International Research Journal of Biological Sciences _____ ISSN 2278-3202
Vol. **3(12),** 80-85, December **(2014)** *Int. Res. J. Biological Sci.*

Importance and Application of Potassic Biofertilizer in Indian Agriculture

Indra Bahadur[1*] Vijay Singh Meena[1] and Sanjay Kumar[2]
[1]Deptt. of Soil Science and Agril. Chemistry, I.A.S., BHU, Varanasi, UP, INDIA
[2]Deptt. of Plant Physiology, I.A.S., BHU, Varanasi, UP, INDIA

Available online at: www.isca.in, www.isca.me
Received 28th June 2014, revised 10th September 2014, accepted 6th November 2014

Abstract

India totally depends on import of potassic fertilizers for other countries. In Indian condition farmers mainly used nitrogenous fertilizers, some phosphorous and very less or not used potassium in crop production. Biofertilizers are one of the best modern tools for sustainable agriculture. It is a gift of our modern agricultural technological view. Bio fertilizers are applied in the agricultural field as a substitute to inorganic/chemical fertilizers. Most of the farmers used chemical fertilizers for agricultural production system. However, chemical fertilizers have many negative impacts such as environmental pollution, global warming, soil microbial diversity etc. Moreover, they also influenced soil plant dynamic with its microbial distribution, and its cause to degradation of soil-environmental sustainability. But Indian agricultural system use nitrogenous and phosphatic biofertilizer, it helps to enhance sustainability of system. Nowadays many researcher works to develop potassic bio fertilizer.

Keyword: Potassium, solubilizing, microorganisms, biofertilizer, sustainability.

Introduction

World's population is assumed to increase from 7 billion now to 8.3 billion in 2025. The world will need 70 to 100 percent more food by 2050, demands placed upon agriculture to supply future food will be one of the greatest challenges facing the agrarian communities order to meet this challenge, focusing on the soil biological system is enabling better understand the complex processes and interactions governing the stability of crop production as well as soil health[1]. Soil containing essential several minerals but most important minerals are nitrogen (N), phosphorus (P) and potassium (K), these nutrients are essential for a plant to healthy growth and development. There are about 13 mineral nutrients in the soil and they are classified into two categories which are macronutrient and micronutrient depending on the quantity required[2]. Potassium is the third important plant nutrient after Nitrogen and Phosphorous. The entire requirement of around five million tonnes of potassic fertilizers would be met through imports as India does not have commercially viable sources of potash, India is totally depended on import of potassic fertilizers[3]. Nowadays use of efficient rhizospheric microorganisms may offer plant growth promotion, agronomic, pathogenic and environmental benefits for intensive agricultural systems. Plant growth promoting microorganisms exhibit a gradual increase in demand to the world market. One possible mechanisms for the effectiveness of biofertilizers, such as mobilization of sparingly available plant mineral nutrients nitrogen fixer, phosphorus[4], potassium[5,6] and zinc solubilizers[7], production of growth promoting substances[8], enhanced and induced resistance to environmental stress factors and direct or indirect suppression of plant pathogens[9].

Eco-friendly agricultural system has emerged as an important priority area globally in view of the growing demand for safe and healthy food and long term soil-environmental sustainability and concerns on environmental pollution associated with indiscriminate use of agrochemicals[10]. Microorganisms also play very important role as the component of the biological soil phase and also indicator of soil fertility and soil degradation[11]. Biofertilizers are being essential component of organic farming are the preparations containing live or latent cells of efficient strains of nitrogen fixing, phosphate solubilizing or cellulolytic microorganisms used for application to seed and, soil bio-priming or composting areas with the to enhance the effective microorganisms and accelerate those microbial processes which augment enhance the availability of nutrients that can be easily assimilated by plants. Biofertilizers play a very significant role in improving soil fertility by fixing atmospheric nitrogen, both, in association with plant roots and without it, solubilise insoluble soil phosphates minerals and produces plant growth substances in the soil[12]. Biofertilizer contains microorganisms which promote the adequate supply of nutrients to the host plants and ensure their proper development of growth and regulation in their physiology. Effective living microorganisms are used in the preparation of biofertilizers. They are in fact being promoted to harvest the naturally available, biological system of nutrient mobilization[13]. The role and importance of biofertilizers in sustainable crop production has been reviewed by several authors. But the progress in the field of BF production technology remained always below satisfaction in Asia because of various constraints.

