Plant growth promoting rhizobacteria (PGPR): Biofertliser and Biocontrol agent–Review article

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Abstract

Good health starts with good food. Humans expect agriculture to supply good food with sufficient nutrients, economically and culturally valued foods, fibers and other products. But the excessive application of synthetic pesticides has exerted an adverse effect on bio-flora, fauna and natural enemies. Even a largest part of yield has been lost due to various stresses, like biotic and abiotic stresses to the plant.On this account, plant growth promoting rhizobacteria (PGPR), an eco-friendly biopesticides is boon for the biocontrol of different plant pathogens. Moreover, PGPR strains can enhance the plant growth through the production of various plant growth promoting substances. These are generally a group of microorganism that is found either in the plane of the rhizosphere or above roots impacting some positive benefits to plants. PGPR are associated with plant roots and augment plant productivity and immunity; however, recent work by several groups shows that PGPR also elicit so-called 'induced systemic tolerance' to salt and drought. PGPR might also increase nutrient uptake from soils, thus reducing the need for fertilizers and preventing the accumulation of nitrates and phosphates in agricultural soils. Scientific researches involve multidisciplinary approaches to understand adaptation of PGPR, effects on plant physiology and growth, induced systemic resistance, biocontrol of plant pathogens, bio fertilization, and potential green alternative for plant productivity, viability of co inoculating, plant microorganism interactions, and mechanisms of root colonization.

Keywords: **Biopesticides, Biofertiliser, siderophore, antibiotic, plant growth promoting rhizobacteria (PGPR)**

Introduction

Agriculture has been the largest financial source since the dawn of civilization. Chemical pesticides increased the agricultural and economic potential in the terms of enhanced food and fibres production. On the other hand, application of chemical pesticdes resulted in serious environmental risk and health impact to human (Aktar et al., 2009). Some of the chemical pesticides have started to stop their usage due to its hazardous nature to the non-targeted organisms, public health issues and environmental safety . Hence, the search for alternative nonchemical, ecofriendly strategy is highly desirable for pest control. Out of different ecofriendly approaches, plant growth promoting rhizobacterial (PGPR) strains may acts as an efficient biocontrol as well as plant growth promoting agent for plant growth and yield increment. The PGPR can substantially reduce the chemical inputs in agriculture. Furthermore, the use of indigenous PGPR can be an added advantage since it can easily acclimatize to the natural conditions and enhanced the plant–microbe interactions.

Bacteria able to colonize plant root systems and promote plant growth are referred to as PGPR. PGPR can affect plant growth either indirectly or directly; indirect promotion of plant growth occurs when PGPR lessen or prevent the deleterious effects of one or more phytopathogenic organisms; while direct promotion of plant growth by PGPR involves either providing plants with a compound synthesized by the bacterium or facilitating the uptake of certain nutrients from the environment (Glick, 1995).

PGPR as biofertilisers

PGPR inoculant currently commercialized as novel solution for plant growth enhancements through direct, indirect mechanism and combination of mode of action.

The direct mechanisms of plant growth promotion may involve the synthesis of substances by the bacterium or facilitation of the uptake of nutrients from the environment (Glick *et al*., 1999). The direct growth promoting mechanisms are as follows (1) Biological nitrogen fixation (2) Increasing the availability of nutrients in the rhizosphere (solubilization of phosphorus, facilitated absorption of iron by production of siderophores) and (3) inducing of phytohormonesproduction such as auxins, cytokinins, gibberellins (Kloepper *et al.*, 1989; Glick, 1995; Glick *et al.*, 1999; Patten and Glick, 2002). The indirect mechanism of plant growth occurs when PGPR lessen or prevent the deleterious effects of plant pathogens on plants by production of inhibitory substances or by increasing the natural resistance of the host. The indirect mechanisms of plant growth promotion by PGPR include (1) antibiotic production (2) depletion of iron from the rhizosphere (3) synthesis of antifungal metabolites (4) production of fungal cell wall lysing enzymes (5) competition for sites on roots and (6) induced systemic resistance (Weller and Cook, 1986; Kloepper *et al.*, 1988; Liu *et al.*, 1995; Glick *et al.*, 1999).

PGPR as antagonists
Biopesticides are safe touse as compared to synthetic pesticides and have targeted activity against specific pathogens. It can also be easily decomposed than conventional pesticides .PGpr can be used as biopesticidesbeacause of its antagonistic activity. According to Beattie (2006), bacteria that reduce the incidence or severity of plant diseases are often referred to as biocontrol agents whereas those that exhibit antagonistic activity toward a pathogen are defined as antagonists. The following rhizospheric environment and bacterial antagonistic activities can be highlighted: (1) synthesis of hydro-lytic enzymes, such as chitinases, glucanases, proteases, and lipases, that can lyse pathogenic fungal cells (Neeraja et al. 2010; Maksimov et al. 2011), competition for nutrients and suitable colonization of niches at the root surface (Kamilova et al. 2005; Validov S, 2007, PhD thesis, Leiden University, The Netherlands), (3) regulation of plant ethylene levels through the ACC-deaminase enzyme, which can act to modulate the level of ethylene in a plant in response to stress imposed by the infection (Glick and Bashan, 1997; Van Loon, 2007), and (4) production of siderophores and antibiotics.

