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Phosphorus Management Strategies in Sustainable Agricultural System

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Abstract

Phosphorus limitation is a major challenge for crop production and productivity in the world, as the phosphorus element is less mobile and highly fixed in the soil. Phosphorus deficiency occurs in Indian as well as world soils, and estimates predict no P-reserves by 2050. Nowadays, India does not have any adequate reserves of rock phosphate, posing a threat to sustainable crop production. This article is an attempt to provide necessary strategies that can be employed to manage and improve P availability in the soil for plants. Agronomic interference like weed management, development of P stress-tolerant varieties, deep band placement of P fertilizers, conservation tillage, and use of cover crops improves phosphorus availability in farming systems. Other soil phosphorus management practices like composting, organic amendments, and many soil microorganisms play an important role in increasing phosphorus availability in soil and supplying P to plants in a sustainable and eco-friendly way.

Introduction

Phosphorus (P) was first discovered by Brandt in 1669. The word is derived from Greek, 'phos' meaning light and 'phorus' meaning bringing. Phosphorus is an essential macro plant nutrient required in larger quantities as compared to other elements followed by nitrogen. Globally, more than 50% of soils are deficient in phosphorus and mostly phosphorus deficiency occurs in the acid-weathered soils of tropical and subtropical regions of the world. (Vance *et al.*, 2003). Besides, there is a need to increase the parallel agricultural production and productivity to supply the required food to the growing world population day by day. Only one option to increase soil phosphorus availability and increase crop yield is to apply phosphorus-containing fertilizers. Phosphorus elements play an important role in the maintenance of membrane structures, synthesis of biomolecules, and formation of high-energy molecules. It also helps in cell division, enzyme activation, and carbohydrate metabolism (Razaq *et al.*, 2017). At the whole plant level, it stimulates seed germination; development of roots, stalk and stem strength; flower and seed formation; crop yield; and quality. Hence, phosphorus is essential at all developmental stages, right from germination till maturity. The application of phosphorus nutrition improves many aspects of plant development including fruiting, flowering, shoot growth, and root growth.

Phosphorus Bioavailability in the Soil

Phosphorus is the most abundant element in the earth's crust. About 200 minerals, occurring in nature, have been reported to contain phosphorus, with apatite group of minerals being the most important. Soil phosphorus can be divided into two groups organic and inorganic forms. The surface plough layer of soil (0-0.15 m) contains phosphorus in the range of 200 to 2000 kg ha^{-1}, the average being 1000 kg ha^{-1}. Indian soils had a total P content ranging from 580 to 2,900 kg ha^{-1}. Phosphorus availability in soil solutions is mostly determined by soil components, including soil pH, texture, nature of clay, organic matter, concentration of phosphorus, cations, and anions. Phosphorus is commonly found in soils in inorganic forms, with organic phosphorus content ranging from 20% to 80% of soil phosphorus existing in organic form, and inositol hexaphosphate accounting for a significant portion of the organic phosphorus. The soil microbes' activity releases the immobile forms of P into the soil solution, which is then made available to the plants. The uptake of phosphorus is largely favored between pH 6.5 and 7.5, where it predominates in the H_2PO_4, HPO_4^{-2}, and PO_4^{-3}, which occur at high pH. The major portion of mineral phosphorus fertilizers applied to the soil can not be absorbed by plant roots due to sparingly soluble Fe-phosphates and Al-phosphates in acid and Ca-phosphates in alkaline soils.

Phosphorus Management Strategies in Sustainable Agricultural System

Sustainable crop production aims at maintaining a high crop yield and maintaining ecological balance without adversely affecting ecosystems .There are several techniques to measure the availability and manage phosphorus in soil.

Agronomic Practices

Nutrient utilization efficiency and nutrition uptake can be improved through good agricultural practices, which can reduce the accumulation of nutrients, thus improving their availability in the soil. It also reduces P fixation in soils and increases P availability.

