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Potassium solubilisation in soils

If you want your plants to grow, Potassium is the way to go!

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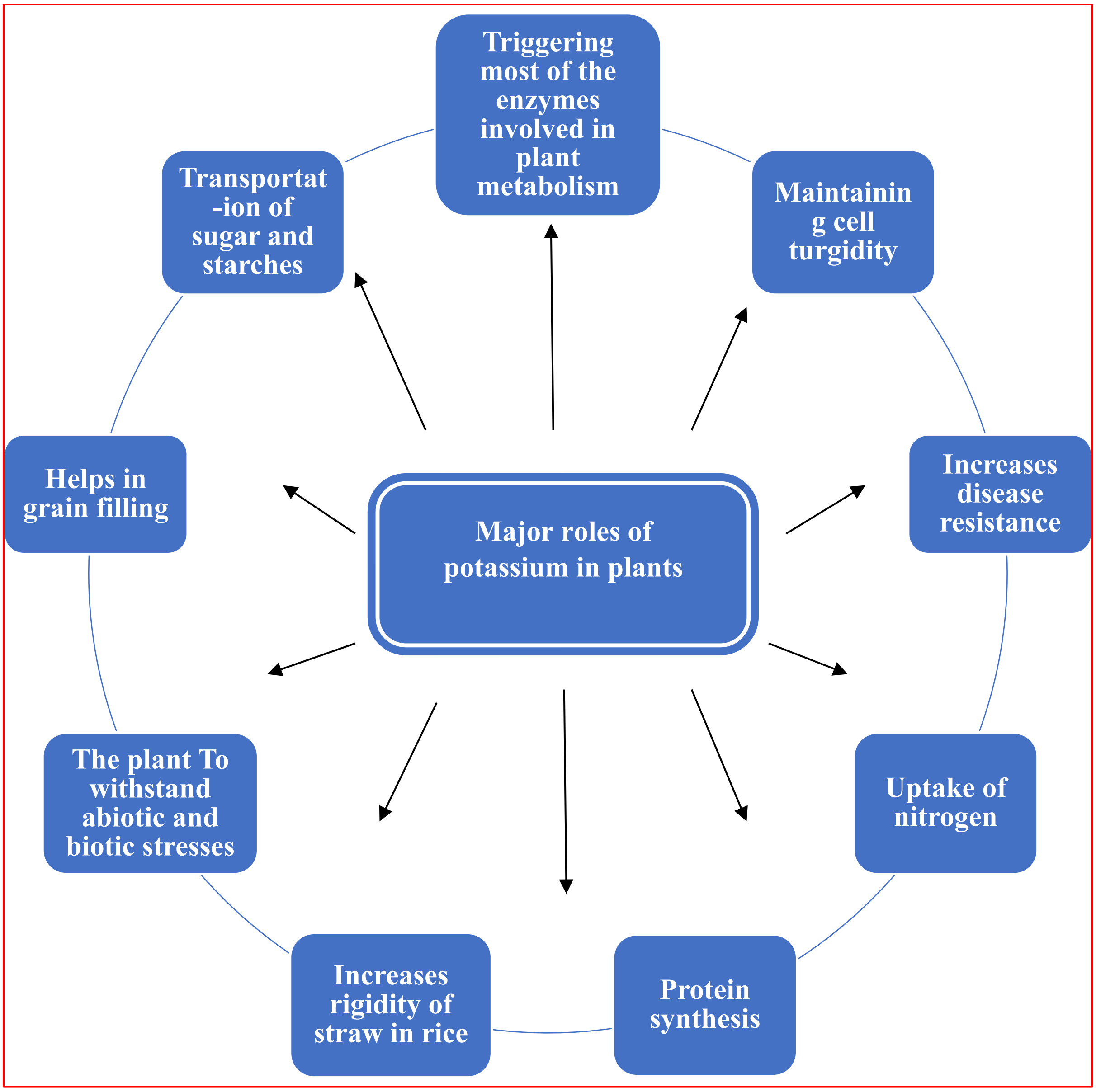
Abstract

