MINERALIZATION OF PHOSPHOROUS BY PHOSPHATE SOLUBILIZING MICROBES AFFECTS SOIL FERTILITY

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ABSTRACT

Organic farming in coming decades is attracting the consideration of researchers and accepted by farmers for improving better production capability of the soil. Uses of extreme chemical fertilizers have lots of detrimental effects on soil composition and nutrient management. By adopting the use of organic manure, biofertilizer and biopesticides instead of chemical fertilizer, we can safeguard the environment and enhance sustainable agricultural production. Phosphorus (P) is one of the essential and critical macronutrients needed for growth and development of plants. P uptake and utilization by plant plays a major role in better crop yield. To meet the demand of plants and reduce the adverse effect of chemical fertilizers, use of PSM (Phosphate Solubilizing Microorganisms) is an effective and eco friendly approach. Most of the soil available in agricultural fields is limiting phosphate, so use of PSM can increase the crop yield as well as enrich the soil fertility. The applications of PSB (Phosphate Solubilizing Bacteria) inoculants with plants can fulfil up to 50 percent of the need for phosphatic fertilizers.

Keywords: Phosphate mineralization, Organic acids, PSM, Biofertilizer

INTRODUCTION:

Excessive application of pesticides and chemical fertilizers resulted in harmful side effects on soil and environmental pollution. They may accumulate in soil, water, and air gave rise to degradation of soil natural properties, soil acidification, mineral depletion, water pollution, soil pollution and human health related issues. Hence maintenance of sustainable agriculture is a prime Importance not only for sufficient food production but also for retaining worldwide environmental sustainability. So organic farming helps in maintain long term soil fertility, biological diversity also can lessen the pollution. After nitrogen phosphorus (P) is the second most essential nutrient that plays a crucial role in plant growth. P is a vital component of nucleic acid, phytin, and phospholipids of plant cells. So an ample of P is necessary for the growth and development of plants (Marschner, 1995; Havlin et al., 1999). Compared with other nutrients, P is the least available to plants and is less mobile in soil due to its adsorption to Ca, Fe and Al in paddy fields (Rodriguez et al.,1999). Particularly in acidic soil, It accounts of 0.2 and 0.8% of the dry weight of plants. Microorganisms are played integral parts in the natural phosphorus cycle. Therefore utilization of phosphate solubilizing microorganisms as biofertilizers for agriculture enhancement has been a subject of study for years. In soil P solubilizing bacteria comprises of 1–50% and P solubilizing fungi includes about 0.1 to 0.5% of the total respective microbial population. Kalayu G. (2019) reported that combination of rock phosphate with PSM inoculum sounds preferable in terms of minimizing the risk of long-term total P soil deficit.

This review focuses on mechanism that contributes the biomineralization of organic phosphate and clarifies the role of organic acid released by various PSM for phosphate solubilisation. It also improved understanding of requirement of phosphorous in plants cell growth and development.

FUNCTION OF PHOSPHOROUS IN PLANTS:

90% of P is commercially used as fertilizer for agricultural needs other 10% act as elemental phosphorous used in different food and chemical industries (Bhatti, 2010). For proper function of plants, maintenance of soil critical P concentration is necessary. Adequate P is required for plant growth as it plays a major role in photosynthesis, plant root formation, cell division, cell enlargement, energy transfer and good crop yield. It is also form an important part of informational biopolymers (such as RNA and DNA) along with energy storage (ATP,

ADP) (Krishnaraj and Dahale, 2014).In earlier stage of cell division and seed formation P is needed in large quantity (Silva and Uchida 2000). Phosphorous is a reactive element so it cannot be existed in elemental form in soil. Due to slow diffusion and low availability P can be major limiting substance available for plants. The concentration of the phosphorous in soil is very limited so plants mostly use active uptake mechanism against the concentration gradient. It is an energy consuming process. P is absorbed by plant roots through the process of diffusion, pi transfer, mobilization and microbial activity (Pikovskaya,1948).

PHOSPHOROUS SOLUBILIZATION MECHANISM BY MICROBES:

Plants depend upon soil for all their nutrients. Microbial diversity in soil is known to influence plant growth by various direct or indirect mechanisms. Microorganism plays a significant role in phosphate solubilization. In nature phosphate rock is the key source of phosphorous. Acidophilic sulfer-iron oxidizing bacteria can help in dissolution of P from the phosphate rock.

In soil phosphorous is available in various organic (Pi) and inorganic(Po)form (Schneider et al, 2019). 90-95% of phosphorous is present in insoluable form so that cannot be utilized by the plants directly(Pradhan and Sukla, 2005). Some bacterial species have been reported by khan et al., 2007 which have potential to convert the inorganic phosphate to organic phosphate. The phosphate solubilization efficiency of microbes depends upon some physical (pH, temperature) and chemical(carbon ,nitrogen source) factors. Organic phosphate can be mineralized by organic acids (lactic,oxalic,citric acids etc.) that are released by microorganisms. The organic acids result in acidification and decreasing the surrounding pH. The capacity and production of organic acids varies with the diverse microorganisms. These organic acids are released from microbial metabolism and fermentation of carbon sources (Satyaprakash et al.,2017; Alam et al.,2002) Later the free phosphate group chelate with hydroxyl and carboxyl group converted to soluble forms (Molla and Chowdhury,1984; Richardson et al., 2011; Arcand and Schneider, 2006). PSMs mineralize soil organic P by the production of phosphatases like phytase that hydrolyze organic forms of phosphate compounds, there by releasing inorganic phosphorus that will be immobilized by plants.

