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Phosphate Solubilizing Bacteria as a Biofertilizer

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ABSTRACT: Phosphorus is a crucial nutrient needed for crop growth, it plays major role in both as a constituent of plant structural compounds and act as activator for many plant biochemical reactions. Phosphorus is mentioned specifically for its role in absorbing and changing sun's power into beneficial plant compound. The utilization of phosphatic solubilizing bacteria in agricultural practice might not only best off set the excessive value of synthetic phosphatic fertilizer however additionally solubilize the insoluble phosphorous within the fertilizer and soils to which they applied. Phosphate solubilizing bacteria across the roots of plant life and in soils has been proven to release soluble phosphorous, enhance plant growth and safeguards the vegetation from pathogen attack.

Keywords: Phosphate Solubilizing Bacteria, Biofertilizers, Solubilization.

INTRODUCTION

Phosphorous is one of the seventeen important nutrients required for plant growth. It is the second maximum crucial micro nutrient subsequent to nitrogen in restricting the crop growth and development. It is a constituent of numerous enzymes and proteins. It is a crucial factor of DNA and the genetic memory unit of all living organisms. It is also an element to construct proteins and different compounds important for plant shape, seed production. The structures of each DNA and RNA are held collectively by means of phosphorous bonds. Phosphorous is an important factor of ATP, the energy unit of vegetation. Phosphorous is major constituent of ATP, which is formed during photosynthesis and performs its role from the starting of seedling boom to the seed formation and maturity. Phosphorous is also engaged in plant processes such as respiration, photosynthesis, biosynthesis of nucelic acid, energy generation and fundamental constituent of various plant structures (Razaq *et al.,* 2017). Phosphorous induce some alterations architecture of roots, cluster roots formation, development of shoots, exudation of organic acids and alternative glycolytic and respiratory pathways (Vance *et al.,* 2003).

During seed development, phosphorous is absorbed via plants and translocated from roots to the seeds (Urbano *et al.,* 2000). However increased P fertilization will enhances the hazard of P losses to surface and floor waters, with the detrimental outcomes on ecosystems via eutrophication (Correll 1998; Raboy, 2001; Smith, 2003; Vats *et al*., 2005). Phosphorous is crucial for the overall fitness and vigour of all flora. Some particular growth factors like stimulated root improvement, enhanced stalk and stem strength, improved flower, seed formation, accelerated nitrogen fixing capacity, extra uniform and early crop maturity, enhanced crop quality and resistance to plant diseases have been associated with addition of phosphorous to the crop.

Crop with limited P shows the stunted growth and appears like week. Colour of older leaves become dark green and purple. In addition to alterations in root architecture, other changes include acidification of rhizosphere, exudation of low molecular weight organic acids, secretion of acid phosphatase and photosynthesis-related enzymes and symbiotic and free-living associations with mycorrhizal fungi and plant growth-promoting bacteria (Neumann and Romheld 2002; Singh and Pandey 2003). Lower concentration of ATP in roots results in reduced relative growth rate under long-term Pi-deficient conditions (Gniazdowska *et al.,* 1998). The full dose of applied P fertilizer is not available to the crops. Some part of the applied P make chelation with cations like aluminium, iron and calcium, magnesium under acidic and alkaline soil conditions respectively. Majority of the global soil is P limited. Moreover, global P resources are reduced at higher charge and in line with few estimates, there might be no soil P reserves in the year 2050. There is a need to increase the agriculture production and productivity in order to overcome the ever increasing population of the world. However the chemical fertilizers are scare, costly and have detrimental effects on soil health.

To overcome this problem, the utilization of phosphatic solubilizing bacteria in agricultural practice might not only best off set the excessive value of synthetic phosphatic fertilizer however additionally solubilize the insoluble phosphorous within the fertilizer and soils to which they applied. Phosphate solubilizing bacteria across the roots of plant life and in soils has been proven to release soluble phosphorous, enhance plant growth and safeguards the vegetation from pathogen attack.

Phosphorous availability of soil. Being a reactive element, in soil solution phosphorous does exit both as insoluble inorganic and organic phosphorous (Walpola and Yoon, 2012). The level of phosphorous in the soil is about 0.05% (Sharma *et al*., 2013). Generally about 95 -99% of soil phosphorous is in the form of insoluble phosphates (Pradhan and Sukla, 2005). The level of soluble P in soil solution is very low, and the concentration of soil P varying from ppb to 1 mg/ml. Several forms of P can be taken up by the plants, but depending upon the pH plant prefers to uptake P anions mainly in the form of HPO_4^{2-} or H_2PO^{4-} only (Mahidi *et al*., 2011; Kumar *et al*., 2018).