A macronutrient that is crucial for plant growth and development is potassium. Potassium availability in soils is diminished as a result of intensive farming and unbalanced fertiliser application. Although the total potassium content of soil is often high, the majority of it is contained in insoluble potassium minerals, making very little potassium available to plants. It is essential to mobilize this reserve form of potassium for plant nutrition in order to lower the cost of applying potassium fertilisers. Soil-based microorganisms that solubilize potassium must be isolated and screened. These organisms are frequently referred to as potassium-solubilizing microorganisms (KSMs). The rate of potassium release from these minerals is accelerated when these potassium solubilising microorganisms are infected with minerals such as mica, illite, orthoclase and others. The existing database makes it evident that inoculating many crops with bacteria and sources of insoluble potassium could boost their growth and nutrition. As a result, this method is advantageous for farmers because it is economical and lowers the danger of environmental degradation.

Introduction

Plants mostly absorb potassium in its cationic form. Vital metabolic activities it plays in plants includes maintenance of cell turgidity, activating the majority of the enzymes involved in plant metabolism, moving sugar and starches, absorbing nitrogen and protein synthesis. Additionally, it aids in grain filling, boosts plant immunity to pests and diseases, increases the rigidity of rice straw and aids the plant's ability to handle biotic and abiotic challenges. Potassium deficiency results in poor plant development and growth which eventually reduces crop output. The potassium content of soils ranged from 0.04% to 3.0% and the majority of this was contributed by minerals that were bonded to clay. The three main types of potassium present in soils that are in dynamic equilibrium are available potassium, non-exchangeable potassium and soil mineral potassium. Of these three types of potassium, mineral potassium makes up more than 90–98% of all soil potassium. Potassium is found in silicate minerals such as muscovite, orthoclase, biotite, feldspar, illite, mica, vermiculite,



smectite etc. in mineral soils. Only 1% to 2% of the total potassium is in the form that is readily available and this form is either present in the soil solution or is exchanged with clay minerals and attached to organic materials in the soil. The average total potassium level of Indian soils was found to be 1.52% according to a soil survey report. India imports 2.4 MT of K_2O at the moment, making us the world's largest importer of potassic fertilisers. As a result, it is advisable to administer fertilisers in divided dosages and at the time of crop demand to maximize their effectiveness. Normally, the process of potassium being released from rock minerals occurs quite slowly. Utilizing a few potential microbes in addition to these insoluble minerals can speed up the rate of release because these microbes can solubilize the insoluble potassium in minerals using a variety of mechanisms. For example, with the production of low molecular weight organic acids or exo-polysaccharides serving as the primary mechanism.

