A Promising Approach for Utilising Phosphate Solubilizing Microbial Inocula to Enhance Sustainable Plant Growth: A Review

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ABSTRACT
Introduction: Phosphorous serve as strategic factor to cater various physiological and developmental needs of a plant, like photosynthesis, carbon metabolism, and membrane formation. However, majority of natural phosphorus occurs in conjugated form complexes with metal ions present in the soil, which is usable only in free form. Hence despite its abundance in soils in both inorganic and organic forms, it has emerged as primary plant growth-limiting nutrient. To surmount this phosphorous necessity of plants, application of synthetic fertilizers is practised, which is not recommended due to risk of environmental degradation. Hence it is vital to look out for an alternative which have a higher efficacy while also aiding sustainable plant growth. Several soil microorganisms, like bacteria, fungi, and actinomycetes solubilize bound phosphorus through various metabolic activities like excreting organic acids, enzymes and siderophores causing chelation of metal ion to increase phosphorus bioavailability. These microbial fauna also exert a constructive influence on crop yield by fabricating various phytohormones.
Conclusion: Therefore, the use of these microorganisms alone or in amalgamation as bio inoculants, can be economic as well as eco-friendly approach. The content covered in this review paper focuses on the strategies adopted by these phospho-solubizers and their use as sustainable growth promoters.

Keywords: Phosphate solubilization, Agriculture, Sustainable Growth, Bio inoculants.

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Introduction

One of the concern which lies among the mounting population of world is the massive demand of food that will be faced by agriculture systems. To meet this dare, a decent covenant of work is needed which can equilibrate among soil biology, associated agro ecosystem, and the resilience of agro lands. Many crop production systems have deprived productivity as the concentration of phosphorus is critical, due to its correlation with cations and anions in soil [1].When phosphate fertilizers are used as a method to curb the problem, even they get immobilized (more than 70%) and are reformed into complexes such as calcium phosphate,aluminum phosphate, and iron phosphate in the soil[2].Also, this resolution is not suitable for a long run and is environmentally undesirable as well as costly affair[3].Many microorganisms contribute to soil health by either their beneficial or detrimental activities. The phosphate solubilizing microorganisms among the microbial fraternity proved to be forerunner. Some of them are *Pseudomona*s [4],*Penicillium*[5], *Aspergillus*[6], *Burlkholderia*[7], *Acinetbacter, Pantoea*, and *Bacillius*[8]. Not only these microorganisms increases phosphorus availability [9] but also uphold plant escalation by producing indole acetic acid [10], fixing nitrogen, and producing siderophores [11]. Therefore, these phosphate solubilizers are perceived as an efficient strategy in refining the productive capacity of crop producing soils. This article reviewed latest functional aspects of phosphate solubilizing microorganisms to amplify their probable range of exploitation.

Bioaccesibility of available soil phosphorus

Inspite of being naturally enriched with phosphate,the total bioavailable level of phosphorus in soil is very insignificant [12].Phosphorus is found in soil as both organic and inorganic form. Of total, 20% is occupied as organic form which in turn is made up of plant and animal residues [13].Inorganic phosphorus which covers around 80% comprises phosphates bound to minerals ike calcium phosphate, aluminium phosphate, and iron phosphate [14].Also, soil pH determine the accessibility of phosphorus in soil[15].Hence this leads to categorization of Phosphorus as a limiting nutrient in soil under cultivation[16].These issues evoked the search for alternative strategies which are environment-friendly as well as economically feasible and can improve productivity in low or phosphorus-deficient soils.

ROLE OF MICROORGANISMS IN PHOSPHORUS BIOAVAILABILITY

Microorganisms comprise the prospective ability to convert fixed phosphorus to readily available form articulating with the sustainable plant growth [17].The diverse microbial community of PSM's includes potent members of fungi like *Acremonium, Hymenella*, and *Neosartorya*[18],*Penicilliumbrevicompactum*and*Aspergillusniger*[19]while bacteria from genera *Pseudomonas, Enterobacter*, and *Bacillus*[20,21],*Rhizobium, Arthrobacter*, and *Burkholderia,* and *Rahnellaaquatilis* HX2 [22,23].