Cations such as Ca^{+2} and Al^{+3}, Fe^{+3} make chelation with Phosphorous under calcareous and acidic soil conditions respectively when phopsphatic fertilizer applied to the soil resulting in formation of complexes like calcium phosphate, alumina phosphate and ferrous phosphate (Satyaprakash *et al*., 2017). This form of P is unavailable to plant because of its insolubility and is sufficient to maintain higher crop yields. So there is a need to develop an alternative low priced technology with sufficient supply of phosphorous to the crops.

Distribution of Phosphate solubilizing bacteria. Phosphorous solubilizing bacteria are kind of beneficial bacteria play important role in solubilization of phosphate present in the soil (Abd-Alla, 1994) by that enhancing availability of soil phosphorous to plants (Zhu *et al*., 2011). Around 10^1 to 10^{10} bacteria are present in one gram of soil, as soil acts as minimal basal media for growth of microbes (Khan *et al*., 2009). About 1-50% are of phosphate solubilizing bacteria, 0.1 to 0.5% are of phosphate solubilizing fungi which in whole microbial population (Chen *et al.,* 2006; Khan *et al*., 2009). Rhizosphere contain PSB are of metabolically much active and are isolated from rhizosphere soil (Selvi *et al*., 2017).

Isolation and Screenng of PSBs. In laboratories PSBs are isolated using various growth mediums. The suitable methodology for isolation and potential screening of PSBs was described by Pikovskaya. The colonies with clear halo zone surrounding to it considered as PSB after incubation at optimum temperature. The colonies with formation of halo zone are selected, purified, sub-cultured under aseptic condition and stored at 4ºC for further morphological, biochemical and molecular studies.

The phosphate solubilization efficiency was calculated using below mentioned formula (Kannapiran and Ramkumar, 2011).

$$\text{Solubilization efficiency (\%)} = \frac{\text{Solubilization zone} - \text{Colony diameter}}{\text{Colony diameter}}$$

Solubilization index on solid media. Solubilization index on the soild media was measured by considering the ratio of diameter of the total (colony + halo zone) colony and diameter of only colony (Edi-Premono *et al*., 1996). Considering the isolates which show the best results on the solid media with respect to solubilization efficiency and solubilization index were subjected to further experimental studies.

Solubilization of phosphate enhances the bioavailability of soil phosphorous to plants (Zhu *et al*., 2011). Phosphate solubilizing bacteria produces and release some organic acid during its metabolic activities there by reduces the soil pH and subsequently leads to the solubilization of phosphate present in soil. Organic acids solubilize the P either by making the chelation with the cations, bound to phosphorous or by reducing the soil pH (Vassilev *et al*., 2006). The PSB produce and releases organic acids such as maleic, oxalic succinic and propionic acids (Panhwar *et al.,* 2011) and the hydroxyl groups of organic acids make complexes with cations bound to P and make it available for the plant uptake.

Table 1: Production and release of various types of organic acides by PSBs.

PSB Isolates	Organic acid produced	Reference
Proteus sp.	Fumaric acid	Selvi *et al.,* (2017)
Bacillus sp., *Azospirillum* sp.	Maleic, tartaric, succinic acid	Selvi *et al.,* (2017)
Pseudomonas sp.	Succinic, 2-keto gluconic acid	Kumar *et al.,* (2018)

The utilization of phosphatic solubilizing bacteria in agricultural practice might not only best off set the excessive value of synthetic phosphatic fertilizer however additionally solubilize the insoluble phosphorous within the fertilizer and soils to which they applied (Rodriguez and Fraga, 1999). Majority of the bacteria especially those belonging to the genus Bacillus and Pseudomonas were solubilized the insoluble form of P with the release of some organic acids like acetic, formic, glycolic, lactic, acetic acids and fumaric acids (Rashid *et al.,* 2014). Four strains of PSB namely *Anthrobacter ureafaciens, Rhodococcus erythropolis, Delfia* sp. and *Phyllobacterium myrsinacearum* were reported by Chen *et al.,* (2006) and were involved in organic acid production thereby solubilize the considerable quantity of TCP in the medium.

