Potassium Solubilizing Microorganisms: An Alternative Technology to Chemical Fertilizers

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Abstract
Potassium (K) is the third important plant nutrient after nitrogen (N) and phosphorous (P). It helps in growth and metabolism of plants. The proportion of soluble potassium in soil is generally low and more than 90% of potassium in soil is available in insoluble rocks and silicate minerals. Rhizospheric microorganism especially bacteria are having potential to solubilize insoluble form of potassium minerals into soluble form, that plants can easily uptake. Potassium availability in soil is about 90-98%, but whole portion is in unavailable mineral form this deficiency leads to unhealthy development of plants. Application of chemical fertilizers also causes severe damage to soil microflora and on totality soil health and crop yield. Utilization of microorganisms e.g., bacteria as bio-solubilizers of potassium is best alternative to overcome all commencing problems. With the application of biofertilizers soil health, crop yield, mineral solubilzation and their availability to plants will get enhanced. Different bacterial species are known to solubilize fixed form of potassium, there bioformulation not only makes potassium available to plants but also maintains soil health, crop yield and soil structure. Application of potassium solubilizing bacteria to agriculture crops will help in avoidance of chemical fertilizers that are highly hazardous to environment. This review provides an overview of potassium solubilizing microorganism and there utilization as biofertilizers, a concept of alternative technology to chemical fertilizers.
Keywords: Potassium, microflora, solibilizers, biofertilizers

Introduction

Potassium (K) is an essential macronutrient, abundantly absorbed cation which plays an important role in the growth, metabolism and development of plants. Potassium (K) constitutes about 2.5% of the lithosphere but actual soil concentration of this nutrient varies widely ranging from 0.04 to 3.0% (Sparks and Huang, 1985). The concentration of soluble Phosphorus and Potassium in soil is very low, and the biggest proportion of Phosphorus and Potassium in soil is available in insoluble form in rocks, minerals and deposits (Goldstein, 1994). As Potassium being an important macronutrient for plant growth but potassium fertilizer, has been imported with large quantity annually. In Indian soils the soluble potassium form are present in about 2% and insoluble are present in range of 98% in form of minerals like muscovite, vermiculite, feldspar, mica, biotite (Akintokun *et al*., 2007). Therefore Potassium is richer than phosphorus and represents 2.6% of the weight of the Earth's crust

(Sangeeth *et al.,* 2001). Plants are absorbing potassium from soil, without satisfactory potassium availability, the plants will have poorly developed roots, grow slowly, produce small seeds and have lower yields.

Soil minerals make up more than 90 - 98% of soil potassium (Sparks, 1987) and most of it is unavailable for plant uptake. Rest 1 - 10% are non-exchangeable form of potassium in soil and consists predominantly of interlayer potassium of non-expanded clay minerals such as illite and lattice potassium in K-feldspars, which contribute significantly to the plant uptake (Memon *et al.,* 1988; Sharpley, 1989). Weathering of rocks plays an important role in number of environmental processes to clay, silt and sand and these minerals are important component of soil in the Earth (Cockell *et al*., 2011). These are the biggest reservoirs of Phosphorus and Potassium in soil because, under appropriate conditions, they can be solubilized and become available for plants (Xiufang *et al*., 2006). Microorganisms are having potentiality to solubilize unavailable form of potassium and make that available to plants.

Soil contains numerous important minerals but most significant minerals are nitrogen (N), phosphorus (P) and potassium (K), these nutrients is necessary for plants healthy growth and development. There are about thirteen mineral nutrients in the soil and they are classified into two categories which are macronutrient and micronutrient depending on the quantity required. Potassium is not a constituent of any organic molecule or plant structure, but it is involved in several biochemical and physiological processes and has essential role in growth, yield, quality and stress of plant (Cakmak, 2005). Potassium (K) being third major essential macronutrient for plant growth and development. The requirement of around five million tonnes of potassium fertilizers would be met through imports as India does not have commercially viable sources of potassium. India is totally dependent on import of potassium fertilizers.

