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Original Article

Plant growth promoting rhizobacteria: A boon to agriculture

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Abstract
Plant Growth Promoting Rhizobacteria (PGPR) are a group of bacteria that enhances plant growth by a wide variety of mechanisms like Phosphate Solubilization, Siderophore Production, Biological Nitrogen Fixation, Rhizosphere Engineering, Production of 1-Aminocyclopropane-1-Carboxylate Deaminase (ACC), Quorum sensing (QS) signal interference and Inhibition of Bio-film formation, Phytohormone production, exhibiting Anti-fungal activity, Production of Volatile Organic Compounds (VOCs), induction of Systemic Resistance, promoting beneficial Plant-Microbe Symbioses, interference with Pathogen Toxin production etc. and yield. PGPRS as bio-fertilizers, are the living micro-organisms which are applied to surface of plant, seed, or soil. They colonize the plant rhizosphere or inside the plant body (as endophyte) and promotes plant growth by providing fundamental nutrients to crop plants. The rapidly increasing population is exerting immense pressure on agricultural lands for higher crop yields, which results in increasing use of chemical fertilizers. But due to negative environmental impact of artificial fertilizers and their increasing costs, microorganisms have a vital role in agriculture as they promote the exchange of plant nutrients and reduce application of chemical fertilizers as much as possible. Substances produced by PGPRS protect the plants against various pathogens by direct antagonistic interactions between the bio-control agent and the pathogen, as well as by induction of host resistance. Resistance-inducing and antagonistic rhizobacteria might be useful in formulating new inoculants with combinations of different mechanisms of action. leading to a more efficient use for bio-control strategies to improve cropping systems. Recent progress in our understanding on the diversity of PGPR in the rhizosphere along with their colonization ability and mechanism of action should facilitate their application as a reliable component in the management of sustainable agricultural system.

Keywords: Plant Growth Promoting Rhizobacteria; Bio-fertilizers; Bio-control

Introduction:

Sustainable agriculture is fundamentally important in today's world because it offers the potential to meet our future agricultural needs because of a fast growing population, something that conventional agriculture will not be able to do. In modern cultivation process, there is a wide indiscriminate use of chemical fertilizers, which has led to pollution of soil, air and water. Excess use of these chemicals exerts deadly effects on soil microorganisms and also contribute in deteriorating the fertility status of soil and polluting the atmosphere. Despite of being costly, the manufacturing of chemical fertilizers depletes non- renewable resources, the oil and natural gas used to generate these fertilizers, and poses human and environmental hazards. The use of these fertilizers on a long term basis leads to decrease in pH as well as exchangeable bases, therefore making them out of stock to crops, as a result of which, the productivity of crop declines [Gupta, 2015]. Thus, the negative environmental impact of artificial fertilizers and their ever-increasing costs, the use of beneficial soil microorganisms such as Plant Growth Promoting Rhizobacteria (PGPR) for sustainable and secure agriculture has increased worldwide during the last couple of decades. Therefore, Agricultural Biotechnology and Microbiology aims to develop microbial inoculants which can increase plant growth and suppress plant diseases, so that focus can be on the use of reduced quantity of chemical fertilizers and pesticides. In this, we review different mechanisms commonly used by the PGPR to influence plant growth and health in the natural environment.

Role of PGPR:

PGPR are free living bacteria that resides in soil. They either directly or indirectly assist rooting [Mayak, et al., 1999]. They play different roles in the soil which proves beneficial for plant health and productivity. They colonize the rhizosphere and protect plant from its pathogens, produce secondary metabolites such as antibiotics that suppress harmful rhizobacteria, produce siderophores, and phytohormones, can fix atmospheric nitrogen, and help in providing nutrition uptake by solubilizing phosphate and produce biologically active substances which influence the plant growth and development [Arshad and Frankenberger, 1998]. PGPR can also clean environment by detoxifing pollutants like, heavy metals and pesticides. Several researches are still going on to understand the diversity and importance of soil PGPR communities and their roles in betterment of agricultural productivity.

