PSM Biological Research ISSN: 2517-9586 – An International Peer-reviewed Journal

Mini-Review 2019 | Volume 4 | Issue 1 | 1-5

Plant Growth Promoting Rhizobacteria and Plants' Improvement: A Mini-Review

Saira Siyar[1*], Naila Inayat[2], Fida Hussain[1]

[1]Department of Botany, Qurtuba University of Science and Technology, Peshawar Campus, Peshawar, Pakistan.
[2]Department of Botany, University of Peshawar, Peshawar, Pakistan.

Article Info

Open Access
Citation: Siyar, S., Inayat, N., Hussain, F., 2019. Plant Growth Promoting Rhizobacteria and Plants' Improvement: A Mini-Review. PSM Biol. Res., 4(1): 1-5.

Received: September 3, 2018

Accepted: October 14, 2018

Online first: October 15, 2018

Published: October 20, 2018

***Corresponding author:**
Saira Siyar;
Email: ssiyarbotany@gmail.com

Abstract
The soil is a rich compendium of diverse organisms which have multifaceted roles in the ecological dynamics. The diversity and functional activity of the soil-borne organisms depend on the soil structure and the types of nutrients available there. From the perspectives of plants growth and development, these organisms may be beneficial, harmful or neutral. Among the organisms, plant growth promoting rhizobacteria (PGPR) constitute a significant and ecologically important portion which directly or indirectly corresponds to the growth improvement of plants. PGPR are of diverse types. Some of these bacteria are found in symbiotic association with hosts while others remain free living. They are efficiently involved in nitrogen fixation, phosphate, and iron solubilization, mitigation of heavy metals and other pollutants, antagonism with phytopathogens, and the production of growth promoting molecules. The net consequences of PGPR activities are growth stimulation of plants. Here we review the importance of PGPR and their role in growth improvement of cultivated crops.

Keywords: Endophytes, symbiosis, antagonism, heavy metal stress, induced systemic resistance.

INTRODUCTION

Plants growth and development is affected by several factors. These factors range from poor soils, metal and pollutants contaminations to different prevailing diseases, drought, and climatic adversities. Poor quality of soil which originate from successive cultivation, salinity, irrigation, and contamination would hinder root development, uptake of water and nutrients which are essential for plants' growth and physicochemical process (Chibuike and Obiora, 2014; Parihar *et al.,* 2015; Zandalinas *et al.,* 2018). Phytopathogens wither soil borne or from other sources results in direct or indirect consequences upon plant survival. Different viruses, bacteria, fungi, and pests challenge plants at germination and later stages of growth in a variable manner (Majeed *et al*., 2018a). Similarly, changes in climatic conditions (very high or low temperature, water availability, UV radiation etc.) offer additional challenges to germination, growth and survival of both wild and cultivated plants, albeit the intensity and outcomes of these challenges vary in different regions (Rosenzweig *et al.,* 2014; Asseng *et al.,* 2015; Li *et al*., 2015). Although plants have evolved different mechanisms to overcome the adverse challenges, in many instances their adapted mechanisms do not work to full extent (Simontacchi *et al*., 2015). In managed agriculture, the imposed challenges to crops are alleviated by the employment of proper agricultural practices while in nature soil is blessed with diverse microorganisms which play eminent roles in minimizing the biotic and abiotic stresses faced by plants and cultivated crops.