Potassium solubilizers

Microorganisms are ubiquitous in nature and are found in every environment on earth. They can live in diverse environments because they have small requirements for sustenance including space and nutritional requirements. They have a boundless capability for adapting environmental changes. They are capable of producing different useful products that benefit science and society. The potassium solubilising microorganisms are rhizospheric microorganisms which solubilize the insoluble form of potassium (K) to soluble forms and is up taken by plants for their growth and yield. In natural Potassium and Phosphorus cycle microorganisms play vital role, most importantly different Potassium and Phosphorus solubilizing bacteria are isolated from soil and from plant rhizospheres (Sperberg, 1958). Numbers of bacterial species are having potential to solubilize inorganic phosphate compounds and silicates.

Bacteria are known to solubilize potassium, silicon and aluminum from insoluble minerals (Aleksandrov *et al.,* 1967). Potassium is important in plant growth and development because

the enzymes responsible for synthesis of starch (starch synthetase) are activated by Potassium that plays vital role in water and nutrient transport. Potassium is also important because it increases shelf life of crops (Prajapati *et al.,* 2013). When we are looking for high crop yield we introduce high crop yielding varieties and the advanced strengthening of agriculture, the soils are getting depleted in potassium reserve at a faster rate. Due to unnecessary fertilizer application, potassium deficiency is becoming one of the major limitations in crop production and leads to search to find a substitute native (indigenous) source of potassium for plants. It will also help in maintaining potassium status in soils for sustaining crop production (Supanjani *et al.,* 2006; Sindhu *et al.,* 2012). It has been reported that application of potassium solubilising bacteria, *Bacillus mucilaginosus*, increased potassium availability in soils and amplified mineral content in plant (Sheng *et al.,* 2002). Soil micro flora is known to play an important role in natural potassium cycle. Consequently, potassium solubilizing microorganisms present in the soil will act as solubilizers and makes unavailable form of potassium, available for plant uptake (Groudev, 1987; Rogers *et al.,* 1998). Isolation and identification of microbial strains capable of solubilizing potassium minerals quickly can preserve our potassium resources. That will help in protecting environment from hazardous chemical fertilizers.

Extensive variety of saprophytic bacteria including *Pseudomonas, Burkholderia, Acidothiobacillus ferrooxidans, Bacillus mucilaginosus, Bacillus edaphicus, B. circulans* and *Paenibacillus* sp. has been reported to solubilize potassium bearing minerals in soils and make them into accessible form for plants (Sheng, 2005; Lian *et al.,* 2002; Li *et al*., 2006; Lue *et al*., 2012). Some important fungal species like *Aspergillus sp*. and *Aspergillus terreus* are known to carry out solubilisation of potassium. Xiufang *et al.,* 2006 reported that diverse micro flora was found in the soil of Tianmu Mountain, Zhejiang, China with herbal plants flourished and they were able to dissolve both phosphorus and potassium containing minerals. As most of potassium solubilizing microorganisms are indigenous rhizospheric microorganism, they show effective interaction between soil and plant systems. The foremost mechanism of potassium solubilizing microorganisms is acidolysis, chelation, exchange reactions, complexolysis and production of organic acid.

Potassium solubilizing microorganisms as bio-fertilizers

In fact aapplication of potassium solubilizing bacteria as bio-fertilizer for agriculture and other related fields will improve eco-friendly crop production and due to this there will be reduction in use of agrochemicals (Kloepper *et al.,* 1989; Requena *et al.,* 1997; Sheng *et al.,* 2003; Sindhu *et al.,* 2010). Biofertilizers have been used as sources to improve plant nutrient status and soil health in sustainable agriculture. Excessive use of chemical fertilizers in agriculture are having adverse effects on soil health and structure, leads to depletion of water holding capacity, soil fertility and disparity in soil nutrients. However uses of biofertilizers in agriculture have tremendous impact on soil flora and crop yield. Biofertilizers are type of

fertilizers, in which useful microorganisms are used and that can be applied to seed, root or soil. These microorganisms help in mobilization and availability of nutrients especially NPK to the plants. They use their metabolic activities and help in building up the micro-flora of soil along enhancing soil health. From long time it was aim of scientists to develop low cost effective and eco-friendly bio-fertilizers which work without disturbing nature. The primarily mark of microbial involvement in solubilization of rock potassium had shown by Muentz (890). Due to indiscriminate use of inorganic fertilizers, soil health is badly getting deteriorated. These fertilizers have a considerable negative impact on the environment. In substitute to these chemical formulation, microbes based inoculants will have optimistic impact on soil health and also on crop yield.

