Available online at www.ijpab.com

DOI: http://dx.doi.org/10.18782/2320-7051.7852

ISSN: 2582 – 2845

Ind. J. Pure App. Biosci. (2019) *7*(5), 375-392

Indian Journal of Pure & Applied Biosciences

Review Article

P Solubilisers for Sustainance of Agriculture- A Review

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Received: 11.09.2019 | Revised: 17.10.2019 | Accepted: 23.10.2019

ABSTRACT

Phosphorus is the most common nutrient which helps the plants to convert metabolites into usable building blocks for growth. The use of phosphate solubilising bacteria as inoculants simultaneously increases P uptake by the plants and hence improves crop yield. Strains from the genera Pseudomonas, Bacillus and Rhizobium are among the most powerful Phosphate solubilisers. The principal mechanism for mineral phosphate solubilisation is the production of organic acids. Acid phosphatase plays a major role in the mineralization of organic phosphorous in soil. Several phosphatase encoding genes have been cloned and characterized. A few genes involved in mineral phosphate solubilisation have been isolated. Therefore, genetic manipulation of phosphate solubilising bacteria can improve plant growth. Synergistic effect of phosphate solubilising microorganisms on TCP solubilisation was highest when triple culture of Aspergillus niger, Aspergillus flavus and Trichoderma sp. was inoculated in NBRIP broth as compared to double and single inoculations.

Keywords: *Soil Samples, Biosolubilisation, Tricalcium phosphate, PVK broth, NBRIP broth, Synergictic effect*

INTRODUCTION

Rose (Rosa) is a flowering plant grown for their beauty and fragrance as well as their cultural significance. Phosphorous is essencial for metabolic activities of plants (Khan et al. 2010). Chemical fertilizers may supply one or more mineral element that is essential for plant growth but have various disadvantages as well.To achieve soil fertility, soil quality should be improved by using phosphate solubilising microbial inoculants (Poonguzhali et al. 2008).

Objective

To envisage the efficacy of phosphate solubilising microorganisms.

MATERIALS AND METHODS

Microbial enumeration of bacterial and fungal population was determined on Nutrient Agar Media (NAM) and Potato Dextrose Agar (PDA), respectively. P solubilisers were isolated on Pikovskaya agar, modified Pikovskaya agar and NBRIP agar. Solubilised P was determined by using Watanobe and Olsen method (Watanabe & Olsen, 1965).

Cite this article: Kaur, P., & Chatli, A.S. (2019). P Solubilisers for Sustainance of Agriculture- A Review, *Ind. J. Pure App. Biosci. 7*(5), 375-392. doi: http://dx.doi.org/10.18782/2320-7051.7852

Review

National and International Status

El-Gibaly et al. (1977) found that two hundred colonies showed positive reaction on the plates prepared for the Phosphate-dissolving bacteria than control. Rhizosphere soils and rhizoplane samples of maize, peas or cotton were isolated at random and fifty isolates were selected as the most efficient isolates according to their capability to increase the amount of available phosphorus in the media with corresponding decreases in pH values. The percentage of the most efficient isolates differed according to type of plant and location. Morphological differences in the isolates from rhizosphere soil and from rhizoplane samples of the same plant were also observed. The abundance of mycelia forming bacteria and of aerobic species was reported.

Singh et al. (1980) examined solubilisation of insoluble Phosphates by thermophilic fungi. The solubilisation of tricalcium phosphate, rock phosphate and assimilation of solubilised P by thermophilic fungi isolated from compost were studied. The solubilisation of tricalcium phosphate was greater than that of rock phosphate on inoculation with fungi in liquid medium, but growth of most of the fungi was greater in rock phosphate. *Torula thermophila* solubilised tricalcium phosphate maximally. There was solubilisation of rock phosphate in semi-solid lignocellulose medium by *Aspergillus fumigatus*.

Kucey (1987) examined increased phosphorus Uptake by Wheat and Field Beans Inoculated with a Phosphorus-Solubilising *Penicillium bilaji* Strain and with Vesicular-Arbuscular Mycorrhizal Fungi. Greenhouse and field experiments were conducted to test the effect of a P-solubilising isolate of *Penicillium bilaji* on the availability of Idaho rock phosphate (RP) in a calcareous soil. Under controlled greenhouse conditions, inoculation of soils with *P. bilaji* along with RP at 45 mug of P per g of soil resulted in plant dry matter production and P uptake by wheat (*Triticum aestivum*) and beans (*Phaseolus vulgaris*) that were not significantly different from the increases in dry matter production and P uptake caused by the addition of 15 mug of P per g of soil as triple superphosphate. Addition of RP alone had no effect on plant growth. Addition of vesicular-arbuscular mycorrhizal fungi was necessary for maximum effect in the sterilized soil in the greenhouse experiment. Under field conditions, a treatment consisting of RP (20 kg of P per ha of soil) plus *P. bilaji* plus straw resulted in wheat yields and P uptake equivalent to increases due to the addition of monoammonium phosphate added at an equivalent rate of P. RP added alone had no effect on wheat growth or P uptake. The results indicate that a biological system of RP solubilisation can be used to increase the availability of RP added to calcareous soils.

Nahas (1996) observed factors determining rock phosphate solubilisation by microorganisms isolated from soil. Forty two soil isolates (31 bacteria and 11 fungi) were studied for their ability to solubilise rock phosphate and calcium phosphate in culture medium. Eight bacteria and 8 fungi possessed P solubilising ability. *Pseudomonas cepacia* and *Penicillium purpurogenum* showed the highest activity. Maximum correlation was observed between final pH and soluble phosphate only for the rock phosphates inoculated with the highest concentration of solubilising bacteria (r=-0.73 to -0.98).

Nautiyal (1999) investigated microbial growth medium, National Botanical Research Institute's phosphate growth medium (NBRIP), which is more effective than Pikovskaya Medium. The result was based on a criterion of formation of visible halo/zone on agar plates. The screened PSM on NBRIP media showed more efficient microbes.

Johri et al. (1999) reported occurrence of salt, pH, and temperature-tolerant, phosphate-solubilising bacteria in alkaline soils. An ecological survey was conducted to characterize 4800 bacterial strains isolated from the root-free soil, rhizosphere and rhizoplane of *Prosopis juliflora* growing in alkaline soils. Of the 4800 bacteria, 857 strains were able to solubilise phosphate on plates.

