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IMPORTANCE OF PHOSPHATE SOLUBILIZING MICROORGANISMS IN PHOSPHORUS ACQUISITION: A REVIEW

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ABSTRACT

The microorganisms involved in phosphorus acquisition include phosphate solubilizing microorganisms and mycorrhizal fungi. Phosphate solubilizing microorganisms play an important role to make use of unavailable forms of phosphorus and also help in making phosphorus available for plants to absorb. These microorganisms promote growth of plants by providing unavailable form of phosphorus of soil in available form. Phosphorus solubilizing microbes and mycorrhiza play role in phosphorus nutrition by enhancing its availability to plants through release from inorganic and organic soil Phosphorus (P) pools by solubilization and mineralization.

KEYWORDS: Fungi, Microorganisms, Mycorrhiza, Phosphorus, Phosphorus Solubilization

INTRODUCTION

Phosphorus (P) is a major growth-limiting nutrient, and unlike the case of nitrogen, there is no large atmospheric source that can be made biologically available. Phosphorus plays a very important role in the growth and yield of the plant and it is the second most important macro-nutrient required by the plants, next to nitrogen is reported to be a critical factor of many crop production systems, due to the fact that the limited availability in soluble forms in the soils (Xiao *et al*., 2011).

Microorganisms contribute directly and indirectly to the soil health through their beneficial or detrimental activities. The organisms possessing phosphate solubilizing ability called Phosphate Solubilizing organisms and they can convert the insoluble phosphate compounds into soluble form in the soil and make them available for plants to absorb (Pradhan and Shukla, 2005). Given the negative environmental impacts of chemical fertilizers and increasing costs, it is urgently needed to employ eco-friendly and cost effective agro. Technologies to increase crop production. Therefore, utilization of phosphate solubilizing microorganisms in improving the productivity of lands and crop production.

Wide range of soil microorganisms (bacteria and fungi) is able of mineralizing and solubilizing P from the organic and inorganic soil pools (Gomes *et al*., 2014; Souchie*et al*., 2005, Richardson, 2001). Several soil bacteria, particularly those belonging to the genera *Pseudomonas* and *Bacillus*, and fungi of the genera *Penicillium* and *Aspergillu*s possess the ability to bring insoluble soil phosphates into soluble forms by secreting acids such as formic, acetic, propionic, lactic, glucolic, fumaric and succinct. These acids reduce the soil pH and bring about the dissolution of bond forms of phosphate (Bolan *et al*., 1997; Mohammadi & Sohrabi, 2012) and also help in making phosphorus available for plants to absorb. When phosphate fertilizers are applied to the soil they often become insoluble and are converted into complexes such as calcium phosphate, aluminium phosphate and iron phosphate in the soil (Mittal *et al.,* 2008).

ROLE OF PHOSPHORUS IN SOIL

Phosphorus (P) is considered to be very important and essential macro-elements required for growth and developments of plants (Saber*et al.,* 2005). Phosphate solubilizing microbes could play a pivotal role in making soluble phosphorus available to plants (Khan *et al.*, 2010). Inorganic forms of phosphorus are solubilized by a group of heterotrophic microorganisms excreting organic acids that dissolve phosphatic materials and/or chelate cationic partners of the phosphorus ions that is, $PO4^{3-}$ directly, releasing phosphorus into solution (He *et al.*, 2002).

The microorganisms involved in the solubilization of insoluble phosphorus include bacteria, fungi, actinomycetes and arbuscular mycorrhizal (AM) fungi (Khan *et al.*, 2007; Wani*et al.*, 2007a; Xiao *et al.*, 2009). Due to low solubility and fixation in soils, only a small fraction of phosphorus exists in soil solution, is readily available to plants. The roots take up several forms of phosphorus, out of which the greatest part is absorbed in the form of H_2PO_4 and HPO_4 depending upon soil pH (Mahidi*et al.*, 2011).

Application of a large portion of soluble inorganic phosphate applied to soil as chemical fertilizer is rapidly immobilized and become unavailable to plants. When the fertilizer or manure phosphate comes in contact with the soil, a series of reactions begins which make the phosphate less soluble and less available.