Rhizobacteria are microorganisms found in the rhizosphere which are categorized into diverse groups on the basis of their activities. Some rhizobacteria are pathogenic to plants and other organisms while some owe strong beneficial potentials to other organisms. Some rhizhobacteria are antagonistic in their mode of action (Iqbal and Ashraf, 2017; Islam, 2018.). Plant growth promoting rhizobacteria (PGPR) are essentially beneficial microbes present in the soil. The term 'plant growth promoting rhizobacteria' is used for such microorganisms because they either directly contribute to plants' growth activities or involved in improving the growth and development of plants in an indirect way (Lugtenberg and Kamilova, 2009). Many species of PGPR have been identified which facilitate growth and overall performance of plants. PGPRs can be free-living (species of *Agrobacterium, Pseudomonas, Burkholderia, Bacillus*, etc.*)* or they may be found in symbiotic association with their hosts (species of Frankia, Rhizobium etc.) (Podile and Kishore, 2007; Bhattacharyya and Jha, 2012; Majeed *et al*., 2018b). Both free-living and endophytic species of PGPR have been recognized to enhance plants' growth by a number of mechanisms. They may produce organic compounds which are of different types and may be involved in direct growth promotion of plants (Gutiérrez-Luna *et al*., 2010; Pérez-Montaño *et al*., 2014). Some PGPR is known to solubilize phosphate and iron and make them available to plants (de Souza *et al*., 2015; Walia *et al*., 2017; Iqbal and Ahemad, 2017; Alori *et al*., 2017). Indirectly, PGPR can stimulate the growth potentials of host plants by disturbing a wide array of plant pathogens and disease severity (Liu *et al*., 2017; Xiang *et al*., 2017). Since agricultural crops are equally challenged with different stresses like their wild counterparts, understanding and elucidation of the effects of PGPR on their growth and development can contribute to agricultural sustainability. This review spotlights the important roles of PGPRs in agriculture.

Types and underlying mechanisms of PGPR

PGPRs are of diverse types and origin. The microbes are abundantly found in the rhizosphere as free-living where they do not form any symbiotic association with other organisms. Well known examples of free-living PGPRs include species of *Arthrobacter, Azospirillum, Flavobacterium, Erwinia, Micrococcous, Pseudomonas, Serratia, Agrobacterium, Azotobacter, Bacillus, Burkholderia, Caulobacter* and many others while those of symbiotic PGPRs are *Allorhizobium, Azorhizobium, Bradyrhizobium, Mesorhizobium, Rhizobium, Frankia* etc. (Compant *et al*., 2010; Bhattacharyya and Jha, 2012). The distribution of free-living and symbiotic PGPR in the rhizosphere is ecologically controlled which depend on several factors such as the availability of nutrients in the soil, water status of the rhizosphere and types of vegetation. One of the leading drivers in modulation rhizobacterial dynamics are the root exudates which are produced by plants (Yuan *et al*., 2015). According to Zhang *et al*. (2014) citric acids released by cucumber roots were effective in root colonization of the host plants with PGPRs. Huang *et al*. (2014) have also pointed out the role of secondary metabolites released from the host roots in the successful interaction between PGPR and plants. Ahemad and Kibret (2014) stated that root zone contains amino acids, organic acids, sugars, vitamins, enzymes and different inorganic salts which can drive PGPR to root surfaces or to a specific zone in the rhizosphere. Rasmann and Turlings (2016) proposed that organic compounds produced by roots serve as 'attracting' signals for the accommodation of PGPR in the root zone. Schulz-Bohm *et al*. (2018) suggested that diverse volatile organic compounds produced by the roots of plants play a significant role in attracting PGPR and towards the formation of the symbiotic association.

An illustration of the mode of action of PGPR to promote the growth of plants is depicted in Fig. 1. Plant growth stimulation by PGPR occurs mainly by two mechanisms –direct and indirect. Direct growth promotion is facilitated by PGPRs when they produce several types of organic molecules which range from amino acids, carbohydrates, and enzymes to inorganic substances (Ahemad and Kibret, 2014). Production of hormones and growth regulatory substances such as auxins, abscisic acid, cytokinins, and gibberellic acid by certain species of PGPR can directly enhance the growth of plants (Timmusk *et al*., 2017). Several species of free living, as well as those associated with plants particularly with legumes, can fix nitrogen and thus help plants to overcome their nitrogen requirement (Majeed *et al*., 2017; Pham *et al*., 2017). Chauhan *et al*. (2017) provided evidence that strains of *Aneurinibacillus aneurinilyticus* were capable of efficiently converting nitrogen to simple forms and phosphate to soluble forms. Species of *Aerobacter, Flavobacterium, Erwinia, Bacillus*, and *Pseudomonas* have been also reported to carry out phosphate solubilization and growth enhancement of different plants (Hayat *et al*., 2010).