Role of Potassium in plant: Potassium is absorbed by plants in larger amounts than any other mineral element except nitrogen

and, in some cases, calcium. Potassium is needed in large quantities for a crop to achieve its maximum yield. The exact function of potassium in plant growth has not been clearly defined. Potassium is associated with movement of water, nutrients, and carbohydrates in plant tissue. If potassium is deficient or not supplied in adequate amounts, growth is stunted and yields are reduced. It is involved in the adjustment of plant cellular osmotic pressure and the transportation of compounds in plants. Potassium Helps in the building of protein, photosynthesis, fruit quality and reduction of diseases. Potassium is supplied to plants by soil minerals, organic materials, and fertilizer. It promotes the activation of enzymes, the utilization of nitrogen (N), and syntheses of protein and sugar. It also boosts plant photosynthesis[14]. Plants can only take in K through the soil. In plants, K deficiency causes yellowing of the leaf edges, giving them a burned appearance. It can also cause slow growth and incomplete root development[15]. Without adequate potassium, the plants will have poorly developed roots, grow slowly, produce small seeds and have lower yields[16].

Potassium in Soil: Potassium in soil present in four pools according to the availability of the potassium for uptake to plant[17] Mineral soils contain 0.04–3% K; the total K content of the upper 0.2 m of most agricultural soils[14] generally ranges between10 and 20 g per kg However, most of the soil K (90–98%) is incorporated in the crystal lattice structure of minerals and thus not directly available for plant uptake (Figure 1). e. The availability of K differs greatly with soil type and is affected by physico-chemical properties of the soil. To simplify the complex K dynamics in soil, K in soil is often classified into four groups depending on its availability to plants: water-soluble, exchange-able, non-exchangeable and structural forms. Water-soluble K is directly available for plants and microbes and potentially subjected to leaching and exchangeable potassium is electro-statically bound on outer-sphere to the clay surfaces of minerals[18].

Both fractions are often considered to be easily available for crops. However, the size of both pools is very small. They make up only about 0.1–0.2% and 1–2% of the total K in soil, respectively[14]. Non-exchangeable and structural forms are considered to be slowly- or non-available K sources for plants. However, these pools may also contribute significantly to the plant supply in the long term[5,19, 20].

Quantity of available and unavailable potassium in the soil varies from soil to soil and dynamic equilibrium reactions between the different pools of potassium in soil. Thus, a number of soil physical and chemical properties as well as plant interactions and soil microbial activity affect the fixation and release of potassium from mineral soil. Potassium is absorbed in large quantity by plant than other essential elements except Nitrogen. In the soil, the mineral nutrients are dissolved in water and absorbed through a plant root. However, the amounts of nutrients in the soil are always unpredictable and not enough for plants growth. Potassium constitutes about 2.1% of the earth's crust and thus is the seventh most abundant element. Therefore, soil potassium reserves are generally large in the soil in structural form[21] but large agricultural areas of the world are reported to be deficient in K availability, including 75% of the paddy soils of China, and 66% of the wheat belt of Southern Australia, due to the slow release as compare to requirement of the crop. Bio fertilizer is a good platform to deliver this primary macronutrient from unavailable potassium to plant available potassium by assistance of potassium solubilizing microorganisms (KSMs).

Current status of Potassium in India: Available potassium in Indian soils has been categorized into three classes 21 per cent districts fall in low, 51 per cent in medium and 28 per cent in high potassium content oils[22], thus 72% of India's agricultural area, 266 districts, which need immediate potassium fertilization