MECHANISMS OF PHOSPHATE SOLUBILIZATION

The important agenda of microorganism-mediated phosphate solubilization have been widely worked on [24]. First and commonly studied mechanism of inorganic phosphate solubilization has been mainly related to secretion of low molecular weight organic acids, such as citric, oxalic, malic and gluconic acids, which causes chelation of cations holding phosphorus thus increasing its availability[25].Second mechanism accounts for enzymatic *i.e.* phosphatases degradation of organic phosphorus leading to mineralization [26,27].Third but less reported mechanism is via siderophores which are secondary metabolites secreted by bacteria under iron deficiency. They can extract iron from iron phosphate making the phosphorus available for plants [28]. One more reviewed mechanism is the formation of a compound called as exopolysaccharide(EPS) which can promote microbial dissolution of phosphorus [28].

PHOSPHATE-SOLUBILIZING BACTERIA AS PLANT GROWTH PROMOTERS

There have been different investigates and studies including the utilization of microbial inoculant for plant yield upgrade. This inoculant holds a higher convergence of microorganism than that typically found in soil. Different discoveries are very much archived like an investigation was finished by inoculating pecan seedling with a consortium of N-fixing *Arthrobacter* and phosphorus solubilizing *Pseudomonas chlororaphis*. This investigation showed expanded accessibility of nitrogen and phosphorus in soils emphatically influenced plant development [29]. Another investigation done in underlying foundations of mangrove seedlings when provided with blended inocula of nitrogen fixing microorganisms and phosphate solubilizing microbes revealed in moderate height of nitrogen and phosphate content in shoots and roots [30].Even the achievement pace of 300% improved root development of tomato seeds was seen when administered with *Enterobacterludwigii* EB4B [31].One more investigation including culture of *Mesorhizobium* S27 strain alongside insoluble phosphorus (Ca_2HPO_4) in Chickpea (*Ciceraritenium L.*) brought about productive quantity phosphorus into the plants. This additionally prompted huge expansion in plant biomass, nodule number and nitrogen content under insoluble phosphorus [32].Furthermore, in another investigation inocula including *Bacillus aryabhattai* (JX285) and *Pseudomonas auricularis* (HN038), and a combination of the two strains (1:1) was assessed for the development of *Camellia oleifera Abel.* This viably expanded nitrogen and phosphorus substance of leaf just as of rhizosphere soil [33].Also, an investigation done to examine the impact of a strain of *Enterobacter* on wheat crops with or without manures appeared to build stem prolongation and chlorophyll creation in the yield, and furthermore an improvement in compost use [34].

CONCLUSION AND FUTURE PROSPECTS

Future examinations are expected to explore different conditions, areas and harvests to confirm the unwavering quality of the current investigation. Rhizospheric residing Phosphate solubilizing microorganisms have a high prospective to be used as a catalyst in phosphorus deficient soil management. The various mechanism adopted by them includes production of organic acids, phosphatases and siderophores. Looking at the efficacy of microbial consortium in plant nutrition by varied methods, they can be perceived as game changer inbio fertilizationof agricultural crops. The idea would be to use them single handed or in mixed form as co-inoculants to engender sustainable plant growth. This strategy requires further exploration to mend theact of phosphate solubilizing microorganisms as effective microbial inoculum. Much of the attention is required on studies and formulations of new combinations of phosphate solubilizing microorganisms for augmented results. Most importantly the synergistic affair of this microorganism must be primarily focussed to interpret the biochemical nature of these interfaces. On the other hand, genetic altered make up can be effectively utilized as a tool to progress their phosphate-solubilizing capabilities. One more important and feasible approach that can be worked upon is the induction of this altered trait in strains that could enhance plant growth-promoting effects. Also, mutants with augmented fabrication of organic acids, siderophores and phosphatase activity could constitute an effective approach that cannot be underestimated. Additionally, another interesting approach is the usage of influential and targeted species promoters, which could be triggered under the precise ecological circumstances of soil. Although the above prospects can be considered enlightening but the stability and implementation of the phosphate solubilization trait after inoculation will still be a challenge. Conclusively based on the input of PSMs to support phosphorus cycle there are varied ecological, biogeochemical, and monetary motives to improve our perception on PSM competencies and their exploitation possibilities in agricultural expansion.

