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Plant Rhizosphere Contribution to Sustainable Environment in Terms of Plant Growth Promoting Rhizobacteria (PGPR)

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Abstract
Plants play a crucial role in sustaining the environment, particularly through their rhizosphere, which hosts diverse plant growth-promoting rhizobacteria (PGPR). These microorganisms enhance plant growth by producing phytohormones, solubilizing nutrients, and suppressing pathogens. PGPR improve soil fertility and health, contributing to sustainable agricultural practices by reducing reliance on chemical fertilizers and pesticides. Their multifaceted interactions within the rhizosphere not only support plant resilience against environmental stresses but also promote ecological balance, making them vital for sustainable agricultural systems and environmental conservation.

Keywords: Rhizosphere, PGPR, sustainability, plant growth.

1. INTRODUCTION

The soil is an essential factor for plants to grow and a good habitat for different microorganisms. Plant root zone (rhizosphere) have the diversity of microbes, so the plant and microbial interaction is influenced by many abiotic and biotic factors in the soil. The rhizosphere, the narrow region of soil that surrounds plant roots, plays a crucial role in supporting plant growth and overall ecosystem health. One of the key components of the rhizosphere that contributes to plant growth and sustainability is plant growth promoting rhizobacteria (PGPR). PGPR are beneficial soil bacteria that colonize the rhizosphere and enhance plant growth through various mechanisms, such as nutrient cycling, disease suppression, and hormone production.

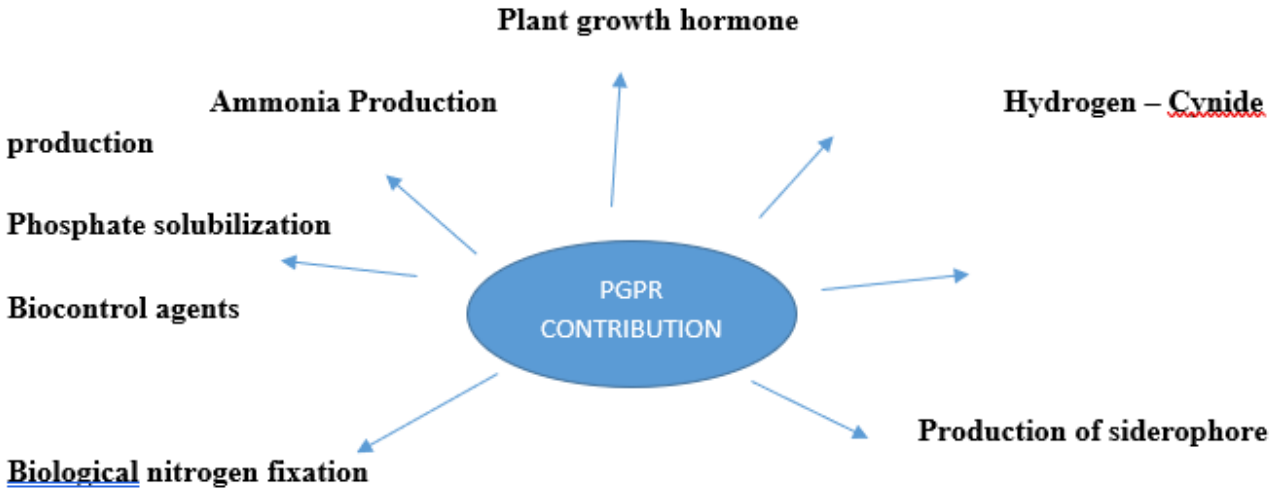
Diverse communities of beneficial soil microorganisms are associated with the root systems of all higher plants (Khalid et al.,2006). Bacterial population in Rhizosphere is influenced by the root which forms the niche for these organisms Hiltner (1904). Plant Growth-Promoting Rhizobacteria (PGPR), the word was coined Kloepper and Schroth (1981). These bacteria inhabit the rhizosphere and are pivotal in enhancing plant growth and health, thereby contributing to a more sustainable agricultural environment. The mechanisms by which PGPR promote plant growth include nutrient solubilization, phytohormone production, and pathogen suppression, which collectively improve soil fertility and crop yield while reducing the reliance on chemical fertilizers and pesticides.

The increasing pressure on agricultural systems due to climate change, soil degradation, and the overuse of synthetic inputs has sparked interest in sustainable alternatives. PGPR offer a dual benefit as both biofertilizers and biocontrol agents. They facilitate nutrient availability by converting unavailable forms

of essential nutrients such as nitrogen and phosphorus into forms that plants can readily absorb. Additionally, PGPR produce various phytohormones that stimulate root development and enhance plant resilience against biotic and abiotic stresses, including drought and salinity**.**