The incidence of phosphate-solubilising bacteria (PSB) in the rhizoplane was highest, followed by rhizosphere soil. Eighteen bacterial strains out of 857 PSB were able to produce halo at 30° C in a plate assay in the presence of 5% salt (NaCl) and solubilised tricalcium phosphate in National Botanical Research Institute's phosphate growth medium (NBRIP) broth, in the presence of various salts, pH, and temperatures. Among the various bacteria tested, NBRI4 and NBRI7 did not produce clear zones in a plate assay at 30° C in the absence of salt. Contrary to indirect measurement of phosphate solubilisation by plate assay, the direct measurement of phosphate solubilisation in NBRIP broth assay always resulted in reliable results. The phosphate solubilisation ability of organisms in NBRIP was higher than in the control in the presence of salts (NaCl, $CaCl_2$, and KCl) at 30°C. Phosphate solubilisation further increased in the presence of salts at 37°C as compared with 30°C. At 37°C, $CaCl_2$ reduced phosphate solubilisation ability of organisms in NBRIP compared with the control. The results indicated the role of calcium salt in the phosphate solubilisation ability of microbes in NBRIP.

Nautiyal et al. (2000) observed stress induced phosphate solubilisation in bacteria isolated from alkaline soils. Phosphate solubilising bacteria NBRI0603, NBRI2601, NBRI3246 and NBRI4003 were isolated from the rhizosphere of chickpea and alkaline soils. All four strains demonstrated diverse levels of phosphate solubilisation activity under *in vitro* conditions in the presence of various carbon and nitrogen sources. Acid production may have contributed to Phosphate solubilisation, but was not the only reason for Phosphate release into the medium. Among the four strains, NBRI2601 was the most efficient strain in terms of its capability to solubilise Phosphorus in the presence of 10% salt, pH 12 at 45° C. The strains showed varied levels of Phosphate solubilisation when the effects of different sources of nitrogen were examined during growth. The presence of low levels of Ca^{2+} and EDTA in the medium enhanced phosphate solubilisation.

Wahid et al. (2000) studied the impact of phosphate-solubilising fungi on the yield and phosphorus-uptake by wheat and faba bean plants. Three fungal isolates (Phosphate-dissolvers), *Aspergillus niger, A. fumigatus* and *Penicillium pinophilum* were isolated from the rhizosphere of different plants grown in Ismailia and South. Sinai Governorates. They effectively solubilised rock phosphate or tricalcium phosphate in Pikovskaya's broth. In pot and column experiments, they significantly reduced pH and increased available phosphorus in the soil treated with either rock phosphate or superphosphate. The yield components of wheat and faba bean plants increased as a result of soil inoculation with the isolated fungi. *Penicillium pinophilum* was the most efficient isolate. It increased the yield of wheat grains by 28.9% and 32.8% in the soil treated with rock phosphate and superphosphate, respectively. Similarly, it increased the production of faba bean seeds by 14.7% and 29.4% with the same treatments. The uptake of phosphorus by both crops significantly increased due to inoculation of the soil with the tested fungi.

Reyes et al. (2002) examined Rock phosphate solubilisation and colonization of maize rhizosphere by wild and genetically modified strains of *Penicillium rugulosum*. Maize root colonization and phosphate solubilising activity of the fungus *Penicillium rugulosum* were assessed in a greenhouse trial using soil-plant microcosms. The bacterial gene hph conferring resistance to hygromicin B was introduced by electroporation in the wild-type strain IR-94MF1 of *P. rugulosum* and one transformant, w-T3, was selected. Maize plants were grown for 5 weeks in a P poor soil and fertilized with a Florida apatite mineral, with Navay, an appetite rock deposit from Venezuela, or with simple superphosphate. Inoculation treatments included strain IR-94MF1, transformant w-T3 and two IR-94MF1 UV-induced mutants with enhanced (Mps++) or reduced (Mps-) *in vitro* mineral phosphate solubilising activity. In the absence of P fertilization, inoculation with any *P. rugulosum* isolate significantly reduced the size of the total and P solubilising bacterial community present in maize rhizosphere. The bacterial community significantly increased in maize inoculated with IR-94MF1 and w-T3 when P was added as apatite Navay or Florida. All *P. rugulosum* strains were able to stimulate the growth of maize plants as indicated by 3.6% to 28.6% increase in dry matter yields. In the presence of rock phosphate, P uptake by maize plants inoculated with the two mutants Mps++ and Mps- was not always in agreement with their P-solubilising phenotypes. Strain IR-94MF1 and transformant w-T3 increased P assimilation by the plants fertilized with Navay rock phosphate by 26% and 38%, respectively. In this treatment, w-T3 showed its highest significant maize rhizosphere colonization. With the simple superphosphate treatment, w-T3 increased P uptake in plants by 8% over the uninoculated control and also decreased significantly the community size of total bacteria, total fungi and P-solubilising fungi in the rhizosphere.

Yasmin et al. (2004) examined the isolation, characterization and beneficial effects of rice associated plant growth promoting bacteria from Zanzibar soils. This study was undertaken to isolate and characterize plant growth promoting bacteria (PGPB) occurring in four soils of Zanzibar, Tanzania as well as to evaluate their potential use as biofertilizers for rice. A total of 12 PGPB strains were isolated from rice and studied for growth characteristics, carbon/nitrogen source utilization patterns using QTS-24 kits, phosphate solubilisation, indole acetic acid (IAA) production, antibiotic resistance patterns and growth at different pH, temperature and salt concentrations. All the isolates were motile and Gram negative except Z3-4. Acetylene reduction activity was detected in all isolates ranging from 5.9-76.4 nmole C_2H_2 reduced/h x mg protein while 9 isolates produced IAA ranged from 20-90.8 mg/l. Most of the isolates showed resistance against different environmental stresses like 10-40°C temperature, 0.2-1 M salt concentration and 4-8.5 pH range. Only one isolate Z2-7 formed clear zones on Pikovskaya's medium showing its ability to solubilise phosphates. Z3-2 was used to develop fluorescent antibodies to check the cross reactivity of the isolates. Inoculation of these bacterial isolates resulted in higher plant biomass, root area and total N and P contents on Tanzanian rice variety BKN PRAT3036B under controlled conditions. *Bacillus sp.* Z3-4 and *Azospirillum sp*. Z3-1 are effective strains and, after further testing under field conditions, can be used for inoculum production of rice in Tanzania. The plant growth promoting effects of these PGPRs suggest that these can be exploited to improve crop productivity of rice in Tanzania.

Rudresh et al. (2005) studied tricalcium phosphate solubilising abilities of *Trichoderma spp*. in relation to P uptake and growth and yield parameters of chickpea (*Cicer arietinum L*.). Nine isolates of *Trichoderma spp.* were investigated for their ability to solubilise insoluble phosphate in Pikovskaya's broth and were compared with an efficient phosphate-solubilising bacterium *Bacillus megaterium subsp*. phospaticum PB that was used as the reference strain. All 9 *Trichoderma* isolates were found to solubilise insoluble tricalcium phosphate to various extents. *Trichoderma viride* (TV 97) (9.03 microg x mL(-1)), *Trichoderma virens* (PDBCTVs 12) (9.0 microg x mL(-1)), and *Trichoderma virens* (PDBCTVs 13) (8.83 microg x mL(-1)) solubilised 70% of that solubilised by the reference strain *Bacillusmegaterium* (12.43 microg x mL(-1)). Pot culture and field evaluations with *Trichoderma harzianum* (PDBCTH 10), *Trichoderma viride* (TV 97), and *Trichoderma virens* (PDBCTVs 12) using chickpea (*Cicer arietinum L*.) 'Annegeri-1' as the test plant and rock phosphate as the phosphorus source showed significantly increased P uptake in plants treated with *Trichoderma harzianum* (PDBCTH 10) followed by *Trichoderma virens* (PDBCTVs 12) and *Trichoderma viride* (TV 97). Inoculation of *Trichodermaspp*.also showed increased growth and yield parameters of chickpea compared with the uninoculated controls under both glasshouse and field conditions.

