Journal of Advances and Scholarly Researches in Allied Education
Vol. 16, Issue No. 6, May-2019, ISSN 2230-7540

Plant Growth-Promoting Bacteria and Their Importance in Vegetable Production

Richa Pandey[1]* Santwana Rani[2]

[1] PhD Scholar, Department of Biotechnology, College of Commerce, Arts, Science, Magadh University, Patna

[2] Assistant Professor, Department of Botony & Biotechnology, College of Commerce, Arts, Science, Magadh University, Patna

Abstract – A large number of soil bacteria may colonize and promote plant growth and health on the surface/inside of the root system. This community of bacteria, commonly known as PGPR, increases the growth of plants, including crops, in traditional and stressed soils. Moreover, several PGPRs indirectly promote crop processing by inhibiting various phytopathogens. Conclusively, PGPR has an effect on plant growth by nitrogen fixation, phosphate solubilization, mineral absorption, development of siderophora, antibiotics and hydrolytic enzymes. The PGPRs that are known for helping to develop a wide variety of plants including potatoes, carrots, onions, etc. belong to the Azotobacter, Azospirillum, Pseudomonas and Bacillus genera. Plants play an important part in supplying vital minerals, vitamins and fibers, which in staple starchy foods are not available in significant amounts. Therefore, the use of PGPR in vegetable cultivation is advised to maximize vegetable output without chemical inputs. Here the importance of PGPR in vegetable production in both common and abandoned soils is underlined.

---------------------------------x--------------------------------

INTRODUCTION

The demand for big grains, such as wheat, is projected to increase by 70% by 2050 (1), primarily as a result of rising crop intensity. In recent decades, farming activities aimed at optimizing yields, mostly by increased fertilization, without regard to the socio-economic and ecological repercussions. Food processing utilizing sustainable technology that mitigate environmental effects, including habitat depletion and high greenhouse gas emissions, will also be of interest (2, 3). Sustainable intensification was described as "maximizing primary output per region without sacrificing the system's ability to maintain its production capability." The question of the sustainability of primary production is acute for wheat, a major cereal crop in many areas of the world used for human consumption, supplies 50 per cent of human dietary energy with maize and rice (4, 5). Hard weed (Triticum turgidum L. subsp durum), an agricultural plant well suited to the Mediterranean basin, is also a staple food used mostly in pasta processing for a part of the world population (6).

Growing and use of vegetables is a potential never properly explored in developed countries including Ethiopia to reduce hunger and improve food insecurity (4). Food and nutrition safety is progressively recognized as important for vegetables

The energy sources, body-building proteins, vitamins and minerals are plentiful and cheap[5]. Horticultural crops, including berries, vegetables and root crops in Ethiopia contribute one quarter to crop output, which represents a significant economic operation spanning from smallholder to major commercial farms (3, 6).

Plant Growth-Promoting Bacteria (PGPB)

Soil is understood for some time that a great many bacteria exist in the soil (offen about 108 to 109 cells per gram of soil) and the amount of cultured bacterial cells in the soil is usually only approximately 1% of the total cell numbers current (7, 8). Time, humidity and prevalence of salt and other pollutants, as well as amount and varieties of plants present in these soils are influenced by both the number and the nature of bacteria found in various soils (9). Moreover, bacteria are not usually spread uniformly in the soil. In other words, the concentration of bacteria present near the plant roots (i.e. in the rhizosphere) is usually far higher than the rest of the soil. This is due to the availability of carbohydrates, including sugars, amino acids, organic acids and other small molecules, which can account for up to one third of the carbon fixed by a plant in plants (10-13).

Regardless of the amount of bacteria in a certain soil sample, in one of three forms, bacteria may influence plants. The relationship between soil bacteria and plants is beneficial, negative or neutral (from the plant's perspective) (14). However, when

www.ignited.in

circumstances evolve, the impact a single bacterium has on a plant will change. For instance, when plants are given a large amount of chemical fertilizer in the soil, a bacterium that promotes plant growth by supplying either fixed nitrogen or phosphorus, compounds openly present in very small quantities in many soils, is unlikely to support plants. In addition, various plants may be affected differently by a certain bacterium. An IAA overproducing Pseudomonas fluorescens BSP53a bacterium muzle, for example, induced root growth in blackcurrant cuttings and impeded the development of roots in cherry belt (15). It is an observation that shows a suboptimal amount of IAA that was increased by the inclusion of the bacterium in the blackcurrant cuttings. The IAA amount was on the other side optimum until the inclusion of a bacterium with the cherry cuttings and the additional IAA from the bacterium became inhibitory. Despite these precautions, it is generally easy to determine whether a bacterium encourages or prevents plant development.

