Editorial

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Potassium-Solubilizing Microorganisms for Agricultural Sustainability

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Potassium is the third most significant nutrient required for growth and development by the plants. Plant absorbs the K mineral in the form of K^+ i.e. soluble and available form of potassium for plant from the soil. The concentration of K^+ ion is low because of over exploitation and to accomplish the K necessity of the plant, agrochemical fertilizer named as potash was discovered. The use of potash has reduced the K scarcity in the plants but arose pollution and depletes the fertility of the soil. Potassium solubilizing microbes have been found as an appropriate alternative of potash. The K-solubilizing microbes avail the K by solubilizing and mineralizing the mechanism through the production various organic acids and extracellular enzyme. Different microbes belonging to genera *Agrobacterium*, *Bacillus*, *Burkholderia*, *Microbacterium*, *Myroides* and *Pseudomonas*, *Pantoea* have been reported as K solubilizer.

Potassium plays a substantial role in both plants and humans life. In plant K helps in activating various enzymes involved in protein synthesis, solute transport and energy metabolism (Figure 1). Potassium also needed for inorganic anions transportation and the maintenance voltage gradient in transmembrane for cytoplasmic pH homeostasis [1]. This element is involved stomatal movement, photosynthesis, phloem loading, transport and uptake. Potassium also plays an imperative role in the alleviation the abiotic/biotic stress in plants [2]. On the other hand in humans K mineral helps in the secretion of hormones, controls in the electrical activity in the heart, renal concentrating, mineral-corticoid action, growth and development of body, metabolism of proteins and carbohydrates [3]. The K deficiency result in several problems such as less yield and shortening of internodes, reduction of photosynthesis, blackening of tubers like potato, and small grains scorching [4]. In the case of human, low level of potassium may causes weakness, muscle cramps, confusion, constipation, abnormal heart rhythm, tingling or numbness, increased urination, decreased brain function, high blood sugar levels, and muscle paralysis, hypokalemia [5].

Plants uptake K in the form of exchangeable K but the amount of this form is low in the soil. To fulfil the potassium requirement of the plants, chemical fertilizers (potash) were being used. The usage of potash fertilizers have resulted in soil precipitation. So, researchers are focusing their efforts on developing alternatives and environmentally friendly approaches to tackle the glitche of K availability. The use of K-solubilizing microbes as plant probiotics is a sustainable and alternative way to achieve a positive impact on crop quality, growth and yield, and help in reduces the fertilizer input. Several K-solubilizing microorganisms have been reported such as *Bacillus*, *Agrobacterium*, *Burkholderia*, *Enterobacter*, *Microbacterium foliorum*, *Myroides*, *Pseudomonas*, and *Pantoea* [6, 7].

In soil, 0.04-3% of potassium is present and it occurs in three various forms namely, exchangeable K, unavailable and fixed K. Unavailable K (feldspars, biotite, muscovite, illite, orthoclase, micas vermiculite, and smectite) accounts 90–98 % of total K present in soil and it is main source of insoluble K, whereas fixed K is 1–10 % in soil. The slowly available i.e. fixed K exists between the layers of the clay minerals [8].

