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Potential Role of Plant Growth Promoting Rhizobacteria (PGPR) to Reduce Chemical Fertilizer in Horticultural Crops

Muhammad Ahsan Altaf[1*], Rabia Shahid[1], Abdul Qadir[2], Safina Naz[3], Ming-Xun Ren[1], Shaghef Ejaz[3], Muhammad Mohsin Altaf[1], Awais Shakoor[4]

[1]*Institute of Tropical Agriculture and Forestry, Hainan University, Haikou, Hainan, China*
[2]*Agricultural Training Institute, Karor, Layyah, Punjab, Pakistan*
[3]*Department of Horticulture, Bahauddin Zakariya University Multan, Punjab, Pakistan*
[4]*School of Resources and Environment, Anhui Agricultural University, Hefei, China*

***Corresponding Author:** Muhammad Ahsan Altaf, Institute of Tropical Agriculture and Forestry, Hainan University, Haikou, Hainan, China, Email:ahsanaltaf8812@gmail.com*

ABSTRACT

The world's food production has been increased from the previous century with the advent of synthetic chemical fertilizers. Chemical fertilizers facilitate enough to produce enormous quantity of food to meet the need of world's population. However, there has been an increase in the excessive use of fertilizers which is consequently causing pollution, thus harming the environment. Excessive uses of chemical fertilizers not only harm the soil properties but also increase the cost of crop production. Therefore, to alleviate the negative impact of useful chemical fertilizers and improve their efficiency even by limiting its use, the crops have been inoculated with bio-fertilizers such as plant growth promoting rhizobacteria (PGPR). This review highlights the role of plant growth promoting rhizobacteria in current agriculture practices based on relevant literature. The review paper focuses on various researches carried out to support the fact that PGPR abates the excessive use of chemical fertilizers and act as an eco-friendly solution to environmental problems caused by excessive use of fertilizers.

Keywords: *chemical fertilizer, environmental contamination, growth promoting, microorganism, PGPR,*

INTRODUCTION

Fertilizers are important part of current agriculture because they supply necessary plant nutrients. The utilization of chemical fertilizer (e.g. calcium nitrate, urea, diammonium phosphate, ammonium phosphate etc) has a good significance for the world food production because it works as a quick food for plants causing them to develop more quickly and efficiently.

While increasing negative effects are being noticed as a result of excessive and imbalanced usage of these chemical inputs. Furthermore, persistent utilization of conventional synthetic fertilizer(chemical fertilizer) disrupt atmosphere and soil ecology, decreases soil fertility status, subsequently pollutes ground water and shows injurious effects on human health (Meenakshi Suhag, 2016; Ayala and Rao, 2002).

The significance of sixteen requisite plant nutrients (for example, N, P, K, Ca, Mg and S are referred to as macronutrients, while Fe, Zn, Cu, Mo, Mn, B and Cl are referred to as micronutrients) in desired amount to attain the highest crop yield is well established. N, P and K are needed in improving the stress resistance of plant against pest, diseases, drought and cold (Tasi et al., 2007). Modern soil and agriculture management techniques are particularly influenced by continuous utilization of synthetic fertilizer (chemical fertilizer) that are industrially manipulated materials, largely water-soluble and comprised of excessively available nutrients concentrations.

However, excessive utilization of inorganic fertilizer (chemical fertilizer) not only enhances environmental pollution but also cost intensively. Sustainable agriculture provides the capacity to generally meet our agricultural needs because it encompasses advances in agriculture by utilizing special farming, technology and management methods at the same time frame to make sure that no harm carried out to the same. Synthetic fertilizer (chemical fertilizer) and their misuse cause air and ground pollutants with the aid of eutrophication of water bodies (Youssef and Eissa, 2014). Formerly, Bhattacharya and

Roy (2000) reported that synthetic fertilizer (chemical fertilizer) inhibited the development of rhizobia. The persistent growth of the human population and the requirement for a more substantial quantity of food has promoted the utilization of synthetic fertilizer (chemical fertilizer) to improve the production. Nitrogen fertilizers are probably the most broadly utilized; they supply the nitrates and ammonium essential for the plants. Unfortunately, the excessive utilization of such fertilizers outcomes in human health problems, toxicity in plants and it causes environmental contaminants (Adesemoye et al., 2009 and Lassaletta et al., 2014).

Nitrogen and phosphorous based fertilizers adulterates the soil, air and water, therefore latest method of cultivation discourages the excessive use of chemical fertilizers. Exaggerated use of chemical fertilizers has harmful effects on microorganism residing in soil, consequently deteriorates the soil fertility and additionally contaminates atmosphere (Youssef and Eisaa, 2014).The prolonged use of fertilizers abates pH of soil and exchangeable bases, hence limiting the crop production.