Bacteria that can encourage plant development, that is PGPB, are free-living, bacterial endophytes that can colonize any or any part of a plants' internal tissue, and bacteria that can stimulate plant growth, i.e., PGPB (formerly called blue-green algae). Despite the distinctions between these bacteria, they do use the same pathways. The PGPB may generally encourage plant growth by either encouraging the acquisition of resources or the modulation of plant hormone levels, or indirectly through reducing the inhibitory impact on growth and the development, by the use of biocontrol bacteria, of different pathogens. Rhizobia spp., historically has been widely researched, with physiological, biochemical and biological views, until a great deal of interest has been seen in attempting to recognize or use other PGPBs to stimulate plant development. These early experiments have been a methodological starting point for mechanical PGPB studies. However, as most PGPBs repair no or just a small amount of nitrogen unlike Rhizobia, experiments in order to better understand some of the mechanisms used by PGPB have covered various mechanisms (16).

Place of PGPR in Food Safety and Agricultural Challenges

Due to various factors threatening agriculture, scientists are looking for ecological and eco-friendly substitutes. This include ecological engineering microbial (bacteria, fungi) techniques for ecological restoration and improving agronomical practices to increase food production (17). Among microflora, the usage of PGPR began around 100 years ago, when countries such as China, Europe, the former Soviet Union and the United States began realistic. The word "rhizobacteria," however, was first described (18) as a bacterial species actively colonizing roots and enhancing plant development. The application PGPR is considered to be one of the most sustainable and cheap ways of raising agricultural productivity by stimulating crop development, controlling plant pathogens and biodegrading pollutants, bioremediating (19, 20). In this chapter, various pathways are explored to increase plant development, plant protection against phytopathogens and soil health and how beneficial soil bacteria participate in the Collaborative Plant Soil Bacteria Framework. In addition, PGPR is emphasized in vegetable development under various agroclimatic conditions. It should be noted that vegetables play an important role in the supply of basic minerals, vitamins and fibres, not found in significant amounts in starchy food and a large provision of proteins and carbohydrates (21).

Mechanism of Growth Promotion by PGPR: A General Perspective

- **Nitrogen Fixation**

Bacteria from "rhizobia" Groups are known to create symbiotic connections with host-specific legumes and to give plants a significant plant nutrient N. Plants such as lucerne, sweet clover, pea, lentil, rice, cowpea can provide in to R. japonicum, R. trifolii, R. meliloti, R. phaseoli, R. leguminosarum, etc (22). Additionally, several other associative nitrogen fixers have been identified to increase the growth and yield of many winter legumes, including pea and chichpea, such as Azospirillum inoculation (23). There was a study of the position of two PGPR (Serratia liquefaciens 2-68 or S. proteamaculans 1-102) strains in growing nodulation, fixation of nitrogen and overall nitrogen yields of two soybean crops over the short season (24). Strains improved nodulation of soybean and increased the initiation of nitrogen fixation. Fixed N, as a percentage of the overall plant N, and the PGPR inoculation improved the output of protein and N. On the other side, Pishchik et al. (1998) documented the inoculatory impact of Klebsiella's nitrogen fixation on the yield of nonlegumes including potatoes. Significant increases in potato yield and N content were obtained by low doses of nitrogen fertilizers after inoculation of the CIAM880 and CIAM853 K. mobilis strains (25).

- **Nitrification**

The biological mechanism is bacterial nitrification, in which energy is derived through sequential nitrogen oxidation as ammonia. Nitrification is known to be the main cause of nitric oxide (NO) released from the soil. Nevertheless, recent work identified NO as a signal molecule in the PGPR interaction. Azospirillum strains, for example, developed ten times the amount of NO contained in the plant. However, when sequestered bacterial nitrogen oxide with special scavengers (cPTIO) it became apparent that the capacity of Azospirillum inoculation to induce the growth of the lateral root

www.ignited.in

of tomato was lost, which shows that NO was involved in Azospirillum root interaction (26).

