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Potassium Solubilizing Microorganisms: Mechanism and Diversity

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ABSTRACT

Potassium (K) is essential to plant growth and development. It is involved in the adjustment of plant cellular osmotic pressure and the transportation of compounds in plants. It promotes the activation of enzymes, the utilization of nitrogen and the syntheses of sugars and protein. It also boosts plant photosynthesis. 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. Soil potassium supplementation relies heavily on the use of chemical fertilizer, which has a considerable negative impact on the environment. Plants can only take in K through the soil. Injudicious application of chemical fertilizers in India has a considerable negative impact on economy and environmental sustainability. There is a growing need to turn back to nature or sustainable agents that promote evergreen agriculture. Among such natural bio-agents, the potassium solubilizing microorganisms, which solubilize fixed forms of potassium to plant available K by various mechanisms including acidolysis, chelation, exchange reactions, complexlysis, and production of organic acids, are considered one such available alternative. KSM represent an enormous potential to transform the problems associated with the agrarian sector. Potassium solubilizing microorganisms play vital role in making potassium available to plants .they solubilize potassium from insoluble forms like fieldspar, mica by producing organic acids and various enzymes. The article includes the work done on various potassium solubilizing microorganisms, mechanism of K solubilization and its use.

Key words: *Potassium, Solubilization, Micro-Organism, Diversity, Mechanism.*

INTRODUCTION

Potassium is the most abundant cation in plant cells and is the second most abundant nutrient after nitrogen in the leaves[4]. Highest proportions of potassium in soils are in insoluble rocks and minerals such as micas, illite, feldspar and orthoclases.kk24. Moreover, K not only participates in nutrient transportation and uptake, but also confers resistance to abiotic and biotic stresses, leading to enhanced production of quality crops and provides resistance to plant diseases.

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The enzymes responsible for synthesis of starch (starch Synthetase) is activated by k, hence it plays crucial role in water and nutrient transport. Potassium increases shelf life of crops[18]. K can be more easily leached than N or P therefore crop need to be supplied with soluble K fertilization, the demand of which is expected to increase, particularly in developing countries. Recent investigations have shown that organic exudates of some bacteria and plant roots play a key role in releasing k from k bearing minerals).use of efficient K solubilizing bacteria is one possibility for enhancing soil fertility, health and agricultural sustainability. It has been reported that KSB strains were used as efficient indigenous bio inoculants for enhancing to the solubilization of K[16].

The concentration of K in straw and grain serves as an indicator whether the K status of crop is sufficient or deficient. However, K uptake by above ground parts of plants is assimilated mainly into the straw but not into the grain. In addition, release of plant growth regulating substances, production of antibiotics, biodegradation of organic matter, and nutrients cycling in the soil by KSM can also be benefited for crop productivity and ecological sustainability .K is thus more abundant than phosphorus (P) and represents 2.6%of the weight of the Earth's crust[20]. N is only present in trace amounts in magmatic rocks. .It is imperative to utilize renewable input, which can maximize the ecological benefits, minimize the environmental hazards and enhance the agricultural sustainability[15]. The rhizosphere is important ecological environment for soil- plant-microbe interactions. It involves colonization by a variety of indigenous microorganisms in and around the roots which may result in symbiotic, associative, naturalistic or parasitic relations with in the soil-plant microbe's interaction, depending on the type of microorganism, soil nutrients Status, plant defence system and micro environmental condition. Global crop production has Intensive cultivation practices like the use of pesticides and mineral fertilizers have improved crop yields, but also contaminated food and the environment, thus leading to a global food crisis. Efficient KSB secrete organic acids and enzymes that act on insoluble K and convert it in to a mineralized form providing a plant available form of K[14]. The KSB also produce amino acids, vitamins and growth promoting substances. One possible way to mitigate K deficiency is by the use of indigenous efficient potassium solubilizing microorganisms (KSMs) that play key roles in K-solubilization through different mechanisms like acidolysis, chelation, exchange reactions, complexolysis and production of organic acids[3]. These efficient rhizospheric microorganisms are commonly known as K-solubilizers and have the ability to enhance K availability in agricultural soils. K solubilizing activity has been reported in various strains belonging to several genera, such as *Pseudomonas*, *Burkholderia, Acidothiobacillus ferrooxidans*, *Bacillus* and *Paenibacillus spp.* which have been reported to mineralize K inaccessible form from K-bearing minerals in soils[5]. Moreover, KSB are able to mineralized rock K, such as micas, illite and ortho classes (feldspar), also through production and excretion of organic acids or chelate silicon ions to bring the K into solution[25]. Potassium exists in various forms in soil including mineral k, non-exchangeable, exchangeable K and dissolved or solution K (K+ ions)[2]. Plants can only directly take up solution K. The content of potassium in Indian soils varies from less than 0.5% to 3.00%. In Indian soils the soluble K form are present in approximately 2% and insoluble are present in range of 98% in form of minerals like muscovite ,vermiculite, feldspar, mica, biotite[1].

