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Use of potassium bio-fertilizers technology for sustainable agriculture in dry areas

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Abstract
Potassium (K) is a third essential macronutrient after nitrogen and phosphorous for the growth and metabolism of plant and its deficiency in plant cause poorly developed roots, slow growth, low resistance to disease, delayed maturity, small seed production and lower yields. Naturally, K is present in higher amounts in soil as compare to other nutrients; however most of the K is unavailable for plant uptake. Application of chemical fertilizers has a considerably negative impact on environmental sustainability. It is known that potassium solubilizing bacteria (KSB) can solubilize K-bearing minerals and convert the insoluble K to soluble forms of K available to plant uptake. Many bacteria such as *Acidothiobacillus ferrooxidans, Paenibacillus* spp., *Bacillus mucilaginosus*, *B. edaphicus*, and *B. circulans* have capacity to solubilize K minerals (e.g., biotite, feldspar, illite, muscovite, orthoclase, and mica). PSM provides an ecofriendly and economically sound approach to overcome the P scarcity and its subsequent uptake by plants through PSMs have been a subject of research for decades, manipulation of PSMs for making use of increasing fixed P in the soil and improving crop production at the field level has not yet been adequately commercialized. The purpose of this review is to widen the understanding of the role of PSMs in crop production as biofertilizers.

Keywords: Bio-fertilizer, potassium solubilizing bacteria, K bearing minerals, potassium solubilization plant and bacteria interactions

Introduction
Potassium (K) is one of the major macronutrients which play a vital role in plant growth and development. After nitrogen and phosphorus (P), Potassium is the important plant nutrient in addition to increasing plant resistance to diseases, pests, and abiotic stresses; for plant and animal processes K is required to activate over 80 different enzyme (Gallegos-Cedillo *et al.*, 2016; Hussain *et al.*, 2016) [2, 3]. E.g. such as energy metabolism, starch synthesis, nitrate reduction, photosynthesis, and sugar degradation nutrient which play vital role in enzyme activation, protein and photosynthesis. In the soil K is present in various forms, including mineral K, non-exchangeable K, exchangeable K, and solution K (Rawat *et al.*, 2017) [6]. In earth crust the K reservoir is associated with primary alumina silicates that are the most abundant K-bearing minerals such as K feldspar, biotite, muscovite, mica and nepheline. The secondary alumina silicates, however, comprise hydrous mica (illite) as well as a continuum of micaceous weathered or inherited products, *viz.* mixed-layer phyllosilicates. In Indian soils potassium content ranges varies from less than 0.5 % to 3.00 %. Micas are a major source of K which is important for plant nutrition, whereas the K in biotite acts as a good fertilizer for plants. The situation of K fertilizer in India, China and Africa are worst due to no reserve of K-bearing minerals is suitable for manufacturing of conventional K fertilizers, therefore the whole consumption of K fertilizers is imported. Thus, there is a need to find an alternative indigenous source of K and maintain K level in soils for sustainable crop production. 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. Some of these mechanisms include the production of inorganic and organic acids, acidolysis, polysaccharides, complexolysis, chelation, polysaccharides, and exchange reactions. Among these microorganisms, K solubilizing bacteria (KSB) have attracted the attention of agriculturists as soil inoculum to promote the plant growth and yield (Kalayu, 2019) [4]. It has been reported that inoculation with KSB produced beneficial effect on growth of different plants. The researcher 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.

Potassium Solubilizing Bacteria (KSB)

Phosphate solubilizing microorganisms (PSMs) are group of beneficial microorganisms capable of hydrolyzing organic and inorganic phosphorus compounds from insoluble compounds. KSB is a heterotropic bacterium which is obtaining their all energy and cellular carbon from pre-existing organic material. In addition, this gram positive aerobic bacterium can produce number of substances that stimulate plant growth or inhibit root pathogens (Kalayu, 2019) [4]. The most important KSB used as K biofertilizers are *Bacillus mucilaginosus, Bacillus edaphicus and Bacillus circulans*. Naturally, KSB were found to grow on muscovite, biotite, orthoclase and micas *in vitro* (Meena *et al.*, 2016) [5]. Various types of culturing media used for potassium solubilizing bacteria such as sucrose- minimal salt medium and Luria-Bertani broth, while the most popular medium used for culturing KSB is Aleksandrov medium. Medium constitutes of Aleksandrov are 0.5% glucose,, 0.05%MgSO4, 7H2O,0.0005% FeCl3, 0.01% CaCO3,0.2% calcium phosphate and 0.2% potassium aluminium silicate. In china aluminium silicate is used for white mica for isolation and screening of silicate dissolving bacteria.

