AGRI MAGAZINE
(International E-Magazine for Agricultural Articles)
Volume: 03, Issue: 07 (July, 2026)
Available online at http://www.agrimagazine.in
©Agri Magazine, ISSN: 3048-8656

Potassium-Solubilizing Bacteria: Mechanisms and Applications in Sustainable Agriculture

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Potassium (K) is an essential macronutrient required for numerous physiological and biochemical processes in plants, including enzyme activation, photosynthesis, osmoregulation, protein synthesis, translocation of assimilates, and stress tolerance. Adequate potassium nutrition improves plant growth, yield, and quality in several crops such as peanut, watermelon, tomato, citrus, mango and wheat. Despite its abundance in soils, only a small fraction of total soil potassium is readily available to the plants, while most exists in mineral and non-exchangeable forms. Soil microorganisms play a crucial role in nutrient cycling and soil fertility through decomposition, mineralization, and nutrient mobilization processes. Among these beneficial microorganisms, potassium-solubilizing bacteria (KSB) have attracted considerable attention due to their ability to convert insoluble potassium-bearing minerals into plant-available forms through the production of organic acids and other metabolites. KSB convert insoluble forms of potassium into soluble forms that are readily available for plant uptake. Potassium (K), the third most important plant nutrient after nitrogen (N) and phosphorus (P), plays a important role in plant growth, metabolism, and development. It enhances plant resistance to diseases, pests, and abiotic stresses and activates more than 80 enzymes involved in essential physiological processes, including photosynthesis, energy metabolism, starch synthesis, nitrate reduction, and sugar metabolism. These microorganisms enhance potassium uptake, improve nutrient-use efficiency, stimulate plant growth, and contribute to sustainable agricultural production systems. Furthermore, microbial-mediated nutrient mobilization has been shown to increase the bioavailability of mineral elements in the soil, thereby supporting crop productivity and soil health. Presently, worldwide war between countries, the import of potassium fertilizer is totally stuck. In the scarcity of potassium fertilizer, government of India also emphasized for the utilization of beneficial microorganism such as KSB which is offers a promising and environmentally sustainable approach to improving agricultural productivity and reducing the dependency on chemical fertilizers.

Benefits of Potassium-Solubilizing Bacteria in Agriculture

Potassium-solubilizing bacteria (KSB) are important biofertilizers that contribute to sustainable agriculture by enhancing soil fertility, increasing nutrient availability, and promoting plant growth. Their primary function is to convert insoluble potassium compounds present in soil minerals into soluble forms that plants can readily absorb.

1. Enhanced Potassium Availability: KSB mobilize potassium from insoluble mineral sources such as feldspar, mica, and other silicate minerals through the production of organic acids and other biochemical processes. This increases the availability of potassium in the soil and improves plant nutrition.

2. Promotion of Plant Growth: Potassium is essential for enzyme activation, photosynthesis, protein synthesis, and carbohydrate metabolism. By increasing potassium

availability, KSB stimulate plant growth, improve root development, and enhance overall crop vigor.

3. Improvement of Soil Fertility: KSB contribute to long-term soil fertility by improving nutrient cycling and maintaining a balanced soil ecosystem. Their activity enhances the release of nutrients from soil minerals, thereby improving soil productivity.

4. Increased Nutrient-Use Efficiency: KSB improve the uptake and utilization of potassium and other nutrients, reducing nutrient losses and increasing fertilizer-use efficiency. This helps farmers achieve higher yields with lower fertilizer inputs.

5. Enhanced Crop Yield and Quality: Several studies have reported that KSB inoculation significantly improves crop productivity. Increased numbers of pods and seeds in groundnut and enhanced growth and yield in several crops have been attributed to KSB application.

6. Improved Stress Tolerance: KSB help plants tolerate various biotic and abiotic stresses, including drought, salinity, nutrient deficiency, and disease pressure. Improved potassium nutrition strengthens plant defense mechanisms and enhances resilience under unfavorable environmental conditions.

7. Promotion of Beneficial Rhizosphere Microorganisms: KSB improve the rhizosphere environment by encouraging the growth of plant growth-promoting (PGP) microorganisms. This beneficial microbial community supports nutrient acquisition, root growth, and overall plant health.