Weed Control

Weeds are also plants. They need phosphorus, much like a crop, for the completion of its life cycle. Proper removal of weeds reduces the demands for nutrition of the cropped field. Application of a half-dose of phosphorus to the weed-free field can produce alternative results compared to the weed-attacked field where the full rate of P may be applied. Weed control technology must be included in the P conservation package.

Development of Phosphorus Stress Tolerant Varieties

Verities such as drought tolerance can survive with low availability of irrigation and deliver good results in terms of yield, so we can introduce phosphorus-tolerant cultivars. These genetically modified varieties should be developed together with field crops. It is preferable that only P dependence and maximum performance can be achieved. (Chin *et al.,* 2010).

Fertilizers are Applied through Band Placement

Application of P fertilizers through band placements is more effective in reducing P fixation, improving availability, and also increasing the efficiency of P fertilizers in soils. This method ensures better distribution of fertilizer in the root zone soil and prevents loss of nutrients by run-off. Therefore, band placement can maintain the fertilizer in a plant-available form for longer than a broadcast-incorporated application.

Conservation Tillage Practices

Conservation tillage is an ecological approach and best agricultural practice to conserve P in soil systems. It maintains a minimum of 25-30% crop residue on the field and includes no-till or minimal tillage methods. Conservation tillage practices mixing surface and subsurface soil increase P adsorption. Conservation tillage practices improve soil structure, increase organic matter, minimize soil erosion risk; enhance soil quality, and reduce particulate bound P export by decreasing the volume of surface runoff.

Cover Crop

Cover crops reduce soil loss by improving soil structure and increasing infiltration, protecting the soil surface, increasing nutrient use efficiency (NUE), and reducing nutrient loss from leaching and erosion. Cover crops increase the total root volume and enhance the surface area in an agricultural system. It also increases mycorrhizal fungi in the root system and enhanced the uptake of phosphorus through higher rates in plant roots.

Organic Amendments

These substances are extremely rich in organic matter and macro-and micro-elements that increase the fertility of soils by ameliorating microclimatic conditions and may also provide substrates for microbial growth. Application of organic amendments greatly improves soil pH, EC, soil structure, organic content, and humus fraction in soil. Decomposition of organic amendments, it converting fixed insoluble soil phosphorus to soluble forms which are more available to plants. Solubilization of phosphorus compounds by organic acids is achieved by complex formation between organic acids/ anions and metal ions, such as Fe, Al, and Ca. The complex formation depends on the number and position of carboxyl (–COOH) and phenolic (–OH) functional groups in the organic acids. Organic acids released during microbial decomposition also assist in to release of soil mineral phosphorus.

Phospho-Compost

Among the organic sources of phosphorus, composts, FYM, phosphocompost, and N-enriched phosphocompost can partially supply the crop phosphorus requirements when applied (5-10 t ha^{-1}). Phospho-compost/ N-enriched phosphocompost is produced by the use of PSMs, namely Aspergillus awamori, Pseudomonas striata, and Bacillus megaterium, phosphate rock, pyrite, and bio-solids to increase the manurial value compared to ordinary FYM and compost.

Composting

It is an important technique for managing and improving the availability of phosphorus in a sustainable agriculture system. Composting is a biological process in which different types of microorganisms decompose organic matter and narrow down the C/N ratio of substrate used. During microbial decomposition of organic matter, various amino acids are produced which solubilize phosphate-bearing minerals, lower phosphate fixation, and thereby increase phosphate availability in soil solution. Decomposition of organic matter microbes produced different organic amino acids-like citrate, tartrate, oxalic, melanic, and acetate are also most effective in reducing P absorption by soils. Soil organic component increases during the composting process, which facilitates increases in soil microbial activity and diversity in the sustainable agricultural system. Phosphorus cycle in agricultural lands represented by Figure 1.

