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Mini Review

Plant Growth Promoting Rhizobacteria (PGPR): Essential Components For Sustainable Agro-Ecosystem

R. U. Gadpayle[1] and D. N. Lanjewar[2]
[1]Dept. of Microbiology, Y. C. College, Lakhandur, Distt. Bhandara- 441308 (MAH)
[2]Dept. of Botany, Y. C. College, Lakhandur, Distt. Bhandara- 441308 (MAH)
rug.sci@gmail.com

Abstract:

Plant Growth Promoting Rhizobacteria (PGPR) are very important microbial components of rhizosphere soil. The PGPR essentially defines plant-microbes interactions that may have far reaching consequences such as improving plant health as well as soil health leading to sustainability of ecosystem and increased agricultural productivity. The beneficial effect on plant by PGPR can be through direct action such as production of plant growth hormones and plant stress control or through indirect action such as reduction of plant pathogens by antibiosis, reduction of competition for nutrients, induction of systemic resistant, etc. The rhizobacterial population can be maintained by eco-friendly practices such as bio-fertilization. The bio-fertilization techniques are employed as modern agriculture practices and have immense potential for improving agricultural productivity in an environmentally friendly and sustainable manner. These practices includes use of animal manure, composts, green manures, microbial inoculants (microbial fertilizers), arbuscular mycorhiza (AM), biosolids, vermicomposts, etc. It has also been reported that the rhizobacteria alter metal availability in soil by forming metal-complexes and favour healthy growth of plants under high metal stress or heavy metal stress. Further, pesticide degradation activity has also been demonstrated in various PGPR isolates resulting in enhancement of plant productivity. Thus, plant growth promoting rhizobacteria (PGPR) are an indispensable microbial population required for better soil quality, high productivity and eco-sustainability.

Keywords: Plant Growth Promoting Rhizobacteria (PGPR), Soil Quality, Metal Stress, Induced Resistance, Ecosystem

Introduction:

The organisms associated with plant root and in the immediate soil (rhizosphere) have long been suggested to play a vital role in the plant health. Although, considerable progress has been achieved to elucidate various biotic activities of these organisms, however, still their importance in ecological and agronomical processes is undervalued. These soil organisms have been found to carry out several bio-geo-chemical processes that not only impact the nearby or associated plant but also change the soil quality, the ecosystem and eventually the environment. The bacterial species associated with rhizosphere, directly and indirectly benefit plants, are termed as Plant Growth Promoting Rhizobacteria (PGPR). In this work, authors are reviewing recent advances in PGPR related research published recently.

[A] Plant Growth Promotion

PGPR mediated plant growth promotion was reported to occur by alteration of rhizosphere microbial population through release of several microbial metabolites (Kloepper and Schroth, 1981). They mobilize soil nutrients, release signaling molecules that control plant growth and induce resistance towards pathogens, protect plants directly from phytopathogens by antibiosis, remodel metal ion bioavailability, reduce metal toxicity and degrade xenobiotic compounds (Ahemad, 2012; Ahemad and Malik 2011; Hayat et al., 2010; Rajkumar et al., 2010; Braud et al., 2009). The direct benefit can be brought about by nutrient mobilization such as nitrogen, phosphorus and essential minerals or by modulating plant hormone levels, or indirectly by inhibiting various plant pathogens (Ahemad and Kibret, 2013). Nitrogen, one of the most vital nutrient elements for plant, is provided through symbionts such as *Rhizobia and nonsymbionts cyanobacteria (Anabaena, Nostoc), Azospirillum, Azotobacter, Gluconoacetobacter diazotrophicus and Azocarus etc. (Bhattacharyya and Jha, 2012).* Phosphate is a absolutely must nutrient for plants after nitrogen. The phosphate-solubilizing bacteria (PSB) are considered as promising biofertilizers since they can mineralize inorganic phosphate and other compounds by various mechanisms otherwise unavailable to plants (Zaidi et al., 2009).

The bacteria isolated from the rhizosphere region of aromatic plant *Mentha piperita* namely *Bacillus subtilis* GB03, *Pseudomonas fluorescens* WCS417 and *Pseudomonas putida* SJ04 were shown to exert a direct positive effect on growth and physiology of plant. It was observed that increase in shoot biomass, root biomass, leaf area, node number, trichome density, stomatal density and levels of mono-terpene content in Mentha plant were associated with presence and growth of these PGPRs (Cappellari et. al., 2015). These PGPRs have high potential in agro-industrial process especially herbal and aromatic plant cultivation.