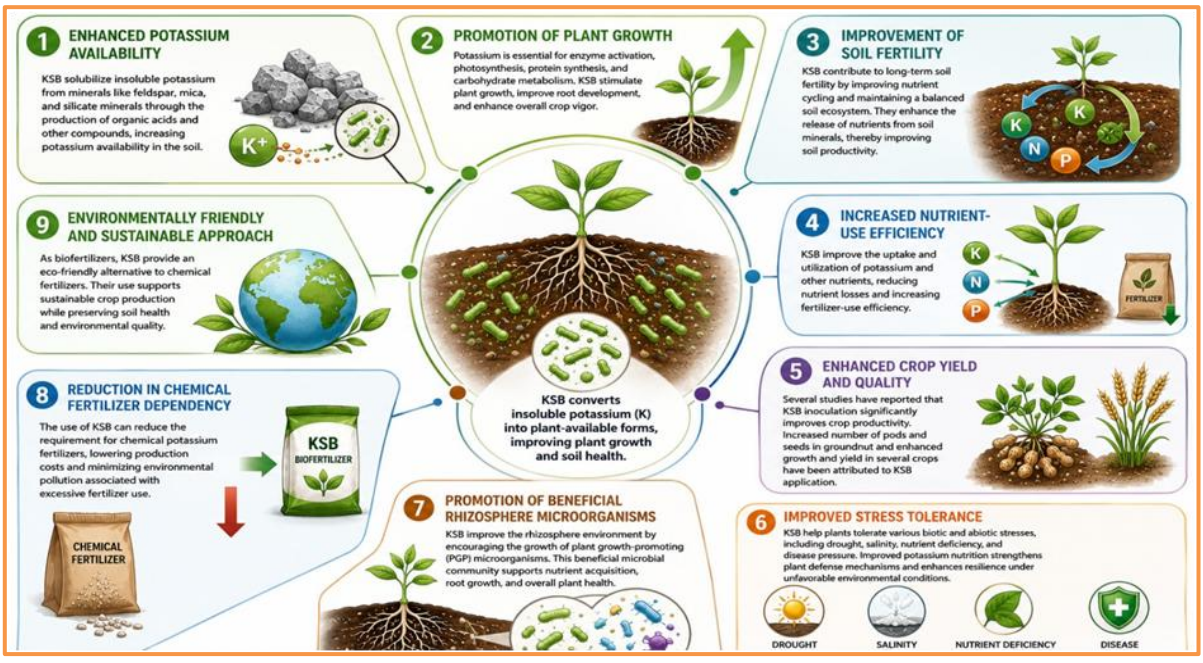
8. Reduction in Chemical Fertilizer Dependency: The use of KSB can reduce the requirement for chemical potassium fertilizers, lowering production costs and minimizing environmental pollution associated with excessive fertilizer use.

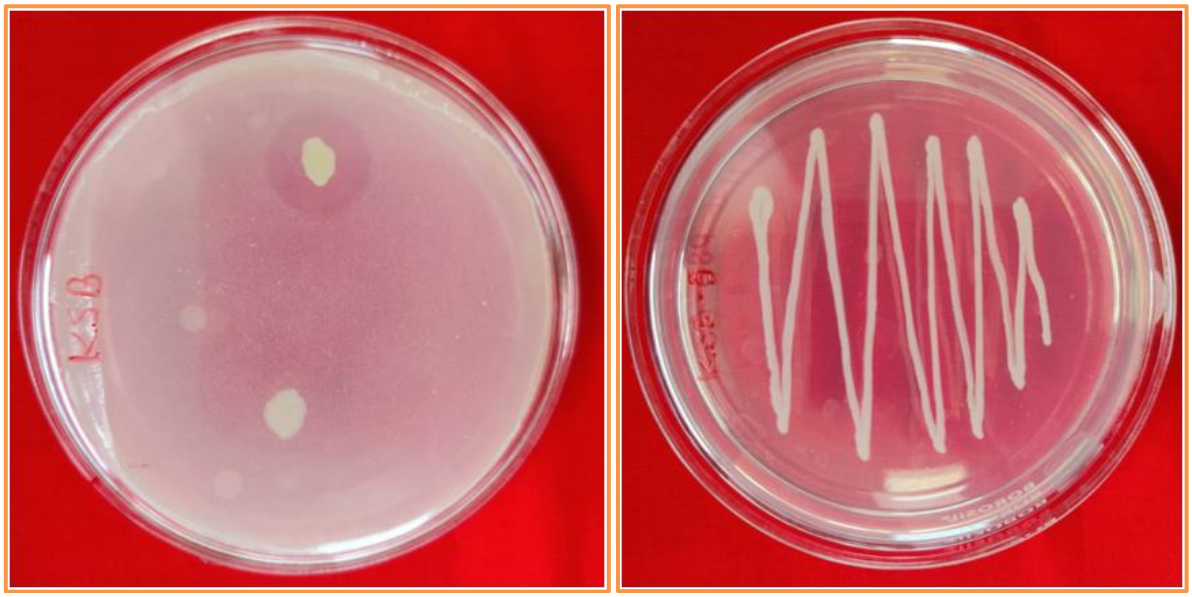
9. Environmentally Friendly and Sustainable Approach: As biofertilizers, KSB provide an eco-friendly alternative to chemical fertilizers. Their use supports sustainable crop production while preserving soil health and environmental quality.

Application methods of Potassium-Solubilizing Bacteria (KSB)

Potassium-Solubilizing Bacteria (KSB) can be applied through

- **Seed treatment:** Seeds are coated with KSB before sowing to enhance early root growth and potassium uptake.
- **Soil application:** KSB culture is mixed with compost or soil and applied to the field to increase potassium availability in the root zone.
- **Soil drenching:** A suspension of KSB is applied directly to the soil around plants, allowing effective colonization of the rhizosphere.





(A) Halo zone by KSB (B) KSB bacteria

- **Drip irrigation systems:** KSB inoculum is delivered through irrigation water, ensuring uniform distribution and efficient application.
- **Root dipping of seedlings:** Seedling roots are dipped in a KSB suspension before transplanting to promote root establishment and nutrient acquisition. These methods ensure effective colonization of the root zone and maximize their beneficial effects on plant growth and nutrient availability.

Conclusion

Potassium-solubilizing bacteria (KSB) play a significant role in sustainable agriculture by increasing the availability of potassium in soils, enhancing nutrient-use efficiency, improving soil fertility, and promoting plant growth. Their ability to reduce dependence on chemical fertilizers while improving crop yield and stress tolerance makes them valuable biofertilizers for modern agriculture. The adoption of KSB-based technologies can contribute to sustainable crop production, environmental conservation, and long-term soil health. Further research is required to identify optimal environmental conditions, including soil pH, organic matter content, texture, moisture, and microbial interactions that maximize KSB activity and potassium solubilization under field conditions.