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Plant Growth Promoting Rhizobacteria (PGPR) *Pseudomonas stutzeri* from forest soil: A Review

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Abstract. PGPR (Plant Growth Promoting Rhizobacteria) are soil microbes that enhance the development and productivity of plants. These microbes are associated with the rhizosphere region of soil. Pseudomonas is an important plant growth promoting rhizobacteria. Prevalence of Pseudomonas sp in agricultural soil and their numerous beneficial characteristics make them appropriate as plant growth promoting bacteria. P. stutzeri are highly adaptable to any condition due to their particular metabolic capacities like transforming atmospheric nitrogen into fixed nitrogen, nitrate reduction and degradation of aromatic compounds. Among the Plant Growth Promoting Bacteria (PGPB) the most extensively studied is Plant Growth Promoting Rhizobacteria (PGPR).

Keywords: P. stutzeri, Rhizosphere, Plant growth promoters, Rhizobacteria,

1. Introduction

Microbial diversity in soil plays a vital role in maintaining the soil fertility. Soil microbes play a crucial role in enhancing the plant development and soil quality [1]. Use of chemical fertilizers has a harmful effect on the ecosystem. The alternative method is using Plant Growth-Promoting Rhizobacteria (PGPR) [2].PGPR is soil microbes that enhance the development and productivity of plants. These microbes are associated with the rhizosphere region of soil that is enriched by the root secretions [3].The term PGPR was first explained by Schroth and Klopper. Bacteria belonging to the species of *Pseudomonas*, *Bacillus*,

Enterobacter, *Rhizobium*, *Alcaligens*, *Azospirillum*, *Klebsiella*, *Arthrobacter*, *Serratia* and *Flavobacterium* have been documented to promote plant growth [4]

PGPR directly promotes plant development through nitrogen fixation, enhanced production of plant hormones, lowering ethylene, increasing iron availability and phosphate solubilisation. In some cases it indirectly induces resistance against plant pathogen, competing for nutrient and space [5]. Addition and utilization of PGPR in agro system enhances the association of microbe and plants, so that it increases the agricultural productivity [6]

2. General consideration of Plant Growth Promoting Rhizobacteria (PGPR)

Soil microorganisms play a vital role in cycling of organic and inorganic inputs that have been used extensively for several years in crop productivity. Microorganisms are used to differentiate the soil functional qualities and microbial diversity can be considered as natural indicator of soil quality. In agricultural practices, use of rhizobacteria, microorganisms adhering to the surface of plant roots, is gaining momentum, as the conventional chemical fertilizers carry their disadvantages along, by being ecologically unfriendly, ultimately having negative effect on plants, soil and microbes. Presence of beneficial microorganisms is abundant in rhizosphere region. These rhizobacteria play a vital part to support the plant nutrient exchange[7]). The extraordinary activities of microorganisms are usually based on their astounding; differing metabolic qualities and genetic adaptability.

3. Mechanism of action

The mode of action of Plant Growth Promoting Bacteria is given by (a) producing plant hormones that stimulate and enhance the growth of plants (b) suppressing the growth of plants pathogens (c) acting as microbial inoculants.

Beneficial microorganisms that are present on the surface of the roots are termed as Plant growth promoting rhizobacteria. The PGPR has induced great interest among the scientific community because PGPR offers a viable alternative to harmful chemical fertilizers which greatly degrade soil fertility and adversely affect the environment. Plant growth promoting bacteria induces plant growth and increases crop productivity and many of the PGPR are commercially available [8].Several microorganisms have been reported to enhance the plant growth of tomato like *Pseudomonas, Azotobacter, Enterobacter, Bacillus, Arthrobacter, Azospirillum, Klebsiella, Serratia* and *Burkholderia* [9].Phosphorus plays a vital role in the

growth of seeds thereby enhancing the development of various plants. Phosphorus supports root development and strengthen the plants against pathogens. Uptake of phosphorus is limited to the plants due to its presence in soil as insoluble form. Plant Growth Promoting Bacteria enables the plants to utilize the insoluble form by converting them into soluble form. The insoluble phosphorus is made available to the plants by the phosphate solubilising bacteria and they can also fix nitrogen [10].Significant number of soil microorganisms like bacteria, Actinomycetes and Fungi are involved in the phosphate solubilisation process. Pseudomonas is the predominating bacteria in phosphate solubilisation [11].

