R., Phosphate solubilization and mobilization through soil microorganisms, In: Dardawal, K.R. (Ed.), Biotechnological Approaches in Soil Microorganisms for Sustainable Crop Production, Scientific Publishers, Jodhpur, India, 293-30 **(1997)**

8. de Freitas J. R., Banerjee M. R., Germida J. J., Phosphate solubilizing rhizobacteria enhance the growth and yeild but not phosphorus uptake of canola (*Brassica napus*), *Biol. Fertil. Soils*, **24,** 358-364 **(1997)**

9. Rodriguez H., Fraga R., Phosphate solubilizing bacteria and their role in plant growth promotion, *Biotechnology Advances*, **17**,319-339. **(1999)**

10. Chen Y.P., Rekha P.D., Arun A.B., Shen F.T., Lai W.A., Young C.C., Phosphate solubilizing bacteria from subtropical soil and their tricalcium phosphate solubilizing abilities, *Appl Soil Ecol.,* **34**,33–41 **(2006)**

11. Greiner R. and Larsson Alminger M**.,** Stereospecificity of myo-inositol hexakisphosphate dephosphorylation by phytate-degrading enzymes of cereals, *J Food Biochem*., **25***,* 229-*248* **(2001)**

12. Moura D.S., Bergey D.R., Ryan C.A. ,Characterization and localization of a wound-inducible type I serine-carboxypeptidase from leaves of tomato plants (Lycopersicon esculentum Mill.), *Planta* **212**, 222–230 **(2001)**

13. Graham D.L., Steiner J.L., Wiese A.F., Light absorption and competition in mix sorghum-pigweed communities, *Agron. J.*, **80**, 415-418 **(1988)**

14. Höfte M., Classes of microbial siderophores. In: Barton LL, Hemming BC (eds) Iron chelation in plants and soil microorganisms, *Academic Press, San Diego*, 3–26 **(1993)**

15. Kloepper J.W., Leong J., Teintze M., Schroth M.N., Pseudomonas siderophores: a mechanism explaining disease suppressive soils. *Current Microbiol*., **4**, 317-320 **(1980)**

16. Marschner H. and Rohmeld V., Strategies of plants for acquisition of iron. *Plant Soil*, **165**, 261-274 **(1994)**

17. Crowley D.E., Reid C.P.P., Szaniszlo P.J., Utilization of microbial siderophores in iron acquisition by oat, *Plant Physiol.,* **87**, 680-685 **(1988)**

18. Bar-Ness E., Chen Y., Hadar Y., Marschner H., Römheld V., Siderophores of *Pseudomonas putida* as an iron source for dicot and monocot plants, *Plant and Soil*, **130**, 231-241 **(1991)**

19. Wang G.M., Stribley D.P., Walker C., Effect of pH on arbuscular mycorrhiza I. Field observations on long-term liming experiments at rothamsted and Woburn, *New Phytol.,* 124, 465-472, **(1993)**

20. Imsande J., Iron, sulfur and chlorophyll deficiencies: A need for an integrative approach in plant physiology, *Physiol. Plantarum.,* **103**, 139-144 **(1998)**

21. Gutierrez-Manero F.J., Ramos B., Probanza A., Mehouachi J., Talon M., The plant growth promoting rhizobacteria *Bacillus pumilus* and *Bacillus licheniformis* produce high amounts of physiologically active gibberellins*, Physiol Plant,* **111**, 206–211 **(2001)**

22. de Salamone I.E.G., Hynes R.K., Nelson L.M., Role of cytokinins in plant growth promotion by rhizosphere bacteria. In: Siddiqui ZA (ed) PGPR: biocontrol and biofertilization. Springer,The Netherlands, 173–195 **(2005)**

23. Salisbury F.B., The role of plant hormones. In: Wilkinson R.E., ed. Plant-environment interaction, New York, USA: Dekker, 39-81 **(1994)**

24. Belimov A.A., Safronova V.I., Sergeyeva T.A., Egorova T.N., Matveyeva V.A., Tsyganov V.E., Characterization of plant growth promoting rhizobacteria isolated from polluted soils and containing 1-aminocyclopropane-1-carboxylate deaminase, *Can. J. Microbiol*., 47, 242–252, **(2001)**

25. Sharma D., Chauhan S., Kumar G., Singh K.P., Kumar R., Cadmium stabilization by plant growth promotory fluorescent pseudomonas in combination with Indian mustard *var.* Kranti, *South Asean J Exptl. Biol*., **3**(2), 128-135 **(2012)**