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Phosphorus nutrition of plants: a microbial perspective

Abstract

Challenges in agriculture are increasing day by day. Sustainable nutrition of plants is one of the major concerns now a day. It is a major challenge to provide sufficient nutrient like phosphorus to the plants. Nutrition of phosphorus is of major concern as it is poorly available and having essential role for growth and development of plants. Fixation of applied phosphorus makes the situation worst. In this situation, few of the microorganisms efficiently dissolve fixed phosphorus forms so that it can be taken up by plants. Varieties of mechanisms are involved in phosphorus solubilization. Different microbes have been reported in almost all the agricultural crops for phosphorus solubilization. These microbes are not only providing precious phosphorus to the plants but also reduce the input cost by saving some parts of phosphatic fertilizers. In this review, different plant microbial interactions involved in phosphorus nutrition is discussed.

Keywords: phosphorus nutrition, p-fixation, phosphorus solubilization, plant–microbe interaction

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Microbial agents in plant nutrition

Expanding world population demands more food and other produce to sustain and support life. Present agriculture production majorly depends on heavy agrochemical inputs. Nutrients are necessary for plant growth and this have to be replenish in soil. Unfortunately, the practice is to supply only nitrogen, phosphorus and potassium to it. Apart from fertilizers, a huge amount of chemical is poured for pest control and growth promotion in plants. These heavy chemical inputs also have negative impacts on soil fertility.[1] Microorganisms are sustainable partial substitutes for costly and hazardous agrochemicals. Microbes provide benefits to plants by enhancing nutrition, protecting from abiotic stresses and biotic stresses. Phosphorus (P) is one of very crucial fertilizer for plants and most important next to Nitrogen in limiting plant productivity. In last 50years, phosphorus use has increased by four times.[2] Plants need P for carrying out vital functions as it is part of nucleic acids, energy transfer, photosynthesis, respiration, etc.[3] Although P is available in large quantities in soil, it is not present in plant-available forms. Substantial amount of the applied phosphorus also tend to get fixed in soil colloids in form of Ca, Al and Fe phosphates. This all left only small amount (below 1%) of phosphorus directly available to plants.[4] Large array of microorganisms help plant in this situation by solubilizing fixed P of soil. *Bacillus megaterium*. *Acinetobacter* sp. *Penicillium, Glomus, Gigaspora*, etc. are prominent microorganisms help plant in efficient P-uptake. These microbes establish interaction with host plants and provide P-nutrition to plants. Arbuscular mycorrhizal (AM) fungi are very popular P-mobilizers found as symbiont in most of the crops.[5] It enhances the nutrient absorption by roots by enhancing surface beyond the depletion zone.[6] Apart from P mobilization, Am fungi also help plant in absorption of nitrogen, potassium, calcium, sulfur, and micronutrients like Fe, Zn and Cu.[7,8] Some of the bacterial genera are associated with beneficial effects of mycorrhiza, called as mycorrhiza helping bacteria[5] or mycorrhizospheric.[9] They support mycorrhiza and plants by producing plant growth promoting effects, nitrogen fixation, P-solubilization, phytohormones, siderophores and antimicrobials, etc.[5] There are countless such interactions in and around plant roots that enhances ultimate uptake of phosphorus by plants. A significant correlation found between numbers of P-solubilizers and the levels of total P in soil.[10]

Mechanisms of Phosphorus Solubilization

Several mechanisms have been determined which are responsible for solubilization of fixed phosphorus. Most common mechanism for solubilization of mineral phosphate is production of organic acid like citric acid, succinic acid, lactic acid, propionic acid, gluconic acid and keto gluconic acids.[11–13] Organic and inorganic acids produced by phosphorus solubilizing microbes, chelate cations bound to phosphate by their hydroxyl and carboxyl groups and thus release phosphorus in soluble forms. Production of phosphatase enzyme is another mechanism. Acid phosphatases play a significant role in organic phosphorus mineralization in soil. Microbes from genera like *Pseudomonas, Bacillus, Acinetobacter, Rhizobium, Alcaligenes, Arthrobacter, Azospirillum, Burkholderia, Enterobacter, Erwinia, Flavobacterium, Paenibacillus, Serratia, Penicillium, Trichoderma and Aspergillus* are the most powerful P- solubilizing bacteria and fungi.[13] Siderophore production also releases phosphorus by chelating Fe (Table 1).

