



Sustainable Agriculture with Rhizobacteria (PGPR)

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ABSTRACT: In the present scenario, the demand for food and nutrient has increased due to population growth. Ascribable to industrialization and urbanization, a very small area of productivity land is available for maintenance of life process. Agricultural growth depends upon the microbial population present in the soil over the last few years. plant growth promoting rhizobacteria has turned out to be the most efficient tool for sustainable agriculture. PGPR, exert its effect by creating an intracellular and extracellular rhizo environment in search of a carbon source. These are the microbes that are found near or around the roots of the plant. So, the mode of action of PGPR is a new ray of hope for the farmers and the government to maintain the continuous supply of food for the increasing population. PGPR, as a growth booster increases phosphate solubilization, siderophore production, biological nitrogen fixation, and secretion of phytohormones (like indole acetic acid, cytokinin, gibberellin). PGPR is important artillery to control plant pathogens. It is ecofriendly and helps to maintain ecological and economical balance. In the perspective of this, the review widens the scope of the use of PGPR as a green microbial consortium for greater agrobiolgy and sustenance especially in the areas, wherein paucity of facts on its use, implementation, and alertness of genetically modified organisms has long prevailed.

KEY WORDS: Ascribable, Agrobiolgy PGPR, Phytohormones, Sideophore.

INTRODUCTION

The world population is increasing rapidly and it may be expected to be around 10 billion within the year 2060 as in line with the survey. However, the demand for food grain will increase over the years due to overpopulation [1]. Unfortunately, the food grain is indirectly proportional to the thundering increase in population. Due to industrialization and urbanization, the agricultural land available is limited. Food production must be progressed for that reason in coming years globally [2]. The surfacing of the green revolution in the 20th century brought an economic boom worldwide. The production of grains increased multiple times due to the usage of hybrid seeds and high-yielding varieties [3]. Mechanized agricultural practices are the source of pollutants in the form of fossil fuel used to power plants, agrochemicals contaminated sewage sludge during irrigation, and excessive consumption of fertilizers. These practices not only leave an unbelievable effect on the soil environment but also change the microbial population which assists in plant growth [4]. To feed the growing population with limited agricultural space available by the engineering favourable microorganism denizer in the soil that attributes with the potential of reducing the correlated difficulties in agricultural practices [5]. For sustainable agriculture consumption of chemical fertilizers must be reduced and usage of biowaste must be intensified as well as increasing the genetic efficiency of crop plants and microorganisms is a very effective way to deal with hasty environmental degradation. This ensures good agriculture yield and soil health [6]. The utilization of beneficial microorganisms as biofertilizers appears as an eco-friendly biotechnological tool in the field of agronomics [7]. Microorganisms are the legacy of soil and they improve soil fertility in their unique way. But the bacteria found around the roots of the plants (rhizobacteria) are of great benefit. They help in mobilizing and solubilizing the nutrients at a faster rate as compared to microbes found in bulk [8]. Moist soil is one of the important conditions necessary for PGPR to multiple in the rhizosphere [9]. Thus a wide range of rhizobacteria is found in the soil which helps to recycle the soil nutrients. Thus they are useful biological agents [5]. Agriculturalists are employing this as an effective technique to improve crop production, magnify sustainable agriculture and execute commercialization by using plant rhizobacteria with worldwide applicability [10]. Roots of the plants emit some fluids which we call plant root exudates. This fluid influences the rhizosphere around the roots to prevent the growth of harmful microbes and promotes the growth of self and kin plants [11]. The root system of plants become complex due to a variety of species and micro-organism present in the common soil. Plants respond to the soil conditions and microbes through various mechanisms, one of which is the secretion of root exudates. This secretion allows plants to largely influence the rhizosphere, as well as the organisms that exist within it [11]. Secretion of organic compounds from the lateral roots of the plants help a large number of micro-organisms to aggregate around the rhizosphere. Root