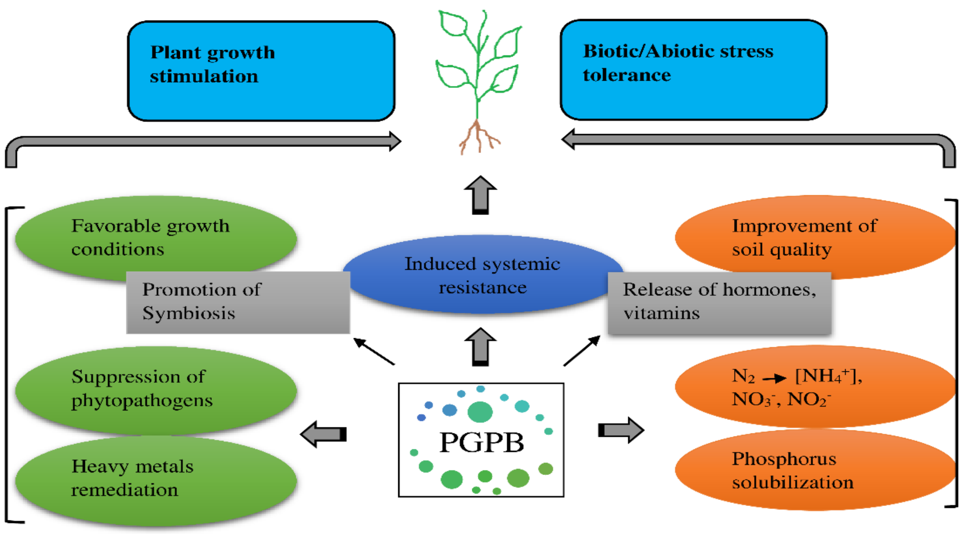

Fig. 1. An illustration of the mode of action of plant growth promoting bacteria in plants' growth improvement (modified from Majeed *et al*., 2018).

Indirect mechanisms involved in plant growth enhancement are the active role played by PGPR in reducing the salinity stress (Kohler *et al*., 2010; Shrivastava and Kumar, 2015; Arshadullah *et al*., 2017; Kumar *et al*., 2018), heavy metals remediation (Sobariu *et al*., 2017; Ashraf *et al*., 2017; Saif *et al*., 2017), drought resistance (Barnawal *et al*., 2017; Jatan *et al*., 2018), and disease resistance and reduction of disease intensity (Rizvi *et al*., 2017; Verma *et al*., 2018; Liu *et al*., 2018). Majeed *et al*. (2018b) stated that there are many bacterial strains of PGPRs which induces systemic resistance to plants against different pathogens, directly suppresses pathogenic agents by competition, antagonism and producing anti-pathogenic compounds.

CONCLUSION

Plant growth promoting rhizobacteria (PGPR) are microbes of significant importance which abundantly present in the rhizosphere. Their distribution is controlled by ecological forces and the root exudates secreted by different plants. PGPR enhance plants' growth in several mechanisms. They directly augment plants by fixing nitrogen, solubilizing phosphate and iron, producing plant growth hormones, enzymes, and other necessary compounds. These compounds are efficiently taken by plants and utilize them for several metabolic activities. PGPR is also involved in the root proliferation and development of plants. Soil fertility is increased as a result of PGPR mediated activities which consequently impart beneficial effects on germination and growth of plants. In soil where salinity, heavy metals, and other pollutants remain agricultural hurdles, PGPR is ideally the solution agents because they mitigate the drastic effects of these conditions. Many PGPR has also the ability to provide protection to plants against different plants disease by inducing systemic resistance and competing with pathogens for resources. Thus, PGPR is valuable microbes and have a prospective role in agriculture to improve the growth of cultivated crops.