- **Denitrification**

In 1856 Reyest made the first explanation of the deterioration of soil organic matter leading to the introduction of nitrogen gas into the atmosphere. The first to characterize denitrification in 1886 were Gayon and Dupetit later (27).

- **Phosphate Solubilization**

The phosphorus (P), after nitrogen, is the most essential macronutrient in biological processes, such as cell division and growth, energy transmission, signal transduction, macromolecular biosynthesis, photosynthesis and plant breathing. Phosphorus is available at soil concentrations of 400–1200 mg/kg. However, only a limited volume (1 mg or less) of P is soluble, while the remainder is insoluble and thus not available for plant reception (28).

- **Siderophores, a powerful tool for competition and antagonism**

Iron, in particular plant growth and creation, is a vital factor for earthly life (29). Why then secrete the organic soluble compounds (binders) which link to ferric ion (Fe^{3+}) to shape the complex chelator-Fe^{3+} (30)? Several plant iron usage studies enabled scientists to differentiate between two plant strategies for iron acquisition from soil (31)

- **Bacterial Phytohormones and Plant Growth Regulation**

Naturally occurring organic compounds are phytohormones or plant growth hormones, and at low doses provide a significant effect on plant growth and physiological upregulation. Among phytohormones, Auxin was the first plant hormone discovered by Kende and Zeevaart, deriving from the Greek word α work (Auxein means 'growing or increasing') (1997). When Went and Thimann published their book Phytohormones, Auxin was the only synonym for phytohormones until 1973. Since then, other phytohormones have been discovered, including gibberellin, ethylene, cytokinin and abscisic acid. Plants, microorganisms and even algae are producing phytohormones. PGPR may also modulate levels of phytohormone in plant tissues that influence the hormonal balance of the host plant among microbes.

- **PGPR Hydrolytic Enzymes**

Enzymes such as chitinase and cellulase degrade by the biocontrollers of fungal cell walls (36, 37). Kathiresan et al. (2011) indicated that Azotobacter sp. formed organic soil, high amylase, cellulase, lipase, chitinase, and protease levels and took part in biological degradation processes. *Bacillus* and *Pseudomonas sp.* bacteria also decreased the growth of filamentous fungi through the secretion of enzymes of lytic substances such as chitinases and glucanase. These bacteria are widely used to protect the biological protection of plants against pathogenes, particularly Chitin and Glucans in their cell walls (38). Kohler et al. (2007) observed that inoculation of B. subtilis rhizosphere plants significantly increased urease, protease and phosphatase production and thus led to increased plant growth and consumption of potassium-calcium. Lytic enzymes produced by bacterium isolate (MIC 3) (protease, amylase, cellulase, chitinase and pectinase) were strongly in vitro antagonistic to the effects of f.oxyspor and phoma sp. (39). The function of chitinolytic Streptomyces vinaceusdrappus S5MW2 has recently been documented to enhance the growth of tomato plants and the biocontrol effectiveness through the supplementation of chitin with rhizoctonia solani. The chitin supplementation with S5MW2 demonstrated substantial growth in tomato plants and superior reduction of diseases in comparison with untreated control and without CC-treated plants, under the greenhouse experiment. The function of S. maltophilia and Chromobacterium sp. in inhibiting the potato cyst hatch Globodera rostochiensis was stated (40). Xu and Kim (2016) evaluated the function of cellulase-protease generating Paenibacillus polymyx strain SC09-21 as the Phytophthora blight biocontrol agent and pepper plants growth stimulation. Strain SC09-21 greatly decreased blight intensity of the Phytophthora and improved ammonia-lyase phenylalanine, peroxidase, Polyphenol Oxidase and dismutase activity in the superoxide. SC09-21 also increased protein gene expression similar to pathogenesis in pepper plants. Singh et al. (1999) found the removal of fusarium f. oxysporum f. sp. cucumerinum from both chitinolytic bacterial species, Penibacillus sp. 300 and Streptomyces sp. 385 in non-sterile soilproof potting medium (41).