exudates actively regulate symbiotic interactions with rhizobacteria in the inactive soil zone of the rhizosphere [12]. This review article briefly and comprehensively provides an extensive awareness of different aspects of PGPR, their possibilities and restrictions and finally a road map towards commercialization. Rhizosphere- The rhizosphere is a thin area of soil immediately surrounding the root system [13]. It is a densely populated area in which roots compete with invading root systems of neighboring plant species for space, water, and mineral nutrients as well as from positive and negative relationships with soil-borne organisms such as bacteria, fungi and insects. The rhizosphere is a very fruitful area since 5%-21% of all photosynthetically fixed carbon is transferred from plants to the rhizosphere via root exudates [14]. Rhizobacteria are root-associated bacteria that have a detrimental, neutral or beneficial effect on plant growth. The name comes from the Greek word rhiza which means root. They form symbiotic relationships with many plants and inhibit the production of harmful microbes and they also have an ecological niche. They can develop (within the case of endophytic microorganisms) an area inside the plant cells in which they do not have to compete with any other microorganisms observed that some rhizosphere bacteria not only makes the plants stronger but safeguard them from pathogens. This group of bacteria is called plant-growth-promoting rhizobacteria (PGPR) [15]. Different generic bacteria are Azospirillum, Bacillus, Burkholderia, Klebsiella, Pseudomonas, etc identified as PGPR. The plant growth-promoting bacteria are like a boom for the plants as they bring growth in plants both directly and indirectly. PGPR helps the plants in the production of phytohormones, providing biologically fixed nitrogen, and helps to uptake the phosphorus by the solubilization of inorganic phosphates. This is a direct procedure whereas the Indirect method involves restraining the growth of different pathogens like bacteria, fungus, protozoa, etc [16]. Bacillus species of bacteria occur widely in the agricultural field, preventing pathogen infection in different ways. Some of them stimulate plant growth directly through improvement in soil nutrients and stimulation of defense mechanisms in plant infection. Thus it is a powerful alternative tool against synthetic chemicals [4]. Pseudomonas and Bacillus can easily be grown in a simple medium at a low expense, in a simple organic compound without the requirement of organic growth factors. In recent years there has been much success in obtaining biological control of plant pathogens using bacterization techniques for wheat production. Bacteria Pseudomonas fluorescens are frequently isolated from soils and plant surfaces. Some of the bacteria produce metabolites, which form ligands with the environmental iron thus making it unavailable to pathogens. Till now a large number of diseases controlling antibiotics have been chemically identified such as phenazines, pyrrole type antibiotics, pyro-compounds 13 and indole derivatives [17].

TYPES OF PGPR

PGPR are very useful for plant growth in different ways.

Plant growth-promoting rhizobacteria colonize more in the rhizospheric region than outside it reasons being the root exudates secrete fluids such as amino acids and sugar which is a rich source of energy and nutrients to these bacteria. Some rhizobacteria live inside the plant in the tissues and are called endophytes [18]. Endophytes are ubiquitous, found in almost all plant species. Endophytes generally produce different types of plant hormones that enhance plant growth. Thus these rhizobacteria are endophytes that colonize the internal tissues of the plant [18]. They could set up themselves on the root floor or within the roots. Hence plant growth-promoting bacteria can be categorized into extracellular plant growth promoting rhizobacteria (ePGPR) that can exist in the rhizosphere, on the rhizoplane or are present in the areas among the cells of the root cortex and intracellular (iPGPR) are found in the root cells generally in the nodular structure [8]. Bacteria like Agrobacterium, Arthrobacter, Azotobacter, Azospirillum, Bacillus, Flavobacterium, Pseudomonas and Serratia belong to ePGPR whereas Allorhizobium, Azorhizobium, Bradyrhizobium, Mesorhizobium are examples of (iPGPR). They belong to the family Rhizobiaceae [19]. Plant Growth Promoting Rhizobacteria is a large community of microbes. They secrete certain substances which through direct and indirect mechanisms enables plants to grow [20]. These rhizosphere bacteria enhance the growth of plants and yield either directly or indirectly. The direct growth-promoting mechanisms are (i) nitrogen fixation; (ii) solubilization of phosphorus; (iii) production of phytohormones such as auxins (indole acetic acid (IAA), Cytokinins, and gibberellins (iv) sequestering of iron by the production of siderophores; (v) lowering of ethylene concentration Micro-organisms promote and enhance the availability of plant nutrients and reduce the need for chemical fertilizers [21]. Nitrogen-fixing and P-solubilizing bacteria will be of great importance for plant nutrition by increasing N, K and P uptake in the plants. Improvement of plant growth may be achieved with direct application of plant growth-promoting rhizobacteria to seeds or plants [10]. The indirect mechanism of plant growth occurs when PGPR lessens or prevents the adverse effects on one or more plants pathogens. This can happen by producing adverse substances or by inducing resistance to pathogens [13].



CHARACTERISTICS OF PGPR

Siderophores production

Siderophores are low molecular weight compounds generated under iron-restricted conditions, where ferric ion (Fe^{3+}) performs a specific activity. It serves as a channel for the movement of Fe^{3+} into a microbial cell. In the rhizosphere, the accessibility of iron for microbial absorption is extremely limiting [22]. So for their survival organisms secrete iron-binding ligands called siderophores which can bind the ferric ion and make it available to the host organisms. Fe^{3+} becomes Fe^{2+} which is then unbound from the siderophores inside the cell. Siderophore production works as a biocontrol mechanism since, with this process, plant growth-promoting rhizobacteria deprives other microorganisms of iron. PGPR also uses siderophores to obtain other heavy metals from the soil and prevents the heavy metal to cause toxicity in plants [23].

