Biological Resources: An Alternate to Chemical P. Fertilizers

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ABSTRACT

Phosphorus (P) is a macronutrient for plants but behaves like a micronutrient in soil. The content of soluble P in soil solution is very low due to poor mobility of the nutrient. Low availability of phosphorus is a major limiting factor to food production globally. To meet the nutritional needs of the crop plants, P has to be applied in quantities in excess of the crop requirement. This not only increases the cost of cultivation but puts financial constraint on the marginal farmers. In addition, high application of chemical P fertilizer results in P accumulation in soil and affects the microbial diversity. Therefore, the need to develop farmer and environment friendly technologies for sustainable agriculture is urgently felt. Microorganisms that have the potential to solubilize inorganic phosphate and mineralize organic phosphate sources can be exploited to develop economical technologies that can reduce the input of chemical P fertilizer. Moreover, the organic matter (a rich source of microbial flora) and manure is an excellent source of phosphorus for crops. Application of fertilizer and manure can maximize the chemical availability of the phosphorus to crops while minimizing the risk of phosphorus being lost to the environment by runoff or erosion. Conservation practices are critical to good phosphorus management and biological input help to alleviate the low availability of P in Indian soils. The present article throws light on some of the natural resources that can circumvent the problem of P deficiency in tropical soils.

1. INTRODUCTION

The first green revolution during early seventies resulted in food security and played an important role in transforming India from being food deficient to food surplus. However, the ever increasing human population has offset the increase in food production. There is need for second green revolution to meet the food demand of growing population. Excessive use of chemical fertilizer for four decades have reduced the soil fertility, degraded the environment and showed stagnation in crop yields.

Phosphorus is the second major nutrient whose low availability limits the crop production. The low level of P is due to high reactivity of soluble P with Ca^{2+}, Fe^{3+}, and Al^{3+} that lead to P precipitation. Under alkaline soils, calcium phosphate is the most predominant form of P whereas; under acidic soil it exists as iron and aluminium phosphate. The content of organic P in soil amended with high input of organic matter may range between 50 to 80 % of total organic P and phytate is the predominant form of organic P in soil. Both inorganic and organic P pool of soil fails to meet the nutritional needs of the crop plant. It is the use of chemical fertilizers that supply the plant with major nutrient. The production of chemical fertilizers is highly energy intensive and it's ever increasing demands increases the cost of cultivation. Moreover, 80-90 % of the added chemical P fertilizers are precipitated by Fe^{+3}, Al^{+3}, and Ca^{+2} present in soils.

2. BIOLOGICAL REMEDIATION OF LOW SOIL P

Microorganisms are the nature's gift to mankind. They can play a significant role in improving the availability of P to plants by bringing favourable changes in soil reaction and soil micro-environment that may result in solubilisation of inorganic phosphate. Inorganic phosphate can be dissolved by organic acids produced by microorganisms. However, organic phosphates can be mineralized by the action of microbial enzymes. Microbial transformation of both organic and inorganic compounds is necessary in soil to make available the bound form of soil P.

The solubilisation of inorganic and insoluble phosphate can be brought about by both plants and microorganisms that produce organic acids in varying concentrations and types. Commonly reported organic acids produced by microorganisms include gluconic, citric and oxalic acids (Richardson 2001), while plants most commonly produce citric, oxalic, and malic acids (Ryan et al. 1995, Zheng et al. 2005). *Aspergillus niger, Aspergillus clavatus* and *Penicillium* sp. and *Sclerotium rolfsii* have been reported to produce oxalic acid as the major organic acid (Gupta et al, 1994). Besides, citric, oxalic and gluconic acids, traces of fumaric acid, malic acid, succinic acid, acetic acid and lactic acid have also been detected in cell free filtrate of several phosphate solubilising microorganisms (Gaind 2013).

The carbohydrate used in the growth medium of phosphate solubilising microorganisms also affect the type and quantity of acid produced. Type and quantity of organic acid produced also varies with different microbial strains, media composition and growth conditions. The ability of organic acids to solubilize mineral phosphate is attributed to acidification, chelation, and exchange reactions. The P solubilising ability of phosphate solubilising microorganisms is also affected by the nature of N source in the medium. Greater solubilisation has been reported in presence of ammonium than nitrate as N source. This may be due to extrusion of proton to compensate for ammonium uptake, leading to pH reduction.

