POTASSIUM SOLUBILIZING MICRO ORGANISM (KSM) TECHNOLOGY BOON TO SUSTAINABLE AGRICULTURE

SHRILA DAS[1]
RUMA DAS[2]
SEEMA SANGWAN[3]
RENU SINGH[4]
KAUSTAV ADITYA[5]

[1, 2]Scientist, Division of Soil Science and Agricultural Chemistry,
[3]Scientist, Division of Microbiology,
[4]Senior Scientist, Centre for Environment Science and Climate Resilient Agriculture, ICAR-Indian Agricultural Research Institute, New Delhi-110012,
5Scientist, Division of Sample Survey, ICAR-Indian Agricultural Statistics Research Institute, New Delhi-110012

Over growing population of India pressurize our agricultural system to harvest more crops from shrinking cultivable land. However, balanced nutrition of plants and healthy soil are the need of the hour for increasing crop productivity and sustainability of agricultural system. Potassium (K) is an important macronutrient which not only improve productivity but also quality of various crops. Now a days, majority of Indian soils show a declining trend in the status of soil available K due to various reasons i.e. fixation of soil K, higher K removal by crops, less application of K by farmers due to higher price of K fertilizers, injudicious and imbalanced application of other fertilizers. These altogether lead to a large-scale K mining from soil. Widespread K deficiency has already been identified in different parts of India especially in rice-wheat belt of Indo-Gangetic plains, areas with horticultural, plantation crops, even in ornamental, aromatic and avenue plants too. Deficiency symptom of some crops are given in figure 1. The ill-effect of K deficiency includes declining nutritional quality, instability in mechanical and pathogen resistance of crops etc. Therefore, it is the prime time to follow sustainable technology like use of microbial consortia of potassium-solubilizing microorganisms (KSMs) in soil to maintain balance of K in soil solution. The KSMs are known to solubilize the fixed (reserve) form of K and make it available to the plants for promoting their growth and minimizing the application of K-fertilizers, reducing environmental pollution and promoting sustainable agriculture. The popular KSMs are *Bacillus mucilaginosus, Bacilluse daphicus, Bacillus circulans, Pseudomonas*, *Burkholderia*, *Acidithiobacillus ferrooxidans*, and Penicillium spp. The application of KSMs in soil also leads to enhanced plant nutrition, root growth pattern, plant competitiveness, and boost up resistance towards external stress factors. The beneficial effect of application of KSMs in soil are as follows: i) they are eco-friendly ii) they do not have any residual effect or accumulate in the soil or environment; iii) they have less generation time, hence they are even harmless towards other ecological processes of the environment.