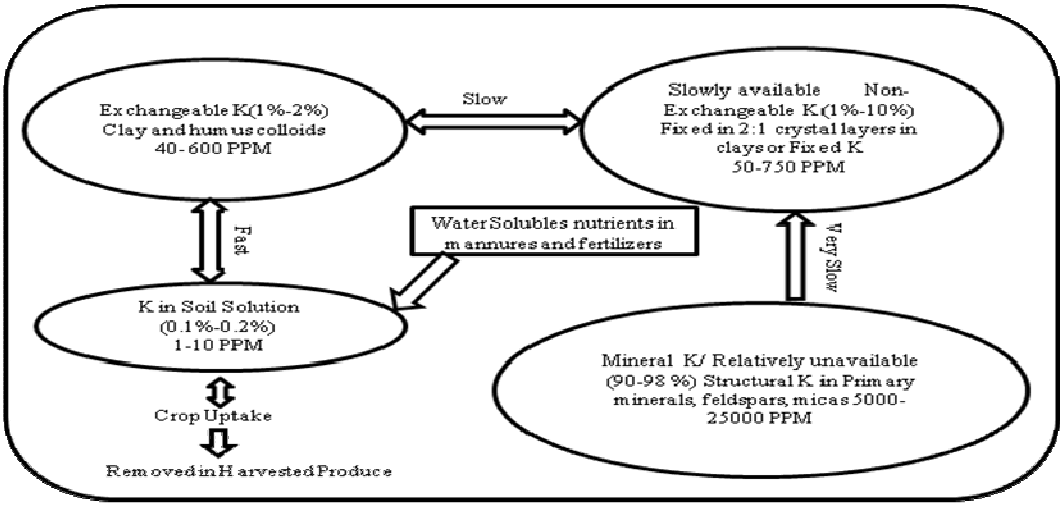

Figure-1
Showing Different Farm of potassium in soil

for healthy crop production. Nowadays potassium is a costly nutrient in India, because totally depend on foreign countries. India ranks 4th in consumption of potassium fertilizers, on an average 1.7 million tonnes of potassium are being imported annually from different country[23]. In India, until the eighties, potassium did not receive much attention because of the general belief that Indian soils were well supplied with potassium. [24]crop removal of potassium often equals or exceeds that of nitrogen estimated that a total of 13.7 million tons of K_2O $year^{-1}$ are being removed by crops in India against the present fertilizer consumption of only 1.57 million tons of K_2O. After considering all the organic and inorganic additions, a net deficit of 7.049 million tonnes K_2O $year^{-1}$ has been estimated which means a depletion of Indian soils. One possible alternative could be to fully exploit the reservoir of K in the soil. Soil has rich reserves of K, among which only 1–2% can be directly absorbed by plants[25] . In the last century, when the chemical fertilizers were first introduced into the agriculture field, most of the problems faced by farmers to increase yield.

Why Potassic biofertilizers: Soil K deficiency and K fertilizer deficiency have become important limiting factors for the development of agriculture[26]. Increasing use of chemical fertilizers in agriculture make country self dependent in food production but it deteriorate environment and cause harmful impacts on living beings. Due to insufficient uptake of these fertilizers by plants results, fertilizers reaches into water bodies through rain water, causes eutrophication in water bodies and affect living beings including growth inhabiting micro organism. The excess uses of chemical fertilizers in agriculture are costly and also have various adverse effects on soils i.e. depletes water holding capacity, soil fertility and disparity in soil nutrients. It was felt from a long time to develop some low cost effective and eco-friendly fertilizers which work without disturbing nature. Now, certain species of micro-organism are widely used which have unique properties to provide natural products, and serve as a good substitute of chemical fertilizers. The mass application of fertilizer can increase costs, decrease the efficiency of K fertilizer and damage the environment[27]. An alternative to chemical K fertilizer is necessary for the sustainable development of agriculture. It is estimated that by 2020, to achieve the targeted production of 321 million tonnes of food grain, the requirement of nutrient will be 28.8 million tonnes, while their availability will be only 21.6 million tonnes being a deficit of about 7.2 million tonnes[28]. Depleting feedstock/fossil fuels (energy crisis) and increasing cost of fertilizers. This is becoming unaffordable by small and marginal farmers, depleting soil fertility due to widening gap between nutrient removal and supplies, growing concern about environmental hazards, increasing threat to sustainable agriculture. Besides above facts, the long term use of bio-fertilizers is economical, eco-friendly, more efficient, productive and accessible to marginal and small farmers over chemical fertilizers[29]. Indiscriminate use of synthetic fertilizers has led to the pollution and contamination of the soil, has polluted water basins, destroyed micro-organisms and friendly insects, making the crop more prone to diseases and reduced soil fertility. Demand is much higher than the availability.