CONFLICT OF INTEREST

All the authors have declared that no conflict of interest exists.

REFERENCES

Ahemad, M., Kibret, M., 2014. Mechanisms and applications of plant growth promoting rhizobacteria: current perspective. JKSU Sci., 26(1): 1-20.

Alori, E.T., Glick, B.R., Babalola, O.O., 2017. Microbial phosphorus solubilization and its potential for use in sustainable agriculture. Front. Microbiol., 8: 971.

Arshadullah, M., Hyder, S.I., Mahmood, I.A., Sultan, T., Naveed, S., 2017. Mitigation of salt stress in wheat plant (*Triticum aestivum*) by plant growth promoting rhizobacteria for ACC deaminase. Int. J. Adv. Res. Biol. Sci., 4(6): 41-46.

Ashraf, M. A., Hussain, I., Rasheed, R., Iqbal, M., Riaz, M., Arif, M. S., 2017. Advances in microbe-assisted reclamation of heavy metal contaminated soils over the last decade: a review. J. Environ. Manag., 198: 132-143.

Asseng, S., Ewert, F., Martre, P., Rötter, R. P., Lobell, D. B., Cammarano, D., Reynolds, M. P., 2015. Rising temperatures reduce global wheat production. Nat. Clim. Change, 5(2): 143.

Barnawal, D., Bharti, N., Pandey, S. S., Pandey, A., Chanotiya, C. S., Kalra, A., 2017. Plant growth-promoting rhizobacteria enhance wheat salt and drought stress tolerance by altering endogenous phytohormone levels and TaCTR1/TaDREB2 expression. Physiol. Plant., 161(4): 502-514.

Bhattacharyya, P. N., Jha, D. K., 2012. Plant growth-promoting rhizobacteria (PGPR): emergence in agriculture. World J. Microbiol. Biotechnol., 28(4): 1327-1350.

Chauhan, A., Guleria, S., Balgir, P. P., Walia, A., Mahajan, R., Mehta, P., Shirkot, C. K., 2017. Tricalcium phosphate solubilization and nitrogen fixation by newly isolated *Aneurinibacillus aneurinilyticus* CKMV1 from rhizosphere of *Valeriana jatamansi* and its growth promotional effect. Brazilian J. Microbiol., 48(2): 294-304.

Chibuike, G. U., Obiora, S. C., 2014. Heavy metal polluted soils: effect on plants and bioremediation methods. Appl. Environ. Soil Sci., 2014.

Compant, S., Clément, C., Sessitsch, A., 2010. Plant growth-promoting bacteria in the rhizo-and endosphere of plants: their role, colonization, mechanisms involved and prospects for utilization. Soil Biol. Biochem., 42(5): 669-678.

de Souza, R., Meyer, J., Schoenfeld, R., da Costa, P. B., Passaglia, L. M., 2015. Characterization of plant growth-promoting bacteria associated with rice cropped in iron-stressed soils. Ann. Microbiol., 65(2): 951-964.

Gutiérrez-Luna, F. M., López-Bucio, J., Altamirano-Hernández, J., Valencia-Cantero, E., de la Cruz, H. R., Macías-Rodríguez, L., 2010. Plant growth-promoting rhizobacteria modulate root-system architecture in Arabidopsis thaliana through volatile organic compound emission. Symb., 51(1): 75-83.

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(4): 579-598.

Huang, X. F., Chaparro, J. M., Reardon, K. F., Zhang, R., Shen, Q., Vivanco, J. M., 2014. Rhizosphere interactions: root exudates, microbes, and microbial communities. Bot., 92(4): 267-275.

