

## 6. Agrominerals and rocks for forestry, plantation crops and pasture

### 6.1 Applications of agrominerals in forestry

In sub-Saharan Africa, more forests are destroyed through human intervention than are regrown. So far, afforestation efforts have concentrated almost exclusively on plantation forestry with the aim of producing tree products for industrial purposes for export. This results in large amounts of nutrients being harvested and exported. Soils under managed plantation forests in Nigeria showed significant declines in organic carbon, N, P, K, Ca and Mg (Kadeba 1998). Examples from other parts of the tropics indicate that logging and other exports of biomass from natural tropical rainforests can cause serious depletion of nutrients (Nykvist 1998). Sustainable forestry is not possible without replenishing these losses. So far, however, forest management practices in large parts of the world do not include fertilization, largely because of lack of immediate responses in tree production and high costs.

Forestry studies in North America, Europe and countries along the Pacific indicate that some of the tree decline is due to changes in tree nutrition. While the tree decline and die-back in Europe is largely related to industrial and agricultural air pollution and subsequent nutrient losses (especially Mg), the die-back in the Pacific area is largely related to soil nutrient stress (Mueller-Dombois 1991). At a limited scale, tree fertilization and liming has been practiced in forests affected either by acid rains and/or those with nutritional disorders related to high atmospheric nitrogen loads (Wilmot *et al.* 1996). Several naturally occurring minerals have been tested as soil amendments in forests of Central Europe. One way of correcting the pollution damages to Europe's conifer forests is the application of kieserite (Mg-sulfate), and/or dolomite (Huettl 1990). In fact, liming forest soils is a widely practiced form of correcting deficiencies in forests of northern Europe (Huettl and Zoetl 1993). In New Zealand, where Mg deficiencies have damaged large plantation forests of *Pinus radiata*, the application of calcined magnesite (MgO) has resulted in a significant increase in soil exchangeable Mg (Mitchell *et al.* 1999).

Other agrominerals, for example, phosphate rocks from carbonatite operations, have been used with success in central Brazil for plantation forestry with *Eucalyptus* (Cerqueia *et al.* 1982, quoted in Appleton 1994). Simpson (1998) describes the widespread application of biogenic Nauru phosphate rock to pine plantations in south-east Queensland, Australia. In the early 1950s Nauru PR was applied by hand, but this was superseded in the 1970s by aerial nutrient spraying with TSP. The rate of application was 50 kg PR ha<sup>-1</sup>. In Brazil, the application of 2 kg basaltic rock into the planthole of *Eucalyptus* species in lateritic soils resulted in higher height and standard diameter than the application of 170 g of NPK (5-10-2) per hole over a six year period (Leonardos *et al.* 1987). The application of 2 kg of limestone with NPK also showed good responses.

So far, little work on replenishing tree nutrients in the form of fertilizers or agrominerals has been carried out in sub-Saharan Africa. For trees with high values grown in farmers fields, the use of local slow-release phosphate rocks in combination with locally available N and K organic resources (e.g. the prolific shrub *Tithonia diversifolia*) should be tested. As trees are long-term crops, the use of slow-release, cation-rich ground silicate rocks (petrofertilizers) in combination with locally available organic N sources should be tested agronomically in long-term trials.

### 6.2 Application of agrominerals in perennial plantation crops

The management of plantation crops like bananas, coconut, coffee, cacao, oil palm, pineapple, rubber, sugar cane and tea, as well as floricultural operations, requires considerable financial, technical and material inputs. Plantation schemes are for the most part export oriented, and run by large overseas or national companies. Plantation crops require considerable external inputs such as fertilizers, as well as efficient pest, disease and weed control. There are many social, environmental and market-related economic problems and vulnerabilities associated with the growing and managing these kinds of monocultures.

Imported fertilizers form the commonly used soil inputs in plantation systems. While there have been considerable efforts to formulate site-specific, highly effective soluble nutrient inputs for various plantation crops, there is increasing interest in less soluble, slow-release and maintenance-type nutrient inputs as well.

The nutrient requirements of plantation crops differ. While some require mainly N inputs, there are some perennial plantation crops for which slow-release agromineral inputs are suitable and in use. The main agrominerals involved are phosphate rocks, Mg-containing rocks and liming materials. In particular, the application of phosphate rock on tea, rubber, oil palm, and to a lesser degree sugar cane, seem to have positive value-to-cost ratios (van Kauwenbergh and Hellums 1995).