Systemic Tolerance and Systemic Resistance Induction by PGPR

PGPR has been shown to stimulate plant defense by inhibiting phytopathogens in various studies. It causes physical or chemical changes in plants and thus improves plant resistance through mediated systemic resistance (ISR) (42). For example, when evaluated in pot trials of Sclerotium cepivorum, Bacillus subtilis B4 and B. subtiliis B5 caused white onion red occurrence of disease decreased by 33.33 percent and 41.67 percent respectively in comparison to control. Because of their capacity to reduce disease, Bacillus strains were considered appropriate to increase growth and productivity of onion plants (43). Furthermore, the capacity of Pseudomonas sp. endophytic strains to support potato plant growth and tolerance to necrotrophic Pectobacterium atrosepticum infection is also recorded (44). In addition to its capacity to stimulate the development of potato shoots, Pseudomonas sp. improved herbal tolerance to soft rot. Inhibition of the disease was inversely proportional to the scale of the bacterial inoculated community. Raupach et al. (1996) analyzed the effects on cucumber and tomato cucumber mosaic Cucumovirus of two bacterial strains P. fluorescens 89B 27 and S. marcescens 90–166 (CMV). Both strains demonstrated high capacity to promote protection of tomatoes and cucumbers against CMV, the findings indicate that both strains should be assessed in order to determine their capacity for help in the management of viral plant diseases (45).

CONCLUSION:

Among different techniques, more emphasis has been paid to the use of PGPR in agricultural practices. Clearly, there is currently no clear antithesis on the useful and eco-friendly impact of PGPR on a worldwide sustainable agriculture. However, several problems need to be tackled to allow good use of this technology. The lack of uniformity and variance in responses are of prime concern for different causes. In addition, a special focus is needed to detect plants specific PGPR and to recognize the interpersonal relationship between PGPR and vegetable to produce vegetable inoculants. Furthermore, the difficulties experienced in inoculum processing, storage, distribution, viability and productivity in the modern environment following its implementation are some of the other major challenges requiring both scientists and farmers to take maximum advantage of the technology to boost vegetable production in various agroecological niches.

REFERENCES:

1. Godfray HCJ, Beddington JR, Crute IR, et al. (2010) Food security: the challenge of feeding 9 billion people. Science 327: pp. 812–818.

2. de Souza R, Ambrosini A, Passaglia LMP (2015) Plant growth-promoting bacteria as inoculants in agricultural soils. Genet Mol Biol 38: pp. 401–419.

3. Adesemoye AO, Torbert HA, Kloepper JW (2009) Plant Growth-Promoting Rhizobacteria allow reduced application rates of chemical fertilizers. Microb Ecol 58: pp. 921–929.

4. FAO (2009) How to Feed the World in 2050. Rome, Italy, Food and Agriculture Organization.

5. FAO (2014) 19 December Rome. Available from: http://www.fao.org/ news/story/ en/item/2733 03/icode.

6. Troccoli A, Borrelli GM, De Vita P, et al. (2000) Durum wheat quality: a multidisciplinary concept. J Cereal Sci 32: pp. 99–113.

7. L. Schoenborn, P. S. Yates, B. E. Grinton, P. Hugenholtz, and P. H. Janssen (2004). “Liquid serial dilution is inferior to solid media for isolation of cultures representative of the phylum-level diversity of soil bacteria,” Applied and Environmental Microbiology, vol. 70, no. 7, pp. 4363–4366.

8. S. Timmusk, V. Paalme, T. Pavlicek et. al. (2011). “Bacterial distribution in the rhizosphere of wild barley under contrasting microclimates,” PLoS One, vol. 6, no. 3, Article ID e17968.

9. B. R. Glick, C. L. Patten, G. Holguin, and D. M. Penrose (1999). Biochemical and Genetic Mechanisms Used by Plant Growth Promoting Bacteria, Imperial College Press, London, UK.

10. D. V. Badri, T. L. Weir, D. van der Lelie, and J. M. Vivanco (2009). “Rhizosphere chemical dialogues: plant-microbe interactions,” Current Opinion in Biotechnology, vol. 20, no. 6, pp. 642–650.

11. D. V. Badri and J. M. Vivanco (2009). “Regulation and function of root exudates,” Plant, Cell and Environment, vol. 32, no. 6, pp. 666–681.

12. H. P. Bais, T. L. Weir, L. G. Perry, S. Gilroy, and J. M. Vivanco (2006). “e-role of root exudates in rhizosphere interactions with plants and other organisms,” Annual Review of Plant Biology, vol. 57, pp. 233–266, 2006.