Symbiotic association between plant and certain soil fungi known as arbuscular mycorrhiza (AM) can also contribute greatly to plant P nutrition. Mycorrhizal fungi are believed to enhance P nutrition in plants by scavenging the available P due to large surface area of their hyphae. These fungi also have high affinity P uptake mechanisms (Mosse, 1980). They have been reported to mobilize P from soil solution. Ecto-mycorrhizal fungi have been reported to possess P solubilising activities (Lapeyrie et al, 1991). These fungi can also make use of P from inositol phosphate and possess phosphatase activity that can release P from soil organic matter. Cyanobacteria *Anabaena* ARM 310 has also been found to solubilise insoluble tricalcium phosphate.

Mineralization of organic phosphorus is mediated by the production of phytase and phosphatase enzymes that hydrolyze the C-O-P ester bonds during mineralization of soil organic P. Plant roots, mycorrhizal fungi and soil microorganisms produce these enzymes in soil. The acid phosphatase synthesis is stimulated in soil under conditions of P deficiency. Tarafdar and Junk (1987) reported that concentration of soil organic P gets depleted in soil with in 1 mm of clover and wheat roots with high activity level of phosphatase and microbial population. Therefore, phosphatase in soil recapture organic P compounds leaked from root cells (Barrett-Lennard et al, 1993). White lupin has been reported to evolve effective mechanism to mineralize and acquire phosphorus from soil organic P compounds. White lupin can access a pool of P that is unavailable to soybean (He, 1998). Phosphate mineralizing enzymes can be much more effective, if heavy metals are removed from the added organic matter that contains humic substances. This can be done by plant secreted metal complexing agent such as citrate anion. Increasing concentration of citrate greatly enhance the effectiveness of the enzyme in mineralizing soil organic phosphorus compounds.

As P is required for microbial cell synthesis, many non P-solubilizing bacteria can take up the sparingly soluble P through their high affinity transporters. This P becomes available to plants through mineralization as the bacteria die. Phosphorus starvation results in induction of glucose dehydrogenase, an enzyme involved in glucose metabolisms in *Enterobacter asburiae* (Gyanashewar et al, 1999). Microbial P can represent up to 6 % of the total P in many ecosystems which indicate the importance of soil microorganisms in catalyzing the P transformations in these soils. In Rhizobium, P limitation leads to higher P transport rates and induction of alkaline phosphatase (Al Niemi et al, 1997). Significant amounts of P can also be released from soil microorganisms without net change in the size of the microbial biomass pool due to recycling and turnover. Estimates suggest a turnover time of the total microbial biomass in bulk soil of between 42 and 160 d depending on the farming system, with faster rates of turnover occurring in C-amended soils (Bünemann et al, 2007). From these studies it is evident that a significant amount of P is cycled through the microbial biomass on an annual basis (i.e. with estimates of up to 100 mg P kg^{-1} soil $year^{-1}$), given that turnover of microbial P is largely driven by the availability of C. This is therefore of particular significance in the rhizosphere. To be available to plants, orthophosphate (or dissolved organic P) must diffuse through the rhizosphere.

Soil organic matter is important in relation to soil fertility, sustainable agricultural systems, and crop productivity, and there is concern about the level of organic matter in many soils, particularly with respect to global warming. The amount of organic matter in soil depends on the input of organic material, its rate of decomposition, the rate at which existing soil organic matter is mineralized, soil texture, and climate. All four factors interact so that the amount of soil organic matter changes, often slowly, toward an equilibrium value specific to the soil type and farming system. Organic matter increases P availability by forming complexes with organic phosphates which increases phosphate uptake by plants. Organic anions can displace sorbed phosphate. Humus coats aluminium and iron oxides which reduces P sorption. Organic matter is also a source of P through mineralization reaction. Trends in long-term crop yields show that, yields are often larger on soils with more organic matter compared to those on soils with less. Benefits from building up soil organic matter are bought at a cost with large losses of both carbon and nitrogen from added organic material. The exploitation of natural resources for improving the soil P availability will certainly improve the soil quality and fertility

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