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Original Research Article

Potassium Solublisers: Occurrence, Mechanism and Their Role as Competent Biofertilizers

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A B S T R A C T

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Potassium is the third essential nutrient required by plants. Potassium solublising microorganisms play vital role in making available insoluble forms of potassium by mineralization. They solublise potassium from insoluble forms like mica, fledspar and others by producing organic acids, siderophores and also capsular polysaccharides. Potassium uptake of plants can be increased by using potassium solublisers as bio-inoculants further increasing the crop production. Also co –inoculation with other bio inoculants like Phosphate- solublisers has also shown positive co-relation with yields of crops. This article includes the work done on various potassium solublising microorganisms, their mechanism of potassium solublisation and their use as a bio-inoculant.

Introduction

Potassium [K] is seventh most common element in the earth's crust. Potassium was isolated in 1807 by Sir Humphry Davy, who obtained it through the electrolysis of very dry molten caustic potash (KOH, potassium hydroxide). Potassium was the first metal isolated by electrolysis and was collected at the cathode (Holmes, 2011). Potassium exists in several forms in the soil, including mineral K, non-exchangeable K, exchangeable K, and dissolved or solution K (K^+ ions). Plants can only directly take-up solution K.

It exists in exchangeable, non changeable and in form of soil minerals. The potassium content of Indian soils varies from less than 0.5 %to 3.00 % (Mengel,1987).In Indian soil the soluble K form are present in approximately 2% and insoluble are present in range of 98% in form of minerals like biotite, feldspar, mica, muscovite, vermiculite (Goldstein,1994).

Among the three essentials nutrients required by plants, one of them is Potassium. It is involved in numerous biochemical and physiological processes in plants like stomatal regulation for plants depend upon K to regulate the opening and closing of stomata's. Proper functioning of stomata is essential for photosynthesis .The activation of enzymes by K and its involvement in adenosine triphosphate (ATP) production is important in regulating the rate of photosynthesis, sugars produced in photosynthesis must be transported through the phloem to other parts of the plant for utilization and storage .The plant's transport system uses energy in the form of ATP. If K is inadequate, less ATP is available, and the transport system breaks down. Potassium also plays a major role in the transport of water and nutrients in the plant through xylem. The enzyme responsible for synthesis of starch (starch synthetase) is activated by K, hence it plays crucial role in water and nutrient transport (Usherwood, 1985; Doman, 1979; Marschner, 1995 Pettigrew, 2008).Due to deficiency of K severe loss was faced in yield and quality of crop production. Its role is known in improving shelf life of crops, disease resistance (Khawilkar, 1993).

Potassium solubilizing microorganisms and their occurrence

Muentz showed the first evidence of microbial involvement in solubilization of rock potassium (Muentz,1890). Microorganisms like *Aspergillus niger*, *Bacillus extroquens* and *Clostridium pasteurianum* were found to grow on muscovite, biotite, orthoclase microclase and mica *in vitro* (Archana, 2013). Different bacterial species like silicate bacteria were found to dissolve potassium, silicates and aluminium from insoluble minerals (Aleksandrov, 1967) (Table 1).

Mechanism of Potassium solublization by microorganisms

Organic matter after decomposition produces acids like citiric acid, formic acid, malic acid, oxalic acid. These organic acids produced, enhance the dissolution of potassium compounds by supplying protons and by complexing Ca^{2+} ions .Previous work has shown organic compounds produced by micro-organisms such as acetate, citrate and oxalate can increase mineral dissolution in soil (Sheng, 2003). Solubilization of potassium occurs by complex formation between organic acids and metal ions such as Fe^{2+}, Al^{3+} and Ca^{2+} (Styriakova, 2003).