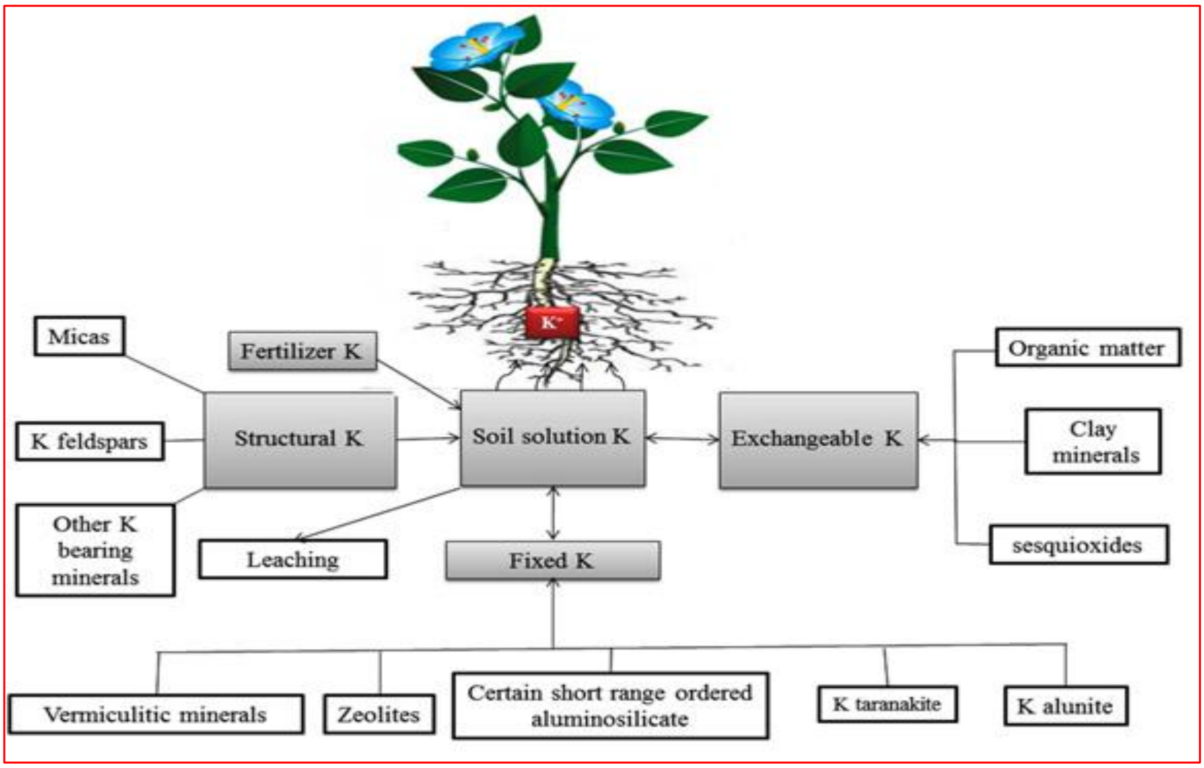


Fig.2 Interrelationships of various forms of soil potassium

Microorganisms involved in potassium solubilisation

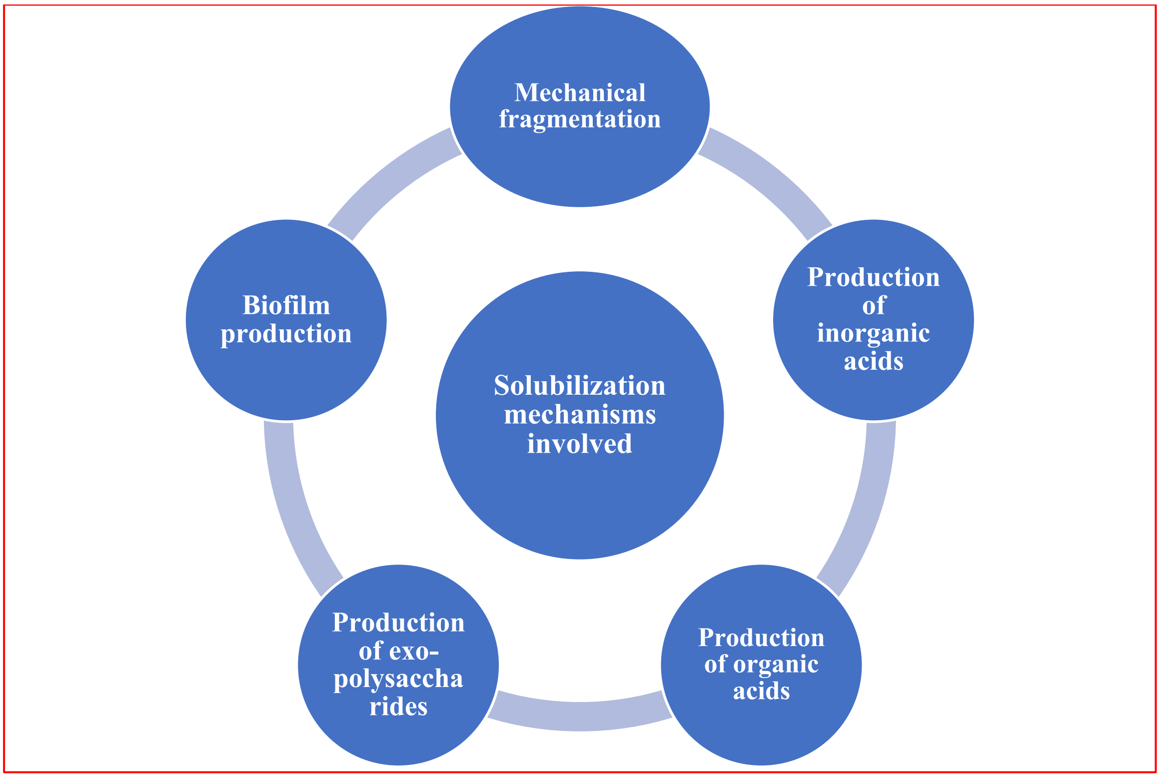
Normally, the process of potassium being released from rock minerals occurs quite slowly. Using a few potential microbes in addition to these insoluble minerals can enhance the rate of release.