Iqbal, J., Ahemad, M., 2017. Phosphate-Solubilizing Bacteria as Plant Growth Promoters and Accelerators of Phytoremediation. In: Phytoremediation of Environmental Pollutants (pp. 241-258). CRC Press.

Iqbal, M.N., Ashraf, A., 2017. Antagonism in Rhizobacteria: Application for Biocontrol of Soil-borne Plant Pathogens. PSM Microbiol., 2(3): 78-79.

Islam, S., 2018. Microorganisms in the Rhizosphere and their Utilization in Agriculture: A Mini Review. PSM Microbiol. 3(3): 105-110.

Jatan, R., Chauhan, P. S., Lata, C., 2018. *Pseudomonas putida* modulates the expression of miRNAs and their target genes in response to drought and salt stresses in chickpea (*Cicer arietinum* L.). Genomics.

Kohler, J., Caravaca, F., Roldán, A., 2010. An AM fungus and a PGPR intensify the adverse effects of salinity on the stability of rhizosphere soil aggregates of *Lactuca sativa*. Soil Biol. Biochem., 42(3): 429-434.

Kumar, A., Singh, V. K., Tripathi, V., Singh, P. P., Singh, A. K., 2018. Plant Growth-Promoting Rhizobacteria (PGPR): Perspective in Agriculture Under Biotic and Abiotic Stress. In Crop Improvement Through Microbial Biotechnology (pp. 333-342).

Li, T., Hasegawa, T., Yin, X., Zhu, Y., Boote, K., Adam, M., Gaydon, D., 2015. Uncertainties in predicting rice yield by current crop models under a wide range of climatic conditions. Glob. Change Biol., 21(3): 1328-1341.

Liu, K., Newman, M., McInroy, J. A., Hu, C. H., Kloepper, J. W., 2017. Selection and assessment of plant growth-promoting rhizobacteria for biological control of multiple plant diseases. Phytopathol., 107(8): 928-936.

Lugtenberg, B., Kamilova, F. (2009). Plant-growth-promoting rhizobacteria. Annual review of microbiology, 63, 541-556.

Majeed, A., Muhammad, Z., Ahmad, H., 2018a. Evaluation of foliar and stem susceptibility of three cultivated Solanaceous crops to *Phytophthora infestans*. J. Plant Pathol., 100(2): 301-303.

Majeed, A., Muhammad, Z., Ahmad, H., 2018b. Plant growth promoting bacteria: role in soil improvement, abiotic and biotic stress management of crops. Plant Cell Reports. Doi:10.1007/s00299-018-2341-2

Majeed, A., Muhammad, Z., Islam, S., Ullah, Z., Ullah, R., 2017. Cyanobacterial Application as Bio-fertilizers in Rice Fields: Role in Growth Promotion and Crop Productivity. PSM Microbiol., 2(2): 47-50.

Parihar, P., Singh, S., Singh, R., Singh, V. P., Prasad, S. M., 2015. Effect of salinity stress on plants and its tolerance strategies: a review. Environ. Sci. Pollut. Res., 22(6): 4056-4075.

Pérez-Montaño, F., Alías-Villegas, C., Bellogín, R. A., Del Cerro, P., Espuny, M. R., Jiménez-Guerrero, I., Cubo, T., 2014. Plant growth promotion in cereal and leguminous agricultural important plants: from microorganism capacities to crop production. Microbiol. Res., 169(5-6): 325-336.

Pham, V. T., Rediers, H., Ghequire, M. G., Nguyen, H. H., De Mot, R., Vanderleyden, J., Spaepen, S., 2017. The plant growth-promoting effect of the nitrogen-fixing endophyte *Pseudomonas stutzeri* A15. Arch. Microbiol., 199(3): 513-517.

Podile, A. R., Kishore, G. K., 2007. Plant growth-promoting rhizobacteria. In Plant-associated bacteria (pp. 195-230). Springer, Dordrecht.

