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Review

Role of plant growth promoting rhizobacteria in sustainable production of vegetables: Current perspective

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A B S T R A C T

In order to optimize the crop production and hence, to achieve food security, synthetic fertilizers have largely been used in high input agronomic practices to offset major and sometimes minor nutrient deficiencies of soils with concomitant intensification in food production. When used repeatedly in horticultural practices, such environmentally un-friendly fertilizers have deleteriously impacted soil fertility and consequently, the crop productivity. Taking these threats into account, scientists are desperate to find inexpensive, environmentally benign and easy to operate options to overcome fertilizer toxicity problems. In this regard, plant growth promoting rhizobacteria (PGPR) have magnetize the agrarian communities due in part to their low cost, easy access and simple mode of application. Broadly, PGPR when used either alone or in consortia, have resulted in tremendous positive impact on horticultural production. Among horticultural crops, the interest in quality of vegetables in recent times among consumers has increased worldwide. The results of studies conducted so far worldwide on the impact of PGPR carrying numerous multi-functional plant growth promoting activities on horticultural crops especially vegetables grown distinctively in different production systems is discussed and considered. The review will conclude by identifying several PGPR for future researches aiming to improve the health and quality of vegetables grown in different production systems. Also, the findings presented here are likely to reduce the use of chemical fertilizers in horticultural practices and to protect human health (via food chain) from the ill effect of fertilizers used in different agronomic environment.

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1. Plant growth promoting rhizobacteria (PGPR)—definition, origin, introduction

Plant growth-promoting rhizobacteria (PGPR) were first defined by Kloepper and Schroth (1978) to describe soil bacteria that colonize the roots of plants following inoculation onto seed and that enhance plant growth. The PGPR is one of the most important and agronomically useful soil microbiota that involves free living growth promoting rhizobacteria (Lutenberg and Kamilova, 2009; Bhattacharya and Jha, 2012) and widely studied symbiotic nodule bacteria, for example, rhizobia (Peix et al., 2015). The microbiological preparation including those of PGPR often called as biofertilizers “a substance which contains living microorganisms which, when applied to seed, plant surfaces, or soil, colonizes the rhizosphere or the interior of the plant and promotes growth by increasing the supply or availability of primary nutrients to the host plant (Vessey, 2003)” when applied to seeds and/or soils, have been found to affect the growth of horticultural crops (Esitken, 2011) including vegetables, for example, potato (Singh, 2013), tomato (Bernabeu et al., 2015), brinjal (Seymen et al., 2013), cucumber (Gül et al., 2013), radish (Yildirim et al., 2008b), chilli (Silva et al., 2013) and lettuce (Chamangasht et al., 2012) and broccoli (Yildirim et al., 2011). The effects of PGPR on crops growing in different agronomic regions may range from neutral (Ahemad and Khan, 2011) to positive (Wani and Khan, 2010) to deleterious (Akello et al., 2007). The externally applied (allochthonus) or soil inhabiting (autochthonous) PGPR firstly colonize very quickly onto the surface of seeds and roots in response to chemically variable photosynthates released by different plant genotypes in and around root/soil surfaces (Frankenberger and Arshad, 1995). Following successful colonization and ramification, they facilitate the growth by supplying major (NPK:BNF:PSM:K biofertilizers) and minor nutrients to plants (Khan et al., 2013). Additionally, various plants require different phytohormones, for example, IAA (Wani et al., 2007), gibberellins (Cassan et al., 2009) and cytokinin (Cassan et al., 2014) for root morphogenesis and shoot development. The IAA affects the root development, tissue differentiation, and responses to light and gravity. Roots with larger surface area absorb more water and nutrients from the soils and translocate them to various organs of the plants resulting in profound growth and high yielding biomass and grain production. Gibberellins on the other hand, influence seed germination, stem elongation and development, flowering, and fruit setting of plants. Also, the stress induced by ethylene on plants is circumvented by 1-aminocyclopropane -1-carboxylate (ACC) deaminase synthesized by PGPR which reduce the ethylene level (Glick et al., 2007; Nascimento et al., 2014). Some other potential metabolites secreted by PGPR also affect the development of plants (Ghyselinck et al., 2013). For example, siderophores released by PGPR sequester iron and make it inaccessible for uptake by phytopathogens (Ahmad et al., 2013). And hence, such PGPR indirectly promotes plant growth. Other benefits that may be provided by PGPR to plants include improvements in seed germination rate, shoot development, grain yield, leaf area, chlorophyll content, hydraulic activity, and protein content (Adesemoye and Kloepper, 2009). Apart from free living PGPR, the microorganisms belonging to nitrogen fixing group for example *Rhizobium*, *Mesorhizobium* and *Bradyrhizobium* etc. have also been used to optimize vegetables productions (Antoun et al., 1998; Flores-Félix et al., 2013).