1. **Bacterial species involved in potassium solubilisation:** The potassium solubilising bacteria (KSB) population is quite abundant in both the soil and the rhizosphere of plants. These isolates range from aerobic to anaerobic. However, aerobic potassium solubilising bacteria are more frequently discovered in soil. Potassium solubilising bacteria are frequently found in much higher concentrations in the rhizosphere than in non-rhizospheric soil. Most of them belonged to the *Bacillus, Pseudomonas, Acidithiobacillus* and *Burkholderia* genus families**.** Numerous researchers have made an effort to isolate and screen potassium-solubilizing rhizosphere bacteria from the roots of cereal crops growing in soils modified with potassium and silicate. Only a few bacteria including B. *edaphicus* and B. *mucilaginosus* have a high ability for solubilizing potassium from soil minerals among all the bacterial species. Usually heterotrophic in nature, the potassium-solubilizing bacteria get their energy and cellular carbon from the breakdown of organic matter in soils. As a result, it is thought that they contribute to the humus formation in soil and the cycling of other minerals bound to organic matter**.**
2. **Fungi for potassium solubilisation:** When inoculated with insoluble potassium sources in a proper environment, some strains of filamentous fungus and yeasts can solubilize potassium. When inoculated in liquid media containing insoluble potassium minerals such as feldspar and potassium aluminium silicate, fungi like *Aspergillus terreus* and *Aspergillus niger* release a significant amount of soluble potassium from these minerals, demonstrating their capacity to solubilize insoluble potassium in soils on both

insoluble potassium sources, A. *terreus* displayed the best solubilization and acid generation results. By releasing protons, H^+ or CO_2 as well as organic acid anions like citrate, oxalate and malate, arbuscular mycorrhizal fungus can improve the solubility of potassium in its crystalline form. This also increased the nitrogen, potassium, calcium and iron in the plant leaves and fruits.

Mechanism involved in potassium-solubilization/mobilisation

The weakening of the strong connection between the K^+ ion and the silicate minerals is the fundamental principle underlying the solubilization of insoluble potassium. Microbes disrupt that inert bond by the release of organic acids, production of H^+ ions, formation of bio-film and other mechanisms which increases the release of bound potassium as soluble potassium in soils.



1. **Production of organic acids:** Microbes increased the solubilization of potassium by producing low molecular weight organic acids like citric, tartaric and oxalic acids. The production and release of organic acids into the environment by microorganisms acidify both the cells and surroundings of the microbes which ultimately causes the release of K^+ ions from the mineral potassium through protonation and acidification mechanisms. Organic acids produced by microbes promote the solubilization of potassium compounds by supplying protons and complexing Ca^{2+} and other ions with soil silicate minerals. The complex that forms between organic acids and metal ions like iron, calcium and aluminium causes the solubilization of potassium. A reduction in pH, an increase in the chelation of potassium, aluminium, iron and acidolysis of rhizospheric minerals are all effects of bacterial colonies which release acids. Protons are released as the pH

of the rhizosphere decreases which speeds up the solubilization process.