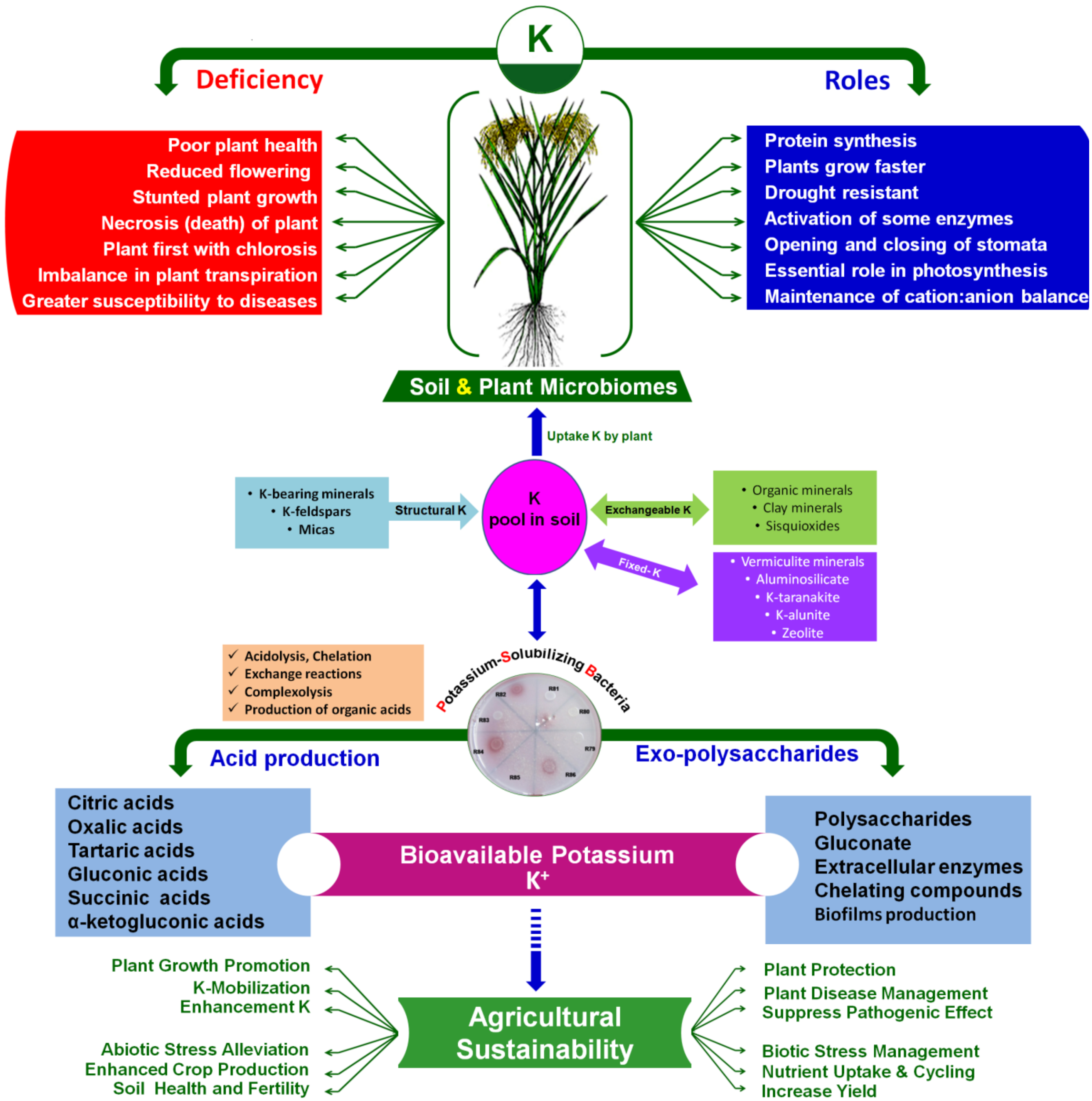

Figure 1: Schematic presentation of potassium solubilization by potassium-solubilizing microorganisms and their role for agricultural sustainability.

The exchangeable form of K is present around 1-2% and it is mixed with the soil water [9]. The form slowly available and exchangeable K comes from the primary minerals i.e. unavailable K through the weathering process. The K mineral in soil also comes from the plants (leaching) and animals (urine). Diverse groups of microbes from different environment have been stated to play a major role in solubilization of the potassium and increase its availability to the plants. KSMs could be considered as the treasury bioresources involved in releasing K in soluble form for plants. Capsule absorption, acidolysis, enzymolysis and complexation through extracellular polysaccharides (EPS) have been known to be the major processes in enhancing the solubility of K minerals [10]. The microbial communities exhibiting K solubilizing ability produce citric, gluconic acid, oxalic, and tartaric acids, low molecular weight organic acids which release protons for the insoluble K displacement from K minerals. The produced organic acids could also speed up the K minerals weathering by forming metal–organic complexes in turn destabilizing the lattice structures and releasing K into soil [11].

Potassium solubilizing microorganisms have also been found to dissolute Al, K, and Si from micas, orthoclases and illite by producing the acids in ecosystems and other actions i.e. production of exopolysaccharides, extra-cellular enzymes and formations of biofilms [12]. On reviewing the literature, K release from the illite and feldspar minerals through beneficial soil and plant microbes know as silicate bacteria, a stage model has been suggested and bacteria-mineral complexes development supported by EPS have been proposed [13, 14]. The capsular polysaccharide and carboxylic acids produced by *Bacillus edaphicus* and *Bacillus mucilaginosus* are responsible for solubilization of feldspar [15, 16]. Among different acids produced by KSMs, gluconic acid is the most important and play significatnt role in solubilization of potassium. There are huge numbers of finding on potassium solubilization for agro-environmental sustainability (Figure 2).

Plants are routinely exposed to a variety of abiotic and biotic stress. Abiotic stress including drought, salinity, extremes of temperature and the biotic stress such as the pathogen infection can have a devastating effect on plants and can lead to extensive losses to agricultural production worldwide. Additionally, another important abiotic stress faced by the plants is obtaining the adequate nutrients from soil [17]. Potassium is important macronutrients that provide the stress resistance to the plants1. On the contrary, it has also been evidenced that under the conditions of the water-fed stress growth of root and the K^+ diffusion rates in the soil towards the roots gets restricted thereby limiting the acquisition of K. Thus, the resulting lower K concentrations further lower the tolerance of the plants to the water stress and also the absorption of K. In the presence of the salinity stress, growth of root is impacted by osmotic imbalance and toxic effects of the ions which negatively affects the nutrient uptake and inhibits the mineral nutrients translocation, particularly K^+ ions [18].