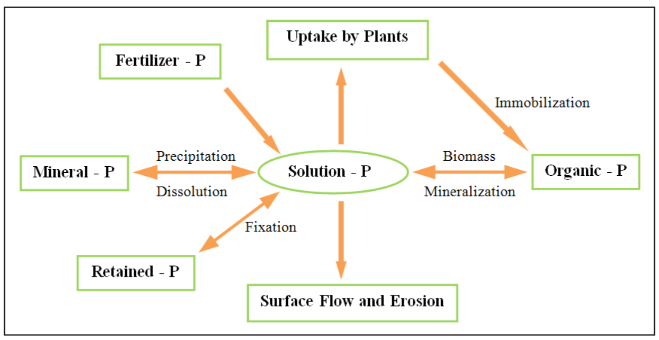

Figure 1: Phosphorus cycle in agricultural lands (Source: Mahdi and Mouhamad, 2018)

Arbuscular Mycorrhiza

The symbiotic association between fungal hyphae and plant roots is known as mycorrhiza. Arbuscular mycorrhizal (AM) symbioses are widespread in the plant root and contribute significantly to plant P nutrition and growth. It is important implications, especially in the low P soils. It has been shown that the external hyphae of the AM fungi could deliver up to 80% of the plant P to the host plant over a distance of more than 10 cm from the root surface.

P-Soubilizing Microorganisms

A large number of heterotrophic microorganisms existing in the soil, which include bacteria, fungi, actinomycetes, and cyanobacteria, can dissolve insoluble inorganic phosphorus sources present in the soil solution and are collectively known as phosphorus-solubilizing microorganisms (PSM). Soil microorganisms the production of amino acids like oxalic, citric, tartaric, acetic, and maleic that dissolve the insoluble mineral phosphorus at low pH and form chelates with metal ions (Ca^{+}, Fe^{+}, Fe^{3+}, Al^{3+}), which otherwise render phosphorus unavailable. Solubilizing bacteria, mainly Bacillus, Pseudomonas, and Enterobacter, are very effective for increasing the plant-available P in the soil as well as the growth and yield of crops. Phosphate solubilizing microorganisms (PSMs) are widely accepted as eco-friendly phosphorus in sustainable agricultural systems.

Slow Release Fertilizer

Phosphorus products are now available on the market. These consist of di-ammonium phosphate or mono-ammonium phosphate with a high charge-density polymer, resulting in larger and longer-term plant availability of P.

- Di-carboxylic acid copolymer-coated fertilizer P product (Avail®) significantly improved crop yields compared to the normal P fertilizer source (Sanders *et al.,* 2012).
- Crop may experience a shortfall in P supply due to slow release of the phosphorus.
- The use of such products would be in situations where P is at risk of loss by leaching, such as coarse-textured soils in high rainfall regions and soils prone to P fixation.

Conclusion

Worldwide phosphorus reserves are rapidly being depleted. Besides agricultural soils, especially acid-weathered, tropical and subtropical regions of the world are particularly prone to P deficiency and ultimately affect crop yields. To ensure food security, especially in developing countries with their increasing populations and often P-deficient soils, and to use P efficiently, the most appropriate strategy will undoubtedly be to aim to increase plant-available P in the soil to the critical level appropriate. We needed extensive research in various disciplines of agricultural systems, and we needed to develop superior strategies to face the challenge of improving the P nutrition of plants.

References

Chin, J.H., Lu, X., Haefele, S.M., Gamuyao, R., Ismail, A., Wissuwa, M., Heuer, S., 2010. Development and Application of Gene-Based Markers for the Major Rice QTL Phosphorus Uptake. *Theoretical and Applied Genetics* 120(6), 1073-1086.

Mahdi, H.H., Mouhamad, R.S., 2018. Behavior of Phosphorus in the Calcareous Soil. *Adv Agri Tech Plant Sciences,* 1(4), 180018.

Razaq, M., Zhang, P, Shen, H., 2017. Influence of nitrogen and phosphorus on the growth and root morphology of Acer mono. *PLoS One* 12, 1-13.

Sanders, J.L., Murphy, L.S., Noble, A., Melgar, R.J., Perkins, J., 2012. Improving phosphorus use efficiency with polymer technology. *Procedia Engineering* 46, 178-84.

Vance, C.P., Uhde-Stone, C., Allan, D., 2003. Phosphorus acquisition and use: critical adaptation by plants for securing non-renewable resources. *New Phytologist* 15, 423-447.