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**THE EFFECT OF POTASSIUM SOLUBILIZING BACTERIA (KSB) AND ITS
MECHANISMS FOR PLANT GROWTH PROMOTION, AND FUTURE PROSPECTS –
A REVIEW**

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ABSTRACT

Soil is an important living matrix and plays an extremely important role to plant life. Soil is the bases of life because it provides the most important nutrients such as C, O and H from the atmosphere and the 13 nutrients like (N, P, K, Ca, Mg, S, Cl, Fe, Mn, Cu, Zn, B and Mo) from soil. The potassium (K) is considered as a key nutrient and a major constituent within all living cells. In order to increase productivity or to kill pathogens, pests and weeds the chemical fertilizers are being used, which have negative impact on environment and ecosystem. Naturally soils contain potassium in larger amount, but most of the potassium is unavailable for plant uptake. It is being noted that potassium solubilizing Bacteria (KSB) can solubilize potassium bearing minerals and changes the insoluble potassium to its soluble form so that potassium is available for the plant uptake. There are various bacteria which have the capacity to solubilize potassium minerals they are *Acidithiobacillus ferrooxidans*, *Paenibacillus spp.*, *Bacillus mucilaginosus*, *B. edaphicus*, and *B. circulans*. KSB can break down silicate minerals and release potassium by the production of organic and inorganic acids, acidolysis, polysaccharides, complexolysis, Chelation and exchange reactions. So, the production and management of biological fertilizers containing KSB can be an effective alternative to chemical fertilizers. Thus, this article presents an overview of current trends and challenges on KSB, mechanisms and their

role in plant growth promotion, and in return it gives some perspectives for research on potassium in sustainable agriculture.

Keywords: Plant growth Promoting Bacteria (PGPRs), Bio – fertilizer, Potassium Bearing minerals, Bio-control, Potassium solubilization, plant and bacteria interactions, sustainable agriculture

I. INTRODUCTION

For the high production of food, the soil condition is very much important as the world population is increasing day by day so to feed them, the agriculture must be intensive and viable in the future. At present agriculture is becoming very difficult as, the agricultural land become nutrient deficient due to repeated agricultural practice. Many agricultural soils lack adequate amount of one or more of essential plant nutrients so that plant growth is substandard. To obviate this problem and obtain higher plant yields, farmers have become increasingly dependent on chemical sources of fertilizers [1]. The chemical fertilizers helped the plant to grow faster, gives its protection from pest, etc. But on the other hand, it also has many harmful impacts on the soil as well as directly or indirectly on the organisms which consume that food product. It is well known that the constant use of chemical fertilizers, mainly phosphorous, nitrogenous, and potassic fertilizers have harmful effects on the environment [2].

After nitrogen (N) and phosphorus (P), potassium (K) is the most important plant nutrient that has a key role in the growth, metabolism and development of plants. In addition to increasing plant resistance to diseases, pests, and abiotic stresses, potassium is required to activate over 80 different enzymes responsible for plant and animal processes. E.g. such as energy metabolism, starch synthesis, nitrate reduction, photosynthesis, and sugar degradation [3-5]. The importance of potassium (K) in Indian agriculture has increased with intensification of agriculture. The gap between removal of K and its application to crop is widening. It is, therefore, imperative to understand dynamics of potassium in soil and then apply K fertilizer, matching with the K-needs of crops, to provide balanced nutrition, harvest good yield and maintain the potassium fertility status of Indian soil.

Potassium, among mineral cations essential for plants, is the biggest in non-hydrated Size (0.1333 nm) with a large number (8 or 12) of

oxygen atoms surrounding it in mineral structure, which suggests that the strengths or K-O bond is relatively weak. Potassium has polarity equal to 0.088 nm', which is higher and that of Ca^{2+} , Mg^{2+} , Li^+ and Na^+ , but lower than that of Ba^{2+} , Cs^+ , NH^+ and Rb^+ ions. Ions higher polarizability is preferred in ion exchange reactions. Potassium has hydration energy of 142.5 kJ g' ion', which indicates little ability to cause swelling [6].