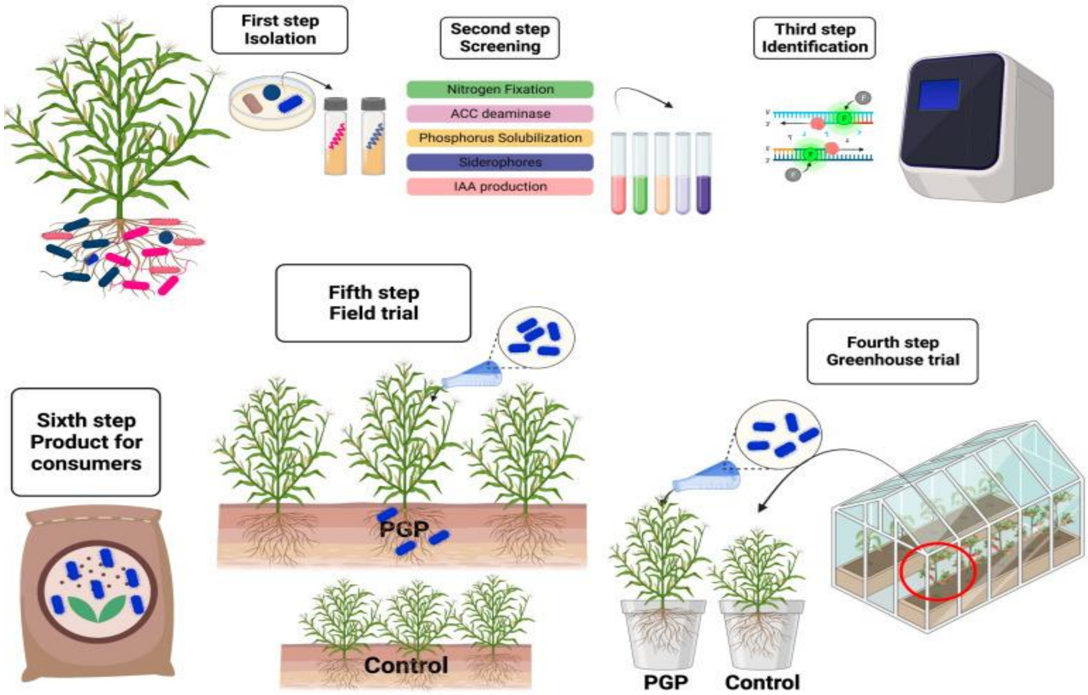

Fig. 1: Schematic representation of the steps required to isolate and characterize bacteria that promote plant growth.

Occurrence and forms of PGPR:

The mechanism by which PGPR exerts beneficial effect on plants can be very diverse. They can establish themselves on root's suface or inside the roots. PGPR can be classified into extra-cellular Plant Growth Promoting Rhizobacteria (ePGPR) that may exist in rhizosphere, on rhizoplane or in spaces between the cells of root cortex and such bacterial genera are Agrobacterium, Arthrobacter, Azotobacter, Azospirillum, Bacillus, Flavobacterium, Serratia and Pseudomonas. The other category is intra-cellular Plant Growth Promoting Rhizobacteria (iPGPR) that locates generally inside the specialized nodular structures of root cells [Figueiredo, et al., 2011] and belongs to family of Rhizobiaceae includes Allorhizobium, Bradyrhizobium, Mesorhizobium and Rhizobium, Endophytes and Frankia species both of which can symbiotically fix atmospheric nitrogen with the higher plants.

Mechanism of action:

PGPR affect plant growth in two different ways, indirectly or directly. The direct promotion of plant growth by PGPR is either by providing the plant with a compound that is synthesized by the bacterium, for example phytohormones, or by facilitating the uptake of certain nutrients from the environment [Glick, 1995]. Isolates exhibiting 2-3 PGPR traits, as combination of Ammonia Excretion, IAA production ability, Phosphorous Solubilization and Siderophore production ability of bacteria may promote plant growth synergistically or individually. They have good prospects to improve plant growth as they have nitrogen fixing ability too, especially in soil which is affected by salts [Kochar and Gera 2015], the tested. Thus, multi-strain inoculant bio-fertilizers may be particularly beneficial. The indirect promotion of plant growth occurs when PGPR lessen or prevent the deleterious effects of one or more phytopathogenic organisms. This can happen by producing antagonistic substances or by inducing resistance to pathogens [Glick, 1995].