PSB in plant growth promotion. Various phosphate of solubilizing bacteria are resides in the soil. The quantity of P released by PSB is generally not adequate for actual improvement of plant growth. So there is a need to inoculate the plants with targeted microbes with higher concentration than that generally present in the soil for the enhancement of yield. Numerous reports reported that capability of the PSB to mineralize or to solubilize the organic and inorganic P in the soil, which in turn leads to increased plant growth promotion activities (Kloepper *et al.,* 1988; Subba Rao, 1982).

Beneficial metabolites such as siderophores, antibiotics and phytohormonres are produced and released by PSB and they played crucial role in plant growth and yield enhancement. The availability of P is a limiting measure in plant development (Goldstein, 1988). This proof indicated the principle contribution of PSB in nutrition and growth performance of plants. Datta *et al.*, (1982) found that strains of *Bacillus firmus* NCIM 2636 produce IAA along with inorganic phosphate solubilization.

Phosphate solubilizing bacteria *i.e.,* eighty Pseudomonas strains were screened by Jha *et al.,* (2009). Among 80, three isolates viz., *Pseudomonas plecoglossicida, P aeruginosa, P. mosseli* were able to solubilize TCP. *Pseudomonas plecoglossicida* produced siderophores and indole acetic acid along with maximum solubilization of phosphate. Stress tolerant phosphate solubilizing *Arthobacter* spp and *Bacillus* spp were isolated from tomato rhizosphere by Banarjee *et al.,* (2010) in addition to phosphate solubilization activity they were also engaged in bocontrol and plant growth promotion activities including IAA production. PSB isolates were showed positive results for the production of organic acid and hormones such as IAA. Majority of the isolated PSB strains were *Bacillus* spp. and were capable to produce siderophores.

Phosphate solubilizing bacteria has promoted both growth enhancement and uptake of nutrients by plants simultaneously. *Pseudomonas putida*, a strain of PSB promoted growth of both soot and roots along with P uptake by Canola plants (Lifshitz *et al*., 1987). Murty and Ladha, (1988) reported rice seeds inoculated with *Azospirillum lipoferum* showed improved root growth, biomass along with increased uptake of phosphate ions. Increase in uptake of P and yields have been also associated with *Bacillus firmus* (Datta *et al.,* 1982) *Bacillus polymyxa* (Gaur and Ostwal, 1972**)** *Bacillus cereus* and others.

Mixed or co-cuculture with other microbes is the alternate move towards the use of phosphate solubilizing bacteria as a microbial inoculation. Monib *et al*., (1984) demonstrated the co-inoculation of *Azospirillium* and PSB influenced positively on uptake of P, N along with better yield in various crops. Combined inoculation of *Pseudomonas striata Bacillus polymyxa* and *Azospirillium* brasillense showed increased P and N uptake, improved root and shoot growth with significant yield as compared to single inoculation. Both pot and field experiments were conducted by Bakshandeh *et al*., (2015) to study the efficiency of four PSB isolates *Enterobacter* sp, *Rahnella aquatilis, Pseudomonas putida* and *Pseudomonas fluorescence* showed increased grain and biological yield in different varieties of rice cultivars as compared to individual inoculation.

Vikram and Hamzehzarghani, (2008) isolated sixteen PSB isolates and were promoted growth parameters like increased nodule numbers, nodule weight, dry weight and shoot weight of green gram under green house circumstance. Significantly increased uptake of P and improvement in morphology of aerobic rice were demonstrated by Panhwar *et al*., (2011). Inoculation of PSB and its ecological effects on growth and biological yields of winter maize was studied by Rima and Dulley, (2013) under two subsequent winter seasons, and highest values were recorded by all growth parameters after inoculation with PSB.

CONCLUSION

Application of PSB in soil appears to be an efficient way to convert insoluble form of P compounds to soluble form of P resulting in significantly increased growth yield and quality. Most potential PSBs are *Bacillus* spp, *Pseudomonas* spp and *Rhizobium* spp etc., Application of PSB enhances both vegetative and reproductive parameters of plant along with increased nutrient uptake like P and N. They also involved in production of siderophores, antibiotics and plant growth promoting hormones IAA, GA and thereby improve the plant growth and development. They also serve as bio control agents against several plant pathogens. Thus PSB acts as a promising substitute for inorganic P fertilizer to fulfil the needs of P to the plants.

FUTURE SCOPE

The strains need to adjust different locations so multi location trials are necessary to evaluate the phosphate solubilizing bacterial strains due to larger variations in soil and climatic condition.