3. Advantages of PGPR

Chemical fertilizers are used for decades with an intention to get higher yield in shorter time period. But chemical fertilizers pose a serious threat to the biota by disrupting environment nutrient cycles, destroying the biological communities present in the environment and they are also associated with adverse health outcomes. Further, soil fertility has reduced because of the continuous application and routine chemical fertilizers usage [12]. The association between plant and bacteria is one of the contributing factors to improve soil fertility and plant growth [13].This association can influence greatly the growth and development of plants. PGPR adhere to the surface of plant roots and the soil surrounding it. PGPR has attained more attention due to their bio-safety and has been extensively used as an alternative for chemical fertilizers. Plant growth promoting bacteria decreases the harmful effects of chemical fertilizers by sustaining sufficient plant nutrients[14]. PGPR receives extensive attraction because of their capability to increase the yield of crops even under adverse conditions

4. Occurrence, distribution and characterisation of *Pseudomonas stutzeri*

Genus *Pseudomonas* contains the most divergent group of microbes on this planet which are referred by their generic term Pseudomonads. Genus *Pseudomonas* falls under subclass gamma of proteobacteria. The universality of this proteobacteria can be assessed by their potential to habitat various environmental niches like fresh water, terrestrial and marine ecosystem. They also form a close relationship with higher forms of life and it is one of the most studied bacterial species [15].Another study by Deshwal and Kumar, 2013[16] on 140

Pseudomonads concluded that most of the strains showed positive results for IAA, siderophore, HCN and P-solubilization.

Pseudomonas stutzeri was first described in 1895 by Burri and Stutzer in 1895[17]. It is a group of non-fluorescent *Pseudomonas* member .Soil bacteria *P.stutzeri* is gram negative and motile by single polar flagella [18].They are non-fermenting, oxidase positive, aerobic and gram negative organism. They are generally found in soil and seldom causes hospital acquired diseases.

They show a wide range of phenotypic and genotypic heterogeneity and totally eighteen genomovars are observed within the species. *P.stutzeri* JM300 isolated from soil showed denitrifying characteristics which are also used as model for natural transformation [19].

Production of IAA, siderophore and HCN and phosphate solublization in *Pseudomonas stutzeri* were identified by many researchers [20-22].*Pseudomonas stutzeri* A1501, a nitrogen fixing bacteria was found to enhance the production of rice [23].

5. Significance of *Pseudomonas stutzeri*

Pseudomonas stutzeri encounter much attraction due to its precise metabolic assets. (a) They ensure a natural transformation trait, which makes them well suited for the studies involving gene transfer; (b) *P.stutzeri* was projected as a model bacterium for nitrate reduction research; (c) some of them have contributed to degradation of toxic substances like metals; (d) *P.stutzeri* is capable of fixing nitrogen [24]. *P.stutzeri* is used as model system to know the nomenclature and phylogenesis. They are most widely involved in agronomy process and a distinct species *Pseudomonas stutzeri* occurs in more than 70 research papers since 2006 signifying its importance in research involving microorganisms [25].

6. Consequences of bacterial –plant interaction

Plant Growth Promoting Bacteria enhances the growth of plants due to phyto hormones produced by them [26]. Number of root hairs and lateral roots tends to increase when inoculated with PGPR and it leads to improved uptake of minerals that are present in soil [27].

PGPR stimulates the growth of plants by producing certain substances that act either directly or indirectly. The outcomes of direct mechanism of Plant Growth Promoting Bacteria consist of production of phyto hormones such as indole acetic acid (IAA), nitrogen fixation and solubilisation of phosphorus (P) [28].

The outcomes of indirect mechanism of PGPR include antibiotic production, competition for the sites on the roots, depletion of iron from rhizosphere, synthesis of antifungal cell wall lysis substances, synthesis of antifungal metabolites and induced systemic resistance. Several PGPR stimulate the growth of plants by controlling the pathogenic microorganisms [29].