[B] Antibiosis/Disease Control

The PGPR bacteria isolated from soil contaminated with heavy metals, recalcitrant organic compounds, and petroleum products were found to be genetically similar to that found in non contaminated soil. Furthermore, a few of the isolates have shown antifungal activity against plant pathogens *Rhizoctonia solani* or *Sclerotinia sclerotiorum*. Some of these PGPRs have shown to produce antibiotics such as diacetylphloroglucinol, pyrrolnitrin, pyoluteorin & phenazines (Wang X et. al., 2014). Thus, such work needed to be extended to various crops and cereals so that several of such diseases can be effectively controlled via biocontrol methods and curbing chemical pesticide use.

[B] Induction of Resistance Against Plant Pathogens

Plants under biotic stress such as microbial pathogen & parasitic attack respond through certain physiological changes known as defense mechanism that critically decides the health & survival of a plant. These defenses can also be triggered by certain stimuli to induce resistance against such biotic stress. In plants, two types of induced responses were observed (i) Systemic Acquired Resistance (SAR) and (ii) Induced Systemic Resistance (ISR). It was found that the Rhizobacteria can induce systemic resistance in plants against broad spectrum of root and foliage pathogens similar to resistance induced in plant after a pathogen attack. For example, *Pseudomonas* strains have been shown to induce systemic resistance in Arabidopsis, Radish, Cucumber, Carnation & Tobacco (Choudhary et al., 2007). Other bacterial species such as Bacillus strains namely *B. subtillis, B.*

pateurii, B. cerus, B. pulmilus, B. Mycoids & *B. sphaericus* have been reported to show significant ISR activity in several plants (Choudhary et al., 2007).

Bacteria and plant derived volatile organic compounds (VOCs) have been variously reported to be the inducer signals that trigger resistance pattern in plants. VOCs such as acetoin and 2,3 butanediol have been profoundly reported to be important ISR signals. Park et. al., 2013 reported that Arabidopsis when challenged with pathogens *P. syringae* (biotrophic pathogen) and *Pectobacterium carotovorum* (necrotic pathogen) have shown stronger induction of resistance by VOCs from *PGPR Paenibacillus polymyxa E681* than *Bacillus subtillis* GB03. Further investigations revealed a long chain VOC identified as C16 Hexadecane molecule conferring induced resistance against both the types of pathogens. The above work indicates that there is a huge scope and potential for discovery of new chemical triggers and their identifying their biological responses.

[C] Metal Bioavailability, Metal Stress Resistance & Phytoremediation

The activities of various PGPR strains regarding their response under metal stress have been profoundly reported in scientific literature. The response of an organism with PGP activity towards presence of metal(s) may vary depending upon type of metal and organism. For example, *Pseudomonas putida* CZI, a heavy metal tolerant bacterial strain isolated from rhizosphere of *Elsholtzia splendens* in a hydroponics trial showed about 211.6% increased concentration of Cu in the shoot when inoculated with CZI compared to non-inoculated one suggesting a prominent phytoremediation potential coupled with PGP activity (Xu C). Another study reported that White Lupin (*Lupinus albus* L.) plant's development of Hg-resistance depended upon whether colonizing PGPR organism *Bradyrhizobium canariense* was metal resistant (L-7AH) or sensitive (L-3). It was observed that plant grown in a range of 0-200 µM $HgCl_2$ concentration showed stress such as loss of chlorophyll & carotenoids and lesser photosynthetic efficiency above 20 µM $HgCl_2$ and metal sensitive strain *B canariense* L-3 could not rescue plants where as plants grown with metal resistant strain *B canariense* L-7AH did not show apparent metal stress even at very high concentration. Abou-Shanab et. al., (2005) reports that PGPRs isolated from rhizosphere of *Diplachne fusca* from industrial metal contaminated soil have shown multiple metal resistance towards Cr, Pb, Cu, Zn, Co, Cd & Ni. The PGP activity correlated with siderophore production, phosphate solubilizing and acid producing activity. Similarly, Zn toxicity in Maize is characterized by inhibited biomass production, decreased chlorophyll, total soluble protein and strongly increased accumulation of Zn in both root and shoot, increased levels of H2O2, electrolyte leakage and lipid peroxidation. The Maize grown with PGPR *Proteus mirabilis* (ZK1) had shown reduced oxidative stress caused under Zn toxicity (Islam F, 2014). These results indicate that PGPRs can be effectively used in a variety of situation for benefit of plants ranging from herbs and aromatic to cereals or used for phyto-remediation of soil.