Conflict of Interest. None.

REFERENCES

Abd-Alla, M. H. (1994). Phosphatases and the utilization of organic phosphorus by Rhizobium leguminosarum biovar viceae. *Letters in Applied Microbiology, 18*: 294–296.

Chen, Y. P., Rekha, P. D., Arun, A. B., & Shen, F. T. (2006). Phosphate solubilizing bacteria from subtropical soil and their Tricalcium phosphate solubilizing abilities. *Applied Soil Eco*logy, *34*: 33-41.

Correll, D. L. (1998). The role of phosphorus in the eutrophication of receiving waters: A review. *Journal of Environmental Quality*, *27*(2): 261-266.

Banerjee, S., Palit, R., Sengupta, C., & Standing, D. (2010). Stress induced phosphate solubilization by *Arthrobacter* spp. and *Bacillus* spp. isolated from tomato rhizosphere. *Australian Journal of Crop Science, 4*(6): 378-383.

Datta, M., Banik, S., & Gupta, R. K. (1982). Studies on the efficacy of a phytohormone producing phosphate solubilizing Bacillus firmus in augmenting paddy yield in acid soils of Nagaland. *Plant and Soil*, *69*(3): 365-373.

Edi-Premono, M., Moawad, A. M., & Vlek, P. L. G. (1996). Effect of phosphate solubilization *Pseudomonas putida* on the growth of maize and its survival in the rhizosphere. *Indonesian Journal. Crop Science, 11*: 13-23.

Gaur, A. C., & Ostwal, K. P. (1972). Influence of phosphate dissolving Bacilli on yield and phosphate uptake of wheat crop*. Indian Journal of Experimental Biology*, *10*: 393-4.

Gniazdowska, A., Mikulska, M., & Rychter, A. M. (1998). Growth, nitrate uptake and respiration rate in bean roots under phosphate deficiency. *Biol. Plant, 41*: 217–226.

Goldstein, A. H. (1986). Bacterial solubilisation of mineral phosphates: historical perspective and future prospects. *American Journal of Alternative Agriculture*, *1*: 51-57.

Jha, B., Thakur, M. C., Gontia, I., Albrecht, V., Stoffels, M., Schmid, M., & Hartmann, A. (2009). Isolation, partial identification and application of diazotrophic rhizobacteria from traditional Indian rice cultivars. *European Journal of Soil Bio*logy, *45*: 62-72.

Kannapiran, E., & Sri Ramkumar, V. (2011). Isolation of phosphate solubilizing bacteria from sediments of Thondi coast, Palk Strait, Southeast coast of India. *Annals of Biological Res.*, *25*: 157-163.

Khan, A. Jilani, V., Akhtar, M. S. Naqvi, M. S., & Rasheed, M. (2009). Phosphorous solubilizing bacteria: occurance, mechanisms and their role in crop production. *Journal of agriculture and Biological Science*, *1*: 48-58.

Kloepper, J. W., Lifshitz, K., & Schroth, M. N. (1988). Pseudomonas inoculants to benefit plant production. *ISI Atlas. Sci. Animal Science*, 60-64.

Kumar, A., Kumar, A., & Patel, H. (2018). Role of microbes in phosphorous availability and acquisition by plants. *International Journal of Current Microbiology and Applied Science*, *7*(5): 1344-1347.

Lifshitz, R., Kloepper, J. W., Kozlowski, M., Simonson, C., Carlson, J., Tippng, E. M., & Zaleska, I. C. (1987). Growth promotion of canola seedlings by a strain of Pseudomonas putoda under gnotobiotic conditions. *Can. J. Microbiol*., *33*: 390-395.

Mahidi, S. S. Hassan, G. I., Hussain, A., & Faisul-Ur-Rasool (2011). Phosphorous availability issue-its fixation and role of phosphate solubilizing bacteria in phosphate solubilization case study. *Research Journal of Agriculture Science*, *2*: 174-179.

Monib, M., Hosny, I., & Besada, Y. B., & Besada, Y. B. (1984). Seed inoculation of castor oil plant (*Ricinus communis*) and effect on nutrient uptake. *Soil Biological Conservation Biosphere*, *2*: 723-732.

Murty, M. G., & Ladha, J. K. (1988). Influence of Azospirillium inoculation on the mineral uptake and growth of rice under hydroponic condition. *Plant Soil*, *108*: 281-285.

