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Review on plant growth promoting rhizobacteria and its effect on plant growth

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Abstract

Both biotic and abiotic stresses are major constrains to agricultural production. Under stress conditions, plant growth is affected by a number of factors such as hormonal and nutritional imbalance, ion toxicity, physiological disorders and susceptibility to disease. Plant growth under stress conditions may be enhanced by the application of microbial inoculation including PGPR. These microbes can promote plant growth by regulating nutritional and hormonal balance, producing plant growth regulators and solubilizing nutrients. In addition to their interactions with plants, these microbes also show synergistic interactions with other microbes in the soil environment. These interactions may be vital for sustainable agriculture because they mainly depend on biological process rather than on agrochemicals to maintain plant growth and development as well as proper health under stress conditions. Biological interactions of PGPR with soil microbes are believed to cause a cumulative effect on all rhizosphere components which regulating the plant growth.

Keywords: promoting, rhizobacteria, plant growth

Introduction

The term PGPR was proposed by Kloepper *et al*. (1980) [15] who defined it as a group of bacteria capable to actively colonize the plant root system and improve their growth and yield (Wu *et al*., 2005) [22]. A wide range of species belonging to the genus pseudomonas, azospirillum, azotobacter, klebsiella, enterobacter, alcaligenes, arthrobacter, burkholderia, bacillus and serratia were reported to have PGPR properties (Saharan and Nehra, 2011) [19]. PGPR represent about 2 to 5% of total rhizospheric bacteria (Antoun and Kloepper, 2001) [1]. The rhizosphere is a soil volume that is under the influence of plant root. The microbial population present in this environment is relatively different from that of its surroundings due to the presence of root exudates that serve as source of nutrition for microbial growth. Very important and significant interactions were reported among plant, soil and microorganisms present in the soil environment (Antoun and Prevost, 2005) [2]. The interactions may be beneficial as well as harmful and can significantly influence plant growth and development (Lau and Lennon, 2012) [16].

The microorganisms colonizing plant roots generally include bacteria, algae, fungi, protozoa and actinomycetes. Enhancement of plant growth and development by application of these microbial population is well evident and have a pronounced effect on plant growth both under non stress and stress conditions by a number of direct and indirect mechanisms (Glick *et al*., 2007) [9]. Exploring the mechanism of growth promotion by PGPR could be very useful for enhancing plant growth particularly under stressful environment. Although a number of applications have shown that combined application of PGPR and fungi could be a meaningful approach for sustainable agriculture but still there are certain aspects which need further investigations for obtaining maximum benefit in terms of improved plant growth from this naturally occurring soil microbial population particularly under stress conditions.

Hence in the following sections, efforts have been made to appraise the role and underlying major mechanisms of PGPR and its effect on plant growth.

Effect of PGPR on growth and development

Rhizosphere is influenced by the physical, chemical and biological processes of root, which is an ideal place for the proliferation of these microbes (Sorenson, 1997) [20]. These microorganisms generally exist more or less near the roots due to the presence of root exudates, which are used as a source of nutrients for microbial growth (Doornbos *et al*., 2012) [7]. Many of these microorganisms depend on plant root exudates for their survival. The microorganisms termed as PGPR residing in the soil environment can cause dramatic changes in plant growth by the production of growth regulators and improving plant nutrition by supplying and facilitating nutrient uptake from soil (Zahir *et al*., 2004) [24].

The two major ways through which PGPR can facilitate plant growth and development include indirect and direct mechanisms (Glick, 1995) [12]. Indirect growth promotion occurs when PGPR prevent or reduce some of the harmful effects of plant pathogens by one or more several different mechanisms (Glick and Bashan, 1997) [10]. These include inhibition of pathogens by the production of substances or by increasing the resistance of the host plant against pathogenic organisms. PGPR produce metabolites which reduce pathogen population and produce siderophores that reduce the iron availability for certain pathogens thereby causing reduced plant growth. Similarly PGPR can also increase plant resistance against disease by changing host plant vulnerability, through the mechanism called induced systematic resistance and therefore provide protection against pathogen attack.

Direct growth promotion takes place in different ways like providing beneficial compounds to the host plant synthesised by the bacterium and facilitating the uptake of nutrients from the soil environment. They also facilitate the growth of their host plant by fixing atmospheric nitrogen and synthesising and secreting siderophores which may solubilise and sequester iron there by increasing its uptake, producing and solubilizing minerals such as phosphorous so as to increase its availability (Glick, 1995) [12].