13. J. M. Whipps (1990). “Carbon utilization,” in e Rhizosphere,, J. M. Lynch, Ed., pp. 59–97, Wiley-Interscience, Chichester, UK.

14. J. M. Lynch (1990). Ed., e Rhizosphere, Wiley-Interscience, Chichester, UK.

15. A. N. Dubeikovsky, E. A. Mordukhova, V. V. Kochetkov, F. Y. Polikarpova, and A. M. Boronin (1993). “Growth promotion of blackcurrant so□wood cuttings by recombinant strain Pseudomonas uorescens BSP53a synthesizing an increased amount of indole3-acetic acid,” Soil Biology and Biochemistry, vol. 25, no. 9, pp. 1277–1281.

16. B. R. Glick (1995). “e enhancement of plant growth by free-living bacteria,”

www.ignited.in

Canadian Journal of Microbiology, vol. 41, no. 2, pp. 109–117, 1995.

17. Ahmed AQ, Javed N, Khan SA (2016). Efficacy of rhizospheric organism Rhizobium leguminosarum against Meloidogyne incognita in soybean. Pak J Agric Sci 53: pp. 377–381

18. Al Mughrabi KI, Vikram A, Poirier R et. al. (2016). Management of common scab of potato in the field using biopesticides, fungicides, soil additives, or soil fumigants. Biocontrol Sci Technol 26: pp. 125–135

19. Bell AA, Hubbard JC, Liu L et. al. (1998). Effects of chitin and chitosan on the incidence and severity of Fusarium yellows of celery. Plant Dis 82: pp. 322–328

20. Brewer JH, Thrasher JD, Hooper D (2013). Chronic illness associated with mold and mycotoxins: is naso-sinus fungal biofilm the culprit? Toxins (Basel) 6: pp. 66–80

21. Chethana BS, Ganesh G, Manjunath B (2011). Screening of genotypes and effect of fungicides against purple blotch of onion. J Agric Technol 7: pp. 1369–1374

22. Yamaguchi M. (1983). World vegetables: principles, production and nutritive values. AVI Publishing Company, Inc., Westport, CT

23. Zehr JP, Jenkins BD, Short SM, Steward GF (2003). Nitrogenase gene diversity and microbial community structure: a cross-system comparison. Environ Microbiol 5: pp. 539–554

24. Wang CJ, Yang W, Wang C, Gu C, Niu DD, Liu HX, Wang YP, Guo JH (2012). Induction of drought tolerance in cucumber plants by a consortium of three plant growth-promoting rhizobacterium strains. PLoS ONE 7: pp. 1–10

25. Pishchik VN, Chernyaeva II, Kozhemaykov AP, Vorobyov NI, Lazarev AM, Kozlov LP (1998). Effect of inoculation with nitrogen-fixing Klebsiella on potato yield. In: Malik KA et al (eds) Nitrogen fixation with non-legumes. Kluwer Academic Publishers, Great Britain, pp. 223–235

26. Cohen MF, Lamattina L, Yamasaki H (2010) Nitric oxide signaling by plant-associated bacteria. In: Hayat S et al (eds) Nitric oxide in plant physiology. WILEY-VCH Verlag GmbH and Co. KGaA, Weinheim

27. Ullah U, Ashraf M, Shahzad SM, Siddiqui AR, Piracha MA, Suleman M. (2016). Growth behavior of tomato (Solanum lycopersicum L.) under drought stress in the presence of silicon and plant growth promoting rhizobacteria. Soil Environ. 2016; 35(1): pp. 65–75.

28. Xun F, Xie B, Liu S, Guo C. (2015). Effect of plant growth promoting rhizobacteria and arbuscular mycorrhizal fungi (AMF) inoculation on oats in salinealkali soil contaminated by petroleum to enhance phytoremediation. Environ Sci Poll Res. 2015; 22: pp. 598–608.

29. Tariq M, Noman M, Ahmed T, Hameed A, Manzoor N, Zafar M. Antagonistic features displayed by plant growth promoting rhizobacteria (PGPR): A review. J Plant Sci Phytopathol. 2017;1: pp. 38–43

30. Jadhav H, Sayyed R. (2016). Hydrolytic enzymes of rhizospheric microbes in crop protection. MOJ Cell Sci Rep.; 3(5): pp. 1–2.