Potassium dynamics in soil

There are four forms K in soil depending on their

Figure 1. Deficiency symptom of K in some crops

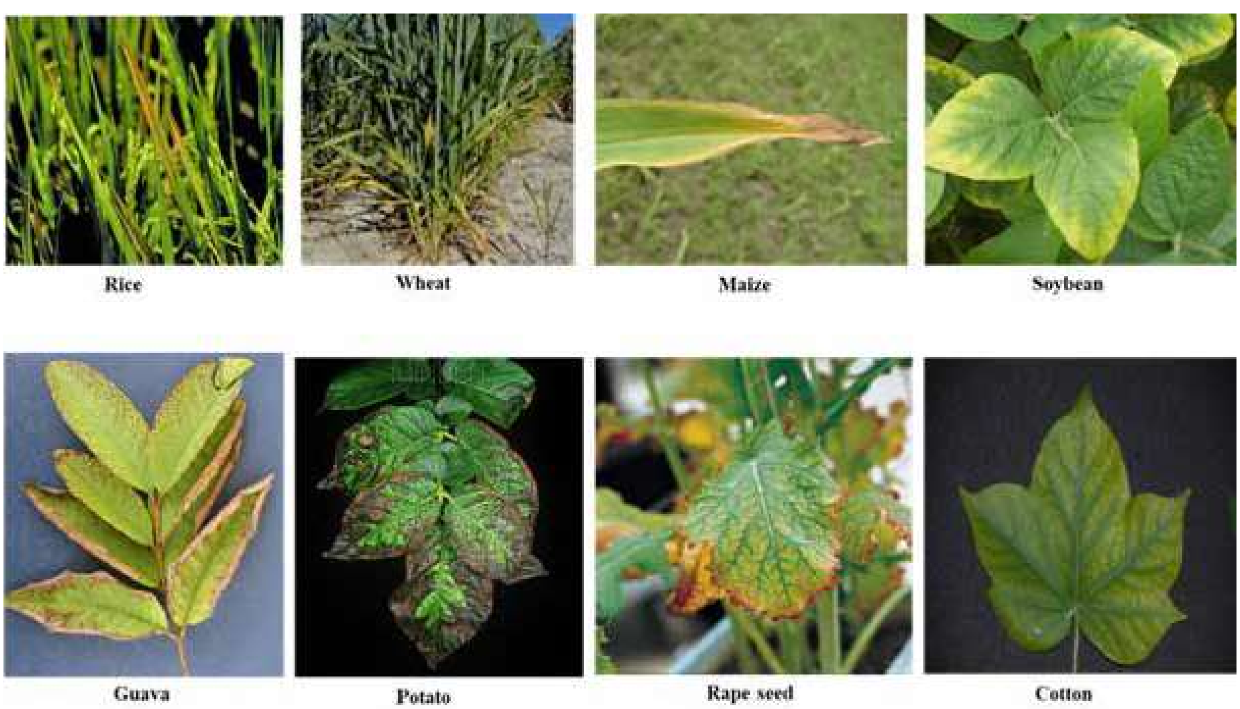

Table 1. Form of Soil Potassium

Forms of Potassium (K) in soil	% of K present
Structural or Mineral-K (lattice K such as K-feldspars)	90-98
nonexchangeable K (consisted predominantly of interlayer K of non-expandable clay minerals such as illite)	1-10
Exchangeable or Available K (held by negatively charged clay minerals and organic matter in soils)	1-2
soil solution K (water-soluble)	0.1-0.2

Table 2 Major potassium bearing mineral with Potassium Contents (Expressed as Oxide)

K bearing minerals	
Potash ore/minerals (% K_2O)	**Silicate minerals (% K_2O)**
Sylvite (63.09)	Potassium feldspar (16.91)
Carnallite (16.94)	Muscovite (10.88)
Kainite (18.91)	Biotite (9.18)
Langbeinite (22.71)	Phlogopite (11.30)

Table 3: Potassium solubilizing microorganisms (KSMs) involved in potassium (K) solubilization

Potassium solubilizing microorganisms (KSMs)		
Bacteria	**Fungi**	**Actinomycorrhizal fungi (AMF)**
Bacillus mucilaginsus	*Aspergillus niger*	*Glomus mosseae*
Bacillus edaphicus	*Penicillium purpurogenum*	*Glomus intraradices*
Bacillus globiospora	*Aspergillus terreus*	
Paenibacillus mucilaginosus	*Aspergillus fumigatus*	

availability to plants and microbes (Table 1).

The details of major K bearing minerals are given on Table 2. They remain in quasi-equilibrium with each other in the soil. At a given time, K in the solution and exchangeable from constitute the fraction readily available to plants. The exchangeable K tend to attain equilibrium rapidly with solution K but, only slowly with non-exchangeable K. When solution and exchangeable K are depleted from soil then only nonexchangeable K or slowly available K is released and become available to plant uptake. The different forms of K in soils and their transformation into solution are represented schematically in Figure 2. It is evident from the figure that KSM has the major potential to replenish the gap between the non-exchangeable K and mineral K through its biological interventions.

Role of potassium solubilizing microorganisms (KSMs)

A lot of studies have been conducted to find the ability of different K-bearing minerals (phlogopite, biotite, muscovite, feldspar, etc.) to release K in the soil solution. However, it is already established that application of silicate minerals as a source of K is less effective than commercial K fertilizers. Here lies the importance of biological interventions through KSM to fasten the K release rate from the mineral K (Figure 2). Soil microbial activity play an inevitable role in the release of K from K-bearing minerals in the rhizospheric region. Some microbes help in the release of K in soil solution either directly from the nonexchangeable reserve as well as from the mineral structure or degrade the silicate mineral structure. Some microorganisms solubilize the mineral K (micas, illite, and orthoclase) by excreting organic acids or chelating the silicon ions (Basaket al., 2017).

