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Plant Growth Promoting Rhizobacteria: A boon for farmers and environment

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Plants need nutrients for their proper growth and development. These nutrients are classified as macronutrients and micronutrients. To provide these nutrients to plants different chemical fertilizers are available which farmers are using on their crops. India is one of the largest consumers of fertilizers in the world. As per the latest data shared by government, the use of chemical fertilizers has increased by 16% from 2015-16 to 2020-21. The consumption of chemical fertilizers increased from 510 Lakh Metric Tonnes (LMT) in 2015-16 to 590 LMT in 2020-21. Among all the chemical fertilizers such as Urea, NPK, DAP, and MOP, Urea is the most consumed chemical fertilizer with a consumption value of around 300 LMT per year. In 2019-20 Bihar consumed the highest amount of chemical fertilizers per hectare (245.25 Kg). The top five states in use of chemical fertilizers are Bihar, Pudduchary, Punjab, Haryana and Telangana. But these chemical fertilizers have many adverse effects on crop, soil and environment. Continuous use of these fertilizers reduce the soil fertility with time and contaminate ground water. Use of chemical fertilizers makes soil acidic and repels earthworms which are very essential for soil fertility. Due to acidity the microbial population of soil gets affected resulting in less nutrient availability. Runoff of these chemical fertilizers contaminate water bodies. Overuse of nitrogen fertilizers over the years has increased possibility of nitrate contamination of ground water. Contamination of groundwater and water bodies cause several human health issues. Therefore, there is need to reduce the use of these agrochemicals to safeguard human health and environment without any reduction in crop production.

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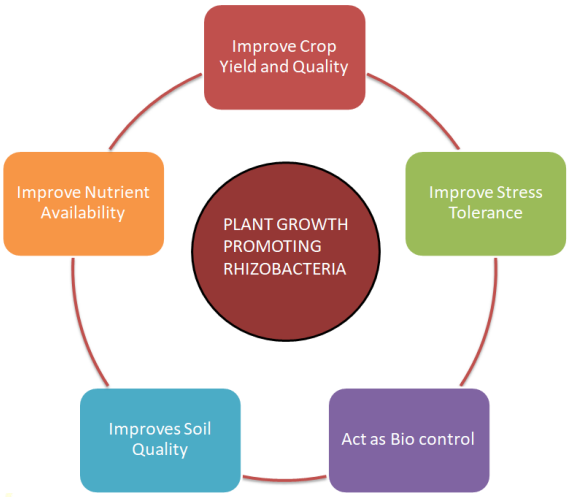
Biofertilizers are a good alternative to chemical fertilizers and pesticides. Biofertilizers contain living microorganisms which are added into soil or are used for seeds or seedlings treatment. Among biofertilizers plant growth promoting rhizobacteria are a good candidate. These are the microorganisms which colonize the rhizosphere of plants. The number of microorganisms is generally more in the vicinity of roots than other parts of soil as these microorganisms get nutrients from roots. These microorganisms increases plant growth and crop yield so are considered as Plant Growth Promoting Rhizobacteria (PGPR). Plant Growth Promoting Rhizobacteria are gaining very much importance all over the world for their benefits toward agriculture. These rhizobacteria are considered as a potential tool for promoting sustainable agriculture because of their eco friendly and efficient nature. PGPR enhance the plant growth by increasing the nutrient availability and by preventing plants from biotic and abiotic stresses. Use of PGPR also maintains the soil quality. PGPR based biofertilizers are better non hazardous and eco friendly alternative to the hazardous agrochemicals. The integrated use of these microorganisms use a combination of different mechanisms which are beneficial for the crop growth. These microorganisms can be used as both bio fertilizers and bio control agents to improve the agriculture.



Applications of PGPR

There are a number of mechanisms by which PGPR help the plants such as mineral acquisition (N, P, K, Zn and Fe), phytohormone production and by decreasing the inhibitory effects of various abiotic and biotic stresses.

Nitrogen fixation: Nitrogen is the most basic building block for all life forms. Atmosphere is the major source of nitrogen with a concentration of about 78 percent . This atmospheric nitrogen is present in gaseous form N_2 and is inaccessible by the life forms. Nitrogen from atmosphere is fixed by the process of Biological Nitrogen Fixation by microorganisms. Nitrogen fixation is considered as one of the most important interaction between

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microorganisms and plants. In this interaction nitrogen fixing microorganisms convert the atmospheric nitrogen (N_2) to others forms which can be utilised by plants. Microorganisms convert atmospheric nitrogen to ammonia with the help of nitrogenase enzyme. Most of the nitrogenous fixing bacteria such as *Rhizobium, Mesorhizobium* and *Bradyrhizobium* live in symbiotic association with the roots of leguminous plants where the plant provide the microbes energy through photosynthesis and bacteria supply the nitrogen in form of ammonia to plant. In natural terrestrial ecosystem, the amount of biological nitrogen fixation by legumes is estimated to be around 11.3-33.9 Kg N/ha/year. The another process is asymbiotic nitrogen fixation where there is no such relationship between the plant and bacteria, this includes microbes like lichens, blue green algae and free living soil bacteria.

