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

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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 rhizobacteria 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, Micrococcus, Pseudomonas, Seratia, Agrobacterium, Azotobacter, Bacillus, Burkholderia, Caulobacter and many others while those of symbiotic PGPRs are Alchorhobium, 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).

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


