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Importance Of PGPR (Plant Growth Promoting Rhizobacteria) For Sustainable Agricultural Production

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Abstract:

The utilization of excessive synthetic chemical fertilizers in crop fields to get a high level of yield reduces the quality of soil as well as crops. The modern and sustainable cultivation technique must increase the utilization of organic fertilization. Rhizobacteria are very efficient microorganisms that decrease the nitrogenous content in crops and provide harmless food for mankind. Plant growth-promoting rhizobacteria enhance crop yield and quality, and also protect from plant diseases. This organic fertilizer also reduces environmental pollution; hence it is eco-friendly. Plant Growth Promoting Rhizobacteria (PGPR) has gathered significant attention in agricultural research for their positive impacts on plant growth and yield. This review aims to explore and analyze the effect of PGPR on the cultivation of rice and legumes, emphasizing the mechanisms underlying their beneficial impacts, and discussing potential applications in sustainable agricultural systems and future application perspectives.

Keywords: Rhizobacteria, Plant growth promoting rhizobacteria, nitrogen fixation, phosphate solubilization.

Introduction:

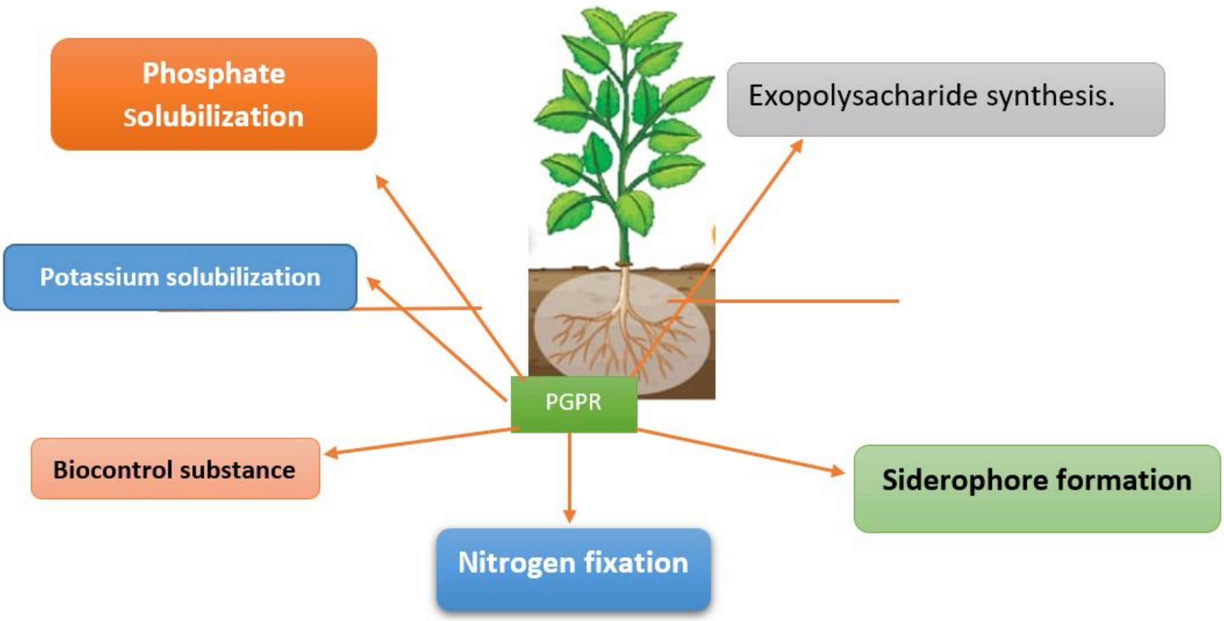
Rice is a key food commodity for the human population and is considered an essential crop for food security (IRRI International Rice Research Institute, 2016). Excessive N- and P-based fertilizer use to maintain and/or boost productivity has resulted in unprecedented soil and water contamination, harming ecosystems, polluting the environment, and spreading disease. Inadequate soil management is also frequently associated with depletion of nutrients, acidification of soil, etc.(Basosi et al., 2014). Excessive consumption of high-nitrate diets can cause various diseases such as thyroid disorders, diabetes, and certain types of cancer. (Ahmed et al., 2017). Additionally, the excessive use of Synthetic chemical fertilizers has disrupted the global nitrogen cycle, increasing greenhouse gas emissions, reducing stratospheric ozone, decreasing soil organic content, etc. (Hakeem et al., 2016; Singh, 2018).

