Smart Phosphorus Management for Quality Crop Production and Soil Health Sustenance

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ABSTRACT

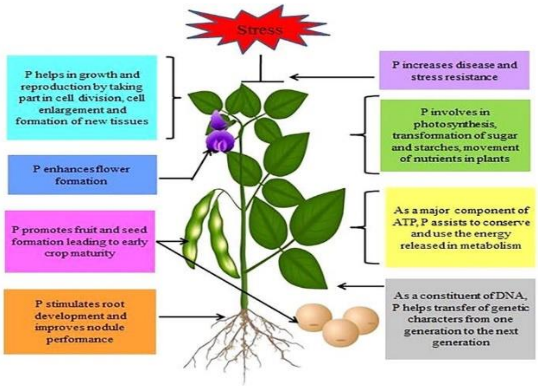
Phosphorus (P) is an essential macronutrient for plant growth and development. Despite the fact that soil contains 1000 times more P than plants do, limited diffusion and a high rate of fixation imply that P is rarely accessible for plant uptake. Therefore, in the absence of P-fertilization, plants are susceptible to P-deficiency, which may result in a 30–40% loss in crop yield. This emphasises how crucial it is to apply a lot of phosphate fertilisers in order to satisfy crop demands. P-fertilizer comes from a limited and non-renewable supply of rock phosphate, which is depleting over time. Furthermore, P resources are being lost as a result of farmers applying P fertilisers sporadically without taking the soil stock into account. The low P-use-efficiency (PUE) of plants under field conditions (15–20%) indicates that the majority of P applied through soil stays unavailable to plants. excess P leads to runoff and leaching that contaminates ground and surface waters (eutrophication), which in turn pollutes the environment. In order to prevent pollution of the environment and ensure the sustainable management of P resources, P fertilisers must be applied while taking the soil test value and PUE into account. Phosphorus solubilising bacteria are highly useful for increasing the plant available P in soil. Technological advancements like fertigation, nano fertilizers, etc. have potential to sustain food grain production.

INTRODUCTION

Along with nitrogen (N) and potassium (K), phosphorus (P) is one of the three primary elements that plants need for growth and reproduction. Phosphorus is one of the 17 necessary nutrients. It actively participates in the growth and development of plants at the cellular and overall levels as a structural component of sugars, lipids, and nucleic acids within plant cells. Younger leaves are the first to show signs of phosphorus deficit in plants since it is a mobile nutrient. Primary root growth is markedly inhibited by a P shortage in the soil. By causing lateral root growth and increasing the length and density of root hairs, it modifies the root architecture (morphology, topology, and root distribution). Significant crop loss arises from decreased root development, which also inhibits plant growth. A significant portion of P-fertilizer comes from phosphate rock, a limited and non-renewable resource. The phosphate fertiliser cost increase linked to agricultural productivity is a worry for the fertiliser sector. As a result, scientific experts are focusing more on the sustainable long-term management of P-fertilizer. P is one of the most significant non-renewable materials; its poor availability in soil (mostly because of sluggish diffusion and high fixation in soil) has already drawn attention from around the world. The difference in availability of differing P-sources is related to their solubility in soils rather than susceptibility to phosphatases (Adams M and Pate J., 1992). In farming, optimal P-fertilization is required to turn a profit, but applying P-fertilizer to soils that already contain an excess of P is not profitable. Plants absorb P from the soil reserves if P is not added to the soil. Conversely, though, it can be lucrative to farm P added to low P soil. P-rich soils must be carefully maintained, with the right quantities of fertiliser added to preserve (or marginally reduce) their P-level. According to predictions, if present trends continue, the world's current supplies of rock phosphate might run out over the next 50–100 years, or within ten years owing to the need for agricultural productivity worldwide. Reducing fertiliser costs through efficient P-fertilizer management would also lessen the harm that runoff and leaching pose to the environment. (Roberts and Johnston ,2015).

Biological and Physiological functions of phosphorus

No other nutrient can carry out the tasks of P, which increase crop output and quality. Without an appropriate supply of P, a plant cannot attain its maximum yield potential or finish its regular reproductive process. This is because P is a macronutrient that is essential to many different cellular processes. P participates in all aspects of growth and development at the cellular and whole plant levels as a structural component of nucleic acids, sugars, and lipids. These processes include cell division/elongation, maintenance of membrane structure, enzyme activation or inactivation, biomolecule synthesis, photosynthesis, respiration, formation of high-energy molecules such as carbohydrate metabolism, nitrogen fixation, seed germination, seedling establishment, root and shoot development, flower and seed formation, and enhancement of disease and stress resistance, among other things.



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Global phosphorus consumption

Future P-use will be impacted by the increased demand for bioenergy crops, especially when they are produced on more marginal land with poor P-status because of expanding global population and rising food consumption. The overall amount of P used worldwide grew five times between 1961 and 2013, reaching 31 million metric tonnes. With 9 billion people on the planet by 2050, P-demand for current and affluent diets would increase by 40 and 96%, respectively. The total P content in agricultural crops from 0.1% to 0.5% (Tiwari,2012). With almost 11 million metric tonnes used, China led the world in phosphate fertiliser consumption in 2020. India and Brazil came in second and third, with 8.98 and 6.04 million metric tonnes, respectively.