WHY POTASSIC BIO FERTILIZERS

Deficiency of k has become important limiting factors for the development of agriculture. Indiscriminate use of synthetic fertilizers has led to the contamination of soil ,has polluted water basins ,destroyed microorganisms and friendly insects ,reduced soil fertility and making the crop prone to diseases[6] .Use of chemical fertilizers in agriculture causes harmful effect on living beings .The excess use of chemical fertilizers in agriculture are costly and have various adverse effects on soils that is 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[8] .Now certain species of Microorganisms like potassium solubilizing microorganisms (KSM) are widely used as a good substitute of chemical fertilizer. Besides above fact, the long term use of bio fertilizers is eco-friendly, more efficient, productive and accessible to marginal and small farmers over chemical fertilizers[19].

OCCURRENCE OF POTASSIUM SOLUBILIZING MICROORGANISMS

Soil biota Contribute to the soil health and sustainable crop production in a number of ways including nutrient recycling, soil aeration, soil aggregate formation[7]. Critical reviewing of various research papers and books have revealed that soil management practices have also positive effect on soil microbial and faunal activities and increase soil microbial populations, their diversity and functions1[5]. Certain groups of micro-organisms are known to solubilize potassic minerals into soluble form which can be utilized by the plants[13]. A study shows highlighted beneficial functions of soil microorganisms which include release of plant nutrients from insoluble inorganic forms, decomposition of organic residues and release of nutrients, formation of beneficial soil humus by decomposing organic residues and synthesis of new compounds, production of plant growth promoting compounds, improvement of plant nutrition through symbiotic relationships that lead to transformation of atmospheric nitrogen into plant available nitrogen, increasing root surface area for phosphorus absorption, improvement of soil aggregation through production of binding agents such as glomalin (from mycorrhizal fungi) and polysaccharides (from bacteria), improvement of soil aeration and water infiltration, antagonistic actions against insects, plant pathogens and weeds (bio control), help in pesticide degradation and bioremediation. Solubilization of rock potassium by microorganisms was first showed by Muentz[17]. Microorganisms like *Bacillus extroquens, Clostridium pasteurianum, Aspergillus niger* were found to grow on biotite, muscovite, and mica. Different bacterial species were found to dissolve potassium and silicates[22]. The potassium solubilizing fungi (KSF) strains such as For instance, *Aspergillus spp., A. terreus*, *A. niger, Penicillium sp*. enhanced the K-solubilization by mobilizing inorganic and organic K and release of structural K from rocks and minerals. *A. terreus* and *A. niger* which could solubilize insoluble potassium and showed the highest available potassium in liquid medium by using two various insoluble sources of potassium i.e., feldspar and potassium aluminum silicate, based on their colonies and morphology characters. *A. terreus* shows the highest solubilization as well as acid production on both of the insoluble potassium sources[24]. The concentration of trace elements is another relevant factor in the context of rock solubilization by fungi *(A. niger*), also reported by the production of acids. Furthermore, symbiotic nitrogen fixing rhizobia and Pseudomonas, which fix atmospheric nitrogen into ammonia and export the fixed nitrogen to the host plants, have also shown K and P-solubilizing activity[23].