The degree of fixation and precipitation of phosphorus in the soil is highly dependent upon the soil conditions such as pH, moisture content, temperature and the minerals already present in the soil. Therefore, phosphorus is often regarded as a limiting nutrient in agriculture soils (Guinazu*et al.*, 2010). The total phosphorus level of soils is low, which is usually no more than one-tenth to one fourth of nitrogen and one twentieth of potassium (Jones and Eva, 2011). Unlike nitrogen, there is no large atmospheric P source that can be made biologically available phosphorus. Therefore, deficiency of phosphorus severely restricts the growth and yields of crops. Before being absorbed by the roots, a considerable amount of applied phosphorus is rapidly transformed into less available forms by forming a complex with aluminium or iron in acid soil or with calcium in calcareous soils (Toro, 2007). Therefore, in order to sustain the production, problems of phosphorus deficiency are needed to be arrested through the application of phosphorus fertilizers (Khan *et al.,* 2010).

The repeated use of the phosphorus containing fertilizers leads to the loss of soil fertility (Gyaneshwar*et al.*, 2002). Due to this drawback, chemical source of phosphorus replaces by environment - friendly and economically feasible phosphate solubilizing microorganisms.

ISOLATION OF PHOSPHATE SOLUBILIZING MICROBES

Soil dilution and plate count method of Timonin (1940) were used for isolating/counting of phosphate solubilizing microbes from the rhizospheric soil. Soil was washed thoroughly in flask containing 100 ml sterilized distill water. It was shaken thoroughly for ten minutes. 10ml of the suspension containing composite samples of rhizosphere soil was transferred to a flask containing 90ml sterilized distilled water. The diluted suspension was further diluted a number of times in the same way so as to get the desired dilution. For the isolation of phosphate solubilizing microbes, 0.5ml of an aliquot of appropriate dilutions was plated in sterilized Petri plates containing 10ml of Pikovskaya's Medium (Glucose, 10g; Tricalcium Phosphate, 5.0g; Ammonium Sulphate, 0.5g; Sodium Chloride, 0.2g; Magnesium Sulphate, 0.1g; Yeast Extract, 0.5g; Ferrous Sulphate, traces; Manganese Sulphate, traces; Agar, 15g; Distilled water, 1000ml). The petri plates were rotated by hand in broad swirling motions to distribute the suspension over the medium.

After incubation at 28±20C, usually for 24-48 hours, the resulting colonies were identified and counted. They were identified with the help of specific monographs.

PHOSPHATE SOLUBILIZING MICROORGANISM

There are a number of soil microbes *viz., Pseudomonas striata, Bacillus polymyxa, B. megaterium, B. pulvifaciens, B. circulans, Citrobacter sp., Aspergillusawamori, Penicilliumdigitatum, Aspergillusniger*etc. which solubilize insoluble Al and Ca phosphates and rock phosphate and increase the availability of phosphates to the plants. Gerretsen (1948) was the first to report an increased P uptake and better growth of the plants (oat) when inoculated with soil containing PSM, as compared to uninoculated control. Increase in plant performance, yield and P uptake has been reported by several workers. Though most of the work has been done on agricultural crops, inoculation of the nursery seedlings with such microbes along with the rock phosphate may be helpful in removing the phosphorus deficiency and improving their performance under extreme stress conditions.

Thus the microbial communities are not only responsible for the development of soil structure conducive to macrophyte growth, but also for the production of plant nutrients through their contributions to various biogeochemical cycles and the alleviation of physico-chemical limitations.

A wide range of soil microorganisms (bacteria and fungi) is able to mine, realizing and solubilising P from the organic and inorganic soil pools (Gomes *et al*., 2014; Souchie*etal*., 2005; Richardson, 2001). Several soil bacteria, particularly those belonging to the genera *Pseudomonas* and *Bacillus*, and fungi of the genera *Penicillium* and *Aspergillus* possess the ability to bring insoluble soil phosphates into soluble forms by secreting acids such as formic, acetic, propionic, lactic, glucolic, fumaric and succinct. Several fungal and bacterial species, popularly called as phosphate solubilizing microorganisms. Among the whole microbial population in the soil, PSB constitute 1 to 50 %, while phosphorus solubilizing fungi (PSF) are only 0.1 to 0.5 % of P solubilisation potential (Chen *et al.,* 2002). So, Microorganisms involved in phosphorus acquisition include mycorrhizal fungi and PSMs (Fankem*et al*., 2006).