In a study it was reported that potassium soluiblizing bacteria *B. mucilaginosus* are able to soluiblize rock K mineral powder such as micas, illite and orthoclases through production and excretion of organic acids (Ullaman, 1996). Microbially produced organic ligands include metabolic by products, extracellular enzymes, chelates and both simple and complex organic acids enhance the dissolution of aluminosilicate mineral or quartz both in field and laboratory experiments (Grandstaff, 1986; Surdam1988). Production of capsular polysaccharides along with organic acid production like tartaric and oxalic acid by the microorganisms leads to solublisation of feldspar and illite to release potassium (Sheng,2006) . Another report showed that potassium was soluiblized by production of inorganic and organic acids and due to production of mucilaginous capsules containing of exopolysaccharides by *Bacillus, Clostridium* and *Thiobacillus* (Groudev, 1987). The weathering ability of the bacteria involves production of protons, organic acids, siderophores and organic ligands. This was seen in *Cladosporoides*, *Cladosporium* and *Pencillium* Sp. These fungal species isolated have the capacity to produce large amounts of oxalic, citric and gluconic acids in broth culture that leads to deterioration of clay silicates, mica and feldspar. It was concluded that filamentous fungi able to cause an extensive weathering of stone due to organic acid excretion. The production of gluconate promotes dissolution of silicates like albite, quartz and koalinite by subsurface bacteria (Argelis, 1993). In an another study the production of organic acids, growth period and K released in wild-type strain of *B. edaphicus* and its mutants was assayed .It was found oxalic acid production caused dissolution of fledspar while oxalic and tartric acid were involved in mobilizing illite (Hu,2006).

Screening of potassium solublising microorganisms

Potassium solubilizing microorganisms can be isolated by serial dilution method using Aleksandrov medium constituting 1% glucose, 0.05% $MgSO_4.7H_2O$, 0.0005% $FeCl_3$, 0.01% $CaCO_3$, 0.2% $CaPO_4$ and 0.5% potassium aluminium silicate (usually mica) , as a source of insoluble form of potassium, agar 3 % , pH-6.5 .The plates should be incubated at 28±2°C for 3 days and the colonies exhibiting clear zones should be selected and diameter of solubilization zone can be calculated using following Khandeparkar's selection (Prajapati,2012):

Ratio = Diameter of zone of clearance / Diameter of growth

Quantitative estimation of potassium relies of flame photometry or atomic absorption spectrophotometer wherein culture broth is centrifuged and supernatant is used for precipitation of cobaltnitrite. Potassium chloride is used as standard for quantification of potassium (Hu, 2006).

Effect of potassium solublising microorganisms on crop production

In the context of unbalanced fertilization, lower potash application results in a significant depletion of soil potash reserves, yield loss and higher economic risk for farmers. Microbial inoculants that are able to dissolve potassium from mineral and rocks have influence on plant growth and have both economic and environmental advantage. The following table summarizes work done on effect of potassium solublisers on the crop production (Table 2). Nitrogen, phosphorus and potassium are the primary nutrients for plant growth and development. Indiscriminate use of synthetic fertilizers for nourishment of plant has caused the contamination of the soil, has polluted water basins, destroyed micro-organisms, making soil less fertile. Application of biofertilizers is an environment friendly approach for supplementation of nutrient to the plants. These bioinocluants include plant growth promoting microorganisms, nitrogen fixers, phosophate mobilizers and solublisers. Like *Azotobacter sp* & *Rhizobium sp*. are well known as nitrogen fixers while *B.megaterium*, *Aspergilus sp.* are the phosphate solublisers, In order to achieve optimum plant growth, Potassium is also required in adequate amount, therefore we need to exploit more and more microorganisms that have ability to solublise potassium as well. Biofertilizer is a good platform to deliver this primary macronutrient by assistance of Potassium Solubilizing microorganisms. Solubilization of this soil mineral, by fungi and bacteria are well established, which reflects their use as competent biofertilizers. Isolation, characterization and development of liquid carriers for these potash solublisers can be the means towards sustainable agriculture development. Apart from the identification of potash solublisers there is strong need for field demonstration studies of these isolates along with standardization of the dose for application for various crops so that the technology can be easily adopted by farmers for multiplication at their own level.