Delvastro et al. (2006) observed Mineral-Phosphate Solubilisation Activity of Iron ore Associated Microflora. A high P iron ore was screened for mineral phosphate solubilising activity within its associated microflora. Microorganisms belonging to genera *Burkholderia, Clavibacter* and *Aspergillus*, were isolated. A pH-sensitive dyed medium was used to approach the solubilisation mechanism of selected isolates. Only isolate *Aspergillus niger* was able to acidify the medium while solubilising phosphate. By way of shake flask experiments, P-solubilisation of some isolates was assessed. Implications of these findings on biodephosphorization of iron ores were discussed.

Son et al. (2006) examined Solubilisation of insoluble inorganic phosphates by a novel salt- and pH-tolerant isolated from soybean rhizosphere. To develop environment-friendly biofertilizer solubilising insoluble phosphates, salt- and pH-tolerant, insoluble inorganic phosphate-solubilising bacterium was isolated from soybean rhizosphere. On the basis of its physiological characteristics, this bacterium was identified as *Pantoea agglomerans*. The optimal medium composition and cultural conditions for the solubilisation of insoluble phosphate by *P. agglomerans* R-42 were 3% (w/v) of glucose, 0.1% (w/v) of NH_4 NO_3, 0.02% (w/v) of $MgSO_4$ x $7H_2O$, and 0.06% (w/v) of $CaCl_2$ x $2H_2O$ along with initial pH 7.5 at 30°C. The soluble phosphate production under optimal condition was around 900 mg/l, which was approximately 4.6-fold higher than the yield in the MPVK medium. The solubilisation of insoluble phosphate was associated with a drop in the pH of the culture medium. *P. agglomerans* R-42 showed resistance against different environmental stresses like 5-45°C temperature, 1-5% salt concentration and 3-11 pH range. Insoluble phosphate solubilisation was highest from $CaHPO_4$ (1367 mg/l), hydroxyapatite (1357 mg/l) and $Ca_3(PO4)_2$ (1312 mg/l). However, the strain produced soluble phosphate to the culture broth with the concentrations of 28 mg/l against $FePO_4$, and 19 mg/l against $AlPO_4$, respectively.

Alikhani et al. (2007) enumerated Phosphate solubilisation activity of rhizobia native to Iranian soils. Agricultural soils in Iran are predominantly calcareous with very low plant available phosphorus (P) content. In addition to their beneficial Nitrogen-fixing activity with legumes, Rhizobia can improve plant P nutrition by mobilizing inorganic and organic P. Isolates from different cross-inoculation groups of Rhizobia, obtained from Iranian soils were tested for their ability to dissolve inorganic and organic phosphate. From a total of 446 Rhizobial isolates tested for P solubilisation by the formation of visible dissolution halos on agar plates, 198 (44%) and 341(76%) of theisolates, solubilised Calcium (TCP) and inositol hexa-phosphate (IHP), respectively. In the liquid Sperber TCP medium, phosphate-solubilising bacteria (*Bacillus sp*. and *Pseudomonas fluorescens*) used as positive controls. The results indicate that many rhizobia isolated from soils in Iran are able to mobilize P from organic and inorganic sources and this beneficial effect should be tested with crops grown inIran.

Morales et al. (2007) observed the effect of inoculation of *Penicillium albidum*, a Phosphate-solubilising fungus, on the growth of *Trifoliumpratense* cropped in a volcanic soil. Volcanic soils in the South of Chile have an elevated quantity of total P, which is scarcely available due to its high P fixation capacity. One strategy for increasing the availability of P for the vegetables that grow there would be to use phosphate-solubilising microorganisms. In one assay conducted in a greenhouse on a volcanic soil, the effect of inoculation with *Penicillium albidum*, a phosphate-solubilising fungus, was studied on the growth of red clover (*Trifolium pratense L*). Some chemical and biological properties of the soil were also evaluated. There were three treatments *viz*, active inoculum [In(+)], inactive inoculum (autoclaved) [In(-)] and without inoculum [In(0)], each one done in triplicates. The In(+) significantly ($P < 0.050$) increased the growth of the plants, contributing particularly to root development. The P mobilized to the shoot with In(+) was higher than two fold related to In(0) and In(-) treatments; however, the In(+) plants had similar concentration of shoot P. In the soil, available-P was not statistically different ($P < 0.050$) among the treatments but phosphatase activity in In(+) was higher ($P < 0.050$) in comparison to In(0). The results suggest that *Penicillium albidum* contributed to growth and nutrition of the Red clover through the induction of root development and enhancing phosphate mobilization from the soil and into the plant. It is concluded that *Penicillium albidum*, under greenhouse conditions, in soils deficient in available P can increase the inoculation potential for volcanic soils in Chile.

Wakelin et al. (2007) examined the effect of *Penicillium* on plant growth and phosphorus mobilization in neutral to alkaline soils from Southern Australia. The Phosphate solubilising fungi *Penicillium radicum*, *Penicillium bilaiae* (strain RS7B-SD1), and an unidentified *Penicillium sp*. designated strain KC6-W2 were tested for their ability to increase the growth and phosphorus (P) nutrition of wheat and lentil in three soils of neutral to alkaline pH reaction. The strongest plant growth promoting (PGP) strain was *Penicillium sp*. KC6-W2, which stimulated significant increases in shoot growth and dry mass in seven of the nine experiments conducted. Levels of PGP by *Penicillium sp*. KC6-W2 ranged from 6.6% to 19% and were associated with increased uptake of P to the shoot. The PGP properties of *Penicillium sp.* KC6-W2 were evident on each of the three different plant species and soil types, a level of reliability not observed in other strains tested. Inoculation of seed with *P. radicum* increased lentil growth by 5.5% ($P < 0.05$) in soil from Tarlee but did not affect plant growth in the eight other experiments. Inoculation of plant seed with *P. bilaiae* RS7B-SD1 resulted in significant PGP in two of the nine experiments conducted. However, when significant, stimulation of PGP by *P. bilaiae* RS7B-SD1 was strong and resulted in increases in lentil shoot dry matter (15%). A soil microcosm experiment investigated the effect of *Penicillium* on cycling of soil P. *Penicillium bilaiae* RS7B-SD1 was the only fungus to significantly increase HCO_3-extractable P (23% increase; $P < 0.05$). Production of phosphatase enzymes was not associated with increased HCO3-extractable P. Addition of carbon in the form of rye grass seed significantly increased microbial respiration and movement of P to the microbial biomass ($P < 0.05$), but these parameters were irrespective of *Penicillium* treatment. This work has established the potential for use of *Penicillium* inoculants to increase plant growth in alkaline soils of Australia. The role of *Penicillium* fungi in plant P uptake and soil P cycling requires further exploration.