PGPR as Bio-fertilizers:

A vast amount of artificial fertilizers are used to replenish soil N and P, resulting in high costs and increased environmental pollution. Thus, biofertilizers are improve nutrient availability to plants and contribute to plant nutrition both by facilitating nutrient uptake and by increasing primary nutrient availability in the rhizosphere by different methods, as fixing atmospheric nirogen, solubilizing mineral nutrients, mineralizing organic compounds and producing phytohormones [Bhardwaj, et al., 2014], [Arora, et al., 2012]. They are also used to increase crop growth and yield when applied complementary to, or as substitute for, chemical fertilizers. The plant-PGPR cooperation plays an important role by enhancing growth and health of plants.

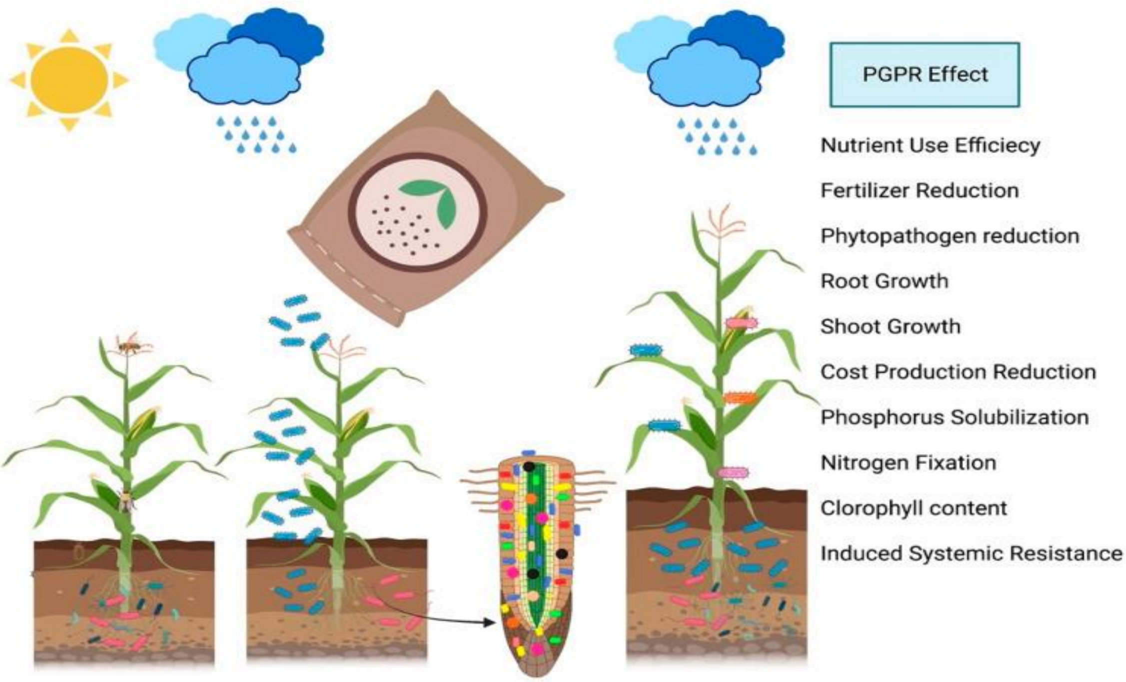

Fig. 2: This schematic diagram compares uninoculated plants with those that have been inoculated with bacterial endophytes, illustrating several important benefits of this process for promoting plant growth in crops. These benefits include increased aerial growth, reduced susceptibility to disease, enhanced nutrient uptake, improved root growth, reduced presence of harmful phytopathogens, and induced systemic resistance. By harnessing the power of beneficial bacteria within plants, farmers can ensure healthier and more productive crops, leading to higher yields and better food security.