The most efficient mineral phosphate solubilization mechanism reported in gram negative bacteria is oxidation of glucose to gluconic acid by quinoprotein glucose dehydrogenase.(Goldstein et al.,1999; Puente et al., 2004; Kpomblekou and Tabatabai

1994).Moreover through the process of bacterial oxidation *A.ferroxidans* and *A.thioxidans* can solubilize P from rock phosphate by producing sulphuric acid.Production of phytohormone substances like Indol Acetic Acid , Giberalin, auxin, cytokinin etc whose role is greater in crop productivity from the Plant growth promoting rhizobacteria strains also showed high effectiveness in mobilizing P from insoluble sources(Bianco and Defez .,2010).

PHOSPHATE SOLUBILISING MICROBES:

Phosphate-solubilizing microorganisms have the ability to convert the insoluble forms of phosphorus into its soluble form, which later gets available to plants; this biological phenomenon is referred as mineral phosphate solubilisation. Microorganisms involved n solubilization of phosphorous include bacteria, fungi and actinomycetes (Khan et al.,2007; Wani et al.,2007; Chun-qiao et al.,2009; Santos et al.,2012). Both gram –ve and gram +ve bacteria have potential to mineralise phosphate. Studies suggested that mineralization of phosphorous by bacteria were tested for their P-solubilizing capacity and it was found that the inorganic P-solubilizing bacterial strains solubilized 25.4-41.7 µg P mL^{-1} inorganic P and mineralized 8.2-17.8 µg P mL^{-1} organic P. Rhizospheric bacteria such as *Rhizobium, Pseudomonas, Azotobacter, Bacillus* were reported to have capability of phosphate solubilisation in the agricultural soil ((Rodriguez et al.,1999).

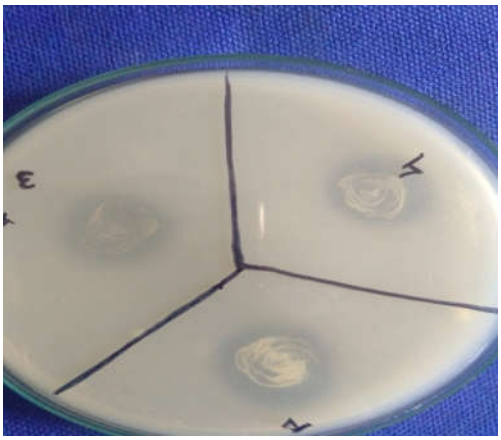

Fig: Phosphate solubilization by *Azotobacter* in pikovskaya agar media in vitro (the zone appears surrounding the microbes indicate the phosphate solubilization)

Other genera which are able to perform this are *Micrococcous, Achromobacter, Erwinia, Agrobacterium, Flavobacterium, Mesorhizobium* and *Mycobacterium* (Rodriguez et al.,1999).Chung et al.,(2005) isolated identified and reported the bacterial under the genera

Klebsiella, Pantoea, Enterobacter that can actively solubilize phosphate in vitro. Mixture of arbuscular mycorrhiza and phosphate solubilising bacteria can be given the better result of phosphate uptake in plants (Landry et al., 2008; Thirkell et al., 2017).

TABLE: Organic acids produced by some common phosphate solubilizing microbes (Krishnaraj and Dahale, 2014)

Microbial strains	Type of organic acid(s) produced	References
Pseudomonas putida	Citric acid Gluconic acid	Taha et al .,1969; Ponraj et al .,2013;Van Schie et al .,1985.
Aspergillus niger	Gluconic acid	Xiao et al .,2013
Rhizobium leguminosarum	2-keto gluconic acid	Halder et al.,1990
Pencillum bilaii	Citric acid Oxalic acid	Cunningham and Kuiack,1992
Enterobacter sp.	Gluconic,succinic, glutamic,pyruvic malic acid	Perez et al .,2007

CONCLUSION AND FUTURE ASPECTS:

Phosphate rock is a non-renewable resource and may run out within few decades. Extensive amount of chemical fertilizer that are used in agricultural practices are converted into insoluble forms. Therefore an improving and environmental friendly alternative approach is, to utilize PSM which have potential to mineralize the phosphate present in the soil. Increase in organic matter will promote increase in organic P mineralization rate. High quality, multifunctional and stress tolerant PSM strains are required for commercial biofertilizer that can enrichment of soil nutrition and increase the soil fertility.

PSM supports the plant growth with multiple growth stimulating attributes like production of IAA,GA, siderophore and antibiotics (act as biocontrol agent) but the trail of PSM inoculums directly on filed has not yet been effectively commercialized. Thus for better knowledge field studies are required to investigate the effect of PSM application on different crop type. Several crop species have varied P mobilizing capacity and internal P utilization efficiencies. Along with the crop species P mobilizing abilities and internal P utilization efficiencies has varied. Development of research in area of molecular genetics, it may provide an opportunity to know the more detail mechanism of phosphate solubilisation by the microbes and its relation with increase the plant root and shoot development.

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