UNRAVELING THE POTENTIAL OF WASTE MICA AS A POTASSIC FERTILIZER USING POTASSIUM SOLUBILIZING BACTERIA

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Boosting crop yields of our farmlands using cost-effective native resources, is one of the key agricultural issues of the present time in India hence, research efforts are largely directed towards realization of this objective. In this aspect, use of chemical inputs such as fertilizers cannot be undermined. Potassium (K) is one of the essential plant nutrient required in high quantity to promote growth and development of plants as this nutrient element have a crucial role in cell metabolism, enzyme activation, starch synthesis *etc*. However, its incessant use over a long period of time is gradually becoming a costly affair as the entire quantity of K fertilizer is currently being imported from foreign countries like Canada, Russia, Belarus, Germany, Israel and Jordan. The total consumption of potash in India for the year 2019-2020 was about 2.6 million tonnes (FAI, 2021) which clearly indicates the extent of our dependency on foreign countries.

Developing countries like India with no mineral deposits have very little scope to become self-sufficient in K nutrition by only depending on the conventional fertilizer sources like muriate of potash and sulphate of potash. In this regard, it is imperative that other alternative source for K fertilizers have to be identified and explored. Fortunately, certain Indian states have huge deposit of low grade K bearing minerals like mica with 5-10 percent total K in them. This unrealized and unutilized source of K can be of great value both in terms of boosting soil fertility and reducing the huge dependency on costly K fertilizers if modified suitably.

AVAILABILITY AND CURRENT USE OF MICA

Mica deposits are there in many parts of the country particularly in the states viz., Andhra Pradesh, Bihar, Jharkhand, Maharashtra, Odisha, Rajasthan and Telangana. Minor deposits are also reported in some pockets of Gujarat, Haryana, Kerala, Tamil Nadu and West Bengal. According to National Mineral Inventory (2015) database, around 635 thousand tonnes of mica mineral deposits are available in India. Andhra Pradesh leading with a majority share (41%) in country's total mica deposits followed by Rajasthan (28%), Odisha (17%), Maharashtra (13%), Bihar (2%) and a small quantity of resources is found in Jharkhand (Figure1) and Telangana (Indian mineral year book, 2019).

Mica mineralis comprised of a group of 34 phyllosilicate minerals which exhibits layered or platy structure. Out of different mica, muscovite (potash or white mica) and phlogopite (Magnesium or amber mica) are recognized as commercially important. Muscovite mineral have the property of splitting in to thin sheets. It also exhibits properties of elasticity, flexibility and transparency with high resistance to heat and high dielectric strength. Therefore, it is mainly utilized in electrical industries as an insulator, capacitor *etc*. Mica in small quantities is also employed for cosmetic application. However, all these uses are restricted to industries. Applicability of mica in agriculture is an entirely new area. Hence, researchers are in the process of exploring its potential to utilize as a source of potassic fertilizer.

Figure 1. Mica blocks (left) and mica flakes (right) obtained from mica mining areas of Jharkhand

K SOLUBILIZING MICROBES TO ENHANCE K AVAILABILITY FROM WASTE MICA

A special group of bacteria known as plant growth promoting rhizobacteria (PGPR) are able to colonize the rhizosphere and improve diverse processes like plant establishment, plant fitness and nutrition uptake, particularly under conditions of unbalanced nutrition. In the current context, the ability of these microbes to solubilize insoluble mineral K to soluble forms can be used to promote plant growth. Many groups of microbes have been identified as K solubilizing microorganisms. Mostly bacteria and fungi are listed in above category with bacteria being the dominant member. *Bacillus edaphicus*, *B. circulans*, *B. mucilaginosus*, *Paenibacillus* sp., *Pseudomonas*, *Burkholderia* sp. (Basak et al., 2017) have been identified by researchers as important K solubilizing bacteria (KSB) or silicate dissolving bacteria (SDB).

MECHANISMS OF ACTION OF K SOLUBILIZING MICROBES

The complex interactions between microflora and plants are continuously being explored and investigated yet a lot remains to be explored from this black box. Many investigators have come forward with different mechanisms of K solubilization which is explained below and has been summarized in the Figure 2.