Year	Diet	P-consumption (kg/capita/y)		Total global P-consumption (Mt)	Fertilizer P-use (Mt)
		Developed countries	Developing countries		
2003	Current	0.64	0.43	3	16.24
2020	Current	0.64	0.43	3.6	19.4
	Affluent	0.64	0.64	4.9	26.7
2050	Current	0.64	0.43	4.2	22.8
	Affluent	0.64	0.64	5.9	31.8

Table. Global anticipated phosphorus consumption. Source: Smit *et al.*

Need to focus on phosphorus management

1. **Resource Conservation:** Phosphorus has limited deposits worldwide and is thus a finite resource. By preserving this priceless resource for future generations, efficient utilization helps guarantee its availability for food security, agriculture, and other vital uses.

2. **Cost Savings:** Fertilizers containing phosphorus are costly for farmers and agricultural enterprises. Effective phosphorus use minimizes waste and lowers input costs, which supports agricultural profitability and economic sustainability.

3. **Environmental Protection:** Overapplication of phosphorus can cause eutrophication of water bodies and other environmental problems, such as contaminated water. We can reduce pollution and nutrient runoff by effectively using phosphorus, safeguarding ecosystems and maintaining water quality.

4. **Regulatory Compliance:** To reduce water contamination and save natural resources, phosphorus application is governed by rules and guidelines in many places. By using phosphorous wisely, people and companies may avoid penalties, legal ramifications, and reputational harm while adhering to these standards.

5. **Soil Health:** Overuse of phosphorus fertilizers can cause soil deterioration and nutrient imbalances, which over time lower fertility and productivity. Phosphorus management that effectively contributes to soil health maintenance, long-term production, and sustainable agriculture methods.

6. **Climate Change Mitigation:** By lowering greenhouse gas emissions linked to fertilizer application and output, sustainable phosphorus management techniques like precision farming and soil conservation can aid in the fight against climate change.

7. **Innovation and Technology:** Encouraging the effective use of phosphorus fosters innovation and the creation of new techniques and technology to improve nutrient management in agriculture. Improvements in resource efficiency, environmental sustainability, and agricultural output may result from this.

Management strategies of phosphorus

Manure, compost, and mineral fertilisers are the most common sources of P in agricultural runoff. Limiting P-fertilizer sources quantity, timing, and application techniques are among the practices that can lower the danger of P contamination of agricultural land. P-levels measured by soil tests exhibit a high association with P-rate and application time, particularly in recently fertilised plots where the dissolved P in surface runoff is mostly caused by the quantity of soluble P in the fertiliser source. It was shown that runoff from fields receiving broadcast P fertiliser had a greater concentration of dissolved P than runoff from sites where similar amounts of P were absorbed 5 cm below the soil surface. It is possible to lessen the possibility of fertiliser loss in all circumstances, even areas with significant rainfall and high fertiliser application rates. Integrated effect of AM fungi in combination with organic compost was the best treatment as compared with the solely ones, such finding is emphasized by phosphorus recovery (Nader *et al*., 2008).

Furthermore, in some places (such as those with high rainfall), less water-soluble fertilisers should be used in order to reduce the amount of P that is transferred into runoff water. It's crucial to time fertiliser P applications to coincide with dry weather in order to minimise accidental P-losses during applications, particularly in areas with frequent irrigation or high rainfall. Runoff P-loss would be avoided by avoiding solid storms, which are responsible for a large amount of the yearly runoff P-loss. Reduced tillage and green manuring also help in reducing P runoff. It has been discovered that putting off applying P-nutrition sources until after a runoff or rainfall event lowers the quantity of P that ends up in runoff. Preventing the transportation of P-sources is the ultimate aim of P management for environmental protection. Magnesium coated biochar also helps in reducing P leaching. P pollution may be addressed in two different ways: first, by using intercepting technologies such as buffer strips to remove P from the landscape, and second, by using preventative measures like cover crops. Some of the strategies for enhancing P use efficiency are choice of fertilizer, soil test-based P application, phosphorus placement, fertigation, residual P utilization etc. To lessen P-movement through erosion and runoff, buffer strips and terracing have been recommended in addition to conservation tillage and crop-residue management techniques. Additionally, recommendations have been made regarding riparian zones, grassed streams, and cover crops.

CONCLUSION:

P deficiency in agricultural regions, which is brought on by high soil fixation and limited non-renewable P-stock, is the main focus of research globally. P's involvement in numerous physiological and biochemical processes have been carefully examined in a number of studies. Low P availability in the soil affects plant development overall because it reduces the quantity of P absorbed by plant roots. The P-demand can be increased by using fertilisers containing P, but haphazard application pollutes surface bodies. Reduced environmental contamination and the promotion of sustainable P management can be achieved by applying P fertilisers with consideration for the PUE and soil test value. Further research should focus on improving understanding of P-uptake, -utilisation, and -transport systems in low P settings. More comprehensive research in the realm of root biology is required, along with the discovery and optimisation of gene expression, to be able to improve P-acquisition and utilisation efficiency.

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