PHOSPHATE SOLUBILISING BACTERIA

Pseudomonas fluorescens, Bacillus megatherium var. phosphaticum, Acrobacter acrogens, Bacillus polymyxa are the bacteria that have phosphate solubilising ability. They increased about 10 to 20 % crop yield (Cooper, 1959) and also produces plant growth promoting hormones, which helps in phosphate solubilising activity of the soil. Gerretsen (1948) first showed that pure cultures of soil bacteria could increase the P nutrition of plants through increased solubility of Ca-phosphates. Their solubility increases with a decrease of soil pH. Phosphate solubilization is the result of combined effect of pH decrease and organic acid production (Fankem*et al*., 2006). Microorganisms through secretion of different types of organic acids, e.g. carboxylic acid (Deubel and Merbach, 2005) and rhizospheric pH lowering mechanisms (He and Zhu, 1988) dissociate the bound forms of phosphate like Ca_3 (PO4) $_2$. Nevertheless, buffering capacity of the medium reduce the effectiveness of PSB in releasing P from tricalcium phosphates (Stephen and Jisha, 2009). Among the whole microbial population in soil,PSB constitute 1 to 50 %, while phosphorus solubilizing fungi (PSF) are only 0.1 to 0.5 % in Psolubilization potential (Chen, *et al*., 2006) and *Bacillus megaterium*, *B. circulans*, *B. subtilis*, *B. polymyxa, B. sircalmous, Pseudomonasstriata*, and *Enterobacter* could be referred as the most important strains (Subbarao, 1988; Kucey, *et al*., 1989).

PHOSPHATE SOLUBILIZING FUNGI

Fungi of the genera *Penicillium*and *Aspergillu*s possess the ability to bring insoluble soil phosphates into soluble forms by secreting acids such as formic, acetic, propionic, lactic, glucolic, fumaric and succinct. These acids reduce the soil pH and bring about the dissolution of bond forms of phosphate (Bolan *et al.*, 1997; Mohammadi & Sohrabi, 2012).

MYCORRHIZAL FUNGI

It has been established during the last few decades that mycorrhizal association is helpful in improving the overall performance of the plants. This association is gaining importance in the reclamation of various types of lands and researches of AM fungi have reached a stage of practical application in many countries for reclaiming the adverse sites. AM fungi have a number of assets to prove it a magic tool, e.g. AM fungi increase the absorptive surface of roots manifold and improve the uptake of nutrients and water resulting in better performance of host plants. Mycorrhization ensures a better supply of water and nutrients, especially phosphorus, calcium and zinc to the plants, thereby improved growth and productivity. The PSM along with other beneficial rhizospheric micro flora enhance crop production. Simultaneous application arbuscular mycorrhizae (AM) fungi (Zaidi*et al.*, 2003) has been shown to stimulate plant growth more than with their sole inoculation in certain situations when the soil is P deficient. Synergistic interactions on plant growth have been observed by co inoculation of PSB with vesicular arbuscular mycorrhizae (Kim *et al.*, 1998).

Gopalkrishna*et al.* (1990) studied the interaction between *Glomus fasciculatum* and two phosphate solubilizing fungi, *Penicillium funiculosum* and *Aspergillus niger* in finger millet. The inoculations produced a synergistic action and resulted in improved growth and nutrient uptake. Gaur and Rana (1990) studied the role of AM, phosphate solubilizing bacteria and their interactions on growth and uptake of nutrients in wheat. Inoculations with PSB's such as *Pseudomonas striata* and *Agrobacterium radiobacter* and AM fungi such as *Glomus fasciculatum* and *Gigaspora margarita* improved dry matter yield. Higher yield was obtained by an application of microbial inoculation and fertilizer together. Tilak*et al.* (1995 b) investigated the synergistic effects of phosphate solubilizing bacterium - *Pseudomonas striata* and *Gigaspora margarita* in the bean. Uniform seed treatment with *Bradyrhizobium japonicum* was also given. They reported a significant increase in root infection, root biomass and yield with *G. mosseae* or *G. fasciculatum* than the soil inoculation with AM or *P. striata* alone. Singh and Kapoor (1999) studied the effect of inoculating wheat (*Triticumaestivum*) with the phosphate solubilizing microorganisms (PSM) *Bacillus circulans* and *Cladosporiumherbarum* and AM fungus *Glomus* sp. With or without Mussoorie rock phosphate (MRP) amendment in a nutrient-deficient natural sandy soil. In the sandy soil of low fertility root colonization by AM fungi was low. Inoculation with *Glomus* sp. improved root colonization. At maturity, grain and straw yields as well as N and P uptake improved significantly following inoculation with PSM or the AM fungus. These increases were higher on combined inoculation of PSM and the AM fungus.

CONCLUSIONS

Phosphate solubilizing microorganisms play a very important role in solubilisation of Phosphorus. It increases the availability of phosphorus to the plants by natural means and acts as the best substitute for chemical fertilizers. It has advantages over chemical fertilizers, because they are non-polluting, inexpensive, utilize renewable resources. So, exploitation of phosphate solubilizing microorganisms through biofertilization has enormous potential for making use of ever increasing fixed Phosphorus (P) in the soil.

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