IMPORTANT PHOSPHATE SOLUBILIZING MICROBES FOR AGRICULTURE

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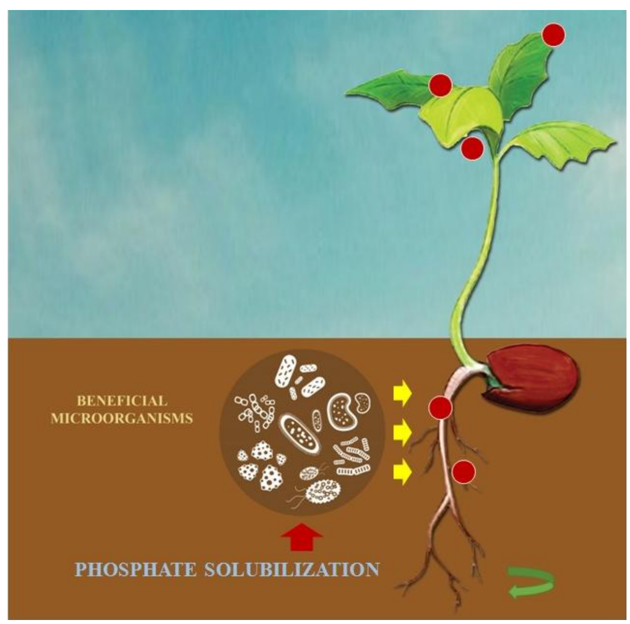
Soil microorganisms mediate a number of biochemical reactions and thus act as a sink and source of Phosphate (P) in soil. The phosphate solubilizing microorganisms (PSM) are the important contributors to soil P pools which constitute 0.4% to 2.4% of total P in arable soils. They also decompose the organic residue by immobilization and mineralization thus maintaining equilibrium with soil solution P pools. Phosphorus solubilization is carried out by a large number of saprophytic bacteria and fungi acting on sparingly soluble soil phosphates, mainly by chelation-mediated mechanisms. Phosphorus solubilizing activity is determined by the ability of microbes to release metabolites such as organic acids, which through their hydroxyl and carboxyl groups chelate the cation bound to phosphate, the latter being converted to soluble forms. Organic acids produced by Phosphate solubilising bacteria (PSB) solubilize insoluble phosphates by lowering the pH, chelation of cations and competing with phosphate for adsorption sites in the soil. Inorganic P is solubilized by the action of organic and inorganic acids secreted by PSB in which hydroxyl and carboxyl groups of acids chelate cations (Al, Fe, Ca) and decrease the pH in basic soils.

Earlier studies have reported that cheap source of rock phosphate in India can be used with PSM which can give similar yield as that of superphosphate. Acidic soils predominantly found in tropical and subtropical soils are often extremely phosphorus-deficient with high phosphorus fixation capacities. Unlike other mineral nutrients in soil solution which are present in millimolar amounts, phosphorus is present only in micromolar or lesser quantities. The low levels of phosphorus are due to high reactivity of soluble phosphate with other elements. For instance, in acidic soils phosphorus is associated with aluminium and iron compounds, whereas calcium phosphate is the predominant form of inorganic phosphate in calcareous soils. Use of microbial inoculants (biofertilizers) including PSM in agriculture represents an environmentally friendly alternative to further applications of mineral fertilizers. Therefore phosphate solubilisation with microbes can siphon out appreciable amounts of nutrients from the natural reservoir and enrich the soil with the important but scarce nutrients. The crop microbial ecosystem can thus be energized in sustainable agriculture with considerable ecological stability and environmental quality (Khan et al., 2017). Phosphate-solubilizing microbes have the potential to increase the availability of soluble phosphate. Their activity enhance plant growth by increasing the efficiency of biological nitrogen fixation or enhancing the availability and crop uptake of other trace elements like iron, zinc, etc., and also by producing plant growth-promoting regulators.



(Source: microbebio.com)

ROLE OF DIFFERENT PSM IN AGRICULTURE

Several soil bacteria and a few species of fungi possess the ability to bring insoluble phosphate in soil into soluble forms by secreting organic acids.