Microorganisms are critical for the maintenance and health of soil function in both natural and managed agricultural systems because they participate in fundamental processes such as soil structure formation, organic matter decomposition, toxin removal, plant disease suppression, and overall C, N, P, and S cycling. Some bacterial populations in the soil microbiota have been found. They colonize plant roots in a competitive manner, promote growth, and minimize the occurrence of plant illnesses. These bacteria are known as plant growth-promoting rhizobacteria (Olanrewaju et al., 2017).

The utilization of bioinoculants (Bacteria) has greatly assisted in preventing this abiotic climate change that reduces the capacity of plants to perform as a whole under stress (Staudinger et al. 2016).

The interaction between plants and rhizobacteria that promote plant growth:

Root metabolism occurs in a thin layer of soil immediately near the plant roots. Rhizosphere refers to the living area of soil around a plant's roots. Rhizobacteria are helpful microorganisms that live in the rhizosphere. These bacteria have gotten a lot of attention because of their profound impact on plant health, growth, and development. Plant performance and agricultural sustainability are improved by the interaction between PGPR and plants, Which is characterized by a complex network of physiological, biochemical, and molecular reactions.



Mechanisms of PGPR Action:

Rhizobacteria that promote plant growth are beneficial microorganisms that benefit plants through multiple methods, including improved nutrient uptake, stress tolerance, and growth. They cannot promote sustainable agriculture practices without these systems.

Biological Nitrogen Fixation:

Since atmospheric nitrogen (N2) is comparatively inert and cannot be directly absorbed by most plants, it is a necessary ingredient for plant growth. Some PGPR may fix ambient nitrogen to produce ammonia or ammonium ions, which are easily absorbed by plants. In addition to giving plants a direct supply of nitrogen, biological nitrogen fixation lessens the need for synthetic nitrogen fertilizers, which are energy-intensive to make and may pollute the environment. Smith, S. E., & Read, D. J. (2008).

Biochemical nitrogen fixation is thought to be one of the main ways that plants benefit from photosynthesis-induced photosynthesis reaction (PGPR).

A lot of the mechanisms involved in crop production require nitrogen (N). (Bhavya, K.et al.2021). Nitrogen has become more and more necessary as the demand for food rises.(Riaz, U et al.2021). The application of additional nitrogen fertilizer can increase the yield of rice, maize, potatoes, and wheat crops. Nitrogen is the most significant nutrient required in high quantities for maize production since it is required for the synthesis of nucleic acids, adenosine triphosphate (ATP), chlorophyll, and amino acids. Therefore, the potential yield of maize growth directly relates to the amount of nitrogen fertilizer used (de Andrade, L. A. et al). One way to lessen dependency on chemical nitrogen fertilizers is through biological nitrogen fixation or BNF. Furthermore, nearly 60% of Earth's fixed N is found in BNF. Because of this, it is essential to maximize BNF in agriculture in order to meet the world's population's growing demand for food production.

Plant Growth Hormones Production:
Plant growth and development are controlled significantly by some chemical factors produced by plants, called phytohormones**.** (Santner et al., 2009). Plant regulatory processes may be modulated through the synthesis of hormones or other chemicals that affect plant growth as one method of improving plant development. (Van Loon, 2007). Numerous bacterial strains are capable of producing ethylene and/or auxins. Additionally, there have been reports of the production of gibberellin and cytokinin. (Van Loon, 2007). Treatment of Arabidopsis seedlings with WCS417 resulted in notable growth promotion. The WCS417 strain's capacity to produce auxins, which are known to encourage the production of lateral roots, maybe the cause of this growth promotion. (Tanimoto 2005)

Enhance Root Architecture with PGPR
Drought primarily affects the root system because of its direct contact with the soil. One significant way that plants respond to water shortages is by altering the architecture of their root systems (RSA) (Huang, X.F, Grover, M.). Numerous studies have demonstrated that osmotolerant PGPR strains are a good way to boost plant growth and root-stock tolerance (RSA) when injected into stressed plants. As a result of the growth of roots and the production of absorptive hairs, the amount of soil surface that the roots occupy increases, improving the absorption capacity of plants. (Timmusk, S, Ambreetha, S). By secreting low-molecular-weight signaling chemicals like 2,4-diacetylphloroglucinol (DAPG), which is produced by fluorescent Pseudomonas, PGPR can alter the root architecture.(Turan, M).

