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Role of PGPRs in Augmenting Soil Macronutrients

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***Abstract:** The current crop land is under severe stress on account of excessive use of chemical fertilisers and conversion of more forest land to crops will make the carbon sinks of the world into carbon emitters. The only alternative is to use innovative means of retaining productivity of the existing arable land without having to use more chemical fertilisers. As a low hanging fruit to solve the current crisis like situation, the most accessible alternative towards environmentally less damaging and sustainable crop output growth is the use of plant growth promoting rhizobacteria (PGPR) as supplements in soil to maintain and improve soil health. Plant Growth Promoting Rhizobacteria (PGPR) are a microbial group with ability to colonize plant roots, influence plant growth through various direct and indirect mechanisms and act as a defence against diseases and pests. The direct mechanisms include Nitrogen fixation, Phosphate and Potassium solubilization, Phytohormone production, Siderophore production while the indirect mechanisms include Antibiotic and hydrolytic enzymes production and Induced Systemic Resistance, etc.*

***Keywords:** plant growth promoting rhizobacteria (PGPR), Nitrogen fixation, Phosphate solubilisation, Potassium solubilization.*

1. INTRODUCTION

The increasing population and the fast-changing food habits towards high animal protein and processed diets is putting a strain on the ability of the old Green revolution mode of crop production to feed the world in the coming decades. Added to this is the damage Climate change is causing - and expected to cause much more in the coming decades - to crop yields, biodiversity, arable land, water availability/scarcity and temperature extremes. (Lobell et al., 2011; Lipper et al., 2014)

There are severe limitations and huge environmental cost attached to increasing the area under crop production and more intensive usage of the existing arable land. Rather, the current crop production systems are themselves a major contributor to climate change and other negative environmental impacts through shrinking biodiversity, physical degradation of the soil, high acidity and salinity of the soil, ground water depletion and its pollution, etc. The current fertilisers and pesticides in use are essentially drawn from high GHG emitting fossil fuels like natural gas and crude oil. Even the hydrogen used in chemical fertilizer manufacture (ammonia) is derived from fossil fuels.

The current crop production practices are a cause of climate change, and the consequence of climate change is that yields/output under current crop production practices will drop across almost the entire crop producing belts of world.

2. PGPRS TO THE RESCUE

Among the most accessible alternative towards environmentally less damaging and sustainable crop output growth is the use of plant growth promoting rhizobacteria (PGPR). Plant Growth Promoting Rhizobacteria (PGPR) represent one such microbial group with ability to colonize plant roots, influence plant growth through various direct and indirect mechanisms and act as a defence against diseases and pests. The direct mechanisms include Nitrogen fixation, Phosphate and Potassium solubilization, Phytohormone production, Siderophore production while the indirect mechanisms include Antibiotic and hydrolytic enzymes production and Induced Systemic Resistance, etc.

PGPRs are the free living rhizobacteria that provide beneficial effects through improve water and nutrient uptake, abiotic and biotic stress tolerance. Numerous soil bacteria have been reported to promote plant growth and development

3. PLANT-GROWTH-PROMOTING RHIZOBACTERIA (PGPR) AS FERTILISERS

PGPRs are the most common biofertilizers, acting by plant rhizosphere colonization, making the plant 'productive' as in increased plant growth and 'robust' as in strong against natural pathogens and external stresses like drought, extreme heat/cold or hither precipitations. The plant growth promotion happens through increased seed germination rate, wider/deeper spread of the root, higher grain/fruit yield and nutrient content, chlorophyll content and area of the leaf, water flow through the root and the stem, climate tolerance, timing of senescence, etc.

Some commonly usable PGPR microbes are:

Plant Growth Promoting Rhizobacteria	Functional Usage in the Plants
Azotobacter chroococcum	nitrogen fertilisers

Plant Growth Promoting Rhizobacteria	Functional Usage in the Plants
A. vinelandii	Nitrogen fertilisers
Bacillus megaterium	Phosphorous fertiliser
B. amyloliquefaciens	Phosphorus fertiliser
Pseudomonas fluorescens	Phosphorus fertiliser
Frateuria aurantia	Potassium fertilisers
Thiobacillus thiooxidans	Zinc, Sulphur, Silicate fertilisers
Delfia acidovorans	Zinc, Sulphur, Silicate fertilisers

4. EFFICIENT AND SUSTAINABLE NITROGEN FIXATION/NUTRIENT ACQUISITION

The key nutrient for crop production, including photosynthesis and protein synthesis, is Nitrogen (N). Despite being present in abundance in the atmosphere plants are unable to use it directly because of N2 triple covalent bond. As soil needs copious amounts of nitrogen to remain healthy after each harvest in under intensive agriculture practice, this nitrogen is supplemented artificially through chemical based nitrogen fertilisers, essentially ammonia.

By its very nature this chemical ammonia is utilized by the plant only to the extent of 50 per cent, the other half remaining in the soil causing ill effects like eutrophication or removed by polluting surface and ground water as runoff and leaching or directly into the atmosphere as a GHG N2O. Incidentally N2O is 265 times higher heat trapping compared to the much-maligned CO2. (Bouchet et al., 2016)

It is therefore essential to make the crop production process sustainable with increasing yields/total output per hectare of land without harming the soil, polluting ground and surface water, and without adding to the GHG load of the process of crop production. Natural alternatives to fix atmospheric Nitrogen on a scale to match the crop nutrient need have to be worked on.