II. ROLE OF POTASSIUM IN PLANT NUTRITION

Potassium is essential nutrient element required by all living organisms, including plants and animals. It is found in large concentration in the plant cell sap. Potassium is not incorporated into the structure of organic compound but remains in ionic (K^+) form in solution in the cell and is mobile in plant. Potassium is required for the activation of over 80 enzymes. It plays vital role: (1) Water relation (osmotic regulation, control of ionic balance, etc.), (2) Energy relations, (3) Translocation of assimilates, (4) Photosynthesis, (5) Protein and starch synthesis, (6) Metabolic processes and grain/seed formation, (7) Improving quality of flowers, fruits, vegetables and other field crops in terms of size, shape, color, taste, shelf-life, and fiber quality, etc., (8) Preventing lodging in crop, (9) Imparting

resistance against environmental stresses such as drought, cold and frost, and (10) Improving resistance to pest and diseases. K solution is the form of K that is directly taken up by the plant and microbe in soil. It is observed that concentration of soil solution K varies from 2 to 5 mg/L for normal agriculture soils. As a result, the deficiency of K has been reported in most of the crop plants. It is also known that the cost of K fertilizer is increasing, and it also has negative impact on the ecosystem.

It has been proven that microbial soil community is able to influence soil fertility through soil processes viz. decomposition, mineralization, and storage / release of nutrients [8]. It has been reported that some beneficial soil microorganisms, such as a wide range of saprophytic bacteria, fungal strains and actinomycetes, could solubilize the insoluble K from soils by various mechanisms. K solubilizing bacteria have attracted the attention of agriculturists as soil inoculums to promote the plant growth and yield. It has been reported that inoculation with KSB produced beneficial effect on growth of different plants [9]. The above studies show that KSB can provide an alternative technology to make K available for uptake by plants. Thus, identification of efficient bacterial strains capable of

solubilizing K minerals can quickly conserve our existing resources and avoid environmental pollution hazards caused by heavy application of K-fertilizers.

III. THE MECHANISMS OF POTASSIUM SOLUBILIZING BACTERIA IN SOLUBILIZING K

There is not enough information available on the mechanisms which by KSB can solubilize K-bearing minerals and release K for improving the growth and yield of plant. It is being observed that microorganisms contribute to the release of K^+ from K bearing minerals by several mechanisms and released H^+ can directly dissolve the mineral K. And as a result of slow releases of exchangeable K take place. If we observe the P solubilization, the major mechanism of K mineral solubilization is by production the organic and inorganic acids and production of protons (acidolysis mechanism) [8, 10-15], which are able to convert the insoluble K (mica, muscovite, and biotite feldspar) to soluble forms of K, easily taking up by the plant [11, 16]. It is being observed that different organic acids such as oxalic acid, tartaric acids, gluconic acid, 2-ketogluconic acid, citric acid, malic acid, succinic acid, lactic acid, propionic acid, glycolic acid, malonic acid, fumaric acid, etc. have been reported in KSB, which are effective in

releasing K from K-bearing minerals [16-23]. It has also been known that the type of the organic acid produced by KSB may be different. The prominent acids released by KSB includes tartaric acid, citric acid, succinic acid, α -ketogluconic acid, and oxalic acid [11]. There is decreasing soil pH, organic acids produced by KSB can release of K ions from the mineral K by chelating (complex formation) Si^{4+} , Al^{3+} , Fe^{2+} , and Ca^{2+} ions associated with K minerals [11, 24, 25]. The KSB weathered phlogopite via aluminum chelation and acidic dissolution of the crystal network [15]. The *B. altitudinis* strain dissolved potash feldspar and significantly released more Si, Al, and Fe elements by producing organic acids [26]. Microorganisms including KSB can have a considerable role in proving K to plant by storing K in their biomass (a significant quantity of fixed K), which is potentially available to plants [27]. It has been reported that the production of various extracellular polymers (primarily proteins and polysaccharides) can also be led to release of potassium from potassium bearing minerals for plant uptake [17, 23, 28]. These substances serve as attachment structures to mineral or rock surface. KSB also synthesize biofilms, which create controllable microenvironments around microbial cells