2. PGPR inoculant development and production

The injudicious use and heavy dependence on synthetic fertilizers for future agricultural needs are likely to result in further loss in soil fertility, variable impact on composition and functions of soil microbiota. Also, excessive use of fertilizers have shown negative impact on crop productivity, soil and water contamination, crop susceptibility to diseases and ultimately loss in economy (Savci, 2012; Cristina et al., 2013). To address such serious problems, the advent of biofertilzer including both carrier based and liquid biofertilizers (Pindi and Satyanarayana, 2012) have provided solutions and have shown promising results (Bhardwaj et al., 2014). With regard to biofertilizer, India is one of the important countries in biofertilizer production and consumption (Pindi and Satyanarayana, 2012). The average consumption in the country is about 45,000 ton per annum while its production is less than the half of consumption. The maximum production capacity lies in Agro Industries Corporation followed by State Agriculture Departments, National Biofertilizers Development Centres, State Agricultural universities and private sectors.

The technology used to produce biofertilizer is however, relatively new and evolving. Despite optimum scope, there are certain problems in the production of biofertilizers. These constraints include- (i) crisis of efficient PGPR strains: it has been found that the strains selected for inoculants production should be region specific and competitive enough to established in host soils and be able to colonize plant roots very effectively. However, identifying suitable PGPR strains for inoculant production is pretty difficult due to their varying abilities (ii) non-availability and shorter shelf life of suitable carriers (Ngampimol and Kunathigan, 2008) (iii) variable tolerance among PGPR toward the unpredictable and uncertain crop fields temperature, chances of contamination and poor stability of the biofertilizer and (iv) possible genotypic changes: during biofertlizer production there are chances that specifically selected organisms may interact with undesired organisms and hence, may lead to changes in the basic character of organisms. Also, there are possibility that during fermentation the selected PGPR strains may undergo mutations leading to altered efficacy and viability. This in turn may result in economical loss and increased cost of production. Other factors that hamper the production and distribution of biofertilizers include the lack of sufficient and well equipped storage facility and insufficient transport system, poor and inconsistent demand of biofertilizers, and limited marketing opportunities.

Despite expressing numerous important characteristics, the PGPR formulations have not been popular among farmers (Jangid et al., 2012). And hence, biofertilizers have not been adopted at larger scale. There are several reasons why biofertilizers are not so popular among farmers. Chief among them is the lack of awareness among the end users (farmers). Communication gap between farmers and manufacturer and miscommunication about the quality and sustainability of biofertilizers are the other major hurdles in popularizing the use of biofertilizers. To substantiate these, Srinivas and Bhalekar (2013) conducted a survey to ascertain the constraints faced by farmers in adoption of biofertilizers. This survey revealed that about 85% respondent had no confidence toward biofertilizers practices while half of the 85% respondents reported that lack of knowledge about biofertilizers was reason for unacceptability of this technology. Therefore, in order to make full use of biofertilizers and to compete with synthetic fertilizers, there is need to consistently generate awareness among farmers by organizing various