Figure 1: Potassium solubilizing bacteria showing solubilization zone on Aleksandrov Agar.

The use of plant growth promoting rhizobacteria (PGPR), including phosphate and potassium solubilizing bacteria as biofertilizers, was suggested as a sustainable solution to improve plant nutrient and production (Vessey, 2003). The inoculation of potassium solubilizing bacteria and other useful microbial inoculants in the soil become compulsory to restore and maintain the effective microbial populations (**Figure 1**) They are used in for solubilization of chemically fixed potassium and availability of other macro and micronutrients to harvest good sustainable yield of various crops (Maliha *et al*., 2004). Rock potassium (K) materials are inexpensive sources of potassium; but they are not readily available to plant because minerals are released slowly and their use as fertilizer often causes insignificant yield increase in crops (Zapata and Roy, 2004). Potassium solubilizing bacteria are known to be best option for converting insoluble potassium of soil into a soluble form that plants can access. Potential of biofertilizers in long run are economical, eco-friendly, more efficient, productive and accessible to marginal and small farmers over chemical fertilizers. Potassium bio-fertilizers play key role in improving soil fertility, yield characters and thereby final yield (Epstein and Bloom, 2005). Potassium fertilizers are more expensive than other chemical fertilizers. Use of potential

potassium solubilizing microorganisms should be applied for solubilisation of fixed form of potassium to an available form of potassium. Numerous information has been reported in regard of ability of different bacterial species to solubilize insoluble inorganic phosphate compounds, such as tri-calcium phosphate, di-calcium phosphate, hydroxyl-apatite, and rock phosphate. Among the bacterial genera following are capable of solubilisation: *Pseudomonades, Bacillus, Rhizobium, Burkholderia, Achromobacter, Agrobacterium, Microccocus,* and *Aereobacter*. As earlier reported, utilization of potassium solubilizing bacteria as biofertilizers for agriculture improvement can reduce the use of agrochemicals and support eco-friendly crop production (Gundala *et al*., 2013).

Unselective use of artificial / chemical fertilizers has led to the contamination and adulteration of the soil, spoiled water basins, ruined microbial flora of soil and eco-friendly insects. Application of inorganic fertilizers makes crops more susceptible to diseases and reduce soil fertility and soil health. Solubilization of potassium is primarily due the production of organic acids by potential microbes. Application of potassium solubilizing microbes will help the farmers in mobilization of potassium present in field soil. Due to rare uptake of fertilizers including potassium by plants, they (fertilizers) reache into water bodies through rain water, lead to eutrophication in water bodies and affect all flora and fauna. Most of the farmers use only nitrogen and phosphorus and not use the K fertilizer due to unawareness so that the problem of potassium deficiency occurs in rhizospheric soils. The use of microbial inoculants or bio-formulations as biofertilizers in sustainable agriculture will provide an alternative tool to chemical fertilizer. Application of such bio-formulations in agriculture fields, leads to soil health improvement, soil structure, water holding capacity of soil and total crop yield and they also enhance resistance of plants to soil born pathogens.

Conclusion

In the environmentally conscious world consumption of food material treated with pesticides or chemical based fertilizers is disregarded, and the food materials produced through organic farming are gaining preference. Similar is case with application of chemical fertilizers as source of potassium, which directly leads to the spoilage of soil, human health, crop in general and whole together an environment. There are possible ways out to make alternative strategies to such hazardous chemicals by application of bio-formulations of bacterial/fungal origin. Utilization of potential potassium solubilizing microorganisms for availing insoluble form of potassium from rocks or other sources to soluble from, for plant growth and development. Thus use of efficient microbial strains for solubilisation of potassium is a progressive approach to avoid chemical fertilizers and to improve soil health, soil micro flora and crop yield.