Table 1: List of potassium solubilizing micro-organisms

	PSM
Bacteria	*Alcaligenes* sp., *Aerobactor aerogenes*, *Achromobacter* sp., *Actinomadura oligospora*, *Agrobacterium* sp., *Azospirillum brasilense*, *Bacillus* sp., *Bacillus circulans*, *B.cereus*, *B.fusiformis*, *B. pumils*, *B.* megaterium, *B. mycoides*, *B. polymyxa*, *B. coagulans*, *B.chitinolyticus*, *B. subtilis*, *Bradyrhizobium* sp., *Brevibacterium* sp., *Citrobacter* sp., *Pseudomonas* sp., *P putida*, *P. striata*, *P. fluorescens*, *P. calcis*, *Flavobacterium* sp., *Nitrosomonas* sp., *Erwinia* sp., *Micrococcus* sp., *Escherichia intermedia*, *Enterobacter asburiae*, *Serratia phosphoticum*, *Nitrobacter* sp., *Thiobacillus ferroxidans*, *T. thioxidans*, *Rhizobium meliloti*, *Xanthomonas* sp

Mechanisms for K Solubilization

Low molecular acid produced by microorganisms which is responsible for Solubilization of K mineral. The protons associated with organic acid molecules decrease the pH of the solution and, therefore, induce the releasing capacity of cations such as iron, K and magnesium. Through research experiments it was reported that microbes accelerated the weathering reactions of K minerals, especially when in direct contact with mineral surfaces either by (i) organic acids production, (ii) metal-complexing ligands production,(ii)Biofilms formation and (iv) synergistic effect of microbes and root activities. Application of K solubilizing microorganisms *Bacillus mucilaginosus* and *Bacillus edaphicus* accelerate the dissolution of silicates by the production of carboxylic acids, capsular polysaccharide or extracellular polysaccharides and enzymes. K mobilization is another important mechanism for the production of metal – complexing ligands by potassium mobilizing microbes (Etesami, 2017) [1]. During metabolism microbes have ability to enhance mineral dissolution rate by producing and excreting various organic ligands. Biofilm known as heterogeneous matrices of microorganisms held together and tightly bound to underlying surfaces by extracellular polymeric substances. For mineral weathering bacteria extract inorganic nutrients and energy directly from the mineral matrix in this micro- environment (biofilm).Thus, biofilms is known to help in mobilization of K from K-minerals.

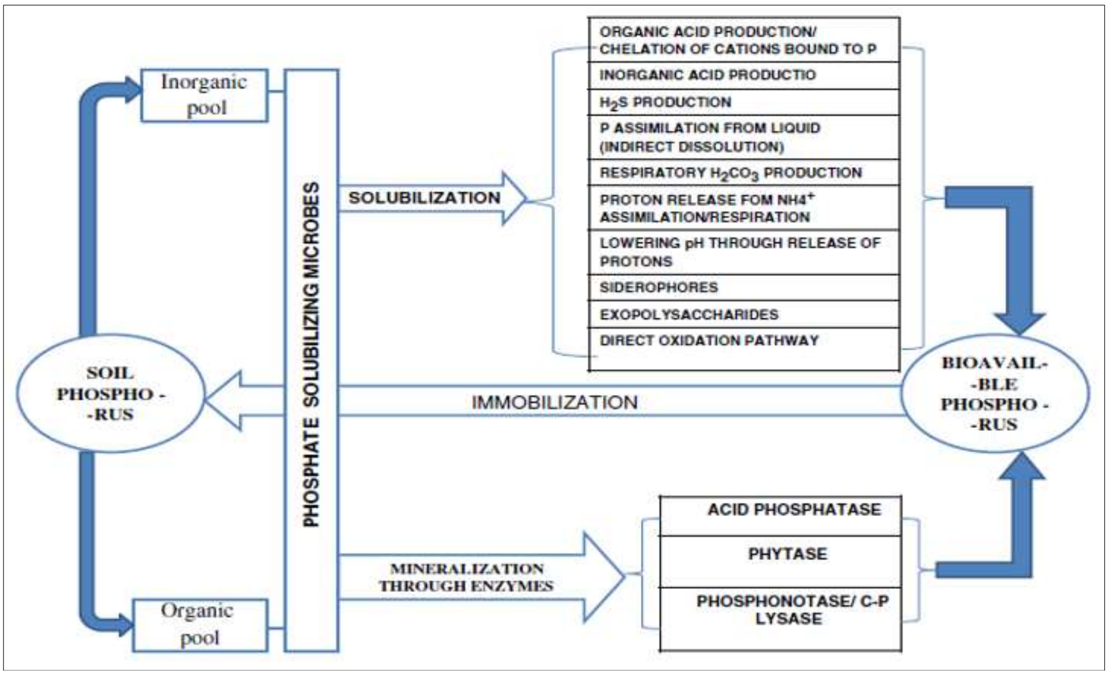

Fig 1: Schematic representation of mechanism of soil P solubilization/mineralization and immobilization by PSM

