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Role of PGPR in Sustainable Agriculture

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INTRODUCTION

Climate change is the burning threat to world's agricultural sustainability in the 21st century (IPCC). Drastic changes in various climatic factors (precipitation, temperature, light, etc.) can tremendously reduce the crop yields globally. India's food grain production is estimated to rise to 2.66 percent to new record of 305.43 million tonnes in the current crop year 2020-2021. Wheat production is estimated to rise to a record 109.24 MT in 2020-2021 from 107.86 MT in previous year. While rice production is pegged at a record 121.46 MT in 2020-2021 crop year as against 118.87 MT in the previous year. The improvement in crop yields under unfavourable conditions by conventional or non-conventional methods pose certain limitations in terms of ethical issues and time requirements. Among abiotic stress drought and extreme temperature are commonly faced by cereal crops (Wheat, Rice and Maize) specially in North India. Drought stress is one of the major agricultural problems reducing crop yield in arid and semiarid regions of the world. Changes in mean global air temperature and precipitation patterns are leading to longer drought periods and more extremely dry years, and more severe drought conditions will hinder food production in some countries. Drought stress tolerance is often a complex phenomenon involving clusters of gene networks. Although many of the networks are resolved by researchers, but still a large gap remains. Therefore, alternative eco-friendly approaches are much more appreciable at this time. One such strategy could be the use of stress-resistant plant growth promoting bacteria (PGPB) with critical roles in enhancing plant growth performance under stressed environments. At present, strategies to increase the ability of plants to tolerate drought stress involve the use of water-saving irrigation, traditional breeding, and genetic engineering of drought-tolerant transgenic plants.

Unfortunately, these methods are highly technical and labour-intensive, and thus difficult to apply in practice. One alternative for growing plants under dry conditions is the use of plant growth promoting rhizobacteria (PGPR), as the soil is a natural habitat of various micro-organisms, among them the bacterial species occupy the pre-dominant role. There are certain micro-organisms which can convert this elemental nitrogen to ammonia and make it available to plants. Among symbiotic nitrogen fixers like Rhizobium and free-living nitrogen fixers like Acetobacter sp. are obligatory aerobic, nitrogen-fixing bacteria that are known for producing acid as a result of metabolic processes. Acetobacter diazotrophicus is also a plant endophyte and has been said to be capable of excreting about half of its fixed nitrogen in a form that plants can use and associated nitrogen fixers like Azospirillium, they play a very important role in maintaining the crop productivity and soil fertility. The soil around the roots is called as rhizosphere, which plays an important role. This is a zone where lots of micro-organisms help the overall productivity and plant health. Some of rhizoshere organisms effect the plant growth favourably and these are known as PGPRs (Plant Growth Promoting Rhizobacteria). PGPRs play a very important role in maintaining the soil health and sustainability. Few species of PGPRs are Rhizobium, Azetobacter, Azospirilluim, Enterobacter, Pseudomonas, Bacillus etc. The beneficial effects of PGPRs are like production of growth promoting substances such as IAA, Gibberellins, Cytokinin's etc; the production of siderophores, nitrogen fixation, enhance in total chlorophyll content, root elongation, increase in production of enzymes, antioxidants, cellular osmolytes and ACC Deaminase-Producing PGPR. The enzyme ACC deaminase catalyses the cleavage of 1-aminocyclopropane-1-carboxylate, an intermediate precursor of ethylene in higher plants, to produce α-ketobutyrate and ammonia. A proper amount of ethylene derived from the existing pool of ACC, or so called the small peak of ethylene in the biphasic ethylene response model described by Glick et al., (2007) and Pierik et al., (2006) is thought to be useful to plants in activating plant defensive responses to stress stimuli (e.g., temperature extremes, drought or flooding, insect pest damages, phytopathogens, and mechanical wounding). Many PGPR have been shown to alleviate drought stress effects in plants by reducing plant ethylene levels that are usually increased by unfavourable conditions (Dung Trinh et al., 2021).

The role of PGPRs in Drought Stress

In soil mineralization and nutrient recovery, the presence of a wide variety of insects, ants, termites, earthworms and, most importantly, microorganisms participate. Root-associated rhizobacteria are primarily responsible for synthesizing the many biomolecules that enhance the quality of soils. It stimulates plant growth as a result of nitrogen fixation, phytohormone production, mineral availability enhanced, as well as phytoremediation. The increased phosphate level available to plants is due to the P solubilization process that the PGPRs possess. PGPRs are also known to produce different volatile compounds and metabolites which improve the health of plants and soils.

These beneficial PGPRs colonize the rhizoshere of the plant and promote growth of plants through direct and or indirect mechanisms. The possible explanation for the mechanism of plant drought tolerance induced by rhizobacteria include: Production of phyto hormones like ABA, gibberellic acid, cytokinin's, IAA (Indole Acetic Acid), ACC deaminase to reduce the level of ethylene in the roots,induced systemic resistance (ISR) by bacterial compound. The rhizobacteria assemblages of many agricultural crops have been studied, and the use of PGPR holds promise for plant growth promotion and alleviation of plant drought stress. However, the drought-tolerant bacteria associated with crop species which are naturally adapted to drought, such as wheat, have not been explored.