Table 1: Summary of work done on isolation and the occurrence of potassium solublising microorganisms

Refrence	WORK DONE
(Raj ,2004)	Isolated Bacillus sp. as silicate solubilizing bacteria from rice ecosystem in a medium containing 0.25 insoluble magnesium tri silicate .
(Mikhailouskaya, 2005)	Isolated Potassium solubilizing bacteria from the roots of cereal crop by the use of specific potassium bearing minerals.
(Bardar, 2006)	Reported a bacterium capable of dissolving silicate minerals from feldspar samples.
(Hua ,2006)	Reported K solubilizing strains from the soil on Aleksandrov medium and they were found to dissolve mineral potassium effectively.
(Zhou ,2006)	Isolated,characterized and identified as *Bacillus mucilaginosus* which solubilizes silicon from illite at 30°C.
(Sugumaran ,2007)	Isolated Potassium solubilizing bacteria from Orthoclase, muscovite mica. Among the isolates *B.mucilaginosus* solubilized more potassium by producing slime in muscovite mica.
(Prajapati,2012)	Isolated fourteen potassium solublisng microorganisms from ceramic industry soil. Among them The best potassium solubilizing bacterial strain was identified as *Enterobacter hormaeche* from cultural, morphological and 16S rRNA gene sequencing. They have also characterized potassium solublsing fungi as *Aspergillus terreus* and as *Aspergillus niger* on the basis of their colonies and morphology characters.
(Bagyalakshmi, 2012)	Here *in vitro* study was undertaken to assess the potassium solubilization activity by indigenous strains of *Bacillus* sp. *Burkholderia* sp. and *Pseudomonas* sp. at different temperature, carbon sources from tea (*Cam e llia s in e n s is)*. Among the various carbon source like glucose,fructose, sucrose and starch, the best carbon source for solubilization of muriate of potash was found to be glucose at 35ºC temperature.
(Sangeeth ,2012)	Isolated *Paenibacillus glucanolyticus*, a promising potassium solubilizing bacterium from rhizosphere of black pepper (*Piper nigrum L*.)
(Diep, 2013)	Isolated Twenty-five strains on Aleksandrov medium from sample soils/weathered rocks of Ha Tien Mountain, Kien Giang, Vietnam and found Seven strains related with *Bacillus megaterium* and *Bacillus coagulans* closely in phylogenetic tree.
(Gundala, *2013)*	Isolated alkaliphilic Bacillus species from mica mines of Nellore district of Andhra Pradesh, India. The 16S rDNA sequence showed 99% similarity with *Bacillus sp19* and closest relative is *Bacillus amyloliquifaciens.*
(Archana, 2013)	Isolated potassium solubilizing bacteria from rhizosphere soil Of different crops from Dharwad and Belgaum districts. A total of 30 bacteria isolates were tested for K solubilization and characterized upto genus level based on morphological and biochemical characters . Out of them, 26 were gram positive rods belongs to genera *Bacillus* and four were gram negative rods belongs to genera *Pseudomonas*.Three strains of present study *viz.*, KSB 11, KSB 62 and KSB 42 showed high potential among the KSB isolates. The amount of potassium released ranged from 2.41 to 44.49 μg/mL.

Table.2 Summary of work done on the effect of potassium solublising microorganisms on different crops