K-solubilizing microorganism (KSMs): The potassium solubilizing microorganisms (KSMs) are a rhizospheric microorganism which solubilizes the insoluble potassium (K) to soluble forms of K for plant growth and yield. K-solubilization is carried out by a large number of saprophytic bacteria (*Bacillus mucilaginosus*, *Bacillus edaphicus*, *Bacillus circulans*, *Acidothiobacillus ferrooxidans*, *Paenibacillus spp*.) and fungal strains (*Aspergillus spp*. and *Aspergillus terreus*). Major amounts of K containing minerals (muscovite, orthoclase, biotite, feldspar, illite, mica) are present in the soil as a fixed form which is not directly taken up by the plant. Nowadays most of the farmers use injudicious application of chemical fertilizers for achieving maximum productivity[30]. However, the KSMs are most important microorganisms for solubilizing of fixed form of K in soil system. The KSMs are an indigenous rhizospheric microorganism which shows effective interaction between soil and plant systems. The main mechanism of KSMs is acidolysis, chelation, exchange reactions, complexolysis and production of organic acid. According to literature, currently negligible use of potassium fertilizer as a chemical form has been recorded in agriculture for enhancing crop yield. Most of the farmers use only nitrogen and phosphorus and not use the K fertilizer due to unawareness so that the problem of K deficiency occurs in rhizospheric soils. The K fertilizer is also costly as compared to other chemical fertilizers. Therefore, the efficient KSMs should be applied for solubilization of a fixed form of K to an available form of K in the soils[31]. This available K can be easily taken up by the plant for growth and development. Our aim of this review is to elaborate on the studies of indigenous K-solubilizing microbes to develop efficient microbial consortia for solubilization of K in soil which enhances the plant growth and yield of crops. Potassium Solubilizing Bacterial isolates that are able to dissolve potassium from mineral soils that increase crop plant growth and yield. The first evidence of solubilization of mineral potassium had shown.

K-solubilizing Bacteria: A wide range of rhizospheric microorganism is reported as potassium solubilizers including *Bacillus mucilaginosus*, *B. edaphicus*, *B. circulanscan* and *Arthobacter sp.* etc potassium solubilizing bacteria (KSB). Potassium solubilization is mainly due the production of organic acids. The use of microbial inoculants as biofertilizers is a sustainable agriculture for providing a alternative tool of chemical fertilizer By using this farmers can mobilize the potassium present in their own field soil and save some percentage of their potassium fertilizer requirement. Several reports have examined the 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 with this capacity are *pseudomonas, Bacillus, Rhizobium, Burkholderia, Achromobacter, Agrobacterium, Micrococcus, Aereobacter,*

Flavobacterium and *Erwinia*[32, 33]. There are considerable populations of phosphate solubilizing bacteria in soil and in plant rhizosphere. These include both aerobic and anaerobic strains, with a prevalence of aerobic strains in submerged soils. A considerably higher concentration of phosphate solubilizing bacteria is commonly found in the rhizosphere in comparison with non rhizosphere soil.

Mechanism of KSB: Many researchers have quantitatively investigated the ability of KSMs to solubilize insoluble potassium in liquid Aleksandrov broth medium[6, 34]. The mechanism of potassium solubilization means by which insoluble potassium and structural unavailable forms of potassium compounds are mobilized and solubilize due to the production of various type organic acids. These acids are accompanied by acidolysis, complexolysis exchange reactions and these are key processes attributed to their conversion in soluble form[28].The organic and inorganic acids convert insoluble K (mica, muscovite, biotite feldspar) to the soluble form of K (soil solution form) with the net result increasing the availability of nutrients to plant. Production of Inorganic acid also helps the solubilization these acids convert insoluble K (mica, muscovite, biotite and feldspar) to soluble form of K (soil solution form) with the net result increasing the availability of the nutrients in to the soil for plants. Enhancing chelation of cations bound to K and acidic dissolution of the crystal network.

Potential Role of Potassic biofertilizer: Soil potassium supplementation relies heavily on the use of chemical fertilizer, which has a considerable negative impact on the environment. Potassium-solubilizing bacteria (KSB) could serve as inoculants. They convert insoluble potassium in the soil into a form that plants can access. This is a promising strategy for the improvement of plant absorption of potassium and so reducing the use of chemical fertilizer[30]. Potassic bio-fertilizers in agriculture plays major role in improving soil fertility, yield attributing characters and thereby final yield has been reported by many workers[35, 27]. In addition, their application in soil improves soil biota and minimizes the sole use of chemical fertilizers. It is an established fact that the Indian soil is reach source of potassium containing secondary mineral but it is not available to plant this can make available to plant using potassium solubilizing bacteria. Therefore, the inoculations with KSB and other useful microbial inoculants in the soil become mandatory to restore and maintain the effective microbial populations for solubilization of chemically fixed potassium and availability of other macro and micronutrients to harvest good sustainable yield of various crops.