Germination Enhancement:
An essential phase of the plant life cycle is seed germination. The growth and yield of a plant can be greatly influenced by the unique performance of each plant in the early phases of its existence. Numerous studies have demonstrated the effectiveness of PGPR in accelerating seed germination. Higher germination rates are indicative of improved seedling growth and development, which is critical for increased agricultural yields. (Ansari, F.A, Bakhshandeh, E, Tiwari, S., Saadaoui, N).

Phosphate Solubilization:
The two main elements that rice needs are phosphorus (P) and nitrogen (N), albeit these are only found in small amounts in areas where rice is grown. One significant family of Rhizobacteria that promotes plant growth is composed of Phosphate Solubilizing Rhizobacteria (PSRB). These are well known for improving P and N absorption, which promotes plant development. Currently, PSRBs are applied as biofertilizers to improve the condition of the soil (Gupta, R. et al). Identification, characterization, and optimization of these microorganisms' capacity to solubilize phosphate at various pH, temperature, and salt concentrations were done as part of the current study.

Biocontrol and Antibiotic Production:
A portion of PGPR generates antimicrobial substances that stop the spread of harmful bacteria. These bioactive metabolites consist of lytic enzymes, siderophores (compounds that chelate iron), and antibiotics. By inhibiting the development of plant pathogens, PGPR helps to prevent illness and lower agricultural losses (Raaijmakers, J. M. et al.). Diseases that are carried by the soil have a catastrophic impact on the growth and output of plants. It has been documented that PGPR strains cause plants to develop resistance to infections of viruses, bacteria, and fungi (Liu et al., 1995). Maurhofer et al.,). It is well known that rhizobacteria that promote plant growth reduce the number of harmful organisms by generating toxic substances (Glick, 1995; Kloepper, 1996). The synthesis of antibiotics by PGPR represents a significant facet of biological control. But sometimes it's really hard to tell the difference between antibiosis and competitiveness. Many papers claim that the production of antibiotics (such as pyrrolinitrin) by rhizobacteria suppresses harmful organisms. (Pierson and Thomashow, 1992; Kloepper, 1993; Subba Rao, 1993; Glick, 1995; Thomashow and Weller, 1995).

Enhanced nutrient uptake:
Rhizobacteria may stimulate plant growth through their metabolic processes (fixing nitrogen, producing hormones, or solubilizing phosphates), by directly altering the plant's metabolic processes (increasing the uptake of water and minerals), encouraging root development, increasing enzymatic activity in the plant, "helping" other helpful bacteria boost their impact on the plant, "assisting" plant pathogens, or any combination of these techniques.(Perez-Montano F , Vocciante M, Bhanse P). Furthermore, they have the ability to alter the rhizosphere (the area of soil around the roots) in order to release nutrients from organic matter and make them accessible to plants Vessey, J. K. (2003).

Siderophore production (Iron chelation):
Iron serves as a cofactor for proteins involved in an array of vital metabolic activities, such as photosynthesis and respiration, and is required for plant growth and development. Iron is the 4th most prevalent element in the earth's crust. Unfortunately, some part of iron in the form of ferric ions (Fe^{3+}) is digested by living organisms (Ammari and Mengel, 2006). In order to get around this obstacle and provide the plant with what it needs in terms of iron, PGPR has created a variety of iron uptake techniques. One of these techniques is the generation of siderophores. Siderophores are small organic substances produced by microorganisms in iron-limited conditions that accelerate iron absorption. (Whipps, 2001; Li et al., 2016).

Future prospects and challenges:
The availability of numerous commercial PGPR formulations demonstrates its suitability for use in contemporary agriculture. To enhance formulations, comprehend interactions with other agricultural methods, and customize PGPR solutions to particular crop and environmental situations, further study is nonetheless required. We should promote the successful implementation of the PGPR in the primary agricultural system in light of the beneficial services it provides (in relation to biofertilization, biopesticide, phytostimulant, and bioremediation), which are beneficial to crop productivity and sustainable agriculture. The quest for new PGPR strains for biofertilizers, as well as the compilation of microbial diversity maps for any place, may also be beneficial. To improve agricultural sustainability and microbial diversity, innovative simulation models that assess the behavior of microorganisms under varied edapho-climatic settings may be beneficial. These models can be created by extensive testing and technical calibrations

Conclusion:

A viable path to achieve sustainable agricultural output is through rhizobacteria that promote plant growth. They serve an array of functions in modern agricultural systems, including nutrient management, disease prevention, stress tolerance, and environmental protection. Utilizing PGPR's potential can help create a more durable and environmentally conscious agriculture system, paving the road for a sustainable future.

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