Plants can form a particular association with microorganism in which the soil microbes are benefited by utilizing the carbon sources from plants and decreases the toxic effect of compounds present in the soil that inhibits the plant growth. Sometimes plants and microbes can be associated commensally, in which the plant root exudates help the soil microorganisms in degrading the toxic substances that are present in the soil. Enhancement of plant growth can also be limited due to less availability of water and infertile soil [30].

Plants require phosphorus for their growth, but they are present as insoluble form in soil that is not readily available for the plants. Plant Growth Promoting Bacteria enables the plants to utilize the insoluble phosphorus by phosphate solubilisation process there by reducing the use of phosphate fertilizers [31]. Indole Acetic Acid (IAA) enhances seed germination, involved in cell division process, regulates vegetative growth, ensures plants survival under adverse conditions and modulates the synthesis of several metabolites .

Isolation of PGPR from the soil of crop field has shown to enhance the growth of tomato plants by increasing the yield of tomato [32].Current studies and research results have shown that inoculation of soils with PGPR considerably enhances the crop yield when compared with uninoculated soils [33]. Candido *et al.*, 2013 [34] inoculated tomato plants with *Pseudomonas* as PGPR that resulted in significant growth and yield of tomato when compared with control plants. The soil that was used for the study had a pH range of 7.7. Marquez-Santacruz *et al.,* 2010[35] reported isolation of an endophytic bacteria from the tomato plant roots called Gamma proteobacteria. Plant growth promoting bacteria enables the plant to use available nutrients and results in Induced Systemic Resistance (ISR). PGPR

reduces the use of chemical fertilizers that result in contamination of soil. They also enable plants to persist even in adverse conditions [36].

7. Isolation of Plant Growth Promoting Bacteria from forest soil

Several researchers have documented the isolation of Plant Growth Promoting Bacteria from forest soil. Isolation and screening of plant growth promoting bacteria for improving crop production from rhizosphere region of Siruvani forest has been reported [37].Microorganisms present in forest soil are essential in providing various nutrients that are required for the growth of forest trees [38]. *Pseudomonas* sp was isolated [39] from rhizosphere region of trees in Pachamalai sengutupatti reserved forest soil with a pH 7. There are also reports of isolation of plant growth promoting bacteria from Western Ghats forest soil with pH ranging at 7.2 that enhanced the growth of the cowpea plants when compared with the uninoculated plants. The isolates showed positive for IAA production and phosphate solubilisation test [40].

Actinomycetes with phosphate solubilizing characteristic has been documented [41] from forest soils of Mahabubnagar. Phosphate solubilizing fungi was studied and reported from tropical forest soil of Indonesia [42] and plant growth-promoting bacteria *Pantoea* have been documented from Western Ghats forest [43].

There are several reports on the presence of bacteria and fungi in forest ecosystem [44]. Among the 70 isolates that were explored for the plant growth promoting activities from the subtropical forest of Meghalaya, *Pseudomonas sp* showed phosphate solubilisation [45].Four different types of rhizobacteria that were isolated from Madhupur forest, Bangladesh exhibited positive results for plant growth characteristics that can be used for the crop production [46]. PGPR isolated from forest soil of Siruvani hills, Coimbatore showed various characteristics of plant growth promoting activities like IAA and phosphate solubilisation [47].Seed bacterization with *Micrococcus* sp isolated from Western Ghats forest have shown to enhance the plant growth by increasing the root and shoot length when compared with the uninoculated plants[48].

Microorganisms isolated from the Kodaikannal forest soil samples were screened for the plant growth promoting substances. From 32 isolates, seven showed positive for ammonia production, nine isolates were found to produce acetoin, five showed positive for phosphate solubilisation and seven isolates showed production of indole acetic acid [49]. Isolation of microorganisms from the soil of Himalayan forest region, having pH ranging from 6.25-6.60 have shown to enhance the growth of root and shoot length of lentil [50]. Similarly Barua *et al.,* 2012 [51] has isolated microorganisms from Sundarbans forest which have also exhibited PGPR characteristics and enhanced the growth of rice plants. Beneficial bacterial isolates from native forest soil of Brazil have also exhibited PGPR traits [52].Ten bacterial strains of Plant Growth Promoting attributes were isolated from *Populus euphratica* rhizosphere in China [53].