Constraints in Potassic Bio Fertilizer use

Production Constraints: Unavailability of appropriate and efficient strains: Lack of region specific potassium solubilizing strains is one of the major constraints as potassic bio-fertilizers are not only crop specific but soil specific too. Moreover, the selected strains should have competitive ability over other strains.

Unavailability of suitable carrier for potassic bio fertilizer: Availability of suitable carrier (media in which bacteria are allowed to multiply) due to which shelf life of bio-fertilizers is short is a major constraint.

Market level constraints: Lack of awareness of farmers: In spite of considerable efforts in recent years, majority of farmers in India are not aware about potassic bio-fertilizers, their usefulness in increasing crop yields in a sustainable way.

Inadequate and Inexperienced staff: Because of inadequate staff and that too not technically qualified who can attend to technical problems. Farmers are not given proper instructions about the application aspects and importance of potassium in crop production.

Lack of quality assurance: The sale of poor quality potassic bio-fertilizers through corrupt marketing practices results in loss of faith among farmers, to regain the faith once is very difficult and challenging.

Seasonal and un-assured demand: The potassic bio-fertilizer use is seasonal and both production and distribution is done only in few months of year, as such production units particularly private sectors are not sure of their demand.

Resource constraint: Limited resource generation for potassic bio- fertilizer production: The investment in potassic bio-fertilizer production unit is very low.

Soil constraint: Among soil and climatic conditions, high soil fertility status, un-favourable pH, high temperature, drought, deficiency of potassium containing secondary mineral (Illite), P, Cu, Co, Mo or presence of toxic elements affect the microbial growth and crop response.

Table-1
Do's and Don't to Potassic Biofertilizers

Do	Don't
Keep Bio-fertilizers away from direct heat and sunlight. Store it in cool and dry place.	Don't store Bio-fertilizers under heat and sunlight
Sell only Bio-fertilizers which contain batch number, the name of the crop on which it has to be used, the date of manufacture and expiry period.	Don't sell Bio-fertilizers after their expiry period is over.
If the expiry period is over, then discard it as it is not effective.	Don't prick holes into the or puncture them to the content
Keep Bio-fertilizers away from fertilizer or pesticide containers and they should not be mixed directly.	Do not mix the Bio-fertilizers with fungicides, insecticides, herbicides, herbicides and chemical fertilizers.

Native microbial population: Antagonistic microorganism already present in soil competes with microbial inoculants and many times do not allow their effective establishment in the soil with the inoculated population.

Faulty inoculation techniques: Majority of the marketing sales personals do not now proper inoculation techniques. Bio-fertilizers being living organisms required proper handling, transport and storage facilities.

How Potassium solubilizing Bacteria applied: Potassium solubilizing bacterial (KSB) inoculants used as a seed treatment it is cheap and easiest means of inoculation shown in. When properly applied, this method ensures that each seed receives the introduced KSB micophos. It also used as a seedling treatment.

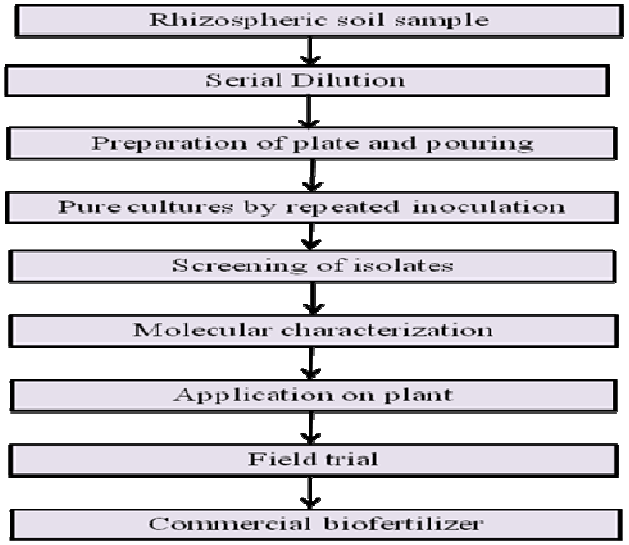

Figure-1
Flow Chart of Isolation Process of Potassium Solubilizing Bacteria from Soil

One packet of inoculants' (200 g) is mixed with 500 ml of water to make slurry. The seeds required are mixed in the slurry so as to have a uniform coating of the inoculants over the seeds and then shade drying for 30 minutes. The shade dried seeds should be sown within 24 hours. One packet of inoculants (200g) is sufficient to treat 10 kg of seeds[29]. The application of potassic bio-fertilizer also used as a seedling root dip this method is used for transplanted crops and it is also used with farm yard manure by broadcasting in main field just before transplanting/sowing of seeds.