Effect of KSB on plant growth and yield

With the introduction of high yielding crop varieties and the progressive intensification of agriculture, the soils are getting exhausted in K stock at a faster rate. Inoculation of seeds and seedlings of different plants with KSB generally showed significant enhancement of germination percentage, seedling vigor, plant growth, yield, and K uptake by plants under greenhouse and field conditions (Xiao *et al.*, 2017) [9]. Some of the recent findings indicate treatment of soil as well as potassium bearing minerals with KSB inoculation significantly increases soil fertility as well as plant growth. Therefore, some of the crops like wheat, sorghum, cotton, rapeseed, tomato and eggplant have been inoculated with KSB bio-fertilizers and found successful in improving soil fertility, plant growth and crop yield under field condition (Table 2).

Table 2: KSB and their effect on soil fertility, plant growth and crop yield

KSB	Parameters
Bacillus edaphicus NBT	Dry matter yield and K content increased in Cotton and Rapeseed
Co-inoculation of *Bacillus mucilaginsus* (KSB) and *Bacillus megatherium* (PSB) *Bacillus cereus*	Increased K status in soil. Enhanced growth and NPK uptake of eggplant K status of soil improved. Yield and K uptake increased in sorghum and
Bacillus edaphicus wild strain(MPs series)	tomato Growth and K content increased in wheat
Co-inoculation of *Bacillus mucilaginsus* (KSB) and *Bacillus megatherium* var phosphaticum (PSB)	Increased availability of K in soil and K uptake by Pepper and Cucumber Improved K status and yield and K content increased in groundnut and
Bacillus mucilaginsus	Sudan grass
Local rhizobacterial strain (K-31, K-81) Co-inoculation of *Bacillus mucilaginsus* (KSB) and *Azotobacter chroococcum* (N-fixer)	Wheat yield and K status of soil improved Yield and K uptake in Sudan grass increased

Role of KSB as Bio- fertilizers in Sustainable Agriculture

In sustainable agriculture potassium is well known for improving shelf life of crops and disease resistance. To increase crop yield as proper amount of potassium in soil can enhance root growth, improve drought resistance, activate many enzyme systems, maintain turgor pressure, reduce water loss and wilting, aid in photosynthesis and food formation, reduce respiration, prevent energy losses, enhance translocation of sugars and starch, produce grain rich in starch, increase protein content of plants, reduce waterlogging and retard crop diseases can be achieved by the use of some amount of potassium in agriculture land (Rawat, 2017) [6]. Therefore, it is essential for the growth and metabolism of plants; the deficiency of potassium in plants causes poorly developed roots, slow growth and low resistance to disease, delayed maturity, small seeds and lower yields.

Nowadays, in sustainable farming biofertilizer is a substitute to chemical fertilizer to increase soil fertility and crop production. Researchers suggested a possible solution to improve plant nutrient and production by the use of plant growth-promoting microorganisms which includes phosphate-solubilizing and potassium-mobilizing bacteria as biofertilizers (Vessey, 2003) [8]. Beneficial microorganisms in the form of biofertilizers are applied on seeds/roots or in soil which mobilizes the availability of nutrients, especially N-P-K by their biological activity, thereby helping in the build-up of positive microflora and enhancing the soil health. To improve the physical properties and water-holding capacity of soil can be enhance by using bioinoculants. Moreover, microorganisms that are applied as biofertilizer can prevent nutrient leaching and lead to soil enrichment with nutrients. As compared to chemical fertilizers, biofertilizes are low in cost, compatible with long-term sustainability, and eco-friendly. Besides, the nutrient supply is constant and sustainable through these microorganisms' activities. In recent years biofertilizer has gained momentum since chemical fertilizers are very expensive and can cause hazardous effect, unfortunately the manufacturing of K biofertilizers not getting as much attention.

Conclusion

Application of Potassium solubilizing bacteria is to improve the soil fertility, crops growth, crops yield and quality by converting the insoluble form of K into soluble form. The K is the third essential nutrient component after nitrogen and phosphorous. Researcher's study that microbial soil community is able to influence soil fertility through soil processes *viz*. decomposition, mineralization, and storage / release of nutrients. For increasing bioavailability of K in soil *Bacillus, Pseudomonas, Rhizobium, Aspergillus, Penicillium*, and AMR are the most efficient P solubilizers. In sustainable agriculture chemical fertilizers replace by biofertilizer in a great amount but the present problem is that no one gives much more attention to potassium biofertilizer manufacturing.

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