PGPR as Phytohormone producers:

PGPRs produces Indole Acetic Acid, Cytokinins, Gibberellins and inhibitors of Ethylene production. The most common best characterized and physiologically the most active auxin in plants is Indole-3-Acetic Acid (IAA) which stimulates rapid (e.g. increase in cell elongation) and long-term (e.g. cell division and differentiation) responses in plants [Cleland, 1990]. Auxins are quantitatively the most abundant phytohormones secreted by Azospirillum. IAA, a phytohormone, produced in young leaves, stems and seeds from transamination and decarboxylation reaction of tryptophan. Tryptophan is an amino acid commonly found in root exudates. It is the main precursor molecule for biosynthesis of IAA in bacteria [Etesami, et al., 2009]. The most common mechanism for the biosynthesis of indole acetic acid by PGPRs like Pseudomonas, Rhizobium, Bradyrhizobium, Agrobacterium, Enterobacter and Klebsiella is the formation via indole-3- pyruvic acid and indole-3-acetic aldehyde [Shilev, 2013]. Several plant growth promoting rhizobacteria Azotobacter sp., Rhizobium sp.,Pseudomonas fluorescens, Bacillus subtilis and Paenibacillus polymyxa can produce cytokinins or gibberellins or both can produce either cytokinins or gibberellins or both. Cytokinins stimulate plant cell division and control root development by inhibiting primary root elongation and lateral root formation and promoting root hair formation [Werner, et al., 2003],]Riefler et al., 2006] while gibberellins promote the development of stem tissue, root elongation and lateral root extension [Yaxley, et al., 2001]. Ethylene is a key phytohormone has a wide range of biological activities that can affect plant growth and development. It plays important role in root initiation, inhibits root elongation, promotes fruit ripening, promotes lower wilting, stimulates seed germination, promotes leaf abscission, activates the synthesis of other plant hormones.

PGPR as Bioformulations for plant growth promotion:

Due to wide use of chemical fertilizers and pesticides, harmful chemicals are accumulating in the environment and thus destroying the ecosystem, causing pollution and spreading diseases. Therefore, PGPR Bioformulations is in great demand now so as to protect our environment. Bioformulations refers to preparations of microorganism that may be partial or complete substitute for chemical fertilization, pesticides, which offers an eco-friendly sustainable approach to increase crop production and health. They are biologically active products used in the agricultural fields containing one or more valuable microbial strains, easy to use and have economical carrier material which maintains the cell viability under adverse environmental conditions. While introducing microbial inoculants, consideration must be taken that kind of plant species and soil type shape microbial communities in rhizosphere is there because there can be the chances of competition between inoculated and resident microflora. As this could rapidly deplete the population of introduced microbes and may account in part for the inconsistencies observed between greenhouse studies and field trials [Martinez-Viveros, et al., 2010]. As compared with chemical fertilizers, microbial inoculants have many advantages. If suitable microbes is selected carefully, there is a reduced risk of environmental damage and potentially human health. They are safer to apply and their activity is more targeted. They are effective in small quantities and they multiply fast if given appropriate conditions and may survive to the next season. Thus PGPR is a promising sustainable and environmentally friendly approach to obtain sustainable fertility of the soil and plant growth indirectly.

PGPR as Bio-control:

Phytopathogenic microorganisms are a major and chronic threat to sustainable agriculture and ecosystem stability. Regular use of chemical pesticides and fungicides has led to environmental concerns and even cause pathogen resistance, forcing constant development of new agents [Fernando, et al., 2006]. According to Beattie (2006), Bacteria that reduce the incidence or severity of plant diseases are often referred to as bio-control agents. PGPRs interact with soil pathogens through several mechanisms such as Antibiosis (production of antimicrobial compounds), competition for Iron and nutrients or for colonization sites, predation and parasitism and induction of resistance factors. The production of antibiotics is considered to be one of the most powerful and studied bio-control mechanisms of plant growth promoting rhizobacteria against phytopathogens [Shilev, 2013]. To prevent the proliferation of plant pathogens (generally fungi), a variety of antibiotics have been identified, such compounds are Amphisin, 2,4-Diacetylphloroglucinol (DAPG), Oomycin A, Phenazine, Pyoluteorin, Pyrrolnitrin, Tensin, Tropolone, and Cyclic lipopeptides produced by Pseudomonads [Loper and Gross, 2007] and Oligomycin A, Kanosamine, Zwittermicin A, and Xanthobaccin produced by Bacillus, Streptomyces, and Stenotrophomonas sp. [Compant, et al., 2005]. Pathogen suppression can also occur competitively through indirect inhibition. Bradyrhizobium, Pseudomonas, Rhizobium, Streptomyces, Serratia, and Azospirillum are Siderophore producing PGPRs. Siderophore producing PGPR that can prevent proliferation of pathogenic microorganisms by sequestering Fe^{3+} in the area around the roots, thus makes iron unavailable to pathogens [Martinez- Viveros et al., 2010]. Both mechanisms have vital functions in microbial antagonism and these mechanisms leads to elicit induced resistance.