To anticipate this issue and achieve maximum crop yield, farmers need to limit the use of chemical fertilizer and enhance its performance with help of microorganisms. Chemical fertilizers are not only expensive but its manufacturing is hazardous since non renewable resources such as natural gas and oil are consumed for its production hence causes threat to humans and ecosystem (Joshi et al., 2006). This review highlights the role of PGPR (plant growth promoting rhizobacteria) in current agriculture practices based on relevant literature.

Plant Growth Promoting Rhizobacteria (Pgpr)

Microorganisms that get attached with plant roots for symbiosis are designated as PGPR. PGPR assembles the growth enhancing chemicals as result of efficiently uptake of micronutrients consequently promoting plant health (Kumari et al., 2018; Khosravi et al, 2018). PGPR are known for enhancing roots' growth pattern. Agro bacterium spp., Bacillus spp., Pseudomonas spp., and Azospirillum spp. are included in PGPR category (Martínez-Viveros et al., 2010). PGPR associated with the plant roots enhances growth and development, alleviates the attack of diseases and promote the accessibility and absorption of nutrients. The utilization of microorganism with the goal at enhancing nutrient availability for plants is a significant practice and is essential for agriculture (Backman and Sikora, 2008; Kloepper et al., 1981). Besides, a sole PGPR not only performs as biological control agent but it performs multiple mode of actions (Kloepper, 2003; Vessey, 2003). PGPR influences the plant growth either actively or passively. Formation of phytohormones or surge in the absorption of nutrients from soil environment is its active mechanism (Glick, 1995; Lugtenberg and Kamilova, 2009). Whereas, the abatement of the deterioration of plant health caused by phytopathogenic organisms is its passive mechanism (Glick, 1995; Sood et al., 2018) PGPR are being used worldwide in sustainable agriculture to enhance the efficiency of nutrients for better plant growth from previous decades.

PGPR may be categorized as extracellular and intracellular PGBR denoted as ePGPR and iPGPR, respectively (Viveros et al., 2010). The rhizophere, rhizoplane or the space pockets between the root cortex cells are the places where ePGPRs resides whereas iPGPRs resides generally in the peculiar nodule like structure of root cells. The genera of bacteria such as Serratia, Pseudomonas, Micrococcous, Flavo-bacterium, Erwinia, Chromobacterium, Caulobacter, Burkholderia, Bacillus, Azospirillum, Azotobacter, Arthrobacter and Agrobacterium belong to ePGPR (Ahemad and Kibret, 2014). Rhizobium, Mesorhizobium, Bradyrhizobium and Allorhizobium, Frankia and endophytes species belong to the Rhizobiaceae family of iPGPR which take nitrogen from atmosphere and symbiotically fix it for the higher plants (Bhattacharyya and Jha, 2012).

Somers et al. (2004) categorized PGPR as biofertilizers, rhizoremediators, biopesticides and phytostimulators on the basis of their activities. PGPR are also classified as biocontrol -PGPB and PGPB (Bashan and Holguin, 1998). PGPR may be defined as, bacteria, the part of soil and rhizosphere settled in the roots of plants in a challenging environment where they are not resided in a pasteurized and autoclaved condition (Kloepper, 2003).

Impact of PGPR on Growth and Yield of Horticultural Crops

Different strains of PGPR have shown encouraging signs of growth in crops. In several countries, plant yield have been enhanced by the inoculation of bacteria and these PGPRs are being sold at commercial level. For instance, in Pakistan, different companies are making bio fertilizers at commercial scale, normally utilizing strains of Bacillusspp., Pseudomonas spp., Azospirillum spp. and Burkholderiaspp. (Naureen et al., 2009; Tabassum ET al.2017; Neumann et al., 2018) Strains of PGPR have increased plant growth, yield and nutrition in potato (Mahendran et al., 1996; Faccini et al., 2007; Malboobi et al., 2009;Naderi et al., 2012; Dawwam et al., 2013), plant growth increased in tomato (Kim et al., 1998; Turan et al., 2004; Hariprasad and Niranjana, 2009; Ordookhani et al., 2010; Ramakrishnan and Selvakumar, 2012; Walpola and yoon, 2013; Ahirwar et al., 2015; Bernabeu et al., 2015) as well as crop yield in tomato and pepper (Cuppels et al.,1999), sugar beet (Cakmakci et al.,2001), apple (Aslantas et al., 2007), cucumber (Yildirim et al., 2015; Tikhonovich et al., 2010; Egamberdieva et al., 2010; Dursun et al.2010; Isfahnai and Besharati, 2012; Isfahani et al., 2013; Gul et al., 2013), Radish (yildirim, 2008a, 2008b; Mohamed and Gomaa, 2012; Lera et al., 2013), potato (Singh, 2013), pepper (Silva et al., 2014), lettuce and eggplant (Fu et al., 2010; Seyman et al., 2013; Patel et al., 2011). Mena and Olalde, (2007) elaborated that the inoculation of tomato seedlings with PGPR increased yield and fruit quality parameters.

