Langbeinite: A Sustainable Alternative for Potassium Supply

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Abstract

Potassium is a valuable plant nutrient involved in enzyme activation, protein synthesis, water balance, and carbohydrate metabolism. Muriate of potash (MOP) is the most widely applied potassium fertilizer, but it is energy costly to produce, can lead to chloride toxicity, and is produced in limited locations. This has motivated individuals to seek alternative sources. Langbeinite ($K_2Mg_2(SO_4)_2$) is one such alternative because it possesses a unique chemical composition, delivering potassium, magnesium, and sulphur in a single package. Langbeinite is less energy costly to produce and process and has a reduced carbon footprint compared to MOP. Studies have established that it can enhance crop yield and nutrient uptake, particularly in sandy soils that are chloride sensitive. Its slow release of potassium, higher cost, and limited geographical distribution, however, make it less convenient to use extensively. Nevertheless, studies go on to advance extraction techniques and develop new langbeinite-based fertilizers. As global agriculture goes on to adopt more sustainable methods, langbeinite can serve as a suitable substitute to conventional potassium fertilizers, facilitating long-term soil health and resource efficiency.

Introduction

Potassium is a vital plant growth macro-nutrient with key functions in activating enzymes, protein synthesis, water relations, and carbohydrate metabolism. Sustaining adequate potassium supply is of utmost importance to ensure resource conservation and global food security. Although muriate of potash (MOP) or chemically referred to as potassium chloride (KCl) continues to be the most widely used potassium fertilizer globally, producing and distributing it is not without obstacles. The factors which have prompted the use of and discovery of alternative potassium sources are concentrated production areas, energy-intensive demands in extraction, and possible chloride toxicity to sensitive plants. Among these alternatives, langbeinite ($K_2Mg_2(SO_4)_2$) is one of the more compelling minerals because it has a distinctive chemical makeup, lower processing needs compared to other minerals. Langbeinite, a natural double sulphate of magnesium and potassium, belongs to the langbeinite mineral group, which crystallizes in the isometric system. It was named after German chemist Albert Langbein. The mineral generally occurs in evaporite deposits, primarily in sedimentary basins with large marine or lacustrine environm-

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ents that experience extended evaporation. These conditions result in the successive precipitation of several salts, such as halite (NaCl), sylvite (KCl), kieserite ($MgSO_4$, H_2O), and finally langbeinite. Most deposits of langbeinite occur in the Permian Basin of the south-central United States (New Mexico and Texas), Germany, Russia, and Canada. The ore typically occurs in association with other evaporite minerals and must be separated and purified before it can be used as a fertilizer. Compared to MOP, langbeinite has a special chemical structure that makes it desirable as a potassium source. MOP is a potassium alkaline salt, providing potassium and chloride. Langbeinite provides three important nutrients: potassium (K), magnesium (Mg), and sulphur (S) in one product. The potassium level of marketable langbeinite is usually between 22-23% K_2O (about 18-19% K), magnesium level is usually 11-12% MgO (about 7-7.5% Mg), and sulphur level is usually between 21-23% S. Such a combination of nutrients may be especially beneficial in areas where one or more of these are lacking in the soil, making it easier to apply fertilizer and possibly eliminating the necessity of multiple separate amendments.

Extraction: The processing and mining of langbeinite are traditionally regarded as having lower energy consumption than MOP production from sylvite. The energy content used in extracting and processing langbeinite is significantly lower for MOP compared to conventional systems of MOP production. It takes about 30% less energy to produce langbeinite compared to other MOP traditional production systems. This is mainly due to a lack of severe grinding and chemical processes required by MOP. On a carbon footprint basis, the production of langbeinite involves more rudimentary mechanical steps that lead to lower emissions of greenhouse gases. MOP production often employs flotation or fractional crystallization processes for the separation of KCl from other salts like NaCl. Such processes entail high energy input in the form of grinding, heat, and chemical treatment. Langbeinite is also often found in higher purity deposits, where simpler procedures like crushing, screening, and electrostatic separation may be used. The crushed ore is processed to release langbeinite crystals. The crushed ore is screened to remove fine particles and is treated with electrostatic separation, which employs conductivity differences to isolate langbeinite from other minerals. This method reduces the requirement of high-energy processes such as thermal treatment or high chemical usage.