Neumann, G., & Romheld, V. (2002). Root-induced changes in the availability of nutrients in the rhizosphere. In: Waisel Y, Eshel A, Kafkafi U (eds) Plant roots, the hidden half, 3rd edn. Marcel Dekker, New York, pp 617–649.

Panhwar, Q. A., Radziah, O., Zaharah, A. R., Sariah, M., & Mohd. Razi, I. (2011). Role of phosphate solubilizing bacteria on rock phosphate solubility and growth of aerobic rice. *J. Environ. Biol.*, *32*: 607-612.

Pradhan, N., & Sukla, L. B. (2005). Solubilization of inorganic phosphate by fungi isolated from agriculture soil. African Journal of Biotechnology, *5*: 850-854.

Raboy, V. (2001). Seeds for a better future: 'low phytate' seeds help to overcome malnutrition and reduce pollution. *Trends Plant Science*, *6*: 458-462.

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

Rima, T., & Dulley, Y. (2013). Application of phosphate solubilizing bacteria and its ecological effect on growth and yield of winter maize (*Zea Mays* L.). *IOSR Journal of Agriculture and Veterinary Science*, *4*(1): 2319-2372.

Rodriguez, H., & Fraga, R. (1999). Phosphate solubilizing bacteria and their role in plant growth promotion. *Biotechnol. Adv*., *17*(4-5): 319-339.

Satyaprakash, M., Nikitha, T., Reddi, E. U. B., Sadhana, B., & Vani, S. S. (2017). A review on phosphorous and phosphate and phosphate solubilizing bacteria and their role in plant nutrition. *International Journal of Current Microbiology and Applied Science*, *6*: 2133-2144.

Selvi, K. B., J. Paul, J. A., Vijaya, V., & Saraswathi, K. (2017). Analyzing the efficacy of phosphate solubilizing microorganisms by enrichment culture techniques. *Biochemistry and Molecular Biology Journal*, *3*: 1.

Sharma, S. B., Sayyed, R. Z., Trivedi, M. H., & Gobi, T. A. (2013). Phosphate solubilizing microbes: sustainable approach for managing phosphorous deficiency in agricultural soils. *Springer Plus*, *2*: 587.

Singh, B., & Pandey, R. (2003). Differences in root exudation among phosphorus-starved genotypes of maize and green gram and its relationship with phosphorus uptake. *Journal of Plant Nutrition*, *26*: 2391–2401.

Smith, V. H. (2003). Eutrophication of freshwater and coastal marine ecosystems: a global problem. *Environmental Science and Pollution Research* (*international*), *10*: 126–139.

Subba Rao, N. S. (1982). Advance in agricultural microbiology. In: Subba Rao NS, editor. Studies in the Agriculture and Food Science. London: *Butterworth Scientific*, 295-303.

Urbano, G., Lopez-Jurado, M., Aranda, P., Vidal-Valverde, C., & Porres, T. J. (2000). The role phytic acid in legumes: Antinutrient or beneficial function. *Journal of Physiol. Biochemistry*, *56*: 283-294.

Vance, C. P., Uhde-Stone, C., & Allan, D. L. (2003). Phosphorus acquisition and use: critical adaptations byplants for securing a nonrenewable resource. *New Phytol*., *157*: 423-447.

Vassilev, N., Vassileva, M., & Nikolaeva, I. (2006). Simultaneous P-solubilizing and biocontrol activity of microorganisms: potentials and future trends. *Appl. Microbiol. Biotechnol.*, *71*: 137-144.

Vats, P., Battacharya, M., & Banerjee, U. (2005). Use of phytases (myo-inositol hexakisphosphatases phosphohydolases) for combating environmental pollution: A biological approach. *Environ. Science Technology*, *35*: 469-486.

Vikram, A., & Hamzehzarghani, H. (2008). Effect phosphate solubilizing bacteria on nodulation and growth parameters of greengram (*Vigna radiata* L. Wilczek). *Research Journal Microbiology*, *3*(2): 62-72.

Walpola, B. C., & Yoon, M. (2012). Prospects of phosphate solubilizing microorganisms and phosphorous availability in agricultural soils: a review. *African Journal of Microbiology Research*, *6*: 6600-6605.

Zhu, F., Qu, L., Hong X., & Sun, X. (2011). Isolation and characterization of a phosphate-solubilizing halophilic bacterium Kushneria sp. YCWA18 from Daqiao Saltern on the coast of yellow sea of China. *Evid-Based Complement Altern.* pp-1–6.

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