Mobilization of phosphorus

Fungus like arbuscular mycorrhizal fungi (AMF) facilitates mobilization of easily available-forms from place away from reach of plant roots and thus enhances availability of phosphorus to plants. Mycorrhiza makes symbiotic relationship with plant roots and other bacteria which enhance phosphorus solubilization and ultimately lead to good plant growth.[14] Mycorrhiza benefits from plant by getting carbon from it and in turn provides water, phosphorus, Zn, calcium, copper, *etc.* which would not be accessible to host. Mycorrhiza facilitates the host roots in nutrient absorption by its fine absorbing hyphae. Popular mycorrhizal genera are *Glomus, Gigaspora, Acaulospora, Scutellospora, Archaeospora, Entrophospora and Paraglomus,* which probably they make most abundant fungal genera in crop lands as it account for almost 5–50% of the total soil microbial biomass[15] In per cm plant roots approximately 10 to 100 m mycorrhizal mycelium can be present and produce glomalin which

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improves soil health.[16] AM fungi also help plants in water absorption in dry seasons by improving hydraulic conductivity of plant roots.[17] It also induce defense in plants, lignifications and protect against plant pathogens by competing for space and colonization.[18–23] AM fungi improve P-nutrition of plants in different P-levels of soil.[24–26]

Table 1 Some of the prominent effects of P-solubilizers in plants

S. no	P-Solubilizer	Crop	Effect	Reference
1	B. circulans and B. megaterium var. phosphaticum	Pea	Increase P-uptake and plant biomass	Raj et al.[26]
2	B. subtilis	Mung bean	Increase P and N-uptake, biomass and grain yield,	Gaind & Gaur[21]
3	AM fungi and Aspergillus niger BCC F. 194	Solubilization in liquid culture	Bioactivation of rock -P	Goenadi et al.[22]
4	G. mosseae and P. thomii	Mentha piperita	Increased plant growth and rock-P solubilization	Cabello et al.[20]
5	PSB	Different food and forage crops	Improve biological nitrogen fixation, P solubilization	Ponmurugan & Gopi[25]
6	PSB	Aerobic rice	Solubilization of different P forms	Panhwar et al.[24]
7	Acidithiobacillus ferrooxidans and Acidithiobacillus thiooxidans	In shake flask leaching experiment	Solubilization of rock-P containing sulfur-mud	Bhatti et al.[14]
8	Acinetobacter sp.	Finger millet	Increased P uptake and plant growth	Sahu et al. 2016a
9	Pseudomonas Fluorescens	Cotton	Enhance growth and yield	Hassan et al.[23]
10	S. meliloti, Streptomyces sp., Bacillus sp.	Maize	Icrease mycorrhizal colonization, P-uptake, plant growth	Battini et al.[25]

Conclusion

Phosphorus is very important for plant growth and yield and also prone for fixation in soil. The serious problem of fixation reduces P-use efficiency and enhances cost of production. P-solubilizing microorganisms are boon for this problem and confer many other benefits to plants. Inoculation with efficient P-solubilizing microorganisms can therefore enhance plant productivity and reduce cost of cultivation. Research leads are also necessary for improving efficiency of existing P-solubilizers, finding their new roles in plant growth, exploring novel microbes for P-solubilization, finding novel mechanisms for further higher P-solubilization efficiency, etc.

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Conflicts of interest

The authors declare there is no conflict of interests.

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