Rasmann, S., Turlings, T. C., 2016. Root signals that mediate mutualistic interactions in the rhizosphere. Curr. Opin. Plant Biol., 32: 62-68.

Rizvi, A., Zaidi, A., Khan, M. S., Saif, S., Ahmed, B., Shahid, M., 2017. Growth improvement and management of vegetable diseases by plant growth-promoting rhizobacteria. In Microbial Strategies for Vegetable Production (pp. 99-123). Springer, Cham.

Rosenzweig, C., Elliott, J., Deryng, D., Ruane, A. C., Müller, C., Arneth, A., Neumann, K., 2014. Assessing agricultural risks of climate change in the 21st century in a global gridded crop model intercomparison. Proceedings of the National Academy of Sciences, 111(9), 3268-3273.

Saif, S., Khan, M. S., 2017. Assessment of Heavy Metals Toxicity on Plant Growth Promoting Rhizobacteria and Seedling Characteristics of Pseudomonas putida SFB3 Inoculated Greengram. Acta Sci. Agric., 1: 47-56.

Schulz-Bohm, K., Gerards, S., Hundscheid, M., Melenhorst, J., Boer, W., Garbeva, P., 2018. Calling from distance: Attraction of soil bacteria by plant root volatiles. The ISME J., 12(5): 1252.

Shrivastava, P., Kumar, R., 2015. Soil salinity: a serious environmental issue and plant growth promoting bacteria as one of the tools for its alleviation. Saudi J. Biol. Sci., 22(2): 123-131.

Simontacchi, M., Galatro, A., Ramos-Artuso, F., Santa-María, G. E., 2015. Plant survival in a changing environment: the role of nitric oxide in plant responses to abiotic stress. Front. Plant Sci., 6: 977.

Sobariu, D. L., Fertu, D. I. T., Diaconu, M., Pavel, L. V., Hlihor, R. M., Drăgoi, E. N., Gavrilescu, M., 2017. Rhizobacteria and plant symbiosis in heavy metal uptake and its implications for soil bioremediation. New Biotechnol., 39: 125-134.

Timmusk, S., Behers, L., Muthoni, J., Muraya, A., Aronsson, A. C., 2017. Perspectives and challenges of microbial application for crop improvement. Front. Plant Sci., 8: 49.

Verma, R. K., Sachan, M., Vishwakarma, K., Upadhyay, N., Mishra, R. K., Tripathi, D. K., Sharma, S., 2018. Role of PGPR in Sustainable Agriculture: Molecular Approach Toward Disease Suppression and Growth Promotion. In: Role of Rhizospheric Microbes in Soil (pp. 259-290). Springer, Singapore.

Walia, A., Guleria, S., Chauhan, A., Mehta, P., 2017. Endophytic Bacteria: Role in Phosphate Solubilization. In Endophytes: Crop Productivity and Protection (pp. 61-93). Springer, Cham.

Xiang, N., Lawrence, K. S., Kloepper, J. W., Donald, P. A., McInroy, J. A., 2017. Biological control of *Heterodera glycines* by spore-forming plant growth-promoting rhizobacteria (PGPR) on soybean. PloS One, 12(7): e0181201.

Yuan, J., Zhang, N., Huang, Q., Raza, W., Li, R., Vivanco, J. M., Shen, Q., 2015. Organic acids from root exudates of banana help root colonization of PGPR strain *Bacillus amyloliquefaciens* NJN-6. Sci. Rep., 5: 13438.

Zandalinas, S. I., Mittler, R., Balfagón, D., Arbona, V., Gómez-Cadenas, A., 2018. Plant adaptations to the combination of drought and high temperatures. Physiol. Plant., 162(1): 2-12.

Zhang, N., Wang, D., Liu, Y., Li, S., Shen, Q., Zhang, R., 2014. Effects of different plant root exudates and their organic acid components on chemotaxis, biofilm formation and colonization by beneficial rhizosphere-associated bacterial strains. Plant Soil, 374(1-2): 689-700.