2. Contributions of PGPR

1. **Biological nitrogen fixation:** A number of bacterial species belonging to genera Azospirillum, Alcaligenes, Arthrobacter, Acinetobacter, Bacillus, Burkholderia, Enterobacter, Erwinia, Flavobacterium, Pseudomonas, Rhizobium and Serratia are associated with the plant rhizosphere and are able to exert a beneficial effect on plant growth. These are divided into two major contributors; A) symbiotic nitrogen fixers and B) Non symbiotic nitrogen fixers. Different PGPR activities can be detected with the help of Jenson Medium (Jenson 1954)
2. **Plant growth hormone:** Plant hormones are chemical messengers that affect a plant's ability to respond to its environment. Hormones are organic compounds that are effective at very low concentration; they are usually synthesized in one part of the plant and are transported to another location.IAA (indole-3-acetic acid) is a member of the group of phytohormones and is generally considered the most important native Auxin. IAA production test can be done according to Gorden and Weber (1951)
3. **Production of Siderophores:** iron is an essential growth element for all living organisms. The scarcity of bioavailable iron in soil habitats and on plant surfaces foments a - furious competition. Under iron-limiting conditions, PGPB produce low-molecular-weight compounds called siderophores to competitively acquire ferric ion. Siderophores (Greek: "iron carrier") are small, high-affinity iron chelating compounds secreted by microorganisms such as bacteria, fungi and grasses.
4. **Phosphate solubilization:**
   Rhizobium and phosphorus (P) solubilizing bacteria are important to plant nutrition. These microbes also play a significant role as PGPR in the biofertilization of crops. These bacteria secrete different types of organic acids (e.g., carboxylic acid) thus lowering the pH in the rhizosphere and consequently release the bound forms of phosphate like Ca3 (PO4)2 in the calcareous soils. Utilization of these microorganisms as environment-friendly biofertilizer helps to reduce the use of expensive phosphatic fertilizers. Phosphorus biofertilizers could help increase the availability of accumulated phosphate (by solubilization), increase the efficiency of biological nitrogen fixation and render availability of Fe, Zn, etc., through the production of plant growth promoting substances. Phosphate solubilizing activity can be analysed according Pikovaskaya (1948)
5. **Biocontrol agents**: PGPR are indigenous to soil and the plant rhizosphere and play a major role in the biocontrol of plant pathogens. They can suppress a broad spectrum of bacterial, fungal and nematode diseases. PGPR can also provide protection against viral diseases. The use of PGPR has become a common practice in many regions of the world.
6. **Hydrogen – Cynide production:** The HCN production also occur in some stains which can be noticed as per the Lorck (1948)
7. **Ammonia Production:** Some bacterial strains have ability to produce ammonia and it can be observed by the method given by Cappuccino and Shermon (1992)



NOTE: Image Reference -The Role of Plant Growth-Promoting Rhizobacteria (PGPR) in Mitigating Plant's Environmental Stresses .(RHizobiome 2023,Science direct)

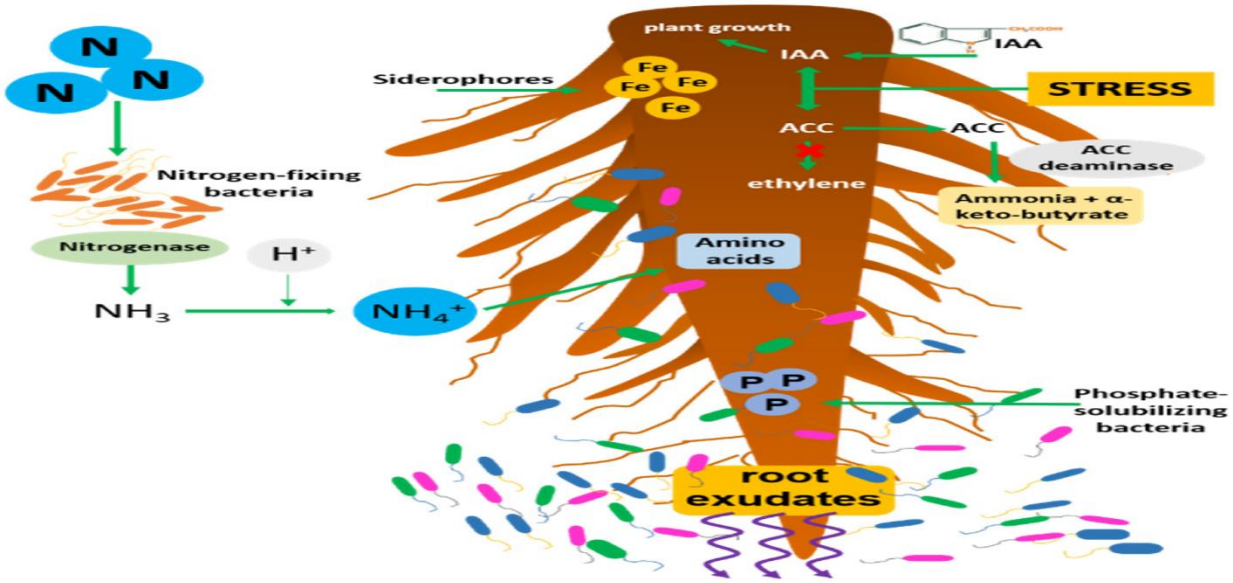


Image showing PGPR and their interactions with the root system; nitrogen-fixation, phosphate solubilization, iron uptake by siderophores, ACC deaminase activity lowering ethylene levels, IAA production stimulating plant cell growth.

Conclusion:

The connections between plants and the Phyto microbiome go back millions of years, showcasing a prolonged period of coevolution. Evolution operates in practical, random, and unyielding ways, suggesting that we will likely uncover many new and sometimes unexpected relationships that benefit crops and, consequently, global food production. It is evident that the Phyto microbiome holds significant promise for developing more sustainable crop management techniques. However, it is also apparent that our current understanding is limited, and there is much more to be explored.

Overall, the presence of PGPR in the rhizosphere is essential for maintaining a sustainable environment and promoting plant growth. By harnessing the beneficial effects of these bacteria, farmers can reduce their reliance on synthetic inputs and improve the overall health of their crops and soil. Incorporating PGPR into agricultural practices can lead to more resilient and productive ecosystems, ultimately contributing to a more sustainable and environmentally friendly approach to farming.

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