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REFERENCES

1. Rawat P, Das S, Shankhdhar D, Shankhdhar SC. Phosphate-solubilizing microorganisms: Mechanism and their role in phosphate solubilization and uptake. *J soil sci plant Nutr*. 2021; 21(1):49-68.
2. Sati SC, Pant P. Evaluation of phosphate Solubilization by root endophytic aquatic HyphomyceteTetracladiumsetigerum. *Symbiosis*. 2019;77(2):141-145.
3. Zeng Q, Wu X, Wen X. Identification and characterization of the rhizosphere phosphate-solubilizing bacterium Pseudomonas frederiksbergensis JW-SD2, and its plant growth-promoting effects on poplar seedlings. *Ann Microbiol*. 2016;66(4):1343-1354.
4. Linu MS, Asok AK, Thampi M, Sreekumar J, Jisha MS. Plant growth promoting traits of indigenous phosphate solubilizing Pseudomonas aeruginosa isolates from Chilli (capsicumannuum L.) rhizosphere. *Commun Soil Sci Plant Anal*. 2019;50(4):444-457.
5. Efthymiou A, Jensen B, Jakobsen I. The roles of mycorrhiza and Penicillium inoculants in phosphorus uptake by biochar-amended wheat. *Soil Biol Biochem*. 2018;127:168-177.
6. Li Z, Bai T, Dai L, et al. A study of organic acid production in contrasts between two phosphate solubilizing fungi: Penicillium oxalicum and Aspergillus niger. *Sci Rep*. 2016;6:25313.
7. Hsu PC, Condron L, O'callaghan M, Hurst M. hemXis required for production of 2-ketogluconate, the predominant organic anion required for inorganic phosphate solubilization byBurkholderiasp. Ha185: Burkholderiaphosphate solubilization genes. *Environ Microbiol Rep*. 2015;7(6):918-928.
8. Almoneafy AA, Kakar KU, Nawaz Z, Li B, Saand MA, Chun-Lan Y. Tomato plant growth promotion and antibacterial related-mechanisms of four rhizobacterial Bacillus strains against Ralstoniasolanacearum. *Symbiosis*. 2014;63(2):59-70.
9. Wei Y, Zhao Y, Wang H, et al. An optimized regulating method for composting phosphorus fractions transformation based on biochar addition and phosphate-solubilizing bacteria inoculation. *Bioresour Technol*. 2016;221:139-146.
10. Astriani M, Siti Zubaidah, Abdul Latief Abadi, Endang Suarsini. Pseudomonas plecoglossicida as a novel bacterium for phosphate solubilizing and indole-3-acetic acid-producing from soybean rhizospheric soils of East Java, Indonesia. *Biodiversitas*. 2020;21(2).
11. Panhwar QA, Radziah O, Zaharah Rahman A, Sariah M, Mohd Razi I, Naher UA. Contribution of phosphate-solubilizing bacteria in phosphorus bioavailability and growth enhancement of aerobic rice. *Span J Agric Res*. 2011;9(3):810.