31. Yandigeri MS, Malviya N, Solanki MK, Shrivastava P, Sivakumar G. (2015). Chitinolytic Streptomyces vinaceusdrappus S5MW2 isolated from Chilika lake, India enhances plant growth and biocontrol efcacy through chitin supplementation against Rhizoctonia solani. World J Microbiol Biotechnol.; 31(8): pp. 1217–25.

32. Radhakrishnan R, Hashem A, Abd-Allah EF (2016). Bacillus: A biological tool for crop improvement through bio-molecular changes in adverse environments. Front Physiol.; 8: pp. 1–14.

33. Singh D, Yadav DK, Chaudhary G, Rana VS, Sharma RK. (2016). Potential of Bacillus amyloliquefaciens for biocontrol of bacterial wilt of tomato incited by Ralstonia solanacearum. J Plant Pathol Microbiol.; 7(327): pp. 1–6.

34. Konappa NM, Maria M, Uzma F, Krishnamurthy S, Nayaka SC, Niranjana SR, et. al. (2016). Lactic acid bacteria mediated induction of defense enzymes to enhance the resistance in tomato against Ralstonia solanacearum causing bacterial wilt. Sci Hortic.; 207: pp. 183–92.

35. Wu G, Liu Y, Xu Y, Zhang G, Shen Q, Zhang R. (2018). Exploring elicitors of the benefcial rhizobacterium Bacillus amyloliquefaciens SQR9 to induce plant systemic resistance and their interactions with plant signaling pathways. Mol Plant Microbe Interact.; 31(5): pp. 560–7.

www.ignited.in

36. Sun D, Zhuo T, Hu X, Fan X, Zou H. (2017). Identifcation of a Pseudomonas putida as biocontrol agent for tomato bacterial wilt disease. Biol Cont.; 114: pp. 45–50.

37. Boukerma L, Benchabane M, Charif A, Khelif L. (2017). Activity of plant growth promoting rhizobacteria (PGPRs) in the biocontrol of tomato fusarium wilt. Plant Prot Sci.; 53(2): pp. 78–84.

38. Rijavec T, Lapanje A. (2016). Hydrogen cyanide in the rhizosphere: Not suppressing plant pathogens, but rather regulating availability of phosphate. Fronti Microbiol.; 7: pp. 1–14.

39. Singh R, Pandey D, Kumar A, Singh M. (2017). PGPR isolates from the rhizosphere of vegetable crop Momordica charantia: Characterization and application as biofertilizer. Int J Curr Microbiol Appl Sci.; 6(3): pp. 1789–802.

40. Shaikh SS, Sayyed RZ. Reddy MS. (2016). Plant growth-promoting rhizobacteria: An eco-friendly approach for sustainable agroecosystem. Springer International Publishing Switzerland; pp. 181–201.

41. Tsegaye Z, Assefa F, Beyene D. (2017). Properties and application of plant growth promoting rhizobacteria. Int J Curr Trends Pharmacobiol Med Sci.; 2(1): pp. 30–43.

42. Murthy KN, Uzma F, Chitrashree CS (2014). Induction of systemic resistance in tomato against Ralstonia solanacearum by Pseudomonas fuorescens. Am J Plant Sci.; 5(12): pp. 1799–811.

43. Boukerma L, Benchabane M, Charif A, Khelif L. (2017). Activity of plant growth promoting rhizobacteria (PGPRs) in the biocontrol of tomato fusarium wilt. Plant Prot Sci.; 53(2): pp. 78–84.

44. Rijavec T, Lapanje A. (2016). Hydrogen cyanide in the rhizosphere: Not suppressing plant pathogens, but rather regulating availability of phosphate. Fronti Microbiol.; 7: pp. 1–14.

45. Singh R, Pandey D, Kumar A, Singh M. (2017). PGPR isolates from the rhizosphere of vegetable crop Momordica charantia: Characterization and application as biofertilizer. Int J Curr Microbiol Appl Sci.; 6(3): pp. 1789–802.

Corresponding Author

Richa Pandey*

PhD Scholar, Department of Biotechnology, College of Commerce, Arts, Science, Magadh University, Patna

pandey.richa768@gmail.com

www.ignited.in