Certain bacteria synthesize a wide spectrum of multifunctional polysaccharides including intracellular polysaccharides, structural polysaccharides, and extracellular polysaccharides. Exopolysaccharides (EPS) helps in Bio-film formation; Root colonization can affect the interaction of microbes with roots appendages. EPS-producing microbes shield the plant from the attack of foreign pathogens, desiccation, protect against stress [Qurashi and Sabri, 2012]. Many PGPRs can synthesize Antifungal metabolites such as Antibiotics, fungal cell wall- Lysing enzymes, or Hydrogen Cyanide, which suppress the growth of fungal pathogens.

Thus PGPRs as biocontrol agents can be commercialized by doing genetic modifications which could further contribute to sustainable development of agriculture. Therefore, the selected bacterial strains can be used practically for the development of plant growth promoting or bio-control inoculants, together with other plant growth promoting microbes [EvaLaslo, et al., 2012].

Conclusion

PGPR can affect plant growth by different mechanisms. Their ability to produce various compounds (such as phytohormones, organic acids, siderophores), fix atmospheric nitrogen, solubilize phosphate and produce antibiotics that suppress deleterious rhizobacteria, and production of biologically active substances or plant growth regulators (PGRs). Significant growth has been achieved in the area of PGPR production. PGPR are potential microbes for enriching the soil fertility and increasing the agriculture yield. Plant growth promotion is a complex phenomenon. Most PGPR influences plant growth through multiple mechanisms, and in some cases their effect may only occur through interactions with other microbes. Resistance-inducing and antagonistic rhizobacteria might be useful in formulating new inoculants,thus, offering an attractive alternative of environmentally friendly biological control of plant disease and improving the cropping systems into which it can be most profitably applied. It requires a systematic approach and design, so as to utilize their valuable and useful properties, even crop yields can be maintained by using the combinations of different mechanisms of action and reducing the use of chemical fertilizers. Keeping in mind the current and future progress of PGPR diversity, ability to colonize, mechanisms of action, formulation and application could aid in their development for sustainable agriculture. PGPR are excellent model systems which can provide the Biotechnologist with novel genetic constituents and bioactive chemicals having diverse uses in agriculture and environmental sustainability.

Reference

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Plant Growth-Promoting Rhizobacteria for Sustainable Agricultural Production; PMID: 37110511, PMCID: PMC10146397, DOI: 10.3390/microorganisms11041088

Gupta, S.S. Parihar, N.K. Ahirwar, S.K. Snehi, V. Singh, (2015) Plant growth promoting rhizobacteria (PGPR): current and future prospects for development of sustainable agriculture. Journal of Microbial & Biochemical Technology, 7, 96–102.

S. Mayak, T. Tirosh, B.R. Glick, (1999) Effect of wild-type and mutant plant growth promoting rhizobacteria on the rooting of mung bean cuttings. Journal of plant growth regulation, 18, 49-53.

M. Arshad, W.T. Frankenberger, Jr. (1998) Plant growth regulating substances in the rhizosphere: Microbial production and functions. Advances in agronomy, 62, 15-151

M.V.B. Figueiredo, L. Seldin, F.F. Araujo, R.L.R. Mariano, (2011) Plant growth promoting rhizobacteria: fundamentals and applications. In: D.K. Maheshwari, (ed.), Plant Growth and Health Promoting Bacteria. Springer-Verlag, Berlin, Heidelberg, pp. 21-42.