They are commonly known as K solubilizing microorganisms (KSM). These microorganisms are also used as "biological K fertilizer (BKF)" for bio-activation of fixed soil K to supplement the need of K fertilizers in China and South Korea.

Mechanisms of K Solubilization

There is scarcity of information regarding the exact mechanism by which KSMs release K from K bearing mineral and its sustainability. A list of popular KSMs are given on Table 3. Basak et al. (2017) proposed three probable mechanisms as follows:

A)Organic acid dissolution:

KSMs are well known to play a key role in the K solubilization mechanism by producing organic acids (oxalic acid, citric acid, tartaric acid, gluconic acid, succinic acid, glycolic acid etc).The protons associated with the organic acid molecules decrease the solution pH, releasing cations such as Fe, K, and Mg from the mineral to the solution. Microbial respiration as well as metabolism within soil solution also enhance mineral weathering by a proton-promoted dissolution mechanism of particulate and that also help in to increase carbonic acid concentration at mineral surfaces. Besides, by producing the exopolysaccharides KSMs also aid in mineral weathering as it strongly adsorbed to organic acids and thus assisted in their attachment to the mineral surface, resulting in an area of high concentration of organic acids near the mineral. There are three steps by which organic acid molecules produced by KSMs fasten the mineral weathering. In the 1st step, they adhere to the mineral surface and extract nutrients from the mineral particles by electron transfer reaction. In the 2nd step, they break the oxygen links. In the 3rd and final step, they chelate ions present in solution through their carboxyl and hydroxyl groups.

B)Metal-Complexing Ligands formation:

Some KSMs also produce high-molecular-weight polymers and organic ligands like mannuronic acid, guluronic acid etc. These ligands accelerate the K release by the following ways, i) it alginates that complex with ions on the mineral surface resulting in weakening of the metal– oxygen bonds, ii) it produces slime layers around the mineral surface, which increases the contact time between water and the mineral, thus accelerate mineral weathering.

C)Biofilm formation:

Biofilm is nothing but a microbial community concentrated on the root–hypha–mineral interface, protected by extracellular polymers produced by themselves utilizing plant and fungal exudates in soils (Gadd, 2007). In such a microenvironment, microorganism extracted inorganic nutrients and energy directly from the mineral matrix and thereby helped in mineral weathering. Extracellular polymers, primarily proteins, and polysaccharides produced by the microorganism served as a catalyst and thereby induced the K release from silicate mineral structure. Paenibacillusmucilaginosus Aspergillus fumigatus

Conclusion and future prospectus:

It can be summarized as K is the third major nutrient after nitrogen and phosphorous for plant growth and yield. Therefore, application of KSMs is a sustainable technology for solubilizing the fixed form of Kinto an available form leading to improved plant growth as well as microbial growth. By production of organic acids, formation of metal-complexing ligands and biofilms, KSMs play an important role in K mineral weathering.

This technology is one of the best alternative means of potassium nutrition under sustainable agriculture. It is also an eco-friendly, cost-effective, and socially acceptable technology. However, very little information regarding the role of potassium-solubilising microorganisms (KSMs) in solubilisation of K mineral and its impact on plant growth vis a vis and its role as a supplement of K deficiency in soil is available.

Therefore, the following points should be considered for future work to popularize the KSMs technology among the farmers:

- Most of the studies related to KSMs were conducted in greenhouse or under in vitro conditions. Therefore, field trials should be conducted to assess the actual potential of KSM technology.
- Detail study should be planned to evaluate the interaction effect among KSMs and other PGPRs (Plant growth promoting rhizobacterias)
- iii) Study should be undertaken to assess the potential of KSMs in other nutrients availability.
- Study should be conducted to know the optimal conditions for KSMs activity, their stability in the different soil with varying mineralogical make up.
- Detailed study of molecular biological aspects of KSMs need to be emphasized.
- Search for new strains of beneficial KSMs for large scale biofertilizer productionshould be encouraged
- The potential of the selected KSMs as effective biocontrol agent should be explored.
- Besides, more emphasis should be given on enhancing the efficacy of biofertilizers with an ideal and universal delivery system coupled with their stabilization mechanism in soil system to exhaust maximum benefits from KSMs application.

References:

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