Chatli et al. (2008) isolated Phosphate solubilising microorganisms (PSM) (bacteria and fungi) associated with *Salix alba* Linn. from Lahaul and Spiti valleys of Himachal Pradesh on Pikovskaya (PVK), modified Pikovskaya (MPVK) and National Botanical Research Institute agar (NBRIP) media by spread plating. The viable colony count of P-solubilising bacteria (PSB) and fungi (PSF) was higher in rhizosphere than that of non-rhizosphere. The maximum proportion of PSM out of total bacterial and fungal count was found in upper Keylong while the least in Rong Tong. The PSB frequently were Gram-positive, endosporeforming, motile rods and belonged to *Bacillus sp*. The PSF mainly belonged to *Penicillium sp*., *Aspergillus fumigatus*, *A. niger*, *A. spp*. and non-sporulating sterile. Amongst the isolates with high efficiency for tricalcium phosphate (TCP) solubilisation, seven bacterial and seven fungal isolates dissolved higher amount of P from North Carolina rock phosphate (NCRP) than Mussoorie rock phosphate (MRP) and Udaipur rock phosphate (URP). However, the organisms solubilised higher-P in NBRIP broth than PVK broth.

Chang et al. (2009) enumerated thermo-tolerant phosphate-solubilising microbes for multi-functional biofertilizer preparation. In order to prepare the multi-functional biofertilizer, thermo-tolerant phosphate-solubilising microbes including bacteria, actinomycetes, and fungi were isolated from different compost plants and biofertilizers. Except *Streptomyces thermophilus* J57 which lacked pectinase, all isolates possessed amylase, CMCase, chitinase, pectinase, protease, lipase and nitrogenase activities. All isolates could solubilise Calcium phosphate and Israel rock phosphate; various isolates could solubilise Aluminum phosphate, iron phosphate and hydroxyapatite. During composting, biofertilizers inoculated with the tested microbes had a significantly higher temperature, ash content, pH, total nitrogen, soluble phosphorus content, and germination rate than non-inoculated biofertilizer. Total organic carbon and carbon-to-nitrogen ratio showed the opposite pattern. Adding these microbes can shorten the period of maturity, improve the quality, increase the soluble phosphorus content and enhance the populations of Phosphate-solubilising and proteolytic microbes in biofertilizers. Therefore, inoculating thermo-tolerant Phosphate-solubilising microbes into agricultural and animal wastes represents a practical strategy for preparing multi-functional biofertilizer.

Xai et al. (2009) observed comparison of media used to evaluate *Rhizobium leguminosarum bivarviciae* for phosphate-solubilising ability. *Rhizobium leguminosarum* is well known for its ability to fix nitrogen (N). In addition, its capacity to solubilize phosphate has been receiving attention in recent years. Our ultimate objective was to select a *R. leguminosarum bv. viciae* isolate with superior Ph-solubilising ability. The first step was to identify a culture medium that is sensitive and effective in identifying the ability of *R.leguminosarum bv. viciae* isolates to solubilise phosphorous. Thirty isolates were evaluated for Ph solubilisation in broth and on solid formulations of three media: yeast mannitol extract (YEM), National Botanical Research Institute phosphate nutrient medium (MNBRI), and Pikovskaya phosphate medium (PVK). All media contained 5 g/L $CaHPO_4$ as the only phosphorus (P) source. All 30 isolates increased the pH concentration in liquid cultures, but the amount of pH released into solution by individual isolates varied from one medium to another. In contrast, only a subset of the 30 isolates solubilised pH on the solid cultures. Furthermore, some of the isolates that were able to solubilise pH were only able to do so on a single medium. Regression analysis revealed no relationship between the pH concentration in the liquid media and the zones of clearing on the solid media ($p > 0.05$). Although the pH of all of the liquid media dropped after 12 days of growth of the isolates, a relationship between pH concentration and pH existed only for the MNBRI medium ($r2 = 0.485$, $p < 0.001$). Increasing the amount of N in the MNBRI medium from 0.1 g/L of $(NH_4)_2SO_4$ to 0.5 g/L of $(NH_4)_2SO_4$ did not affect the amount of pH in solution, but it profoundly reduced the survival of the *R. leguminosarum* by approximately 50-fold. Consequently, the surviving bacteria were either more efficient at solubilising pH in the high N media or organic acids released from the lysis of the dead cells.

Ogbo et al. (2010) observed Conversion of cassava wastes for biofertilizer production using phosphate solubilising fungi. Two fungi characterized as *Aspergillus fumigatus* and *Aspergillus niger*, isolated from decaying cassava peels were used to convert cassava wastes by the semi-solid fermentation technique to phosphate biofertilizer. The isolates solubilized $Ca_3(PO_4)_2$, $AlPO_4$ and $FePO_4$ in liquid Pikovskaya medium, a process that was accompanied by acid production. Medium for the SSF fermentation was composed of 1% raw cassava starch and 3% poultry droppings as nutrients and 96% ground (0.5-1.5mm) dried cassava peels as carrier material. During the 14 days fermentation, both test organisms increased in biomass in this medium as indicated by increases in phosphatase activity and drop in pH. Ground cassava peels satisfied many properties required of carrier material particularly in respect of the organisms under study. Biofertilizer produced using *A. niger* significantly ($p<.05$) improved the growth of pigeon pea [*Cajanus cajan* (L.) Millsp.]in pot experiments but product made with *A. fumigatus* did not.

Park et al. (2010) evaluated rapid solubilisation of insoluble phosphate by a novel environmental stress-tolerant *Burkholderia vietnamiensis* M6 isolated from ginseng rhizospheric soil.

