4.5 Natural K-minerals and rocks

The most commonly used form of K input in agriculture is potassium salts (potash) These naturally occurring K fertilizers are mainly obtained from sedimentary potash (K-salt) deposits providing minerals such as sylvite (KCl) or complex K-Mg chlorides and sulphates. These K-fertilizers are water soluble and are consequently favoured as fast acting K- and K-Mg fertilizers.

The main source of K for plants growing under natural conditions comes from the weathering of K minerals and organic K-sources such as composts and plant residues. The most important K minerals are K-feldspar, leucite, K-micas such as biotite, phlogopite, and glauconite, and clays such as illite. K-rich silicate rocks with relatively fast weathering characteristics are leucite-bearing volcanics.

Potassium occurs in feldspars in very weathering-resistant framework lattice positions (Sanz-Scovino and Rowell 1988). The potassium ion is not easily released and is therefore not easily plant available. In contrast, the minerals of the mica and micaceous clay group have sheet silicate structure. Here, K occupies the interlayer position and Mg and Fe^{2+} in the octahedral positions. Laboratory studies by Schnitzer and Kodama (1976) and Tan (1980) showed that naturally occurring humic compounds can extract a large percentage of K, Mg, Fe, and smaller amounts of Si and Al from the crystal structure of biotite and phlogopite but not from muscovite. Biotite, the tri-octahedral more iron-rich mica, is less stable with acid treatment than phlogopite (Schnitzer and Kodama 1976; Feigenbaum *et al.* 1981). The consequence is that K can be easily and quickly released from both biotite and phlogopite. In contrast, the release of K from muscovite and K-feldspar is too slow to be of much agronomic use.

Mica minerals such as phlogopite and biotite contain considerable amounts of K_2O (usually > 10%), MgO (5-22%) and Fe (5-20%). Most of these nutrients are part of the silicate structure, in a form not readily available to plants and animals. Their release has been studied in fundamental soil and mineral research in laboratory studies (Rausel-Colom 1965; Schnitzer and Kodama 1976; Tan 1980; Feigenbaum *et al.* 1981; Kodama *et al.* 1983; Song and Huang 1988; and others). Weerasuriya *et al.* (1993) conducted experiments with scrap grade phlogopite from a Sri Lankan mica processing centre. The researchers treated phlogopite with various acids and reported that up to 65% of the K and Mg contained in the phlogopite could be recovered. In greenhouse experiments they demonstrated that acidulated phlogopite chips at an application rate of 200 kg ha^{-1} gave significantly higher yields of rice as compared to the control with KCl (Weerasuriya *et al.* 1993).

The release of K from phlogopite and biotite through the actions of rhizosphere microflora has been studied by many scientist including Berthelin *et al.* (1991), Hinsinger and Jaillard (1993), and Hinsinger *et al.* (1993). Electron-microscopic and x-ray studies prove that the roots of rape (*Brassica rapus*) and ryegrass can transform phlogopite into vermiculite, releasing K and Mg to the plants. Roots and rhizospheres of plants are active biological weathering agents that transform micas and release K and other cations.

Glauconite is a hydrous iron potassium mica with the chemical formula $3X_2(Fe^{3+}, Fe^{2+},Y)_6(Si_4O_{10})(OH)_4 \cdot nH_2O$, whereby X is K^+, Na^+, or Ca^{2+} and Y is Al or Mg. Glauconites occur commonly in ‘glauconitic greensands’ as unconsolidated sandy, silty and clayey sediments of marine, near-shore sediments with slow rates of sedimentation. Clean glauconites contain up to 11% K_2O, while glauconite-rich ‘greensands’ contain commonly 5-9% K_2O. Glauconites are often spatially associated with sedimentary phosphate accumulations.

Glauconitic greensands can be used, in large application rates, as slow-release, low-grade K soil amendments with cation exchange capacities around 20 $cmol^+$ kg^{-1}. They have been used in large amounts in the 19th century in the United States and are still produced in the US in low tonnages, but mainly for water purification purposes. In the 1860s the annual production of greensands from New Jersey were almost 1 million tonnes. In 1960 glauconite production for agricultural purposes was only 3,750 tons (New Jersey Geological Survey, cited in Markewicz and Lodding 1983). In current agricultural land management practices higher-grade K sources have largely displaced agricultural use of greensands. The use of glauconitic greensands should only be considered when the glauconite content is > 70-80% glauconite, and for crops that require slow-release potassium resources, for example, coconuts, bananas, oil palm.

Leucite ($K(AlSi_2O_6)$) and nepheline ($KNa_3(AlSiO_4)_4$) as well as kalsilite ($K(AlSiO_4)$) are feldspathoids found in various rock types, specifically silica undersaturated volcanics and other alkaline rock suites. Large areas of East Africa's volcanic provinces are covered with volcanics that contain leucite, nepheline and in rare cases kalsilite. Also, alkaline complexes with nepheline-bearing rock suites are well described in parts of sub-Saharan Africa, mostly in eastern and southern Africa, associated with rift structures (Black *et al.* 1985). No use of nepheline- or leucite-rich rock materials has been reported, although Mathers (1994) mentioned the potential of these K-rich rock types as 'petrofertilizers.' Bioleaching experiments using leucite concentrate and the microorganisms *Penicillium expansum* and *Aspergillus niger* showed that between 21% and 27% of the potassium contained in the leucite mineral could be leached by microbial means (Rossi 1978).

Environmental and economic considerations are the driving forces in the move from highly reactive, soluble fertilizers towards the use of slow release fertilizers. The presently used K-fertilizers are not only soluble and easily available, they are also easily leachable nutrient sources, especially in sandy soils with little clay and organic matter. Many of these soluble K sources traded as K-fertilizers, for instance 'muriate of potash' – KCl, are salts, which can pose problems to salt-sensitive crops.

Novel approaches are needed to 'unlock' K from the silicate structure of these minerals in order to render K more available for plant and animal nutrition. Similar to long-term slow release natural fertilizers like rock phosphates, the two micas biotite and phlogopite, as well as some of the feldspathoids (for example, leucite) will gradually release K and Mg nutrients, but to be practical for agriculture and horticulture, the release rate might have to be speeded up. Some potassium-demanding crops like bananas, coconut trees, and rubber and oil palm plantations may benefit from the slow release of K from these minerals and rocks.