Conclusion

Microbes are effective in inducing plant growth as they secrets plant growth promoters and enhance seed germination and root growth. They also play a considerable role in decomposition of organic materials and enrichment of compost. Chemical fertilizer slowly started to show their side effect on human and environment, but the use of biofertilizer can improve available plant nutrient and production in sustainable way. It is very important to successful research work done for identification of an elite microbial strain capable of solubilizing potassium minerals quickly in large quantity can conserve our existing resources and avoid environmental pollution hazards caused by excessive/ injudicious use of chemical fertilizers. This communication highlighted contributions of rhizospheric microorganisms especially potassium solubilizing bacteria can enhance the productivity of agricultural crops without disturbing environment. This type of microbial consortium is cost effective and eco-friendly for enhancing the sustainable agriculture.

References

1. Khan A.A., Jilani G., Akhtar M.S., Naqvi SMS. and Rasheed M., Phosphorus solubilizing bacteria: Occurrence, mechanisms and their role in crop production., *J. Agric. Biol. Sci.,* **1(1),** 48-58 **(2009)**

2. Lack A.J. and Evans D.E., Instant notes in plant biology, 1st edn. Oxford : Bios Scientific Publishers, **7**, 68-71 **(2005)**

3. Indian Fertilizer Industry at a Glance in, **(2012 – 2013)**

4. Verma J.P., Yadav J., Kavindra N.T. and Jaiswal D.K., Evaluation of plant growth promoting activities of microbial strains and their effect on growth and yield of chickpea (*Cicer arietinum* L.) in India, *Soil Biology and Biochem.,* **70**, 33-37 **(2014)**

5. Meena V.S., Maurya B.R. and Verma J.P., Does a rhizospheric microorganism enhance K+ availability in agricultural soils?, *Microbiol Res* http://dx.doi.org/10.1016/j.micres.2013.09.003 **(2013)**

6. Maurya B.R., Meena V.S. and Meena O.P., Influence of inceptisol and alfisol's Potassium Solubilizing Bacteria (KSB) isolates on release of K from waste mica, This article is published with open access at www.vegetosindia.org., **(2014)**

7. Goteti P.K., Leo D.A.E., Desai S. and Mir Hassan Ahmed S., Prospective Zinc Solubilising Bacteria for Enhanced Nutrient Uptake and Growth Promotion in Maize (Zea mays L.), *Interna. J. of Microbi.*, Article ID 869697, 7 **(2013)**

8. Deshwal V.K. and Kumar P., Production of Plant growth promoting substance by *Pseudomonas*. *J. of Acad. and Indus. Res.* (JAIR), 2, **(2013)**

9. Malhotra M., Srivastava S., Stress-responsive indole-3-aceticacid biosynthesis by Azospirillum brasilense SM and its abilityto modulate plant growth., *Eur. J. Soil Biol.,* **45,**73–80 **(2009)**

10. Kim K.Y., Jordan D. and McDonald G.A., *Enterobacter agglomerans*, phosphate solubilizing bacteria, and microbial activity in soil : Effect of carbon sources, *Soil*

Biol. Biochem, **30**, 995-1003 **(1998)**

11. Milic V., Jarak M., Mrkovacki N., Milosevic N., Govedarica M., Đuric S. and Marinkovic. J., Microbiological fertilizer use and study of biological activity for soil protection purposes, *Field Veg. Crop Res*., **40**, 153-169 **(2004)**

12. Kawalekar J.S., Role of biofertilizers and bio-pesticides for sustainable Agriculture, *J. Bio. Innov.,* **2(3)** 73-78 **(2013)**

13. Venkatashwarlu B., Role of bio-fertilizers in organic farming : Organic farming in rain fed agriculture : Central institute for dry land agriculture, Hyderabad, 85-95 **(2008)**

14. Sparks D.L. and Huang P.M., Physical chemistry of soil potassium. In Potassium in agriculture (ed.) Munson, R.D., *American Soc. Agron. J.,* 201-276 **(1987)**