They isolated and characterized novel insoluble phosphate (P)-solubilising bacteria tolerant to environmental factors like high salt, low and high pH, and low temperature. A bacterium M6 was isolated from a ginseng rhizospheric soil and confirmed to belong to *Burkholderia vietnamiensis* by BIOLOG system and 16S rRNA gene analysis. The optimal cultural conditions for the solubilisation of P were 2.5% (w/v) glucose, 0.015% (w/v) urea, and 0.4% (w/v) $MgCl_2.6H_2O$ along with initial pH 7.0 at 35°C. High-performance liquid chromatography analysis showed that *B.vietnamiensis* M6 produced gluconic and 2-Ketogluconic acids. During the culture, the pH was reduced with increase in gluconic acid concentration and was inversely correlated with P solubilisation. Insoluble P solubilisation in the optimal medium was about 902 mg/l, which was approximately 1.6-fold higher than the yield in NBRIP medium (580 mg/l). *B. vietnamiensis* M6 showed resistance against different environmental stresses like 10°-45°C, 1-5% (w/v) salt, and 2-11 pH range. The maximal concentration of soluble P produced by *B. vietnamiensis* M6 from $Ca_3(PO_4)_2$, $CaHPO_4$ and hydroxyapatite was 1,039, 2,132, and 1,754 mg/l, respectively. However, the strain M6 produced soluble P with 20 mg/l from $FePO_4$ after 2 days and 100 mg/l from $AlPO_4$ after 6 days, respectively. Our results indicate that *B. vietnamiensis* M6 could be a potential candidate for the development of biofertillicable to environmentally stressed soil.

Park et al. (2011) observed isolation of Phosphate solubilising bacteria and their potential for lead immobilization in soil. Lead (Pb), a highly toxic heavy metal forms stable compounds with phosphate (P). The potential of Phosphate solubilising bacteria (PSB) to immobilize Pb by enhancing solubilisation of insoluble P compounds was tested. Eighteen different PSB strains isolated from P amended and Pb contaminated soils were screened for their efficiency in P solubilisation. The PSB isolated from P amended soils solubilised 217-479 mg/L of P while the PSB from Pb contaminated soil solubilised 31-293 mg/L of P. Stepwise multiple regression analysis and P solubility kinetics indicated that the major mechanism of P solubilisation by PSB is the pH reduction through the release of organic acids. From the isolated bacteria, two PSB were chosen for Pb immobilization and these bacteria were identified as *Pantoea sp*. and *Enterobacter sp*., respectively. The PSB significantly increased P solubilisation by 25.0% and 49.9% in the case of *Pantoea sp*., and 63.3% and 88.6% in the case of *Enterobacter sp*. for 200 and 800 mg/kg of rock phosphate (RP) addition, respectively, thereby enhancing the immobilization of Pb by 8.25-13.7% in the case of *Pantoea sp*. and 14.7-26.4% in the case of *Enterobacter sp*. The ability of PSB to solubilise P, promote plant growth and immobilize Pb can be used for phytostabilization of Pb contaminated soils.

Chai et al. (2011) examined Isolation and phosphate-solubilising ability of a fungus, *Penicillium sp*. from soil of an alum mine. The use of microorganisms to solubilise elemental phosphorus from insoluble rock phosphate is a promising method to greatly reduce not only environmental pollution but also production costs. Phosphate-solubilising microorganisms were isolated from soils in China and a fungus strain (PSM11-5) from a soil sample from an alum mine, with the highest phosphate solubilisation potential, was selected and identified as a *Penicillium sp.* Strain PSM11-5 could grow in buffered medium with pH values between 3.0 and 8.0 and showed phosphate solubilising activity at pH values from 5.0 to 8.0. It also exhibited a degree of tolerance to the heavy metal ions, Cd^{2+}, Co^{2+}, and Cr^{6+}. PSM11-5 could rapidly solubilise tricalcium phosphate, and a high phosphate-solubilising efficiency of 98% was achieved in an optimized medium. The strain could solubilise rock phosphate and aluminum phosphate with a solubilising efficiency of approximately 74.5%, but did not solubilise iron phosphate. Solubilization of phosphate was dependent on acidification. Analysis of PSM11-5 culture supernatants by capillary electrophoresis showed that tricalcium phosphate was solubilised to PO_4^{3-} and Ca^{2+}. The organic acid produced by the fungus was mainly gluconic acid. In addition, PSM11-5 produced citric acid when it was used to solubilise rock phosphate. These excellent properties of strain PSM11-5 suggested that the fungus has potential for agricultural and industrial utilization.

Jorquera et al. (2011) identified β-propeller phytase-encoding genes in culturable *Paenibacillus* and *Bacillus spp*. from the rhizosphere of pasture plants on volcanic soils. Phytate is one of the most abundant sources of organic phosphorus (P) in soils, but must be mineralized by phytase-producing bacteria to release P for plant uptake. Microbial inoculants based on *Bacillus spp.* have been developed commercially, but few studies have evaluated the ecology of these bacteria in the rhizosphere or the types of enzymes that they produce. Here, the diversity of aerobic endospore-forming bacteria (EFB) with the ability to mineralize phytate in the rhizosphere of pasture plants grown in volcanic soils of southern Chile was studied. PCR methods were used to detect phytase-encoding genes and to identify EFB bacteria that carry these genes. This study revealed that the phytate-degrading EFB populations of pasture plants included species of *Paenibacillus* and *Bacillus*, which carried genes encoding β-propeller phytase (BPP). Assays of enzymatic activity confirmed the ability of these rhizosphere isolates to degrade phytate. The phytase-encoding genes described may prove valuable as molecular markers to evaluate the role of EFB in organic P mobilization in the rhizosphere.

Zhu et al. (2012) examined conversion of spent mushroom substrate to biofertilizer using a stress-tolerant Phosphate-solubilising *Pichia farinose* FL7. To develop high-efficient biofertilizer, an environmental stress-tolerant Phosphate-solubilising microorganism (PSM) was isolated from agricultural waste compost and then applied to spent mushroom substrate (SMS). The isolate FL7 was identified as *Pichia farinose* with resistance against multiple environmental stresses, including 5-45°C temperature, 3-10 pH range, 0-23% (w/v) NaCl and 0-6M Ammonium ion. Under the optimized cultivation condition, 852.8 mg/l total organic acids can be produced and pH can be reduced to 3.8 after 60 h. The *P. farinose* was used to convert SMS to a phosphate biofertilizer through a semi-solid fermentation (SSF) process. After fermentation of 10 days, cell density can be increased to 5.6×10^8 CFU/g in biomass and pH in this medium can be decreased to 4.0. SMS biofertilizer produced by *P. farinose* significantly improved the growth of Soybean in pot experiments, demonstrating a tremendous potential in agricultural application.

Vessilev et al. (2012) observed Stress-tolerant P-solubilising microorganisms. Drought, high/low temperature and salinity are abiotic stress factors accepted as the main reason for crop yield losses in a world with growing population and food price increase. Additional problems create nutrient limitations and particularly low P soil status. The problem of phosphate fertilizers, P plant nutrition and existing phosphate bearing resources can also be related to the scarcity of rock phosphate. The modern agricultural systems are highly dependent on the existing fertilizer industry based exclusively of this natural, finite, non-renewable resource. Biotechnology offers a number of sustainable solutions that can mitigate these problems by using plant beneficial, including P-solubilising, microorganisms.