Under water stress PGPR surges growth of pepper and tomato seedling by conferring resistance (Mayak et al., 2004). In greenhouse experiment, bacterial strains' co-inoculation surged the activity of nitrogenase, urease and phosphatase enzymes as well as growth and nutrient uptake surged in red pepper and tomato (Madhaiyan et al., 2010).

Floral and foliar inoculation with PGPR enhance plant growth and yield in apricot (Esitken et al., 2003, 2002), sweet cherry (Esitken et al., 2006), mulberry (Sudhakar et al., 2000), raspberry (Orhan et al., 2006), blueberry (De Silva et al., 2000), apple (Pirlak et al., 2007), sour cherry (Arikan and Pirlak, 2016).

In a field experiment, individual and combine application of PGPR stains (Azotobacter brasilense and A. chroococcum) and arbuscular mycorrhizal fungi (Glomus fasciculatum and G. mosseae) indicated that dual PGPR inoculation and arbuscular mycorrhizal fungi led to maximum plant biomass yield and improve the nutrient uptake of N, P, K, Ca, and Mg. in pomegranate (Punica granatum L.) seedling (Aseri et al., 2008).

Barassi et al (2006) revealed that seed inoculated with Azospirillum and irrigated with saline medium showed notable surge in vegetative growth, better germination and fresh and dry biomass weight of lettuce under saline condition. Han and Lee (2005a) studied inoculation of PGPR promote plant growth, increase availability of nutrient and uptake, and improve plant health in egg plant. Esitken et al. (2010) studied that root inoculation with PGPR strains shows significantly increase growth, yield and nutrition content of strawberry plant under organic growing condition. Strawberry inoculated with PGR, fungi and AVM depicted similar results (Kokalis-Burelle, 2003; Malusa et al., 2006).

Farzana and Radziah (2005) revealed that inoculation with rhizo bacterial isolates significantly increased plant growth and uptake of nutrient (N, P, K, Ca and Mg) in sweet potato cultivar. The germination attributes of lettuce and tomato seeds were significantly improved by PGPR strain's inoculation. The PGPR also play an important role to produce plant growth regulators (PGR), thus enhancing metabolic properties (Mangmang et al., 2014).

PGPR in horticultural crops have been found to enhance a notable increase in growth and production of strawberry (Seema et al., 2018), cabbage (Turan et al., 2014), tomato (Almaghrabi et al., 2013; Gravel et al., 2007), pea (Arshad et al., 2008; Zahir et al., 2008; Tariq et al., 2014), black pepper, potato and tomato (Thanh et al., 2009), apple (Karlidag et al., 2007), pepper and cucumber (Han et al., 2006), black pepper (Dibypaul and Sarma, 2006), lettuce (Han and Lee, 2005b; Chamangasht et al., 2012) and broccoli (Yildirim et al., 2011).

Currently, the uses of biological techniques with the combination of synthetic fertilizers are becoming famous for enhancing plant nutrient system and its management.

In this regards, the use of PGPR is being included in sustainable agricultural methods for promoting growth and yield of crops (Shoebitz et al., 2009; Sturz et al., 2000), despite the mechanism of PGPR induced enhancement of growth and yield of several crops is not even completely figured out (Dey et al., 2004).

Potential Outcomes of PGPR in Horticulture

A lot of work has been done on the role of strains of PGPR in plant-growth promotion, biological control, biofertilizers activities, and N2 fixation; but still rhizobacteria-plant interaction related diseases and adverse effects related with environmental stresses are needed to be explored (Kloepper et al., 1999; Vessey, 2003; Jetiyanon et al., 2003; Morrissey et al., 2004). Microbial inoculants enhance growth, nutrient accessibility and uptake, and ameliorates plant health thus supports the integrated approach for the solution of agro-environmental issues (Dobbelaere et al., 2001; Hodge et al., 2001; Bonfante, 2003; Kloepper et al., 2004; Weller, 2007; Adesemoye et al., 2008). Microbial inoculation mixtures have shown encouraging influence on plants (Berg, 2009). Plant relation with the PGPR has exhibited a notable surge in the germination of seeds, growth of roots, and yield of crops.

Leaf area, content of chlorophyll and protein, uptake of nutrients, hydraulic activity, sustainability to abiotic stress, shoot and root weights, biocontrol and delayed senescence (Mahaffee and Kloepper, 1997; Raaijmakers et al., 1997; Bashan et al., 2004; Mantelin and Touraine, 2004; Bakker et al., 2007; Yang et al., 2009). Seedlings of oil palm exhibited a notable surge in the uptake of nitrogen and phosphorous (Amir et al., 2005).

