## 4.7 Ground silicate rocks

Silicate minerals and rocks contain most of the nutrients that plants require for growth and development. Ground silicate rocks have been investigated for their potential to provide these nutrients to plants in various soil environments. The application of ground silicate rocks to highly weathered, low fertility, acid soils has been proposed as alternative to conventional fertilization with water-soluble fertilizers in areas where fertilizers are not available or in organic agriculture (Leonardos *et al*. 1987, 2000; Von Fragstein *et al*. 1988; Coroneos *et al*. 1996). The effects of applying large tonnages of ground silicate rocks as by-products of the quarrying industry are part of an alternative sustainable strategy to 'remineralize' or 'recapitalize' degraded soils (Von Fragstein *et al.* 1988; Leonardos *et al*. 1987, 2000).

Most research on nutrient release from rock-forming minerals has focused on dissolution mechanisms, dissolution rates, pathways and processes of primary minerals in soils. While the mineralogical and geochemical processes involved in the dissolution of various rock-forming minerals have been well covered, pathways and reactions in complex soil systems are less well understood. They include physical, chemical, mineralogical and biochemical factors and interactions that control the processes at the interface between the minerals, solutions, air and organisms in soils. In a comprehensive paper, Harley and Gilkes (2000) reviewed the various factors, which influence the release of plant nutrients from silicate rock powders.

In laboratory studies Blum *et al.* (1989a,b) investigated 5 different silicate rock powders available in Austria for their suitability for agricultural application. They showed that under laboratory conditions the release rate of nutrients from these ground rocks was very low. Ground silicate rocks contain a high proportion of elements that have no importance for plant nutrition. However, Blum *et al*. (1989b) concede that certain smectite-rich volcanic ashes could increase the cation exchange capacity of poor soils, for example of forest soils, but that their use in conventional agriculture under temperate climatic conditions would be not suitable. Von Fragstein *et al*. (1988) carried out similar tests, analyzing 32 different ground rock samples for their water and HCl extractable cations, trace micronutrients and pH. The highest cation release rates were from phonolitic rocks followed by basaltic rock types. Granite powder released the least amounts of cations regardless of extraction method. In water extracts, the pH of all samples was alkaline with ground phonolitic rocks reaching a pH of > 10, basalts pH 8-10, and granites pH 7-10. Von Fragstein *et al.* (1988) question the effectiveness of applying only small amounts of ground silicate rock (1 t $ha^{-1}$ per year) and provide some figures on the high costs for the farmers for the various ground silicate rocks. It is apparent that large volumes are required to provide sufficient nutrients for sustainable growth of crops and trees.

So far, most investigations were carried out under laboratory conditions. In addition, experiments with rocks and minerals as potential nutrient supplying materials come mainly from temperate environments and only few investigations have been carried out under tropical conditions.

Investigations in temperate climates include the work of Bakken *et al.* (1997, 2000), who studied the fertilizing value of various K-bearing rocks and tailings on grasslands in Norway. The results of these trials under field conditions show that considerable parts of the K bound in biotite concentrate (from the feldspar production in Lillesand, Norway) and from nepheline in alkaline complexes and epidote schist is plant available. However, only 30% of the K added as ground silicate rocks was taken up by plants as compared to 70% from KCl. The weathering rate of the rock and mineral products was regarded as too slow to replenish the native pool of plant-available K within a three-year period with five harvests. The potassium held in potassium feldspar was almost unavailable to the grass plants (Bakken *et al*. 2000).

There are various mechanisms that can provide potassium from minerals to crops. For example, potassium can be released from phlogopite by biologically induced transformations (Berthelin *et al*. 1991; Hinsinger *et al.* 1993). The root zone of plants has proved a very active medium and habitat for microorganisms that enhance weathering and mineral concentration. In recent years the importance of biochemical processes at the root surface, and the role of microorganisms in the process of mineral weathering has been highlighted by Berthelin *et al.* (1991), Hinsinger *et al.* (1993) and Hinsinger (1998). Some minerals are more suitable for chemical and biological weathering than others and the release rates of nutrients from rock-forming minerals to roots and crops differ with differing physico-chemical and biological environments. In addition, weathering rates and kinetics in temperate climates are different from those in tropical and sub-tropical climates.

But not only the release of macronutrients from rocks and minerals has been studied. In field studies, Barak *et al.* (1983) demonstrated the effectiveness of finely ground basalt and basaltic tuff in micronutrient (Fe) fertilization of peanuts grown in calcareous soils.

While there are several studies in North America, Europe and Australia on the potential use of rock fertilizers, only very few studies and experiments have been published on rock-forming silicate minerals as soil amendments for agriculture and forestry in tropical soil environments. The few experiments that are reported indicate only the potential of ground rocks with high cation contents in tropical soils. Available data indicate that some of these minerals and rocks can be used as slow-release nutrient-supplying materials for crops in degraded tropical soils for agriculture and forestry (Roschnik *et al.* 1967; Leonardos *et al.* 1987, 2000; Gillman *et al.* 2000).

Leonardos *et al.* (1987) provided positive results of three greenhouse and field trials from lateritic soils in Brazil with beans (*Phaseolus vulgaris* L) and napier grass (*Pennisetum purpureum*). The potential of applying ground silicate rocks for tree fertilization purposes in the tropics is illustrated by the positive results of the initial experiments by Leonardos *et al.*(1987).

Studies by Gillman (1980) and Gillman *et al.* (2000) illustrate the positive effects of the application of large amounts of ground basaltic rocks on weathered soils of tropical Australia. The application of large quantities of ground basaltic rock raised pH, increased cation exchange capacities, and enhanced cation levels in soils.

In sub-Saharan Africa only few results of trials with crushed rock have been published. Among them are the results of greenhouse and field experiments from Zimbabwe and Mauritius. In Zimbabwe, Roschnik *et al.* (1967) tested finely ground basaltic rocks in strongly weathered Kalahari sands in glasshouse experiments. High application rates (5-40 tonnes per acre) showed exponential growth increase in total yield of two slow-growing legumes. The yield increase of sunflowers grown on Kalahari soils following treatment with 5-40 tons per acre of finely ground basalt showed a linear response curve (Roschnik *et al.* 1967). Increased yields of sugar cane are reported from systematic field trials in Mauritius (d'Hotman de Villiers 1961). Here, significant yield responses of sugar cane to the application of large doses (up to 180 tonnes per hectare) of ground basalt have been reported.

More research using ground silicate wastes from rock crushing operations for soil amelioration on acid strongly weathered tropical soils is necessary to validate positive results from greenhouse and field experiments. Also, the combination of ground rocks with soluble fertilizers and organic residues should be assessed. More laboratory, greenhouse and field studies need to be conducted with rocks and minerals with high cation concentrations and relatively high weathering potential, like feldspathoids, and mafic, ultrapotassic and potassic volcanic rocks. It is also important to better understand which soils and which plants may promote the dissolution of rock powders. These experiments must be carried out over a long time period in order to assess their long-term effect.

As with phosphate rocks, it is important to study inorganic-organic interactions and transformations using locally available organic materials in combination with rock and mineral materials. In addition, it is important to conduct economic and ecological studies as well in order to evaluate the practicality and sustainability of these systems.

Extensive parts of sub-Saharan Africa are covered with large volumes of relatively young basaltic and potassic/ultrapotassic volcanics and other potentially suitable silicate rocks. Young volcanic rocks are mainly found in rift valley environments in east and southern Africa, as well as in parts of West Africa. The challenge is to explore these and other suitable rock materials as potential ‘petrofertilizers’ and assess their agronomic potential for perennial crops and trees.