Reference	Work done	Results
(Han, 2005**)**	Here experiments were conducted to evaluate the potential of phosphate solubilizing bacteria (PSB) *Bacillus megaterium* and potassium solubilizing bacteria (KSB) *Bacillus mucilaginosus* inoculated in nutrient limited soil planted with eggplant.	Results showed that rock P and K materials either applied singly or in combination did not significantly enhance soil availability of P and K. PSB increased higher soil P availability than KSB, which was recommended as a K-solubilizer. Inoculation of these bacteria in conjunction with amendment of its respective rock P or K materials increased the availability of P and K in soil, enhanced N, P and K uptake, and promoted growth of eggplant.
(Han, 2006)	Here the potential of phosphate solubilizing bacteria (PSB) *Bacillus megaterium* var. *phosphaticum* and potassium solubilizing bacteria (KSB) *Bacillus mucilaginosus* inoculated in nutrient inadequate soil planted with pepper and cucumber was evaluated.	Results showed that co-inoculation of PSB and KSB resulted in consistently higher P and K availability than in the control without bacterial inoculum and without rock material fertilizer. Both bacterial strains consistently increased mineral availability, uptake and plant growth of pepper and cucumber, suggesting its potential use as fertilizer
(Basak,2009)	In this study the dynamics of K released from waste mica inoculated with potassium solubilizing microorganism (*Bacillus mucilaginosus)* and its effectiveness as potassic-fertilizer was studied using sudan grass (*Sorghum vulgarePers.) var Sudanensis* as test	Significant correlation between biomass yield, K uptake by sudan grass and different pools of K in soils were observed. X-ray diffraction analysis indicates greater dissolution of mica due to inoculation of *Bacillus mucilaginosus* strain in the soil.
(Sangeeth, 2012)	Bacterium possessing high ability to solubilize potash was isolated from the rhizosphere of black pepper which was identified as *Paenibacillus glucanolyticus strain IISRBK2.* The strain was also evaluated for plant growth and potassium (K) uptake of black pepper in soil artificially treated with 0.5,1 and 1.5g K kg^{-1} soil. In this study, wood ash was used as a source of K which contained 53.1 g Kg^{-1} K	Inoculation with strain *P. glucanolyticus* was found to increase tissue dry mass (ranging from 37.0% to 68.3%) of black pepper in 1g K kg^{-1}wood ash amended soil.In the soil treated with 0.5 -1.5 g K kg^{-1}, K uptake in live bacterium inoculated black pepper plants increased by 125.0-184.0% compared to uninoculated control.in the form of wood ash.
*(*El-Hadad 2011)	In a greenhouse experiment, the nematicidal effect of some bacterial biofertilizers including the nitrogen fixing bacteria (NFB) *Paenibacillus polymyxa,* the phosphate solubilizing bacteria (PSB)*Bacillus megaterium* and the potassium solubilizing bacteria (KSB) *B. circulans* were evaluated individually on tomato plants infested with the root-knot nematode *Meloidogyne incognita* in potted sandy soil. .	The results indicated that these bacterial biofertilizers were helpful in providing soil nutrients (nitrogen, phosphate and potassium) and for the biological control of *M. incognita.*

(Prajapati, 2013)	A potassium-releasing bacterial *Enterobacter hormaechei* and fungal *Aspergillus terreus* strains were examined for plant-growth-promoting effects and nutrient uptake on Okra (*Abelmoscus esculantus*) in K-deficient soil in pot experiments.	Inoculation with bacterial strain *Enterobacter hormaechei* was found to increase root and shoot growth of Okra and both microorganisms were able to mobilize potassium efficiently in plant when feldspar was added to the soil. In okra growing in soils treated with insoluble potassium and inoculated with strain *Enterobacter hormaechei* and fungal *Aspergillus terreus* the potassium content was increased. Among all the three applications of microbial inoculants, combined application of seed and soil was found to be more effective on Okra plant growth.
(Tin, 2013)	In this study Seven strains were collected for phosphate solubilizing and potassium decomposing activities from Microbiology Laboratory, Department of Biotechnology, Shweziwa Biofertilizer Plant. It was found that 'Y' strain gave the highest soluble potassium concentration (8.45 ppm). Phosphate solubilizing and potassium decomposing strains were combined differently for four treatments to study their effects on tomato cultivation. Chemical fertilizer was also applied to compare with selected strains.	Among all treatments, T-4 [which included Compost+Gypsum+Zeolite+'Y' strain] showed better result on total yield.

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