MECHANISM OF POTASSIUM SOLUBILIZATION

Mechanism of K-solubilization could be mainly attributed to excrete organic acids which either directly dissolves rock K or chelate silicon ions to bring K into solution. Many researchers have quantitatively investigated the ability of KSMs to solubilize insoluble potassium in liquid Aleksandrove broth medium[10]. The mechanism of potassium solubilization means by which insoluble potassium and structural unavailable forms of potassium compounds are solubilized due to the production of various type organic acids (table.1a.These acids are accompanied by acidolysis, complexolysis exchange reactions and these are key processes attributed to their conversion in soluble form[19]. The organic and inorganic acids convert insoluble K (muscovite, mica, biotite, feldspar) to the soluble form of K (soil solution form) with the net result increasing the availability of nutrients to plant. Sheng and Huang found that K release from the minerals was effected by P^H, O2 and the bacterial strain used[13]. The efficiency of the k solubilization by different microorganisms was found to vary with the nature of potassium bearing minerals and aerobic conditions. The potassium solubilization by *B. edaphicus* in the liquid medium was found greater and better growth was observed on illite than feldspar[21].

Table 1a. **Microorganisms produce various organic acids which solubilize insoluble potassium to soluble potassium**

Microorganisms: **Bacteria and Fungi**	**Organic acid** **Produced**
1.Aspergillus niger 2.*Pencillium regulosum* 3.*Aspergillus flavus* 4.*Aspergilluscandidus,Aspergillusflavus* *5.Serratia marcescens (CC-BC14)* 6.*Chryseobacterium (CC-BC05)* 7.*Trichoderma sp,A.terreus,A.wenti,* *Pencillium sp,Fusarium oxysporium* 8.*Aspergillus niger,Pencillium sp,* 9.*Pseudomonas Trivalis (BIHB 769)* *10.Aspergillus awamori S19* 11.*Enterobacter sp.FS-11* 12.*Aspergillus niger FSI,* *Pencillium islandicum FS30*	1.Succinic 2.Citric, Gluconic 3.Citric, Oxalic, Gluconic, Succinic 4.Malic, Gluconic, Oxalic 5.Citric, Lactic 6.Citric 7.Lactic, Malic, Acetic, Tartaric, Fumaric, Citric, Gluconic 8.Oxalic,Citric 9.Gluconic, Lactic, Succinic, Formic, Malic 10.Malic, Citric, Fumaric, ,Oxalic 11.Malic, Gluconic 12.Citric, Gluconic, Oxalic

K SOLUBILIZING MICROORGANISMS

A diverse group of soil microorganisms was reported to be involved in the solubilization of insoluble and fixed forms of K in to available forms of K which is taken up by plants[12]. The first evidence of microbial involvement in solubilization of rock potassium had shown by Muentz[17]. A number of microorganisms namely *Bacillus mucilaginosus ,Bacillus circulans, Bacillus edaphicus ,Acidothiobacillus ferrooxidans, pseudomonas ,Burkholderia* have been report to release potassium in accessible form from k bearing minerals in soil. A variety of soil microorganisms have been found to solubilize silicate minerals. *Arthrobacter sp*., *Enterobacter hormaechei* (KSB-8), *Paenibacillus mucilaginosus*, *P. frequentans*, *Cladosporium*, *Aminobacter*, *Sphingomonas*, *Burkholderia*, *Paenibacillus glucanolyticus*. The potassium solubilizing fungi (KSF) strains such as *Aspergillus terreus* and *Aspergillus niger* were isolated from various K rich soil samples and observed increase soil fertility[26].