15. Munson J.B., Foehring R.C., Lofton S.A., Zengel J.E. and Sypert G.W., Plasticity of medial gastrocnemius motor units following cordotomy in the cat., *J Neurophysiol***, 55**, 619–634 **(1986)**

16. Sparks D.L. and Huang P.M., Physical chemistry of soil potassium. In: Potassium in agriculture. Munson, R.D., Ed. *Americ. Soci. of Agro. J.*, USA., 201-276 **(1985)**

17. Zakaria A., Growth optimization of Potassium Solubilizing Bacteria isolated from biofertilizer., *Natural Resources Eng. Univ*., 40 **(2009)**

18. Barre P., Montagnier C., Chenu C., Abbadie L. and Velde B., Clay minerals as a soil potassium reservoir : Observation and quantification through X-ray diffraction., *Plant Soil*., **302**, 213–220 **(2008)**

19. Pal D.K., Srivastava P., Durge S.L. and Bhattacharyya T., Role of weathering of fine-grained micas in potassium management of Indian soils., *Appl. Clay Sci*., **20**, 39–52 **(2001)**

20. Basak B.B. and Biswas D.R., Co-inoculation of potassium solubilizing and nitrogen fixing bacteria on solubilization of waste mica and their effect on growth promotion and nutrient acquisition by a forage crop., *Biol. Fertil. Soils*, *Can. J. Microbiol.,* **52**, 66–72 **(2010)**

21. Schroeder B.L., Wood A.W., Hardy S., Moody P. and Panitz J., Soil-specific nutrient management guidelines for sugarcane production in the Proserpine district, BSES Technical Publication TE04003, 59 **(2006)**

22. Ghosh A.B. and Hasan R., Soil fertility map of India, Indian Agricultural Research Institute, New Delhi **(1980)**

23. Anonymous, Information on Horticulture and Various Crops. Directorate General Production of Horticulture and Various Plants, Jakarta Indonesia **(2003)**

24. Bensal S.K., Moiniddin P., crop responces to balanced nutrition management in india. Proceedings of International Symposium of the soil and Water Research Institute, University of Tehran (Iran), 57-68 **(1999)**

25. Mikhailouskaya N. and Tcherhysh A., K-mobilizing bacteria and their effect on wheat yield. *Latvian J Agron*, **8**,154–7 **(2005)**

26. Sheng X.F., He. L.Y. and Huang W.Y., The conditions of releasing potassium by a silicate-dissolving bacterial strain NBT, *Agric Sci China,* **1**, 662–665 **(2002)**

27. Zhang A., Zhao G., Gao T, Wang W, Li J and Zhang S., Solubilization of insoluble potassium and phosphate by Paenibacillus kribensis a soil microorganismwith biological control potential., *Afr. J. Microbiol. Res.,* **7(1),** 41–7 **(2013)**

28. Uroz S., Calvaruso C., Turpault M.P. and Freyklett P., Mineral weathering by bacteria: ecology, actors and mechanisms., *Trends Microbiol*., **17**, 378–87 **(2009)**

29. Subba Roa N.S., An appraisal of biofertilizers in India. The biotechnology of biofertilizers, (ed.) S. Kannaiyan, *Narosa Pub. House, New,* **(2001)**

30. Zhanga C. and Konga F., Isolation and identification of potassium-solubilizing bacteria from tobacco rhizospheric soil and their effect on tobacco plants, *Applied Soil Eco*., **82**, 18–25 **(2014)**

31. Parmar P. and Sindhu S.S., Potassium solubilization by rhizosphere bacteria: influence of nutritional and environmental conditions., *J Microbio. Res*., **3(1),** 25–31 **(2013)**

32. Rajawat M.V.S., Singh S., Singh G. and Saxena A.K., Isolation and characterization of K-solubilizing bacteria isolated from different rhizospheric soil. In proceeding of : Annual Conference of Microbiologists of India, At Punjab University, Punjab, India, **(2012)**

33. Zhao F., Sheng X, Huang Z, He L., Isolation of mineral potassium-solubilizing bacterial strains from agricultural soils in Shandong Province., *Biodiv. Sci*., **16**, 593–600 **(2008)**

34. Archana D.S., Nandish M.S., Savalagi V.P. and Alagawadi A.R., Characterization of potassium solubilizing bacteria (KSB) from rhizosphere soil. *Bioinfolet*, **10**, 248–257 **(2013)**