Effect on crop growth: Cristina *et al*. (2020) conducted a study on the impact of anaerobic digestates from sewage sludge combined with langbeinite on tomato plant growth. The research indicated that incorporating langbeinite into the nutrient regimen improved fruit size and overall yield compared to traditional fertilizers. The blend not only supplied potassium but also improved the health of the soil, and thus it is clear that langbeinite can be efficiently used in organic and sustainable tomato cultivation. Gopinath *et al*. (2024) assessed

the efficiency of langbeinite in enhancing the productivity and quality of peanuts in Southern India. The authors observed notable plant vigour, yield attributes, and nutrient uptake increases when langbeinite was utilized as a source of potassium relative to conventional fertilizers. Mousa *et al*. (2024) reviewed the effects of varying potassium sources, such as langbeinite, on potato crops grown in sandy soils. The study established that potatoes treated with langbeinite recorded improved growth characteristics and higher yields compared to those subjected to conventional potassium chloride applications. The implication is that langbeinite can cause increased efficiency in potassium utilization, particularly on sandy and poor soils. Chaudhary *et al*. (2021) also investigated the effects of combined application of potassium with langbeinite along with microbial inoculants on forage maize growth. The results indicated that langbeinite promoted increased uptake of potassium by the maize plants and increased other micronutrients. This corroborates the fact that the inclusion of langbeinite in balanced nutrition practices can maximize overall crop well-being and productivity.

Advantages: Langbeinite's magnesium and sulphur content is advantageous to the plant's general health and nutrient use efficiency. Magnesium is needed to aid photosynthesis and the production of chlorophyll, and sulphur is needed to aid the production of proteins and enzymes. The application of these nutrients along with potassium can enhance the crop yield as well as the general nutritional value of the harvested crop. Release of potassium from langbeinite in soil is typically slow and consistent compared to rapid release of potassium from MOP. Such slow release is desirable in sandy soil or zones of high rainfall, where rapid leaching of nutrients is likely. By offering a slower release of potassium, langbeinite will minimize loss of nutrients and maximize the long-term availability of potassium to plants. In contrast to MOP, langbeinite contains no chloride and is thus a better option for chloride-sensitive crops such as tobacco, potatoes, and some fruits. Chloride-intensive soil can hinder the uptake of nutrients, decrease the yield of the crop, and adversely affect the quality of crops for tobacco, grapes, potatoes, and some fruit trees. Langbeinite is thus used most commonly for these chloride-sensitive crops and provides potassium without endangering chloride toxicity. Because langbeinite is naturally mined and doesn't involve extensive chemical processing, it also has a lower carbon footprint than processed fertilizers. It's in line with the existing modes of sustainable agriculture to use langbeinite. This not only saves the cost of production by lowering energy usage but also eliminates the carbon footprint of manufacture, particularly the manufacture of fertilizer. This problem becomes important in the context of today's global climate crisis, as agriculture is one of the world's largest greenhouses gas emitters. Its shift towards utilizing fertilizers such as langbeinite, which involves less energy spent in its production, is in harmony with agro-ecological measures that seek

the lowest ecological costs.

Disadvantages: Nevertheless, the slow-release nature of langbeinite means that it may not be the best choice where there is a need for a rapid surge of potassium, such as with intensive crop production or as a treatment for acute potassium deficiency. Under these circumstances, supplementation of langbeinite with a more available potassium source may be necessary. One of these is its relatively higher price compared to muriate of potash (MOP). The primary reason for this is the lesser content of potassium contained in langbeinite compared to MOP (22-23% K_2O versus 60% K_2O, respectively) and the lesser volumes of production involved in langbeinite. The relatively higher cost can be a disincentive to adoption by farmers, particularly where resources are limited or in commodity crop agriculture where profit margins are low. Nevertheless, the value proposition of langbeinite may be higher where high-value crop production occurs or where the benefits of multi-nutrient delivery and lower chloride risk outweigh the higher initial cost. Another weakness is the relatively narrower geographical occurrence of langbeinite deposits. Although large deposits occur in some regions, notably North America, transportation costs to remote markets can make its cost higher and diminish its competitive edge over local alternatives to potassium. Moreover, the particle size and physical properties of langbeinite may require modification of fertilizer application equipment and operations. For instance, langbeinite may need to be granulated or blended with other fertilizers in order to improve its handling and distribution efficiency.

Path forward: The future prospect of langbeinite as a substitute source of potassium is affected by many factors, such as technology advancements in extraction and processing, new products and uses, and shifts in global fertilizer market dynamics (Hirata and Katoh, 2022). Research now focuses on enhancing the efficiency of langbeinite extraction and beneficiation processes, and finding new uses such as the use of langbeinite in controlled-release fertilizers and conditioners for soil. New langbeinite-based fertilizers to be used on particular crops and soil types can enhance its usage and efficiency.

Conclusion

Langbeinite is a worthwhile substitute for traditional potassium fertilizers such as MOP. Its distinctive chemical makeup, offering potassium, magnesium, and sulphur in one product, its comparatively low processing needs, and resistance to chlorides are some of the reasons why it is the best choice for ecologically sustainable agriculture. Although its higher price and present unavailability limit its overall use, continued R&D is focused on overcoming such limitations and maximizing the role of langbeinite in fulfilling world demand for potassium fertilizers. With increasing pressure on agri-resources and the necessity for more sustainable systems, langbeinite will play an increasingly important role in maintaining crop productivity and nutrition security. It is important to understand its strengths and weaknesses in making informed choic-

es regarding its rightful place in various agricultural systems.

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