References

Akintokun, A. K., Akande, G. A., Akintokun, P. O., Popoola, T. O. S. and Babalola, A. O., 2007. Solubilization of insoluble phosphate by organic acid producing fungi isolated from Nigerian soil. ***Int. J. Soil Sci.*** 2: 301–307.

Aleksandrov, V. G., Blagodyr, R. N. and Ilev, I. P. 1967. Liberation of phosphoric aicd from apatite by silicate bacteria. ***Mikrobiolohichnyi Zhurnal.*** 29: 111 -114.

Cakmak, I. 2005. The role of potassium in alleviating detrimental effects of abiotic stresses in plants. ***J. Plant Nutr. Soil Sci.*** 168: 521–530.

Cockell, C. S., Pybus, D., Olsson Francis, K., Kelly, L., Petley, D., Rosser, N., Howard, K. and Mosselmans, F. 2011. Molecular Characterization and Geological Microenvironment of a Microbial Community Inhabiting Weathering Receding Shale Cliffs, ***Microb. Ecol.*** 61: 166-181.

Epstein, E., Bloom, A. J., 2005. Mineral Nutrition of Plants: Principles and Perspectives, 2nd ed. Sinauer, Sunderland, MA. Pettigrew, W.T. Potassium influences on yield and quality production for maize, wheat, soybean and cotton. ***Physiol. Plant.*** 133: 670–681.

Goldstein, A. H. 1994. Involvement of the quinoprotein glucose dehydrogenase in the solubilization of exogenous phosphate by gram-negative bacteria. p.197 - 203. In: ***Phosphate in Microorganisms: Cellular and Molecular Biology*** (Torriani-Gorini, A., E. Yagil and S. Silver. eds) Washington, DC. ASM Press

Groudev, S.N., 1987. Use of heterotrophic microorganisms in mineral biotechnology. ***Acta Biotechnol***. 7: 299-306.

Gundala, P. B., Chinthala, P. and Sreenivasulu, B. 2013. A new facultative alkaliphilic, potassium solubilizing, *Bacillus Sp*.SVUNM9 isolated from mica cores of Nellore District, Andhra Pradesh, India. ***Research and Reviews. J. Microbiol Biotechnol.*** 2(1): 1-7.

Kloepper, J.W., Lifshitz, R. and Zablotowicz, R.M., 1989. Free-living bacterial inocula for enhancing crop productivity. ***Trends in Biotechnology.***7: 39–44.

Li, F.C., Li, S., Yang, Y.Z. and Cheng, L.J., 2006, Advances in the study of weathering products of primary silicate minerals, exemplified by mica and feldspar. ***Acta Petrol Mineral.*** 25: 440–448

Lian, B., Fu, P. Q., Mo, D. M. and Liu, C. Q. 2002. A comprehensive review of the mechanism of potassium release by silicate bacteria. ***Acta Mineral Sinica.*** 22: 179–183.

Liu, D., Lian, B. and Dong, H. 2012, Isolation of *Paenibacillus* sp. and assessment of its potential for enhancing mineral weathering. ***Geomicrobiology Journal.*** 29: 413–421.

Maliha, R., Samina, K., Najma, A., Sadia, A. and Farooq, L. 2004. Organic acid production and phosphate solubilization by phosphate solubilizing microorganisms under in vitro conditions. ***Pak. J. Biol. Sci.*** 7:187–196.

Memon, Y. M., Fergus, I. F., Hughes, J. D. and Page, D. W. 1988. Utilization of non-exchangable soil potassium in relation to soil types, plant species and stage of growth. ***Australian Journal of Soil Research,*** 26: 489-496.

Muentz, A. 1890. Surla decomposition desroches etla formation de la terre arable. ***C. R. Acad. Sci.*** 2: 110-137.

Prajapati, K., Sharma, M. C. and Modi, H. A. 2013. Growth promoting effect of potassium solubilizing microorganisms on *Abelmoscus esculantus.* ***Int. J. Agricultural Science.*** 3 (1): 181–188.