The blend of microbial inoculation revealed more efficiency than the inoculation of sole strain (Adesemoye et al., 2008). The studies of Adesemoye et al., (2009) proposes solution to agro-environmental issues by not eliminating the application of fertilizer but to minimize the use of fertilizers and enhance their efficiency with the use of PGPR thus diminishing the negative influence of excessive fertilizers and promote integrated nutrient management (INM). The roots of plants increase their efficiency against uptake of nutrients with the help of PGPR (Adesemoye et al., 2008).

Caesar and Burr (1987) revealed that apple root stock (M226 and M7), inoculated by dipping and seed priming before sowing in field under greenhouse condition, displayed increase in seedling growth up to 65% and rootstock up to 179% with PGPR strains treatment. Pirlak and Kose (2009) reported that combined (root + foliar) application of strains of PGPR significantly increased in yield of strawberry in field experiment.

Application of PGPR better than Chemical Fertilizer

The discouraging effects of over use of chemical fertilizers are being mitigated with the use of PGPR. Datta et al. (2015) studied that PGPR treatment of chilli seedling can be employed as a beneficial technique for improvement alkaloid contents and yield of plant. Batool and Altaf (2017) studied the effect of PGPR on chilli where six different levels of nitrogen and phosphorous fertilizer were applied at 50, 60, 70, 80 and 100% DAP and Urea recommended amount of fertilizer and potassium applied as recommended dose of fertilizer (RDF). The study confirmed that PGPR increased yield, plant growth and uptake of N, P and K at 75% fertilizer. Consequently, suggestions were made that PGPR inoculation abated the requirement of fertilizers by about 75%. PGPR strains showed remarkable rise in yields, shoot length, root length, shoot biomass, root biomass, uptake of nutrient siderophore production, auxin production and P-solubilization in capsicum under controlled condition (Gupta et al., 2015).

Similarly, Ahmed et al. (2017) studied microbial inoculation could chemical fertilizers and naturally inhabit the rhizosphere trigger the growth and development of tomato plants actively or passively through accessibility of many important nutrients, phytohormones, or via prevention of plant diseases. Ribaudo et al. (2006) reported that tomato seeds primed with PGPR strains showed significantly rise in root and shoot fresh weight, root surface and root hair length which ultimately led to plant growth development.

The different strains of PGPR were tested to evaluate the performance of pepper, tomato and cucumber. The results indicated that strains of PGPR remarkably enhanced seedlings fresh and dry weight in tomato, cucumber and pepper (Kidoglu et al., 2008). Similarly, in another greenhouse experiment during fall and spring, under hydroponic technique same commercial products and PGPR were tested in tomato. The results indicated increase in tomato yield (Kidoglu et al., 2009).

Cakmakci et al. (2007) studied that spinach seed primed with nine strains of PGPR and determined significant increase in growth, leaf area, shoot fresh weight and plant height of spinach (Spinacia oleracea L.) in a pot experiment under greenhouse. Moreover, enzyme activities (glutathione S-transferase, 6-phosphogluconate dehydrogenase, glutathione reductase, glucose-6-phosphate dehydrogenase) in spinach also increased significantly.

Moreover, inoculation of PGPR also improved plant nutrient availability. Gunes et al. (2009) confirmed a fungus and P-solubilizing bacterium to determine their special influence on strawberry plants planted in pots and under greenhouse conditions and suggested that fungus and phosphate-solubilizing bacterium were capable to increase nutrition of strawberry plant and hence may triggers growth and development under low levels of phosphorous.

In another pot experiment, roots were dipped in PGPR solution (bacterial suspension containing 109 CFU/ml) before transplanting which resulted in the increase in phosphorous uptake of the shoot was enhanced up to 67.8% with PGPR strain (Bacillus FS3) and yield of strawberry increased up to 90% as compared to un inoculated control.

Similarly, Attia et al. (2009) revealed that phosphate-solubilizing bacteria enhanced yield (number of bunch /finger, number of bunch /hands and length and bunch weight) and increased plant growth (circumference and stem length.

Area and number of green leaves) at 25% P2O5 (percentage of recommended amount of fertilizer).Consequently, the inoculation of phosphate- solubilizing bacteria (PSB) along with phosphate fertilizer enhanced the performance of fertilizer and also abated it requirement by 75%. Baset Mia et al. (2009) and Adesemoye et al. (2009) also reported the similar results.

Conclusion

Hence, there is a dire need of increasing the growers' interest to adopt the technology of PGPR along with the use of chemical fertilizers in order to enhance their efficiency, and mitigate the negative impact of chemical fertilizers by abating their excessive use, which not only rise the input cost of crop production but also harm the environment and human health.

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