Extensive research in developing eco-friendly and sustainable strategies revealed that microbes with plant growth promoting potential are important candidates. The role of beneficial soil and plant microbiomes in promotion of plant growth and in amelioration of stress has been well documented. Soil and plant microbiomes enhance the fitness of plants under abiotic and biotic stress by different mechanisms [19, 20]. The microbial solubilization of K under the stress conditions is one of the mechanisms for increasing the availability of K for the plants. K-solubilizers exhibit multiple mechanisms for increasing the plants tolerance to abiotic and biotic stress such as solubilization of phosphorus and zinc, nitrogen fixation, production of the siderophores, phytohormones, ammonia, HCN and hydrolytic enzymes [21]. K-solubilizers from diverse stressed environments and their role in plant growth enhancement have been under stressed conditions has also been reported. Bhattacharya, Bachani [22] reported halophilic *Acinetobacter soli* with K-solubilizing potential. Drought tolerant KSB including *Acinetobacter calcoaceticus*, *Pseudomonas libanensis*, *Penicillium* sp., and *Streptomyces laurentii* have been reported [23-25]. The study of Jha [26] reported that K solubilizing *Bacillus pumilus* and *Pseudomanas pseudoalcaligenes* accumulated carbohydrates and regulated membrane permeability in paddy under salinity stress.

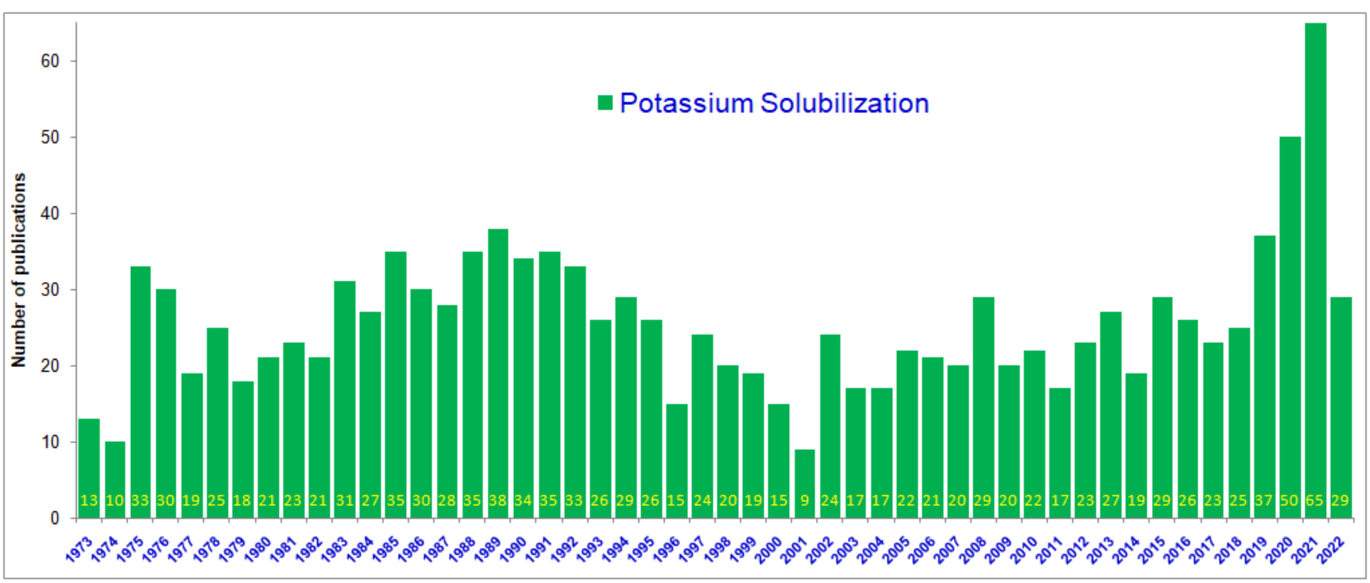

Figure 2 Number of research publications on potassium solubilization [Source-PubMed].

Potassium solubilizing microbes have widely explored and they have been reported for promoting the plant growth [27]. In a report, the co-inoculation of K-solubilizing (*Bacillus mucilaginosus*) and N-fixing (*Azotobacter chroococcum*) bacteria was reported for enhancing the plant growth of sudan grass [28]. In a report, K-solubilizing bacterium, *Klebsiella variicola* was isolated from the rhizosphere of tobacco plant and it was reported for enhancing the nutrient uptake of the tobacco upon inoculation [29]. In another report, *Bacillus amyloliquefaciens* was reported as an efficient K solubilizer and it inoculation on the cold stressed wheat was resulted in the alleviation of cold stress [30]. Kaur et al. [6] reported formulation of *Pseudomonas gessardii* reported improving the growth of barley crop.

In conclusion, the research community is significantly concentrating on more exploitation of potassium solubilizers with multifunctional PGP traits. K- mobilizing and solubilizing microbes could be used as bioinoculants to improve the availability of K and promote the plant growth under the natural as well as stress conditions. KSMs play structural role in plants but also control the metabolic functions of plants. Further understanding and genetics study behind the potassium mobilization and solubilization would also be beneficial for agricultural and environmental sustainability.

CONFLICTS OF INTEREST

Author declares that there are no conflicts of interest.

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