Siderophores
Siderophores are low molecular weight compounds that are produced under iron-limiting conditions, chelate the ferric ion (Fe 3+) with a high specific activity, and serve as vehicles for the transport of Fe (III) into a microbial cell. In rhizosphere, the availability of iron for microbial assimilation is extremely limiting (Loper and Buyer, 1991). To survive in such environment, organisms secrete iron- binding ligands called siderophores which can bind the ferric ion and make it available to the host organisms.

These siderophores can be of different types: hydroxamates, phenol-catecholates, and carboxylates (Podile and Kishore, 2006). The synthesis of siderophores in bacteria is induced by the low level of Fe3+ and in acid soil, where solubility and availability grow, their protective effect comes down. Microbial siderophores in the rhizosphere are frequently associated with biocontrol activities and not with plant nutrition .

The ability of rhizobacteria to produce siderophores and metabolites contributing to antibiosis has been the focus of many studies dedicated to investigating PGPR (Maksi-mov *et al.*, 2011).

Antibiotics
Antibiotics are organic compounds of low molecular weight that are involved in the inhibition of growth and metabolic activities of various microbes. The production of one or more antibiotics is the mechanism most commonly associated with the ability of plant growth-promoting bacteria to act as antagonistic agents against phytopathogens (Glick *et al.*, 2007). The production of antibiotics is assumed as most effective treatment and has antagonistic activity to suppress the phytopathogens. . Thus, antibiotics play an important role in disease management i.e. can be used as biocontrolagents .

According to Haas and Défago (2005), six classes of antibiotic compounds (for which their modes of action are partly understood) are better related to the biocontrol of root diseases: phenazines, phloroglucinols, pyoluteorin, pyrrol-nitrin, cyclic lipopeptides (all of which are diffusible) and hydrogen cyanide (HCN; which is volatile). More recently, lipopeptidebiosurfactants produced by *Pseudomonas* and *Bacillus* species have been implied in biocontrol due to their potential positive effect on competitive interactions with organisms including bacteria, fungi, oomycetes, protozoa, nematodes and plants (de Bruijn *et al.*, 2007; Raaijmakers *et al.*, 2010).

Numerous types of antibiotics have been isolated from fungal and bacterial strains and this diversity includes mechanisms of action that inhibit synthesis of pathogen cell walls, influence membrane structures of cells and inhibit the formation of initiation complexes on the small subunit of the ribosome (Maksimov *et al.*, 2011). Pyrrolnitrin, the antibiotic produced by the *P. fluorescens* BL915 strain, is able to prevent the damage of *Rhizoctoniasolani*during damping-off of cotton plants (Hill *et al.*, 1994). The 2,4-dia-cetylphloroglucinol (DAPG) produced by pseudomonads, an effective and extensively studied antibiotic, causes membrane damage to *Pythium* spp. and is particularly inhibitory to zoospores of this oomycete (de Souza *et al.*, 2003). Phenazine, also produced by pseudomonads, possesses redox activity and can suppress pathogens of plants such as *F. oxysporum* and *Gaeuman-no-mycesgrami-nis* (Chin-A-Woeng *et al.*, 2003). The *P. chlororaphis* PCL1391 strain, isolated from roots of tomato plants, synthesizes phena-zine-1-carboxamide, which is able to release soluble iron from insoluble ferric oxides at neutral pH, raising the possibility that phenazines might contribute to iron mobilization in soils (Hernandez *et al.*, 2004; Haas and Défago, 2005).

Antibiotics, such as polymyxin, circulin and colistin, produced by the majority of *Bacillus* ssp. are active against Gram-positive and Gram-negative bacteria, as well as many pathogenic fungi (Maksimov *et al.*, 2011).

Bacteriocins

Bacteriocins are proteinaceous or peptidic toxins produced by bacteria to inhibit the growth of similar or closely related bacterial strains. Bacteriocins have narrow killing spectrum as compared to conventional antibiotics and these have damaging effect on the bacteria that are closely relative of bacteriocin producing bacteria. Almost all bacteria may make at least one bacteriocin, and many bacteriocins isolated from Gram-negative bacteria appear to have been created by recombination between existing bacteriocins (Riley, 1993). Colicins are most prominent bacteriocins synthesized by Escherichia coli. Similarly, megacins is produced by B. megaterium; marcescins from Serratiamarcescens; cloacins from Enterobacter cloacae; and pyocins comes from P. pyogenes. Bacteriocins that are produced by Bacillus spp. remarkably gain importance due broad range of inhibition of fungal, yeast, gram positive and gram negative species that may have some pathogenic effect on animals and human beings .

Conclusion

Chemical pesticides suppress phytopathogens for improved plant growth and health; nevertheless damage non-targeted bene6icial microorganisms of soil and pollute soil environment. Biopesticides are environment friendly and target only phytopathogens. So, the adoption of PGPR based biopesticides to combat phytopathogens and promote plant growth may substantially contribute to sustainable agriculture and safe environment. The ability of bacterial siderophores and antibiotics to suppress phytopathogens could be of significant agronomic importance. Both mechanisms have essential functions in microbial antagonism but also are able to elicit induced resistance. These PGPR will require a systematic strategy designed to fully utilize all these beneficial factors, applying combinations of different mechanisms of action allowing crop yields to be maintained or even increased while chemical treatments are reduced.

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