8. *Pseudomonas stutzeri* as plant growth promoting bacteria

Islam *et al.,* 2015 [54] isolated *Pseudomonas stutzeri* from the cucumber rhizosphere capable of producing siderophore that can be used as plant growth promoting bacteria. Bacterial genus *Pseudomonas* is found in abundance in soil and has several characteristics that enable them as Plant Growth Promoting Bacteria [55]. *Pseudomonas stutzeri* with various plant growth promoting attributes like IAA, HCN, phosphate solubilisation have been identified [56]. Bacterial isolate *P.stutzeri* with phosphate solubilizing character has been isolated from near rhizosphere of mangrove forest soil [57]. *Pseudomonas* sp is able to affect the various parameters of fruiting stage in tomato plants and increase its productivity [8]. Ahirwar *et al.,* 2015 [58] carried out pot culture experiment with tomato plants by using soil with pH 7.7. Bacterization of tomato seeds with *Pseudomonas* resulted in high yield when compared with the control plants. *Pseudomonas* sp. facilitates the plants to utilize the available phosphorus that is present in the soil as it is a vital macronutrient needed for the growth of plants. Production of HCN by *Pseudomonas* results in suppression of pathogens in tomato plants thereby improving the growth of plants [59]. Nosheen *et al.,* 2011[60] have reported that *Pseudomonas stutzeri* isolated from plant root was used as seed inoculants and it enhanced the growth of safflower.

Pseudomonas sp. isolated from rhizospheric soil of tomato plants was screened for three to four beneficial characteristics of Plant Growth Promoting characters like HCN, Ammonia,

phosphate solubilisation, IAA and showed positive results for all the tests. *Pseudomonas* spin pot culture experiments have shown to increase plant height and root growth of tomato plants [61. Weinmann *et al.,* 2010 [62] did pot culture experiments on tomato plants using *Pseudomonas* sp. that resulted in suppression of pathogens and healthy growth of plants when compared with the uninoculated plants. *P.stutzeri* was able to produce IAA and solubilize phosphate. This strain has the capability to act as PGPR and enhance the plant growth [63]. Bacterial isolate *P.stutzeri* isolated from soil with pH ranging from 7-7.5 when used as inoculant on tomato plants grown in pot showed an increase in plant height and was able to grow under adverse condition including saline soil [64].

From the literature it was found that *Pseudomonas sp* enhanced the growth of tomato plants by early fruit formation and increased dry mass of plants [65]. In another study *Pseudomona*s isolate produce indole acetic acid, phosphate solubilisation, siderophore production and capable of producing various substances that inhibit the growth of plant pathogens [66]. Research was carried out on 2 different types of soils having pH 6 and 7.8. The maize plants were able to grow healthier in soil with pH 7.8 as the *Pseudomonas* that was used as inoculant has enhanced its growth when compared with the controls [67]. In another study two strains of *Pseudomonas stutzeri* isolated from the *P. euphratica* forest, China was able to increase the growth of wheat in pot experiments under adverse conditions [53]. Garcia-Valdes *et al.,* 2010 [68] isolated *Pseudomonas stutzeri* from the rhizospheric soils with pH 7.9 of tomato plants. *P.stutzeri* capable of producing siderophore was isolated from the garden soil that resulted in increased root length of *Vigna radiata* [69].There are also reports of isolation of *Pseudomonas stutzeri* from soil samples that displayed some of the plant growth characteristics like siderophore production, indole acetic acid, phosphate solubilisation and HCN production [70].

Conclusion

PGPR are vital microorganisms that are essential for suppression of plant pathogens and are widely involved in the development of root and uptake of water that are required by the plants for their growth. Most of the rhizobacterial isolates belong to *Pseudomonas* sp

[71]. Application of Plant Growth Promoting Bacteria is essential for the agro ecology [72]. Rhizobacteria provides the essential nutrients that are required for the development of plants [73]. *Pseudomonas stutzeri* is capable of producing antifungal activity substances that suppress the growth of plant pathogens [74].

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