Requena, B. N., Jimenez, I., Toro, M. and Barea, J. M.. 1997. Interactions between plant growth-promoting rhizobacteria (PGPR), arbuscular mycorrhizal fungi and *Rhizobium*

spp. in the rhizosphere of *Anthyllis cytiisoides*, a model legume for revegetation in mediterranean semiarid ecosystems. ***New Phytologist.*** 136: 667-677.

Rogers, J. R., Bennett, P. C. and Choi, W. J. 1998. Feldspars as a source of nutrients for microorganisms. ***American Mineralogy.*** 83: 1532-1540.

Sangeeth, K. P., Bhai, R. S., and Srinivasan, V. 2001. Paenibacillus glucanolyticus, a promising potassium solubilizing bacterium isolated from black pepper (*Piper nigrum* L.) rhizosphere. ***J. Spic. Aromat. Crops.*** 21 (2): 118-124.

Sharpley, A.N., 1989. Relationship between soil potassium forms and mineralogy. ***Soil Science Society American Journal.*** 52: 1023-1028.

Sheng, X. F. and Huang, W. Y. 2002. Study on the conditions of potassium release by strain NBT of silicate bacteria. ***Scientia Agricultura Sinica.*** 35: 673-677.

Sheng, X. F. 2005. Growth promotion and increased potassium uptake of cotton and rape by a potassium releasing strain of *Bacillus edaphicus*. ***Soil Biology and Biochemistry.*** 37: 1918-1922.

Sheng, X. F., Xia, J. J. and Chen, J. 2003. Mutagenesis of the *Bacillus edaphicus* strain NBT and its effect on growth of chilli and cotton. ***Agriculture Science China,*** 2: 400-412.

Sindhu, S. S., Dua, S., Verma M. K. and Khandelwal, A., 2010. Growth promotion of legumes by inoculation of rhizosphere bacteria. In: ***Microbes for Legume Improvement***. (Khan, M.S., Zaidi, A. and Musarrat, J., Eds.) Springer-Wien, New York, Germany. 195-235.

Sindhu, S. S., Parmar, P. and Phour, M. 2012. Nutrient cycling: potassium solubilization by microorganisms and improvement of crop growth. In: ***Geomicrobiology and biogeochemistry: Soil biology. (***Parmar, N. and Singh, A., eds). Springer-Wien/New York, Germany.

Sparks, D. L. and Huang, P. M., 1985. Physical chemistry of soil potassium. In: Potassium in agriculture. (Munson, R.D., Ed.) ***American Society of Agronomy***. pp. 201-276.

Sparks, D. L., 1987. Potassium dynamics in soils. ***Advances in Soil Scienc.,*** 6: 1-63.

Sperberg, J.I. 1958. The incidence of apatite solubilizing organisms in the rhizosphere and soil. ***Australian Journal of Agricultural and Resource Economics.*** 9: 778.

Supanjani, H. S., Jung, S. J. and Lee, K. D. 2006. Rock phosphate potassium and rock solubilizing bacteria as alternative sustainable fertilizers. ***Agronomy and Sustainable Development.*** 26: 233-240.

Tripura, C. B., Sashidhar B, Podile A. R. 2005. Transgenic mineral phosphate solubilising bacteria for improved agricultural productivity. p. 375-392. In: ***Microbial Diversity Current Perspectives and Potential Applications***. (Satyanarayana, T. and Johri B. N. Eds). K. International Pvt. New Delhi, India.

Vessey K. J. 2003. Plant growth promoting rhizobacteria as biofertilizers. ***Plant Soil.*** 255: 571–586.

Xiufang, H., Jishuang, C. and Jiangfeng, G., 2006. Two phosphateand potassium- solubilizing bacteria isolated from Tianmu Moutain, Zhejiang, China. ***World Journal of Microbiology and Biotechnology.*** 22: 983 - 990.

Zapata, F., Roy, R. N. (2004). Use of Phosphate Rock for Sustainable Agriculture. FAO and IAEA, Rome, Italy