Conclusion:

In the present scenario, the need of the hour is to have sustainable agro-industries practices that would put minimal stress on ecosystems and environment simultaneously achieving remediation of contaminated soil. Plant growth promoting Rhizobacteria (PGPR) have highly promising role in achieving this goal. However, great efforts are still needed to clearly understand bioactivity of PGPR organisms and to utilize their plant growth promoting activity to full potential.

References:

1. **Kloepper, J.W., Schroth, M.N., 1981.** Relationship of in vitro antibiosis of plant growth promoting rhizobacteria to plant growth and the displacement of root microflora. Phytopathology 71, 1020–1024.

2. **Ahemad, M., Khan, M.S., 2012a.** Effect of fungicides on plant growth promoting activities of phosphate solubilizing Pseudomonas putida isolated from mustard (Brassica compestris) rhizosphere. Chemosphere 86, 945–950.

3. **Ahemad, M., Malik, A., 2011.** Bioaccumulation of heavy metals by zinc resistant bacteria isolated from agricultural soils irrigated with wastewater. Bacteriol. J. 2, 12–21.

4. **Hayat, R., Ali, S., Amara, U., Khalid, R., Ahmed, I., 2010.** Soil beneficial bacteria and their role in plant growth promotion: a review. Ann Microbiol. 60, 579–598.

5. **Rajkumar, M., Ae, N., Prasad, M.N.V., Freitas, H., 2010.** Potential of siderophore-producing bacteria for improving heavy metal phytoextraction. Trends Biotechnol. 28, 142–149.

6. **Braud, A., Je´ze´quel, K., Bazot, S., Lebeau, T., 2009.** Enhanced phytoextraction of an agricultural Cr-, Hg- and Pb-contaminated soil by bioaugmentation with siderophoreproducing bacteria. Chemosphere 74, 280–286.

7. **Bhattacharyya, P.N., Jha, D.K., 2012.** Plant growth-promoting rhizobacteria (PGPR): emergence in agriculture. World J. Microbiol. Biotechnol. 28, 1327–1350.

8. **Zaidi, A., Khan, M.S., Ahemad, M., Oves, M., 2009.** Plant growth promotion by phosphate solubilizing bacteria. Acta Microbiol. Immunol. Hung. 56, 263–284.

9. **Cappellari D.R., Santoro M.V., Reinoso H., Travaglia C., Giordano W., Banchio E. (2015).** Anatomical, morphological and phytochemical effects of inoculation with plant growth promoting Rhizobacteria on peppermint (Mentha piperita). J. Chem. Ecol. 41(2): 149-58.

10. **Wang X., Mavrodi, D.V., Ke L., Mavrodi O.V., Yang, M., Thomashow L.S., Zheaq N., Wello D.M., Zhang J.(2014).** Biocontrol and plant growth promoting activity of rhizobacteria from Chinese fields with contaminated soil. Microb. Biotechnol. 2014

11. **Choudhary D.K., Prakash A., Johri B.N. (2007).** Induced systemic Resistance (ISR) in plants: Mechanism of action. Indian J. Microbiol. 47(4):289-97.

12. **Park H.B., Lee B., Kloepper J.W., Ryu C.M. (2013).** Exposure of Arabidopsis to hexadecane, a long chain volatile organic compound confers induced resistance against both Pectobacterium carotovorum and Pseudomona syringae. Plant Signal Behavior 8(7):e24619

13. **Xu C., Chen X., Duan D., Peng C., Le T., Shi J. (2014).** Effect of heavy metal resistant bacterium on enhanced metal uptake and translocation of the Cu-tolerant plant Elsholtzia splendens. Environ Sci Poll Res Int. 2014.

14. **Abou-Shanab R, Ghozlan H, Ghanem K, Moawad H (2005).** Behavior of bacterial population isolated from rhizosphere of Diplachne fusca dominant in industrial sites. World J. Microbiol Biotechnol. 21(6,7):1095-1101

15. **Islam F., Yasmeen T., Riaz M., Arif M.S., Ali S., Raza S.H.(2014).** Proteus mirabilis alleviates zinc toxicity by preventing oxidative stress in maize (Zea Mays) plants. Ecoltoxicol Environ Saf. 110:143-152.