Bacteria: Bacteria are more effective in solubilising insoluble phosphate compared to fungi. Among the different microorganisms, phosphate solubilizing bacteris (PSB) constitutes 1 to 50% of whole population. Among the different bacterial communities, *Bacillus* and *Psedumonas* are the effective phosphate solubilizers. The major strains from bacterial genera are *Bacillus megaterium*, *B. circulans*, *B.subtilis, B. polymyxa, B. sircalmous*, *Pseudomonas striata*, and *Enterobacter*. Research studies have proved that PSB like *P. putida, P. fluroescens* etc used in conjunction with single super phosphate (SSP) and rock phosphate can reduce P dose by 25 and 50%. Application of bacterial inoculants as bio fertilizers improves plant growth, plant available P, increase yield and also release indole acetic acid and gibberellic acid that cause growth and elongation of plant cell.

Fungi: Fungi are the second most important phosphate solubilising micro organisms. They constitute about 0.1 to 0.5% of whole microbial population as P solubilizers. Compared to bacteria they do not lose their P dissolving activity upon repeated sub culturing under laboratory conditions. The P solubilizing fungi produces more acids than bacteria and therefore exhibits more P solubilization activity. Fungi in soils are able to traverse long distance than bacteria are more important in P solubilization. Among the different fungi genera *Aspergillus sp., Pencillium sp., Trichoderma sp., Mucor sp., Rhizocotonia solani* etc are the most promising strains of P solubilizers. Among the yeasts, *Yarrowis lipolytica*, *Schizosaccharomyces pombe* and *Pichiafermentans* have the ability to solubilize P. These fungi are known to increase plant growth by 5 to 20%.

Actinomycetes: Among the total population, 20% of actinomycetes are known to solubilize P. the common genera includes Streptomyces and Micromonospora.

Arbuscular mychrozzial fungi (AMF): Arbuscular mychrozzial fungi (AMF) colonise almost all the crop species in agriculture and exploit larger volume of soil for P uptake in P deficient soil. The microbial inocula consist of AMFs *Glomus manihotis* and *Entrophospora colombiana*. Positive response with application of phosphatic biofertilizers like phosphate solubilising microorganism (PSM) and VAM increases the solubility of native P and applied P. In general PSM constitutes 0.5 to 1.0% of soil microbial population with bacteria outnumbering fungi (2-150 fold). The crop species, in extremely low available soil P, develops root clusters effective in capturing P by releasing root exudates like organic anions, enzymes, phenolic acids and protons. The use of inoculants, AMF and plant growth promoting microbes play significant role in phosphate mineralization from both organic and inorganic sources.

Table 1: Biodiversity of PSM

Bacteria	*Alcaligenes sp., Aerobactor aerogenes, Achromobacter sp., Actinomadura oligospora, Agrobacterium sp., Azospirillum brasilense, Bacillus sp., Bacillus circulans, B.cereus, B.fusiformis, B. pumils, B. megaterium, B. mycoides, B. polymyxa, B. coagulans B,.chitinolyticus, B. subtilis, Bradyrhizobium sp., Brevibacterium sp., Citrobacter sp., Pseudomonas sp., P putida, P. striata, P. fluorescens, P. calcis, Flavobacterium sp., Nitrosomonas sp., Erwinia sp., Micrococcus sp., Escherichia intermedia, Enterobacter asburiae, Serratia phosphoticum, Nitrobacter sp., Thiobacillus ferroxidans, T. thioxidans, Rhizobium meliloti, Xanthomonas sp.*
Fungi	*Aspergillus awamori, A. niger, A. tereus, A. flavus, A. nidulans, A. foetidus, A. wentii. Fusarium oxysporum, Alternaria teneius, Achrothcium sp. Penicillium digitatum, P lilacinium, P balaji, P. funicolosum, Cephalosporium sp. Cladosprium sp., Curvularia lunata, Cunnighamella, Candida sp., Chaetomium globosum, Humicola inslens, Humicola lanuginosa, Helminthosporium sp., Paecilomyces fusisporous, Pythium sp., Phoma sp., Populospora mytilina, Myrothecium roridum, Morteirella sp., Micromonospora sp., Oideodendron sp., Rhizoctonia solani, Rhizopus sp., Mucor sp., Trichoderma viridae, Torula thermophila, Schwanniomyces occidentalis, Sclerotium rolfsii.*
Actinomycetes	*Actinomyces,, Streptomyces*
Cyanobacteria	*Anabena sp., Calothrix braunii, Nostoc sp., Scytonema sp.,*
VAM	*Glomus fasciculatum.*

(Adapted from Sharma et al., 2013)

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