Some phytomicrobiomes have shown potential to increase nitrogen use efficiency (NUE), reducing the need for chemical soil nitrogen supplements. The two mechanisms are, directly fixing atmospheric nitrogen through legume-*rhizobium* route or by assisting the nitrogen fixers through their secretions The 'Nitrogen Fixer', based on the type of their association with the plant, are either the symbionts or the free-living nitrogen fixers.

Examples of symbiotic nitrogen fixers are *Rhizobium, Sinorhizobium, Azoarcus, Mesorhizobium, Frankia, Allorhizobium, Bradyrhizobium, Burkholderia and Azorhizobium.* Some free living nitrogen fixers are: *Azoarcus, Herbaspirillum., Gluconacetobacter, Azospirillum, and Azotobacter.* (Vessey, 2003; Babalola, 2010; Pérez-Montaño et al., 2014; Turan et al., 2016)

As per many crop specific experiments and field trials, application of PGPRs reduces the per unit requirement of chemical fertilizers. For example, PGPR inoculants on tomato combined with 25 percent lower chemical fertilizer yielded the same yield, growth, and nutrient uptake. PGPR inoculation with AMF produced same output with 30 per cent lower fertilizer requirement. Maize yield and biomass production increased by 11.7 and 17.9 per cent respectively at 20 per cent lower chemical fertilizer input if PGPR application was in place. (Adesemoye et al., 2009)

5. PHOSPHORUS SOLUBILIZATION

After Nitrogen, Phosphorus (P) is the second essential macronutrient required by plants. Poor solubility severely limits phosphorus availability to the plant, thus necessitating application of phosphorus-based chemical fertilizers for it to be immediately available to the plant. Residual phosphorus ends up being a pollutant of water. (Azziz et al., 2012; Tak et al., 2012)

A range of Bacteria/Microbes (PSB/M) and fungi present in the soil and in the plant, roots can solubilize soil phosphorus. PSMs essentially solubilize phosphorus by producing metabolites – intermediate products of metabolic reactions catalyzed by various enzymes that naturally occur within cells. Phosphorus dissolving happens through compounds such as organic acids, siderophores, protons, hydroxyl ions and CO2. Organic acids and carboxyl and hydroxyl ions chelate the cations to release Phosphorus.

Some of the phosphorus solubilizing Microbes – Bacteria and Fungi - are *Bacillus circulans, Agrobacterium spp, Pseudomonas spp, Bacillus, Rhizobium, Paenibacillus, Burkholderia, Azotobacter, Enterobacter, Erwinia, Alternaria, Achrothcium, Aspergillus, Cephalosporium, Arthrobotrys, Curvularia, Cladosporium, Rhizopus, Chaetomium, Cunninghamella, Glomus, Helminthosporium, Fusarium, Micromonospora, Mortierella, Myrothecium, Penicillium, Phoma, Pythium, Pichia fermentans, Populospora, Rhizoctonia, Trichoderma*

In some studies Phosphorus requirement has come down by upto 25 per cent if PGPRs are used and by upto 50 per cent with AMF co-inoculation (Sundara et al., 2002; Khan et al., 2009).

6. POTASSIUM SOLUBILIZATION

Potassium (K) is the third of the key nutrients essential for plant growth, metabolism and development. Potassium helps the plant in resistance to diseases, pests, and abiotic stresses and by activating different enzymes essential energy metabolism, starch synthesis, nitrate reduction, photosynthesis, and sugar degradation. From Indian point of view, most of the soil is K deficient and this deficiency is getting worsc because of imbalanced NPK usage, quick depletion of available soil soluble K because intensive crop production and burning rather than reuse of crop residue.

As a total Potassium is present in abundance in soils but only a fraction is available to be absorbed by plants directly. Most of potassium in soil is bound with other minerals.

It is now established through recent studies of various soil processes that a range of microorganisms like saprophytic bacteria, Fungi and actinomycetes can make the K present in the soil soluble and make it 'absorbable' by the plants. The meachnisms range from inorganic and organic acid production, poly-saccharides, chelation and many exchange reactions

Some K solubilizing bacteria (KSB) with reported beneficial impact are *B. mucilaginosus*, *B. circulanscan*, *B. edaphicus*, *Burkholderia, A. ferrooxidans*, *Arthrobacter* sp., *Enterobacter hormaechei*, *Paenibacillus mucilaginosus*, *P. frequentans*, *Cladosporium*, *Aminobacter*, *Sphingomonas*, *Burkholderia*, and *Paenibacillus glucanolyticus* (Vessey, 2003; Archana et al., 2012; Prajapati et al., 2013)

As means of sustainable nutrient health in soil the use of PGPM such as potassium solubilizing bacteria (PSB) can play a major crop production stabilization role.

7. CONCLUSION

Usage of PGPRs has shown promise in actual field situations in reducing the need for chemicals sometimes by upto 50 per cent for the same crop yield. They also have long term advantages that they leave the soil nutrient rich and do not harm the surface and ground water.

Phytomicrobiome and the relationship between rhizomicrobiome members and plants have indicated of potential to use this category of organisms to increase crop production in a sustainable manner. The mechanism of action of microbes for plant nutrient acquisition is through higher surface area availability for plant roots, N2 fixation, P and K-solubilization, siderophore production and HCN production.

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