Plant growth under stress conditions

Soil is a complex and dynamic system that supports plant growth. In the soil environment, plant growth and development is influenced by a variety of stresses that are major constraints for sustainable agricultural production. These stresses are biotic (pathogens, pests viruses, bacteria, fungi, insets, nematodes etc.) and abiotic (salinity, drought, flooding, heavy metals, temperature and nutritional. Abiotic sources are considered to be the main source of yield reduction; however, the intensity of these stresses varies with a number of soil and plant factors. Some of the general impacts of these stresses on plant growth include hormonal and nutritional imbalance and physiological disorders such as epinasty, abscission and senescence and susceptibility to disease (Nadeem *et al.,* 2010) [17]. Some stresses cause a particular direct or indirect negative impact on plant growth and development e.g. under salinity, drought, water logging stress etc. elevated levels of ethylene are produced that are inhibitory to root growth therefore affect a number of plant processes. In addition under salinity stress ion toxicity occurs particularly due to excessive amounts of Na^+ and cl^- that causes injurious effects on plant growth and development. Similarly drought stress apart from increasing ethylene concentration also inhibits photosynthesis, causes changes in chlorophyll content and damages the photosynthetic apparatus (Iturbe-Ormaetxe *et al*., 1998) [13].

Mechanism of alleviation of stress induced adverse effects

In a non-stress natural environment, most of the mechanisms used by PGPR for growth enhancements are common. While under stress conditions some strains may not be able to perform efficiently due to their inability to survive and compete in the harsh environment. However certain PGPR strains not only tolerate stress conditions, but also have the ability to promote plant growth under such stressful environment. This enhanced growth by PGPR takes place by a multitude of mechanisms such as lowering of stress induced ethylene level, production of exopolysacchrides, induced systemic resistance etc. (Upadhyay *et al*., 2011) [21]. Lowering of ethylene level is one of the major mechanisms elicited by PGPR for promoting plant growth under stress conditions. The levels of ethylene are usually elevated under stress conditions due to enhanced production of 1-amino-cyclopropane-1 -carboxylic acid (ACC) an immediate precursor of ethylene bio synthetic pathway (Zapata *et al*., 2004) [25]. ACC is believed to cause an adverse effect on plant growth particularly on root elongation that ultimately affects overall plant process including both nutritional and physiological functions. Phytohormones such as indole acetic acid, gibberellins, ethylene, abscisic acid and cytokinins are produced by plants, which are important for their growth and development (Egamberdieva, 2013) [8]. Indole-3-acetic acid (IAA) is the best-characterized auxin produced by many plant associated bacteria, including PGPR (Spaepen *et al*., 2007a) [18]. PGPRs stimulate plant cell growth and division to become tolerant against environmental stresses mediated through biosynthesis of phytohormones (Glick and Pasternak, 2003) [11]. Various plant species inoculated with IAA producing bacteria increased root growth and/or enhanced formation of lateral roots and roots hairs (Dimkpa *et al*., 2009)[9] thus increasing water and nutrient uptake thus helping plants to cope with water deficit. Bacterial treatment in wheat (Arzanesh *et al*., 2011) [3] induced decrease in leaf water potential and increase in leaf water content, which was attributed to the production of plant hormones such as IAA by the bacteria that enhanced root growth and formation of lateral roots their by increasing uptake of water and nutrients under drought stress resulting in better grain yield and higher mineral quality as compared to untreated plants. Cellular dehydration induced biosynthesis of ABA, a stress hormone during water deficit condition (Kaushal and Wani, 2015) [14]. In addition to IAA, production of ABA by Azospirillum lipoferum alleviated drought stress in maize plants (Cohen *et al*., 2009) [5]. ABA is involved in water loss regulation by controlling stomatal closure and stress signal transduction pathways (Yamaguchi-Shinozaki and Shinozaki, 1994) [23]. Arabidopsis plants inoculated with A. brasilense had elevated levels of ABA compared to non-inoculated plants. PGPR *Phyllobacterium brassicacearum* isolated from the rhizosphere of Brassica napus enhanced osmotic stress tolerance in inoculated Arabidopsis plants by elevating ABA content, leading to decreased leaf transpiration conferring drought stress resistance (Bresson *et al*., 2013) [4].

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