2. **Production of inorganic acids:** Different inorganic acids produced by microorganisms speed up the solubilization of potassium from potassium-bearing rocks. When nitrogenous and inorganic sulphur compounds are oxidised, nitrifying bacteria and *Thiobacillus* species produce inorganic acids like nitric acid and sulphuric acid. As an alternative, soil microorganisms produce CO_2 through respiration which when combined with water produces carbonic acid. By causing the breakdown of $CaCO_3$ and potassium minerals this carbonic acid generation aids in chemical weathering.
3. **Production of exo-polysaccharides:** In the close vicinity of minerals, bacteria build bio-films made up of organic acids, proteins and polysaccharides. In the mycorrhizosphere and rhizosphere of vascular plants, the microbial bio-films served as a protective barrier covering the mineral-water-hyphal/root hair interface which not only hastened weathering but also controlled denudation losses.
4. **Mechanical fragmentation:** Plant development causes the mineral to become more fragmented increasing its reactive surfaces, which directly benefits the bacteria's ability to affect mineral weathering. The mechanical forces together with the direct contact between fungal filaments and potassium-containing minerals are two potential ways to improve potassium availability. The biological weathering of minerals causes cracks and fissures to form as fungal hyphae thoroughly penetrate in already created cavities.

Effect of potassium solubilizing microbes on plant growth and yield

It is widely acknowledged that potassium solubilising microorganisms considerably improve crop plant growth, yield and nutrient uptake. The potassium solubilizing microorganism`s ability to promote plant growth suggests that their exudates can significantly improve the release of potassium from clay minerals which in turn promotes potassium uptake and plant growth. Additionally, they have a reputation for secreting vitamins, indole-3-acetic acid and amino acids that promote growth. They also contribute significantly to the enrichment of compost and the breakdown of organic matter. The uptake of N, P and K by eggplants as well as the phosphorus and potassium content of the soil were raised by the simultaneous inoculation of *Bacillus megaterium* (phosphorus-solubilizers) and *Bacillus mucilaginosus* (potassium-solubilizers). The application of inoculation with bacterial strains that can solubilize phosphorus and potassium together with the integration of phosphorus and potassium containing rock materials was shown to be a viable substitute for chemical fertilisers.

Future prospect

Only a few crops can use potassium solubilizing bacteria because they proliferate in the rhizosphere and cannot survive in hostile settings like those with high concentrations of salt and heavy metals. Understanding plant systems for potassium absorption and metabolism requires genotypic investigation of the potassium-solubilizing strains and molecular characterisation of the plant components. Microbes with other advantageous properties such as superior rhizosphere proliferation and survival, nitrogen fixation, phosphate solubilisation and phyto-hormones synthesis, may contain genes responsible for potassium solubilization. Maintaining the richness of these microorganisms will be made easier by isolating and screening Potassium solubilizing microorganisms from a wider variety of geographical regions. Due to challenges in soil inoculation in field settings there is currently limited information available on the field implementation of such approaches. To build a solid database on the impact of potassium solubilizing microorganisms on plant development and nutrition it is also desirable to conduct additional field applications of these inoculums in agricultural crops. It is essential to have a better understanding of the mechanisms underlying potassium release from soil minerals in order to create innovative methods for sustainable agriculture.

Conclusions

Although, Indian soil often contains higher levels of potassium, this potassium is primarily found in the form of minerals. The inoculation of potassium-solubilizing bacteria can enhance the release of potassium. In addition to bio-film development and fragmentation, the microorganisms also create various organic acids and exo-polysaccharides which promote mineral breakdown and potassium release into the soil solution. The solubilization of fixed forms of potassium and making them available for plant uptake through microbial consortia of potassium solubilizing microorganisms and other beneficial microorganisms is a sustainable approach that also increases the amount of potassium that is readily available in soils and available to plants. The price of potassium fertilisers can be reduced with the use of such technology which will also lessen environmental pollution.

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