for weathering [11]. It has been found that the microbial biofilms not only accelerated the weathering process but also regulated denudation losses by acting as a protective layer covering the mineral-water-hyphal/root hair interface in the mycorrhizosphere and Rhizosphere of vascular plants. Other than that, biofilm formation on mineral surface promoted the corrosion of potassium-rich shale and the release of K, Si and Al in the bacteria-mineral contact model. And also, it is known that the release of organic acids

from the plant roots can be effective in enhancing mobilization of potassium [29]. Therefore, it can be suggested that other PGPRs (e.g., IAA-producing bacteria) can also have a role in providing potassium for plant by increasing root exudates (Figure 2) [30]. In general, the most important mechanisms known in K mineral solubilization by KSB are “(i) by lowering the pH; (ii) by enhancing chelation of the cations bound to K; and (iii) acidolysis of the surrounding area of microorganism [11]”.

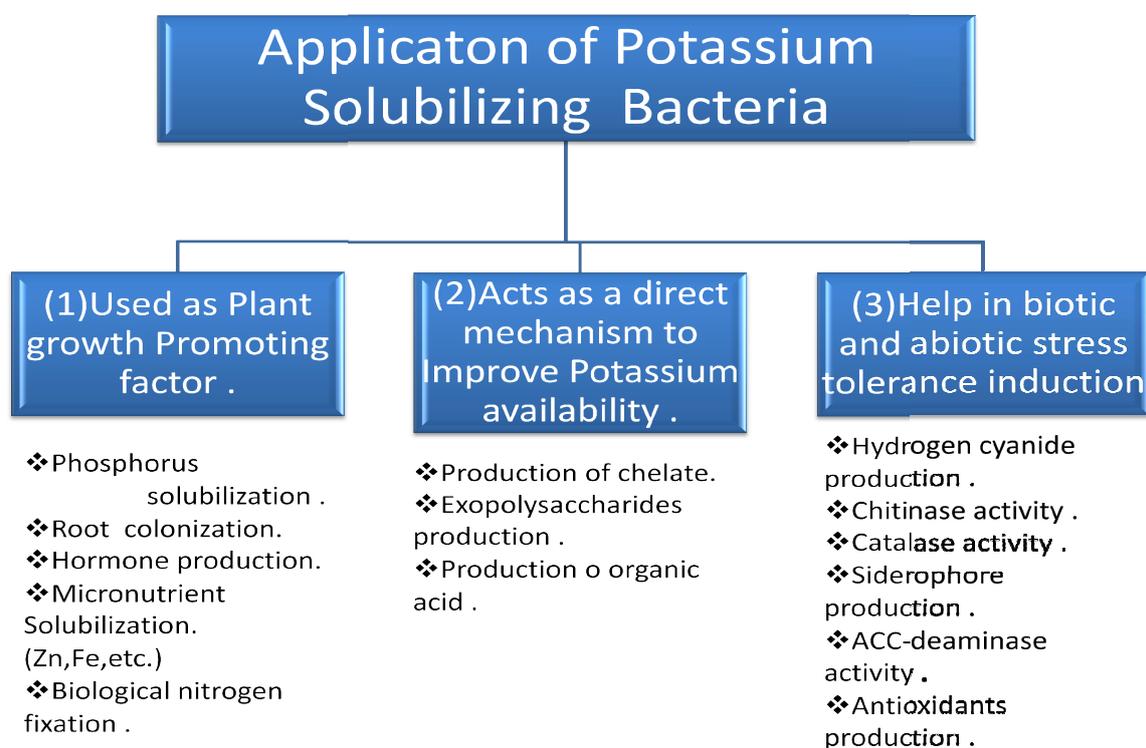


Figure 1: Application of Potassium Solubilizing Bacteria

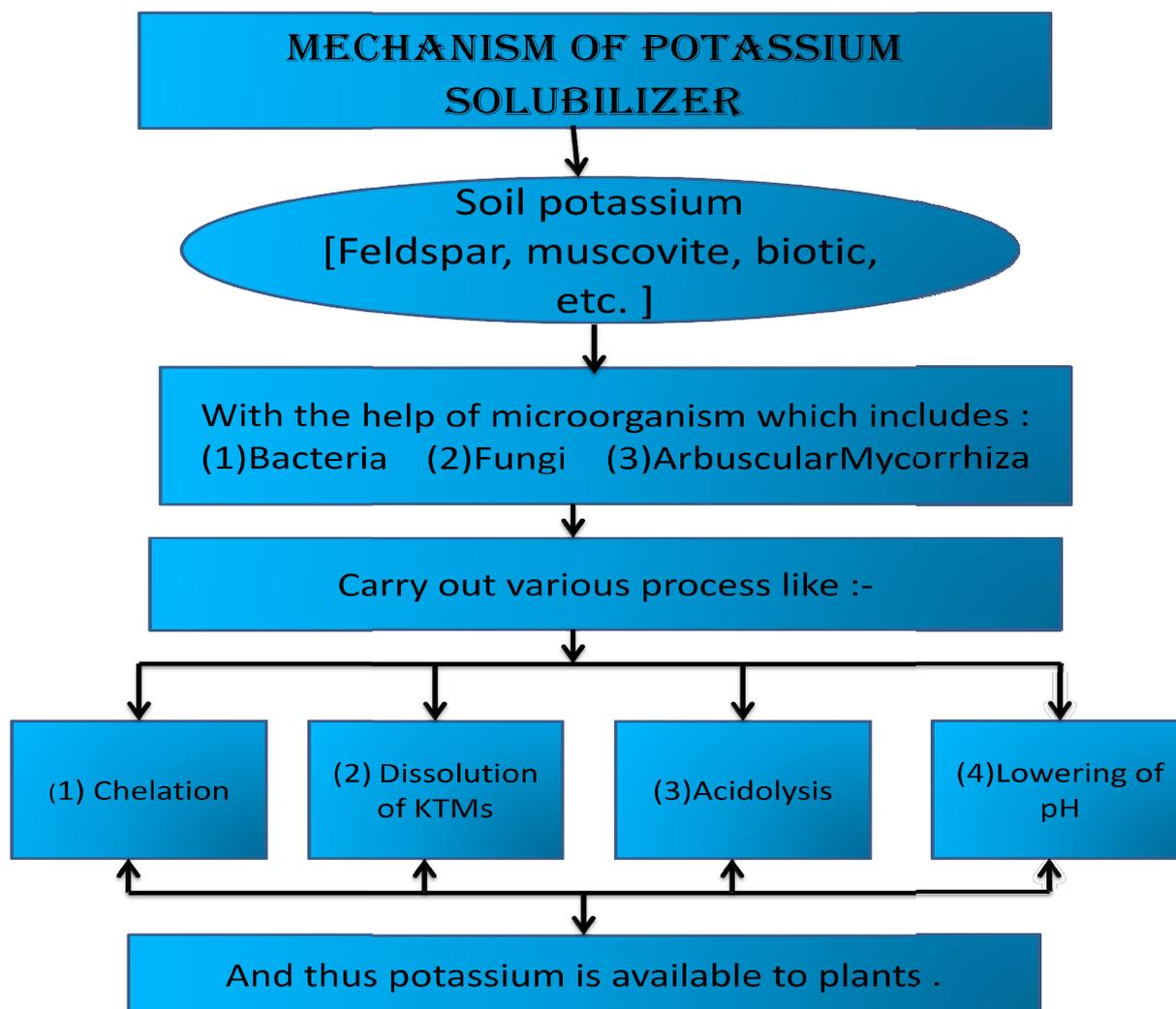


Figure 2: Microbial Mechanism of Potassium Solubilization

IV. DEFICIENCY SYMPTOMS OF POTASSIUM MINERAL ON PLANTS

Potassium deficiency does not manifest immediately in the form of visible symptoms. At first, the growth rate decreases and deficiency symptoms appear at later stages. Under restricted K supply, potassium deficiency symptoms generally appear on older leaves turn yellow (chlorosis) and then die (necrosis), giving a burning look on