Production of Indole Acetic Acids

Indole acetic acid (IAA) is a popular phytohormone secreted in plants called auxin. IAA is usually a product of tryptophan which is an amino acid secreted by root exudates and is the main variant for making indole acetic acid generated by several microorganisms including plant growth-promoting rhizobacteria (PGPR) [8]. These bacteria display various characteristics like the production of plant growth regulators (like auxin, gibberellin, and ethylene), siderophores, HCN, and antibiotics [24]. These rhizobacteria agitate host physiological processes for their benefit [19]. They secrete secondary metabolites like Indole Acetic Acids due to a rich supply of substrates. Indole Acetic Acid plays a vital role in the growth and development of both roots and shoot in plants [25]. For example, it helps in the elongation of roots, the development of more and more root hairs which facilitates the transportation of water and minerals from the soil through the xylem. IAA induces cell division, cell elongation, tissue differentiation, inhibition of axillary buds by changing a few conditions like increasing the osmotic concentration and water permeability of the cell, specific RNA and protein synthesis, increasing more and more cell wall synthesis [19].

Phosphate solubilization

Phosphorus (P) is another very important nutrient necessary for growth in plants after nitrogen (N). It is only 0.2% (w/w) of plant dry weight. (Kumar et al., 2014). It plays an important irreplaceable role in our ecosystem. It helps in the process of photosynthesis, respiration, biosynthesis of macromolecules, energy transfer, etc. Phosphorus (P) is present in huge amounts in soil mainly in two forms being inorganic P (P_i) and organic P (P_o). Yet 95-99% of Phosphorus plants cannot use it as it is in an insoluble, immobilized and in form of precipitate. The average P content in soil is nearly 0.05% (w/w). Nevertheless, only 0.1% of P can be utilized by plants [19]. Chemical fertilizer is rich in phosphate ions available to plants are extremely reactive and they react with Ca^{2+} , Fe^{3+} , and Al^{3+} ions in the soil to form insoluble phosphate salt complexes. The efficiency of the plant to absorb P from chemical fertilizers is only 5–25% [21] leading to the loss of soil fertility. Plant growth-promoting bacteria recruit different action plans to use an unavailable form of phosphorus and satisfy the requirements of Phosphorus P by plants through dissolution and absorption. The usage of PGPR helps to maintain the pH of the soil and forms a micro area of Phosphorus P around the plant rhizosphere. This improves soil quality and strengthens the activity of other beneficial microorganisms, such as Rhizobium and Trichoderma. Thus the management of the PGPR promotes the absorption of nutritive element ions [26]. Production of secondary metabolites having antimicrobial activities. Secondary metabolites are being the subject of many research studies because these compounds exhibit many biological activities. These include antimicrobial, antifungal, anticancer, and anti-inflammatory activities. The different types of secondary metabolites secreted are Alkaloids, flavonoids, Methanol, Tannins, etc [26].

APPLICATION OF PGPR

As it is been cited that using PGPR for improving crop manufacturing, thus reducing the want for chemical fertilizers is very useful for sustaining crops [27]. Inoculation of the seed with ACC- Deaminase helps to reduce ethylene levels in plants. It promotes growth in plants in stressful biotic and abiotic conditions [8]. Rhizobacteria can be commonly used as a biocontrol agents protecting plants from different variety of microbial pesticides [7]. They are like rays of hope in weed control of economically important crops. Hydrogen cyanide (HCN) is an antibiotic produced by gram negative biocontrol bacteria. These unwanted plants which grow along with the main crops are thus suppressed by these volatile compounds. Thus PGPR has not only increased harvest index, and protein content but has decreased fertilizer doses but has also shown differential complementary abilities too.



CONCLUSION

The modern agricultural practice has increased crop production but it resulted in many other related problems such as depletion of soil fertility, increase in soil salinization, soil and water pollution nutrient imbalance, the emergence of new pests and diseases and above all environmental degradation. So for the sustenance of life on Earth natural fertilizers proved to be an integral part of agriculture. These plant growth-promoting rhizobacteria (PGPR) can be efficiently used as a biocontrol in the present scenario to improve crop yield. Awareness has to be created among farmers by guiding how to make these biofertilizers are an intrinsic part of their farming. Small efforts can bring change in their agricultural practices and can reduce environmental pollution like to reduce the emission of greenhouse gases like nitrous oxide(N₂O) which warms our planet 300 times more than CO₂. Plant growth-promoting rhizobacteria help in nitrogen fixation and phosphorus solubilization but very soon research must be done on potassium solubilization, which is the third major essential macro-nutrient for plant growth. Thus these bioagents are economical and will also create confidence among the farmers for their use.

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