Bhattacharyya et al. (2012) studied Plant growth-promoting rhizobacteria (PGPR) for emergence in agriculture. Plant growth-promoting rhizobacteria (PGPR) are the rhizosphere bacteria that can enhance plant growth by a wide variety of mechanisms like phosphate solubilisation, siderophore production, biological nitrogen fixation, rhizosphere engineering, production of 1-Aminocyclopropane-1-carboxylate deaminase (ACC), quorum sensing (QS) signal interference and inhibition of biofilm formation, phytohormone production, exhibiting antifungal activity, production of volatile organic compounds (VOCs), induction of systemic resistance, promoting beneficial plant-microbe symbiosis, interference with pathogen toxin production etc. The potentiality of PGPR in agriculture is steadily increased as it offers an attractive way to replace the use of chemical fertilizers, pesticides and other supplements. Growth promoting substances are likely to be produced in large quantities by these rhizosphere microorganisms that influence indirectly on the overall morphology of the plants. Recent progress in our understanding on the diversity of PGPR in the rhizosphere along with their colonization ability and mechanism of action should facilitate their application as a reliable component in the management of sustainable agricultural system.

Jain et al. (2012) examined effect of Phosphate-solubilising fungi *Aspergillus awamori* S29 on mungbean (*Vigna radiata* cv. RMG 492) growth. A phosphate solubilising fungus, *Aspergillus awamori* S29 was isolated from rhizoshpere of mungbean. The phosphate solubilising activity of *A. awamori* S29 in liquid was 1,110 mg/L for tricalcium phosphate (TCP). The organism was able to solubilise various inorganic forms of phosphate at a wide range of temperatures. Among various insoluble phosphate sources tested, di-calcium phosphate was solubilised the most, followed by TCP. *A. awamori* S29 had significant effect ($p < 0.05$) on mungbean growth, total P and plant biomass under pot conditions, although no obvious difference in available P in soil and number of leaves was found compared to the control.

Wu et al. (2012) observed Isolation of phosphate-solubilising fungus and its application in solubilisation of rock phosphates. Microorganisms have been obtained to improve the agronomic value of rock phosphates (RPs), but the phosphorus solubilisation rate by these approaches is very slow. It is important to explore a high-efficient phosphate-solubilising approach with a kind of microorganisms. This study aimed to isolate a high-efficient level of phosphate-solubilising fungus from rhizosphere soil samples phosphate mines (Liuyang County, Hunan province, China) and apply it in solubilisation of RPs. The experiments were carried out by the conventional methodology for morphological and biochemical fungus characterization and the analysis of 18s rRNA sequence. Then the effects of time, temperature, initial pH, phosphorus (P) sources, RPs concentration, shaking speed and silver ion on the content of soluble P released by this isolate were investigated. The results showed this isolate was identified as *Galactomyces geotrichum* P14 (P14) in GeneBank and the maximum amount of soluble P was 1252.13 mg L(-1) within 40 h in a modified phosphate growth agar's medium (without agar) where contained tricalcium phosphate (TCP) as sole phosphate source. At the same time, it could release phosphate and solubilise various rock phosphates. The isolated fungus can convert RPs from insoluble form into plant available form and therefore it hold great potential for biofertilizers to enhance soil fertility and promote plant growth.

He et al. (2012) screened and identified P solubilising microbes for solubilising capabilities. Various P solubilisers were isolated from the *Hippochaete ramosissimum* rhizosphere in Anhui Province, East China. After many times of screening and purification, a strain B25 with stronger phosphate-solubilising capability was obtained, which belonged to *Bacillus* genus, as identified by transmission electron microscope and DNA molecular approaches. A culture experiment was conducted to study the phosphate-solubilising capability of the B25 bacterial strains under different abiotic conditions. A weak correlation was observed between the phosphate-solubilising capability of B25 and the medium pH. The B25 displayed a better phosphate-solubilising capability when the carbon source was glucose, medium initial pH was 7.0 and culture temperature was 30°C.

Sharma et al. (2013) reported sustainable approach for managing phosphorus deficiency in agricultural soils. Phosphorus is the second important key element after nitrogen as a mineral nutrient in terms of quantitative plant requirement. Although abundance in soils, in both organic and inorganic forms, its availability is restricted as it occurs mostly in insoluble forms. The P content in average soil is about 0.05% (w/w) but only 0.1% of the total P is available to plant because of poor solubility and its fixation in soil (Illmer & Schinner, 1995). An adequate supply of phosphorus during early phases of plant development is important for laying down the primordia of plant reproductive parts. It plays significant role in increasing root ramification and strength thereby imparting vitality and disease resistance capacity to plant. It also helps in seed formation and in early maturation of crops like cereals and legumes. Poor availability or deficiency of phosphorus (P) markedly reduces plant size and growth. Phosphorus accounts about 0.2 - 0.8% of the plant dry weight. To satisfy crop nutritional requirements, P is usually added to soil as chemical P fertilizer, however synthesis of chemical P fertilizer is highly energy intensive processes and has long term impacts on the environment in terms of eutrophication, soil fertilility depletion and carbon footprint. Moreover, plants can use only a small amount of this P since 75-90% of added P is precipitated by metal-cation complexes and rapidly becomes fixed in soils. Such environmental concerns have led to the search for sustainable way of P nutrition of crops. In this regards phosphate-solubilising microorganisms (PSM) have been seen as best eco-friendly means for P nutrition of crop. Although, several bacterial (*pseudomonads* and *bacilli*) and fungal strains (*Aspergilli* and *Penicillium*) have been identified as PSM their performance under *in situ* conditions is not reliable and therefore needs to be improved by using either genetically modified strains or co-inoculation techniques. The diversity of PSM, mechanism of P solubilisation, role of various phosphatases and impact of various factors on P solubilisation was also reported.

Bhattacharya et al. (2013) examined Phosphate solubilising ability of *Emericella nidulans* strain V1 isolated from vermicompost. Phosphorus is one of the key factors that regulate soil fertility. Its deficiencies in soil are largely replenished by chemical fertilizers. The present study was aimed to isolate efficient phosphate solubilising fungal strains from *Eisenia fetida* vermicompost. Out of total 30 fungal strains the most efficient phosphate solubilising one was *Emericella nidulans* V1 (MTCC 11044), identified by custom sequencing of beta-tubulin gene and BLAST analysis. This strain solubilised 13 to 36% phosphate from four different rock phosphates. After three days of incubation of isolated culture with black Mussorie rock phosphate, the highest percentage of phosphate solubilisation was 35.5 ± 1.01 with a pH drop of 4.2 ± 0.09. Kinetics of solubilisation and acid production showed a linear relationship until day five of incubation. Interestingly, from zero to tenth day of incubation, solubility of soil phosphate increased gradually from 4.31 to 13.65 (mg/kg) recording a maximum of 21.23 on day 45 in respect of the V1 isolate. Further, enhanced phosphorus uptake by *Phaseolus* plants with significant pod yield due to soil inoculation of *Emericella nidulans* V1 (MTCC 11044), demonstrated its prospect as an effective biofertilizer for plant growth.