12. Xu X, Mao X, Van Zwieten L, Niazi NK, Lu K, Bolan NS. Wetting-drying cycles during a rice-wheat crop rotation rapidly (im) mobilize recalcitrant soil phosphorus. *J Soils Sediments*. 2020;20(11):3921-3930.
13. Huang J, Xu CC, Ridoutt BG, Wang XC, Ren PA. Nitrogen and phosphorus losses and eutrophication potential associated with fertilizer application to cropland in China. *J Clean Prod*. 2017; 159:171-179.
14. Boitt G, Simpson ZP, Tian J, Black A, Wakelin SA, Condron LM. Plant biomass management impacts on short-term soil phosphorus dynamics in a temperate grassland. *Biol Fertil Soils*. 2018;54(3):397-409.
15. Zhu J, Li M, Whelan M. Phosphorus activators contribute to legacy phosphorus availability in agricultural soils: A review. *Sci Total Environ*. 2018;612:522-537.
16. Guiñazú LB, Andrés JA, Papa D, Pistorio MF, Rosas M. Response of alfalfa (Medicagosativa L.) to single and mixed inoculation with phosphate-solubilizing bacteria and Sinorhizobiummeliloti. *BiolFertil Soils*. 2010;46(2):185-190.
17. Rajwar J, Chandra R, Suyal DC, Tomer S, Kumar S, Goel R. Comparative phosphate solubilizing efficiency of psychrotolerant Pseudomonas jesenii MP1 and Acinetobacter sp. ST02 against chickpea for sustainable hill agriculture. *Biologia (Bratisl)*. 2018;73(8):793-802.
18. Ichriani GI, Syehfani -, Nuraini Y, Handayanto E. Formulation of Biochar-Compost and Phosphate Solubilizing Fungi from Oil Palm Empty Fruit Bunch to Improve Growth of Maize in an Ultisol of Central Kalimantan. *J Environ Eng Ecol Sci*. 2018; 19:45-55.
19. Rojas P, Del Y, Arias C, Ortiz M, Aguilar T, Heredia D. Rodríguez Yon Y. Effects of native arbuscular mycorrhizal and phosphate-solubilizing fungi on coffee plants. *Agrofor Syst*. 2019;93(3):961-972.
20. Biswas JK, Banerjee A, Rai M, Naidu R, Biswas B, Vithanage M. Potential application of selected metal resistant phosphate solubilizing bacteria isolated from the gut of earthworm (Metaphireposthuma) in plant growth promotion. *Geoderma*. 2018; 330:117-124.
21. Buch A, Archana G, Naresh Kumar G. Metabolic channeling of glucose towards gluconate in phosphate-solubilizing Pseudomonas aeruginosa P4 under phosphorus deficiency. *Res Microbiol*. 2008; 159(9-10):635-642.
22. Liu C, Mou L, Yi J, Wang J, Liu A, Yu J. The Eno Gene of Burkholderiacenocepacia Strain 71-2 is involved in Phosphate Solubilization. *Curr Microbiol*. 2019;76(4):495-502.
23. Zhang L, Fan J, Feng G, Declerck S. The arbuscularmycorrhizal fungus Rhizophagusirregularis MUCL 43194 induces the gene expression of citrate synthase in the tricarboxylic acid cycle of the phosphate-solubilizing bacterium Rahnellaaquatilis HX2. *Mycorrhiza*. 2019;29(1):69-75.
24. Khan MS, Zaidi A, Ahmad E. Mechanism of phosphate solubilization and physiological functions of phosphate-solubilizing microorganisms. In: *Phosphate Solubilizing Microorganisms*. Cham: Springer International Publishing; 2014:31-62.
25. Dodd RJ, Sharpley AN. Recognizing the role of soil organic phosphorus in soil fertility and water quality. *Resour Conserv Recycl*. 2015;105:282-293.
26. Onodera SI, Okuda N, Ban S, Saito M, Paytan A, Iwata T. Phosphorus cycling in watersheds: from limnology to environmental science. *Limnology (Tokyo)*. 2020;21(3):327-328.
27. Liu X, Yuan Z, Liu X, Zhang Y, Hua H, Jiang S. Historic trends and future prospects of waste generation and recycling in china's phosphorus cycle. *Environ Sci Technol*. 2020;54(8):5131-5139.
28. Sharma SB, Sayyed RZ, Trivedi MH, Gobi TA. Phosphate solubilizing microbes: sustainable approach for managing phosphorus deficiency in agricultural soils. *Springerplus*. 2013;2(1):587.
29. Yu X, Liu X, Zhu TH, Liu GH, Mao C. Co-inoculation with phosphate-solubilzing and nitrogen-fixing bacteria on solubilization of rock phosphate and their effect on growth promotion and nutrient uptake by walnut. *Eur J Soil Biol*. 2012;50:112-117.

30. Xiong Y, Zhang X, He X, Li M, Liao B. Species-specific effects of P-solubilizing and N2-fixing bacteria on seedling growth of three salt-tolerant trees. *Russ J Ecol*. 2016;47(3):259-265.
31. Bendaha M, Belaouni HA. Effect of the endophytic plant growth promoting Enterobacterludwigii EB4B on tomato growth. *Hell Plant Prot J*. 2020; 13(2):54-65.
32. Imen H, Neila A, Adnane B, et al. Inoculation with phosphate solubilizing Mesorhizobium strains improves the performance of chickpea (Cicer ariteniumL.) under phosphorus deficiency. *J Plant Nutr*. 2015; 38(11):1656-1671.
33. Wu S, Zhao Y, Chen Y, Dong X, Wang M, Wang G. Sulfur cycling in freshwater sediments: A cryptic driving force of iron deposition and phosphorus mobilization. *Sci Total Environ*. 2019; 657:1294-1303.
34. Borham A, Belal E, Metwaly M, El-gremy S. Phosphate Solubilization by Enterobacter cloacae and its Impact on Growth and Yield of Wheat Plants. *J Sustain Agric Sci*.2017; 43(2):89-103.