edges. In several important forage and cover-crop legume species, potassium deficiency produces small white necrotic spots that form a unique pattern along the leaflet margins; this easily recognized symptom is often mistake for insect damage or disease infection. Potassium deficiency leads to (1) slow and stunted growth, (2) weak stalks and susceptibility to lodging, pests, diseases,

frost, etc., (3) low yield and (4) poor quality of produce [31-36].

Seeds from potassium-deficiency plants are small, shriveled, and are more susceptible to diseases. Fruits are lacking in normal coloration and are low in sugar content. Vegetables and fruits have a short shelf-life and deteriorate rapidly when shipped [35-39].

Factors Affecting Availability of Potassium

1. Soil Texture

It influences the status of both available and non-exchangeable potassium. Fine textured soils generally possess larger amount of both forms of potassium compared to coarse – texture soils. The effect of texture on potassium status is more conspicuous in alluvial than in black or red soils because of the presence of K – bearing minerals in them [40].

2. Clay Mineralogy

Potassium availability to plants is a function of quantitative mineralogical make-up, degree of weathering and nature of complementary cations on the exchange complex. The available potassium is generally high in smectite- dominant vertisols, followed by mixed mineralogy, elite and kaolinite dominant soils [41].

3. Soil Depth

Indian soils depict characteristic differences in their potassium content with depth. Calcareous alluvial soils show a decrease in both the available and non- exchangeable forms with depth [38].

4. Soil pH (reaction)

Soil pH plays a significant role in the availability of potassium in soil. In acid soils, hydrogen – aluminum ions compete with potassium ions for the exchange or absorption sites and are able to keep more potassium ions in the solution phase and reduce their susceptibility to fixation [42].

V. CONCLUSIONS AND FUTURE PERSPECTIVES:

K-bearing minerals have important position in the Earth's crust which can give potassium fertilization for crop plants. Here the plants can only take up potassium from the soil solution. Following this uptake, K can be released into soil solution from insoluble minerals but it is generally small in comparison to the plant requirement, because the concentration of soluble K in the soil solution is very low, and K is relatively immobile in the soil. Therefore, in order to fulfill the requirements of potassium fertilizers should be applied, which are a contemporary practice to supply available K in extensive agricultural systems .But the

potassium fertilizers are expensive and its long-term use results in the increase of the cost of inputs, the decrease of the agricultural profitability, and a large number of environmental problems due to having heavy metals accumulating in soil and plant system. And by doing so toxic chemicals get accumulated in the fruits and vegetables, and finally reaches human body and causes harmful effect. It is well known that the application of Potassium solubilizing bacteria can be a promising technique to solubilize. The Potassium reserves from soil and make it available to the plants, resulting in promotion of plant growth and minimizing the application of Potassium fertilizers. K solubilization is carried out by various bacteria such as *B. mucilaginosus*, *B. edaphicus*, *B. circulans*, *Pseudomonas*, *Burkholderia*, *Acidithiobacillus ferrooxidans*, and *Paenibacillus spp.* Previous researches well showed that KSB were able to dissolve potassium from different insoluble K bearing minerals by excreting organic acids. Among action mechanisms of KSB in making potassium available to plant, production of organic acids is major mechanism, which can either directly increase dissolution either by a proton- or ligand-mediated mechanism or they can also indirectly increase dissolution by the formation of complexes in solution

with reaction products. Therefore, application of KSB as biofertilizer not only enhance plant growth and yield but also can lessen the use of agrochemicals and support eco-friendly crop production. These technologies are becoming vital in modern day agricultural practices. The changing scenario of agricultural practices and environmental hazards associated with chemical fertilizers demands more significant role of biofertilizers in coming years.

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