Chatli et al. (2014) reported the solubilisation efficacies of a single or combination of three Phosphate dissolving microorganisms RBC2 (unidentified), RBC4 (unidentified) bacteria and *Penicillium sp*. isolated from rhizosphere of *Robinia pseudoacacia*by using different sources of insoluble inorganic phosphates *viz.* tricalcium phosphates (TCP), Mussoorie Rock

Phosphates (MRP) and Udaipur Rock Phosphates (URP) in Pikovskaya (PVK) and National Botanical Research Institute (NBRIP) broths. Among all the P-solubilisers studied, fungus *Penicillium sp.* solubilised maximum P while RBC2 (unidentified) bacterium the least. RBC4 (unidentified) and RBC2 (unidentified) bacteria and fungus *Penicillium sp*. in combination resulted in less P solubilisation than that by fungus alone, though it was more than the efficacy of bacteria alone. The fall in pH of broth during P dissolution was due to the production of oxalic and citric acids by microbes.

Liu et al. (2015) developed an engineered soil bacterium enabling to convert both insoluble inorganic and organic phosphate into plant available phosphate and represented its use as a biofertilizer. A P-solubilizing bacterium 9320-SD was isolated with the ability to utilize inorganic P and converted it into plant-available P. A bacterial phytase encoding gene was introduced into 9320-SD. One randomly selected transformant, SDLiuTP02, was examined for recombinant protein expression and phytase activity and assessed for its ability to promote plant growth. This indicated that SDLiuTP02 is capable of expressing high levels of phytase activity. Importantly, corn seedlings treated with the SDLiuTP02 cell culture exhibited increased rates of photosynthesis, transpiration and stomatal conductance as well as increased growth rate under laboratory conditions and increased growth rate in pot assays compared to seedlings treated with cell cultures of the parental strain 9320-SD. Field experiments further indicated that application of SDLiuTP02 promoted a greater growth rate in young Cucumber plant and a higher foliar chlorophyll level in Chop Suey Greens when compared to 9320-SD treated controls. The results indicated that SDLiuTP02 had the potential to be a more effective P biofertilizer to increase agricultural productivity.

Suman et al. (2016) observed plant promoting growth attributes of *Pseudomonas fluorescens* isolated from rhizosphere of rice in Rangareddy district**.** Rice is an economically important food crop, which is subjected to infect by a host of fungal, viral and bacterial pathogens. Plant growth-promoting rhizobacteria (PGPR) are beneficial bacteria that colonize plant roots and enhance plant growth by a wide variety of mechanisms. The use of PGPR is steadily increasing in agriculture and offers an attractive way to replace chemical fertilizers, pesticides and supplements. *Pseudomonas fluorescens* is important among PGPR because it is having an ability to induce plant growth as well as control the growth of pathogens. Thirty *P. fluorescens* isolates were isolated, from the rhizospheric soils of rice fields from the Rangareddy district of Telangana state and the isolates were screened and characterized for the PGPR characters like Phosphate solubilisation, ammonia and Indole Acetic Acid (IAA) production. Isolates showing PGP properties were further screened *in vitro* for biocontrol activities like siderophore, HCN and antagonism against soil borne phytopathogen *Rhizoctonia solani* causing sheath blight in rice. Results revealed that all isolates reacted positively for Ammonia production, HCN production and 23 isolates showed Phosphate solubilisation and siderophore production, 28 showed IAA production. The rhizospheric soils were the rich source of *Pseudomonas fluorescens*, which had a potential to be used as a biocontrol agent.

Elias et al. (2016) observed Phosphate solubilisation potential of Rhizosphere Fungi Isolated from Plants in Jimma Zone, Southwest Ethiopia. Phosphate solubilising fungi play a noteworthy role in increasing the bioavailability of soil phosphates for plants. A total of 359 fungal isolates were obtained from 150 rhizosphere soil samples of haricot bean, faba bean, cabbage, tomato, and sugarcane. Among the isolates, 167 (46.52%) solubilised inorganic phosphate. The isolated Phosphate solubilising fungi belonged to genera of *Aspergillus* (55.69%), *Penicillium spp*. (23.35%), and *Fusarium* (9.58%). Solubilisation index (SI) ranged from 1.10 to 3.05. Isolates designated as JUHbF95

(*Aspergillus sp*.) and JUFbF59 *(Penicilliumsp.)* solubilised maximum amount of P 728.77 μg·mL(-1) and 514.44 μg mL(-1), respectively, from TCP (tricalcium phosphate) after 15 days of incubation. The highest (363 μg mL(-1)) soluble-P was released from RP with the inoculation of JUHbF95 in the PVK broth after 10 days of incubation. Two strains of phosphate-solubilising bacteria were isolated from the rhizosphere of Pinustabuliformis in iron tailings vegetation restoration areas in Malan Town, Qianan City, Hebei Pro-vince. The bacterial strain D2 with strong phosphate-solubilising capacity was obtained via screening with plate and shake flask. Based on the morphology, physiology and biochemistry and the sequence analysis of 16S rDNA, the D2 was identified as a member of *Pantoea sp*. A fermentation experiment was conducted to investigate the effect of carbon and nitrogen sources on the Phosphate-solubilising capacity of the strain D2; under different nitrogen sources, the organic acids in liquid culture, as well as their types and contents were determined by high performance liquid chromatography.

Lira et al. (2016) evaluated methods used for phosphate-solubilising bacteria. Phosphorus solubilisers naturally acidify rhizospheric soil and increase phosphorus availability; therefore, their evaluation may help to reduce phosphorus fertilizer use. The different selection methods and select inorganic phosphorus-solubilising bacteria as potential plant-growth promoters. Bacterial isolates obtained from sugarcane roots and soil were tested using solid growth media containing bicalcium phosphate and Irece Apatite ground rock phosphate as phosphorus sources. Seven isolates with high (3), moderate (3) and low solubilisation indices (1) and the *Pseudomonas fluorescens* R-243 strain were tested in two liquid growth media, followed by the pH and soluble P in the solution. The same isolates, in the absence of inoculation, were tested in Leonard jars with two high- and low-solubility sources using Cowpea as a test species. Forty-four days after planting above ground dry mass, the phosphorus content and total above ground phosphorus and substratum phosphorus contents were evaluated. The growth media affected phosphorus solubilisation by the bacteria. Evaluation of liquid media was the most reliable method for analyzing bicalcic phosphorus solubilisation by the bacteria not linked to pH reduction. Isolates UAGC 17, 19 and 65 should be better studied because they were the best solubilisers in culture media; however, they did not demonstrate the same efficiency when inoculated on Cowpea.