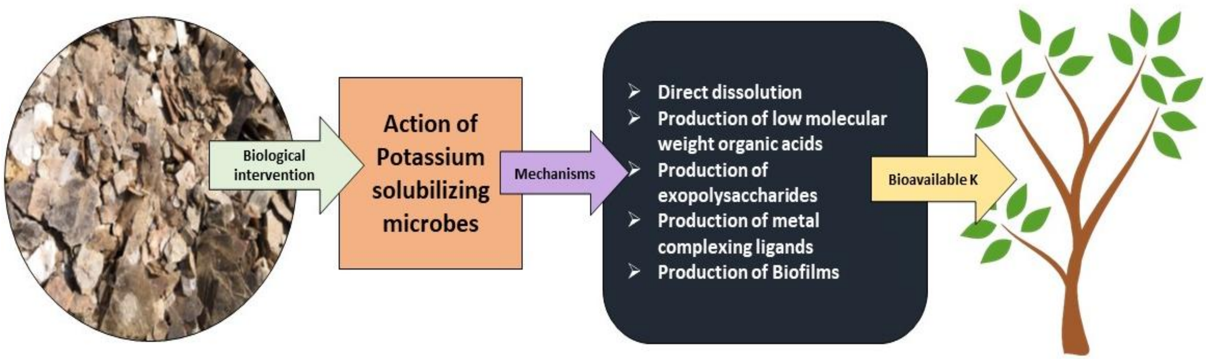

Figure 2. Mechanisms of action of potassium solubilizing microbes

Direct Solubilization of K minerals: Production of low molecular weight organic acids by KSBs are considered to be the most important and accepted method of K solubilization from K minerals. Organic acids such as oxalic, tartaric, citric acids, acetic, glycolic, propionic, fumaric, and malonic acids have been reported to be produced by KSBs. These organic acids as well as H^+ produced by the KSBs reduce the pH of the surrounding medium and bring cations such as K, Mg, Fe in soil solution which is then taken up by the plants (Velázquez et al., 2016). Organic acids binds on the mineral surface and extract ions through a) direct electron transfer b) breaking of oxygen linkages and c) chelation of ions in soil solution in the presence of their hydroxyl and carboxyl groups. The process of microbial decomposition of organic compounds also produces chemical compounds such as ammonia and hydrogensulphide which may be further oxidized in soil to form strong acids such as nitric acids and sulphuric acids. These sources of H^+ ions might displace ions like K^+, Mg^{2+}, Ca^{2+} and Mn^{2+} from cation exchange complex.

Indirect Solubilization of K minerals: In lieu of direct ion exchange with H^+ ion, KSBs can also cause K solubilization indirectly by chelation of cations of the minerals, direct attachment of KSBs on mineral surfaces, production of metal complexing ligands (Basak et al., 2017), and release of phytohormones through microbes. Potassium solubilizers have been reported to form metal organic complexes which in turn accelerate the process of metal dissolution. Some efficient strains of KSBs produce high molecular weight organic ligands or polymers such as guluronic acid, mannuronic acid, and alginates, weaken the metal–oxygen bonding by forming complexes with metal ions of minerals (Basak et al., 2017).

Polysaccharide Secretion: Some of the KSBs (*Bacillus* sp., *Clostridium* sp., *Thiobacillus* sp.,) have been reported to enhance the process of mineral ion dissolution by production of capsular exo polysaccharides or EPS. These EPS has dual role of action. It can act as strong adsorbent of the organic acids produced by the KSBs and thus increase the concentration of organic acids around the minerals and thereby increase K release. Exopolysaccharides have high protein content which may further stimulates the formation of bacteria-mineral complex and eventually cause ion solubilization.

Production of Biofilm: Biofilms are concentrated colony of microbes around root-mineral interface and are self-protected by means of extracellular polymers. These biofilms are extremely stable in adverse environments and extract nutrients from mineral surfaces and cause mineral weathering.

CONSTRAINTS OF UTILIZATION OF WASTE MICA AS K FERTILIZER

Opportunities and challenges go hand in hand. Waste mica is basically an inert mineral with negligible solubility. Attempts to extract K from these minerals have been mostly studied at laboratory scale and preponderance of results and conclusions are obtained from laboratory studies itself. Detailed field experiments and trials are lacking as now. Moreover, the industry of bio fertilizers itself suffers from constraints such as poor shelf life, lack of optimum production unit, lack in uniformity in microbial activity *etc*. and so treating waste mica through biological intervention may also be affected by the above limitations. But challenges may be viewed as opportunity in disguise and therefore it is needed that soil scientists, microbiologists and agronomists come together and work in this area for helping the nation move one step forward towards achieving the vision envisaged by our Honorable Prime Minister of making India as “Atma Nirbhar *Bharat”.*

SUCCESS STORIES

Utilization of K solubilising bacteria along with waste mica has been studied and documented by researchers worldwide. Table 1 gives a brief summary of successful use of this technology in Indian scenario.

Table 1. An outline of national and international studies on K solubilising bacteria and waste mica

Treatments	Salient findings	References
Bacillus pseudomycoides along with waste mica	Increased K availability by 47·0 ± 7·1 mg kg-1 after 105 days incubation which was reflected a higher K uptake by tea	Pramanik et al., 2019
Waste mica along with *Bacillus mucilaginosus*	1 N NH4OAc extractable K increased from 12.3% to 46% over a period of 28 days.	Biswas and Basak, 2014
Waste mica along with *Bacillus mucillaginosus.*	Higher amount of available K and biomass yield of Sudan grass was maintained in soils of Alfisol	Basak and Biswas, 2009
25% recommended K as waste Mica + 50% K as Muriate of potash + *B. pseudomycoides*	Higher tea yield and higher exchangeable K content in soil, effect more pronounced in the second year of study	Pramanik et al., 2021
Pseudomonas sp along with muscovite and biotite mica	37% higher K was observed to be released from biotite over muscovite.	Sarikhani et al. 2016
Bacillus mucilaginosus + *Azotobacter chroococcum* + waste mica	Coinoculation of bacterial strains maintained consistently highest amounts of available K and N in soils even at 150 days of cropgrowth (Sorghum vulgare) growth and recorded higher biomass accumulation and nutrient acquisition than other treatments	Basak and Biswas 2010
50% K (MOP) + 50% K (waste mica) + *Fraturiaaurantia* + *Bacillusedaphicus*	Significant effect on biomass yield, K uptake and recoveries by maize due to higher solubilization of K.	Ahmad et al., 2020
Bacillus sp.+ crop residues(2g kg-1soil) + waste mica	Higher biomass uptake, K recovery and apparent K recovery over treatments with mica alone.	Rani et al., 2022

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