B.R. Glick, (1995) The enhancement of plant growth by free-living bacteria. Canadian Journal of Microbiology, 41, 109-117.

H.K. Kochar, R. Gera, (2015) Isolation of salt tolerant rhizo bacteria and their plant growth promoting activities from sodic soils of Haryana. International Journal of Research 2(11) 215-227

D. Bhardwaj, M.W. Ansari, R.K. Sahoo, N. Tuteja, (2014) Biofertilizers function as key player in sustainable agriculture by improving soil fertility, plant tolerance and crop productivity. Microbial cell factories, 13, 66.

N.K. Arora, S. Tewari, S. Singh, N. Lal, D.K. Maheshwari, (2012) PGPR for protection of plant health under saline conditions. In: D.K. Maheshwari, (ed.) Bacteria in agrobiology: Stress management, pp. 239-258. R.E Cleland, (1990). Auxin and cell elongation. In P. Davies, (ed.), Plant hormones and their role in plant growth and development. Dordrecht: Kluwer Academic. pp. 132-148. H.A. Etesami, H.A. Alikhani, A. Akbari, (2009) Evaluation of plant growth hormones production (IAA) ability by Iranian soils rhizobial strains and effects of superior strains

application on wheat growth indexes. World Applied Sciences Journal, 6, 1576-1584

S. Shilev, (2013) Soil rhizobacteria regulating the uptake of nutrients and undesirable elements by plants. In: N.K. Arora (ed.) Plant Microbe Symbiosis: Fundamentals and

Advances. Springer, India, pp. 147-50

T. Werner, V. Motyka, V. Laucou, R. Smets, H. Van Onckelen, T. Schmulling, (2003) Cytokinin-deficient transgenic Arabidopsis plants show multiple developmental alterations indicating opposite functions of cytokinins in the regulation of shoot and root meristem activity. Plant Cell, 15, 2532- 2550.

M. Riefler, O. Novak, M. Strnad, T. Schmulling, (2006) Arapidopsis cytokinin receptor mutants reveal functions in shoot growth, leaf senescence, seed size, germination, root development and cytokinin metabolism. Plant Cell, 18(1), 40- 54.

J. Yaxley, J. Ross, L. Sherriff, J.B. Reid, (2001) Gibberellin biosynthesis mutations and root development in pea. Plant Physiology, 125, 627-633.

O. Martinez-Viveros, M. Jorquera, D.E. Crowley, G. Gajardo, M.L. Mora, (2010) Mechanisms and practical considerations involved in plant growth promotion by rhizobacteria. Journal of Soil Science and Plant Nutrition, 10(3), 293-319.

W. Fernando, S. Nakkeeran, Y. Zhang, (2006) Biosynthesis of antibiotics by PGPR and its relation in biocontrol of plant disease. In: Siddiqui, Z. (ed.), PGPR: biocontrol and biofertilization. Springer, Netherlands, pp. 67-109

G.A. Beattie, (2006) Plant-associated bacteria: Survey, molecular phylogeny, genomics and recent advances. In: S.S. Gnanamanickam, (ed) Plant-Associated Bacteria. Springer, Dordrecht, pp 1-56.

J.E. Loper, H. Gross, (2007) Genomic analysis of antifungal metabolite production by Pseudomonas fluorescens Pf-5. European Journal of Plant Pathology, 119, 265-278.

S. Compant, B. Reiter, A. Sessitsch, J. Nowak, C. Clément, E.A. Barka,. (2005) Endophytic colonization of Vitis vinifera L. by plant growth-promoting bacterium Burkholderia sp. strain 45. PsJN. Applied and environmental microbiology, 71, 1685-1693.

A.W. Qurashi, A.N. Sabri, (2012) Bacterial exopolysaccharide and biofilm formation stimulate chickpea growth and soil aggregation under salt stress. Brazilian Journal of Microbiology, 43, 1183-1191.

E. Laslo, E. Gyorgy, G. Mara, E. Tamas, B. Abraham, S. Lanyi, (2012) Screening of plant growth promoting rhizobacteria as potential microbial inoculants. Crop Protection, 40, 43-48.