Different beneficial mechanisms of PGPR

1. **Mineral solubilization by soil microbes**: The phosphate solubilizing bacteria (PSB) solubilize Ca, Fe, and Al inorganic soil phosphates by producing siderophores, many acids (organic), hydroxyl and carboxyl groups, and chelating them to the bound phosphates and calcium available. Potassium solubilizing bacteria (KSB) play an important role in K solubilization by solventing the fixed source of potassium from different minerals. This class of soils microbes mainly includes *Pseudomonas sp.*, *Bacillus circulans*, and *B. mucilaginosus*.

2. Biological nitrogen fixation: Nitrogen fixation is one of the most beneficial processes that rhizobacteria conduct. Rhizobium is able to convert gaseous nitrogen (N_2) to ammonia (NH_3) through nitrogen fixation, making it a nutrient accessible to the host plant that can sustain and promote the growth of plants. Legumes are popular nitrogen-fixing crops and have been used in crop rotation for centuries to preserve soil quality.

3. Siderophore production: The concentrated ionic form in the oxidized state of iron (Fe^{3+}) is capable of forming insoluble oxyhydroxides and hydroxides, contributing to unavailability to plants and microbes, while Fe^{2+} ionic phase with low pH is easily accessible and is more readily absorbed by plants. The iron absorption by bacteria and fungi is due to the presence of siderophores, which have iron chelate specificity and affinity.

4. PGPR as biocontrol agents: PGPR produces substances which protect against various diseases as well as PGPR may protect plants from pathogens by direct antagonistic interactions between the biocontrol agent and the pathogen, and by induction of host resistance. Disease is suppressed by systemic resistance caused by the synthesis of antifungal metabolites. Genetically engineered *Pseudomonas* biocontrol strains have been used to increase plant growth and improve the resilience of agricultural crops to diseases.

5. Plant growth regulator production: Such plant growth regulators also called exogenous plant hormones that are used to control plant growth and are essential steps to improve agricultural production. This is characterized as micro-organisms capable of producing or altering growth regulatory concentrations such as IAA, GA, cytokinins, and ethylene. Projected mechanism is the production of phytohormones (plant hormones), such as auxins, cytokinins, and GA.

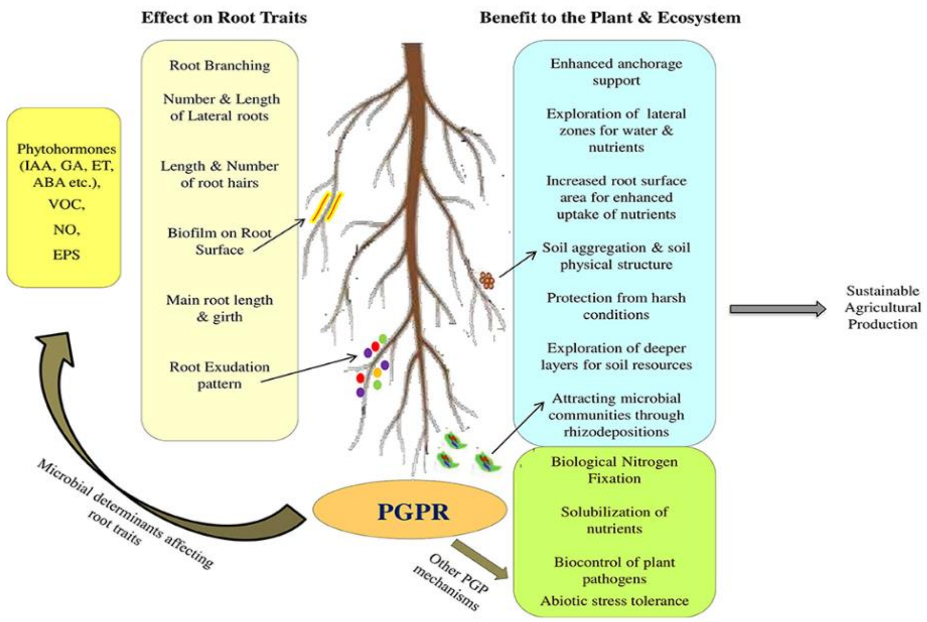

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Fig.1: Various roles of beneficial PGPR in sustainable Agriculture

Fig. 2: A close view of PGPR present on the root nodules of a desert plant

CONCLUSION

To replace chemical pesticides with the system of a bio pesticide should be more effective and economical. It has become apparent that PGPR strains employ several mechanisms to promote plant growth, although studies should be focused on the relative contribution of each mechanism responsible for effective plant growth promotion. 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. Current and future progress in our understanding of PGPR diversity, colonization ability, mechanisms of action, formulation, and application could facilitate their development as reliable components in the management of sustainable agricultural systems.

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