Phosphorus solubilisation : Phosphorus (P) is considered as one of the most important nutrients required by plants for their growth and development. Phosphate availability is generally low in soils globally. Most soils are deficient of available phosphorus and can not provide enough P required by plants, if they are not fertilized. Most of the phosphorus in soil is in insoluble forms and is not available to plants. The phosphate solubilising bacteria (PSB) such as microbes of genera (*Pseudomonas* and *Bacillus*) can solubilise the insoluble phosphorus and make it available to the plants. Phosphorus is usually absorbed by plants in certain defined conditions such as at pH range of 6.5-7 as H_2PO_4 and HPO_4^-. If soil pH is more than 7 phosphorus gets immobilized as calcium phosphate and if pH level drops, it will bound with other minerals like Aluminium, Iron and Molybdenum. PSB improve the phosphate availability to plants by decreasing the soil pH by the actions of organic and inorganic acids released by them and by releasing P-hydrolyzing enzymes like phosphatase and phytase which solubilise the immobilized phosphorus in available phosphorus forms.

Potassium solubilisation : Potassium (K) is the third most essential element to plants after Nitrogen and Phosphorus. Potassium constitutes around 2.6% of the earth crust which makes it the seventh most abundant element in the earth crust. Despite of this much abundance only 1 to 2% of this potassium is available to the plants and rest 98-99% is bound with other minerals and is not available for plant uptake. It is known that potassium solubilising bacteria (KSB) such as *Acidothiobacillus ferrooxidans, Bacillus mucilaginosus* and *B. circulans* have the ability to solubilise K rich minerals so that plants can utilize solubilised potassium which is an important element for crop growth. As phosphate solubilizing bacteria (PSB), KSB also

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solubilize K minerals by production of organic acids, inorganic acids and protons (H^+) which can effectively release K from K rich minerals

Zinc solubilisation: Usually in crops macronutrients such as N, P ,K are provided by highly efficient fertilizers but micronutrients are neglected. Zinc is one of such micronutrient required by plants in very minute concentration but is very crucial for plant growth and development. Most of the soil in world is zinc deficient because just like potassium zinc is also present in mineral forms which are unavailable for plant uptake. Inorganic chemical fertilizers are used to maintain zinc concentration but these are hazardous to environment. PGPR are found to solubilise unavailable zinc minerals through various reactions such as acidification, siderophore production and chelation. *Pseudomnas* sp., *Bacillus* sp. and *Rhizobium* sp. are considered as good zinc solubilising bacteria.

Siderophore production: For the photosynthetic organisms Iron (Fe) is a vital element. Iron is one of the most abundant elements present in the earth crust but is not accessible by the plants. PGPR are known to secrete some low molecular weight compounds named, siderophores which act as chelating agent and convert the inaccessible form of iron into the form that is suitable for uptake by the plants. *Desulfuromonas and Shewanella* are the most commonly known Fe reducing bacteria. Beside iron sequestration siderophores play an important role in preventing plants from biotic stresses by limiting the sufficient iron supply to the pathogenic microbes and reducing their survival.

Phytohormone production: Phytohormones are the naturally occurring chemical messengers which are very crucial for the regulation of plant development. Phytohormones regulates the cellular processes and gene expression which in turn affects plant growth. All important activities of plants like formation of leaves, flowering, fruit ripening are regulated by these phytohormones. Plants can reduce the negative effects of different stresses by adjusting the level of phytohormones. Microbes associated with plant roots are found to play role in alteration of phytohormone level such as Indole Acetic Acid (IAA) , gibberellic acid cytokinin and ethylene. These phytohormone help the plants with improved seed germination, increased root and shoot growth and tolerance toward abiotic and biotic stresses.

What an ideal PGPR biofertilizer should be?

An ideal PGPR biofertilizers should have:

- It should be able to promote the plant growth.

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- After inoculation it should colonize in the rhizosphere in significant number.
- It's interaction should be compatible with other microbes in the rhizosphere.
- It should be eco friendly .
- The microorganism should be tolerant to physiochemical factors like radiation, heat and desiccation.

Indian Council of Agricultural Research warned against the excessive use of chemical fertilizers. To reduce the use of chemical fertilizers ICAR recommended the soil test based management of nutrients by balanced use of organic and inorganic sources. Governments are promoting the use of biofertilizers as the eco friendly alternative to chemical fertilizers for sustainable agricultural practices. There should be conductance of public awareness programmes to educate farmers about the uses and advantages of these microbial formulations as fertilizers. Extensive research work should be done to commercialize these PGPR as biofertilizers and attention should be paid toward the improvement of strains of PGPR.

Government of India has introduced many schemes to encourage the use of biofertilizers instead of harmful chemical fertilizers. Few of those schemes are:

- Paramparagat Krishi Vikas Yojana (PKVY)
- National Mission on Oilseeds & Oil Palm (NMOOP)
- National Food Security Mission (NFSM)
- Under National Program of Organic Farming, Government of India is providing subsidy of 25% to establish the fertilizer production units through NABARD.

CCS Haryana Agricultural University has an biofertilizer production unit which is working under public-private production module with an annual production capacity of 2.5 Lakh Litres. In the year 2021-22. The university is also involved in popularization of biofertilizers through various extension activities like Krishi Mela and demonstration plots in the state.