ROLE OF K BIOFERTILIZERS

Chemical fertilizer has a considerable negative impact on the environment. Potassium solubilizing bacteria could serve as inoculants. They convert insoluble potassium in the soil into a soluble 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. 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[7]. 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 rich source of potassium containing secondary mineral but it is not available to plant this can make available to plant using potassium solubilizing bacteria[6]. 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[14].

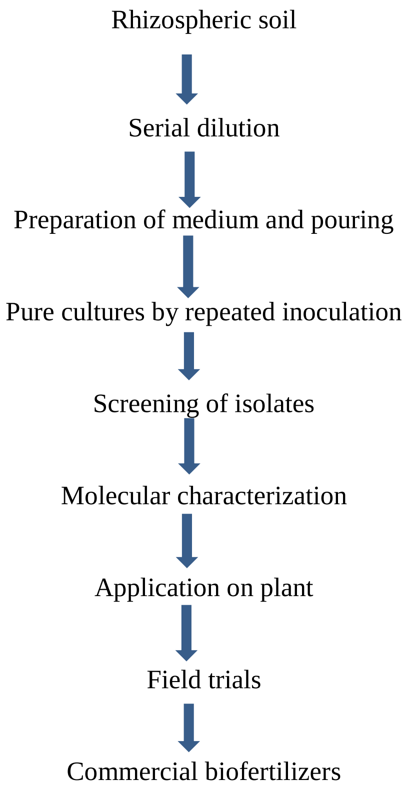
SCREENING OF KSM

Potassium solubilizing microorganisms can be isolated by serial dilution method (Flow chart 1a) using Aleksandrov medium containing glucose, magnesium sulphate heptahydrate ($MgSO_4.7H_2O$), Ferric chloride ($FeCl_3$), calcium carbonate ($CaCO_3$), calcium phosphate ($CaPO_4$) and mica powder as a source of insoluble K, agar as solidifying agent, P^H 7.00 -7.5. The plates should be incubated at 30^{o}C for 48 hours and the colonies exhibiting zone of clearance should be selected and diameter of solubilization can be calculated using following Khandeparkar's selection.

Ratio = Diameter of Zone of clearance /Diameter of growth

Quantitative estimation of potassium relies of flame photometry, where in culture broth is centrifuged and supernatant is used for precipitation of cobalt nitrite. Potassium chloride is used as standard for quantification of potassium.

Fig 1a .Flow Chart Showing Isolation of potassium solubilizing bacteria from soil sample:



EFFECT OF KSM ON PLANT GROWTH AND YIELD

The inoculation of KSM to seeds and seedlings generally showed significant enhancement of germination, plant growth and yield and K uptake by plants under glass house and field conditions in yield of maize[2]. The integration of P and K rocks with inoculation of P and K solubilizing bacteria increased p availability from 12% to 21% and K availability from 13% to 15% respectively[17]. The application of K-solubilizing bacteria as biofertilizers for agriculture improvement can reduce the use of agrochemicals and support eco-friendly crop production[9].

Direct and indirect mechanisms of plant growth promoting properties of potassium solubilizing microorganism and their K-Solubilizing ability on Aleksandrov medium which contain mica powder as source of K.

Direct method for plants growth
Plant growth Hormones: IAA/Ethylene/Abscise acid /Cytokine
Phosphate Solubilization
Potassium Solubilization
Biological nitrogen fixation
INDIRECT METHOD
HCN production
H_2S Production
Starch hydrolysis
Siderophore production
Bio control
Cellulose degradation
Soil health

Fig. 1: PSM. Potassium solubilization on Aleksandrov medium containing mica powder as K source

CONCLUSION

Potassium availability to crop plants in soil is generally low since nearly 90 to 98 per cent of total potassium in the soil is in unavailable mineral forms. Moreover, fixation of added nutrients/fertilizers in soil reduces the efficiency of applied P and K fertilizers and thus, a large quantity of added fertilizers become unavailable to plants. Rhizosphere microorganisms contribute significantly in solubilization of bound form of soil minerals in the soil. These potassium solubilizers are used as biofertilizers for sustainable agriculture.

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