Mukhtar et al. (2017) assessed two carrier materials for phosphate solubilising biofertilizers and their effect on growth of wheat (*Triticum aestivum* L.). Biofertilizers are usually carrier-based inoculants containing beneficial microorganisms. Incorporation of microorganisms in carrier material enabled easy-handling, long-term storage and high effectiveness of biofertilizers. The enriched biogas sludge was assessed. Three phosphate solubilising strains, 77-NS2 *(Bacillus endophyticus*), 77-CS-S1 (*Bacillus sphaericus*) and 77-NS5 (*Enterobacter aerogenes*) were isolated from the rhizosphere of sugarcane, two strains, PSB5 (*Bacillus safensis*) and PSB12 (*Bacillus megaterium*) from the rhizosphere of wheat and one halophilic phosphate solubilising strain AT2RP3 (*Virgibacillus sp*.) from the rhizosphere of *Atriplex amnicola*, were used as bioinoculants. Phosphate solubilisation ability of these strains was checked *in vitro* in Pikovskaya medium, containing rock phosphate (RP) as insoluble P source, individually supplemented with three different carbon sources, i.e., glucose, sucrose and maltose. Maximum phosphate solubilisation; 305.6μg/ml, 217.2μg/ml and 148.1μg/ml was observed in *Bacillus* strain PSB12 in Pikovskaya medium containing sucrose, maltose and glucose respectively. A field experiment and pot experiments in climate control room were conducted to study the effects of biogas sludge and enriched soil based phosphorous biofertilizers on growth of wheat. *Bacillus* strain PSB12 significantly increased root and shoot dry weights and lengths using biogas sludge as carrier material in climate control room experiments. While in field conditions, significant increase in root and shoot dry weights, lengths and seed weights was seen by PSB12 and PSB5 (*Bacillus*) and *Enterobacter* strain 77-NS5 using biogas sludge as carrier. PSB12 also significantly increased both root and shoot dry weights and lengths in field conditions when used as enriched soil based inoculum. This indicated that bacterial isolates having plant beneficial traits such as P solubilisation are more promising candidates as biofertilizer when used with carrier materials.

Nandimath et al. (2017) observed consortium inoculum of five thermo-tolerant Phosphate solubilising Actinomycetes for multipurpose biofertilizer preparation. Alkaline pH of the soil facilitates the conversion of phosphate present in phosphate fertilizer applied in the field to insoluble phosphate which is not available to plants. The biofertilizer with the thermo-tolerant phosphate solubilising actinomycetes consortium that converted insoluble phosphate to soluble phosphate at wider temperature range. As the mesophilic organisms die out at high temperature of composting hence thermo-tolerant actinomycetes would be the better substitute for preparation of phosphate solubilising bio-fertilizer with added potential to degrade complex macromolecules in composting.

Paula et al. (2017) observed stabilisation of spent mushroom substrate for application as a plant growth-promoting organic amendment. Over three million tonnes of spent mushroom substrate (SMS) are produced in Europe every year as a by-product of the cultivation of *Agaricus bisporus*. The management of SMS has become an increasing challenge for the mushroom production industry and finding environmentally and economically sustainable solutions for this organic residue is, therefore, highly desirable. Due to its physical properties and nutrient content, SMS has great potential to be employed in agricultural and horticultural sectors and further contributed to reduce the use of non-renewable resources, such as peat. However, SMS is often regarded as not being stable which hampers its wide use for crop production. Here, the stabilisation of SMS and its subsequent use as organic fertiliser and partial peat replacement in horticulture was demonstrated. The stabilisation was performed in a laboratory-scale composting system, with controlled temperature and aeration. Physical and chemical parameters were monitored during composting and provided information on the progress of the process. Water soluble carbohydrates (WSC) content was found to be the most reliable parameter to predict SMS stability. *In situ* oxygen consumption indicated the main composting phases, reflecting major changes in microbial activity. The structure of the bacterial community was also found to be a potential predictor of stability, as the compositional changes followed the composting progress. The fungal community did not present clear successional process along the experiment. Maturity and quality of the stabilised SMS were assessed in a horticultural growing trial. When used as the sole fertiliser source, SMS was able to support *Lolium multiflorum* (Italian Ryegrass) growth and significantly improved grass yield with a concentration-dependent response, increasing grass biomass up to 300%, when compared to the untreated control. The method employed was efficient in generating a stable and mature product, which had a great potential to be applied in horticulture. It represented a step forward in the management of SMS residue, and also provided an alternative to reduce the use of peat in horticulture, alleviating environmental impacts to peatland ecosystems.

Chatli et al. (2018) isolated Phosphate solubilising microorganismson Pikovskaya (PVK) and Modified Pikovskaya (MPVK) agar media from the soil of Guru Nanak Girls College, Model Town, Ludhiana, Punjab. The percentage of Phosphate Solubilisers was more in rhizosphere than non-rhizosphere. The highest frequency of phosphate solubilising microorganisms was found on MPVK. The Phosphate Solubilising bacteria were endospore formers, Gram-positive and motile rods belonging to the *Bacillus* species. Phosphate Solubilising fungi were *Aspergillus niger* and *Penicillium.* On MPVK agar Phosphate solubilisers formed bigger halo zones than that on PVK agar. Kumar et al. (2018) studied biofertilizers and biopesticides in sustainable Agriculture. Green revolution has revolutionized the world agriculture by increasing the yields of food crops by the development of high-yielding varieties, chemical fertilizers, synthetic herbicides and pesticides. The continuous and excess use of chemical fertilizers has changed the soil characteristics to acidic/alkaline leading to the reduction in the naturally occurring microorganisms in soil that resulted in the stagnation/reduction in crop yields. Use of microorganisms (biofertilizers and biopesticides) as an alternate to synthetic fertilizers and pesticides to increase the soil fertility and disease and pest control in agriculture is gaining prominence. Biofertilizers and biopesticides are environmental friendly products and can be used in integrated nutrient management (INM) and integrated pest management (IPM) techniques.

Kaur et al. (2019) observed Phosphate Dissolution potencial of Screened P Solubilisers isolated from Rose Plant. Phosphate Solubilising Microorganisms (PSM) were isolated from three regions. Phosphate Solubilising Bacteria were motile & gram negative rods belonging to *Bacillus* species. Phosphate Solubilising Fungi (PSF) belonged to *Aspergillus niger*, *Penicillium* sp., *Trichoderma* sp., *Aspergillus fumigatus* & *Fusarium*. The highest efficiency of PSM was found on NBRIP agar.

RESULTS AND DISCUSSIONS

The frequency of PSM was reported to be highest in NBRIP agar, followed by MPVK agar and PVK agar. The bromophenol blue dye resulted in the activation of Phosphatase producing enzyme resulting in bigger halo zones on MPVK agar than that of PVK agar media. In NBRIP agar, the biggest clear zones may be due to the effect of micronutrients present in media. The highest efficacy of microbes was observed in tripple culture of P solubilisers, followed by dual culture and the least in single culture. The P solubilisers were dissoluting TCP in PVK and NBRIP broth due to the production of organic acids, chelating compound etc. These microbes can be used on commercial scale for the production of Biofertilizers.

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