### Cacao

Cacao is grown in many tropical countries approximately 15° North and South of the equator at altitudes not higher than 650 metres. Cacao is grown in plantations and/or interspersed with other crops and trees, largely under shade. The effectiveness of reactive phosphate rock as a P source for cacao has been demonstrated in Malaysia. PR is used in cacao nurseries during pre-planting along with ground Mg-limestone, and in the planthole on acid P deficient soils. In the past, mainly PR imported from the Christmas Islands was applied in the cacao plantations of Malaysia, although in recent years other PRs have also been imported. Recent data show that the imported North Carolina PR was as effective as TSP (Yusdar and Hanafi 2001). Although West Africa (Ghana, Nigeria, Côte d'Ivoire, Cameroon) is the major supplier of cacao in the world, no data on the utilization of phosphate rocks, local or imported, or dolomite in cacao plantations are available.

### Oil palm

The production of edible oil from oil palm plantations plays a major role in the economy of many tropical countries. In Malaysia, the world's leading producer of palm oil, some 3.46 million hectares are covered with oil palm plantations and oil palm growing areas. In sub-Saharan Africa large oil palm plantations are found in West Africa.

Since 1929 long-term experiments comparing various PRs in comparison with soluble P fertilizers have been conducted in Malaysia (Zin *et al.* 2001). The research included studies of P effectiveness in various stages of growth, from the seedling stage to mature oil palm stands. The results of intensive research on the effects of PR treatments on various soils show that soluble P fertilizers are more effective at the seedling stage, but that most PRs are as effective as soluble P sources for mature oil palm production (Zin *et al.* 2001). Limestone and dolomite as well as ground PR (at a rate of 1 tonne per hectare) are applied to the soils for leguminous cover crops between the oil palms in the immature growth phase (Zin *et al.* 2001). The application of K as a major nutrient for oil palm production is important, as is the use of Mg sources. Magnesium nutrition of oil palms in plantations is commonly covered by the application of kieserite (Mg-sulfate) and dolomite. It is not known whether any of the PRs of sub-Saharan Africa have been tested in West Africa's oil palm plantations.

### Rubber

Rubber is grown in equatorial lowlands of tropical Asia, Africa and South America below 200 m altitudes. Rubber exports provide a large contribution to the national revenue of countries like Malaysia, where rubber plantations occupy about 1.4 million hectares.

While water-soluble P fertilizers are clearly more effective in the seedling stage, the application of 2 kg PR per tree over a six year period has been an effective P source for rubber tree growth. With the application of 2 kg of relatively unreactive PR from the Christmas Islands, the trees could be tapped 22 months earlier than the control trees (de Geus 1973). In Indonesia, where about half of the rubber is produced by smallholder farmers/foresters in 'jungle rubber' systems, the application of 1 tonne of PR per

hectare resulted in significantly enhanced growth and brought forward the start of rubber harvesting by 1 or 2 years (Penot *et al.* 1998). The greatest response of PR is in the establishment phase. In addition, the application of PR will also stimulate the growth of cover crops.

Magnesium deficiencies are widespread in rubber plantations of southeast Asia and West Africa. Mg fertilizers are applied in the form of MgO (calcined magnesite) in rubber plantations in southern China (Michalk and Zhi-Kai 1992). From sub-Saharan Africa there are few data on PR utilization on rubber plantations available. Newly planted rubber trees in Ghana use 90 g phosphate rock in the planting hole (de Geus 1973). Kieserite and dolomite are used as the Mg component. Leguminous cover crops of *Pueraria phaseoloides* provide some of the nitrogen requirements during the maturing phase of rubber tree growth.

### Sugar cane

Sugar cane is grown in most tropical and subtropical countries and requires an ample water supply. While N is the prime nutrient required, no good response to N fertilization can be obtained without sufficient P and K. Phosphorus can be supplied in various forms, including phosphate rock. Recent research on acid, P-deficient soils of south China illustrates the effects of various phosphate rocks on sugar cane production (Huang *et al.* 2001). The application of the reactive North Carolina PR showed good residual effects when applied at the highest rates of application (125 - 250 kg P ha<sup>-1</sup>). In comparison, the Moroccan phosphates were less effective, and the PR originating from China was the least effective of those tested (Huang *et al.* 2001).

Sugar cane soils, low in silicon, have responded economically to the application of calcium silicate slags (Ayres 1966; Anderson *et al.* 1991). In Mauritius, large applications of ground basalt increased sugar cane yields (D'Hotman de Villiers 1961). The application of large tonnages of ground rock is made possible by the close proximity of industries in which the crushed rock is a by-product.

Another agromineral required by the sugar cane industry is lime, used in the processing of the sugar juice. The resulting large amounts of 'sugary lime-wastes' have good fertilizing properties but are often discarded.

### Tea

Tea is mostly grown on strongly weathered acid soils. It is commonly cultivated at high altitudes in the humid and sub-humid tropics where annual rainfall exceeds 1,500 mm. While tea plants require significant N applications, the needs for P are small. Phosphorus acquisition by roots is enhanced via higher rhizosphere acidification, root exudation and mycorrhizal association (Zoysa *et al.* 1999). Tea can be fertilized effectively with low cost phosphate rocks. Examples of PR applications are mainly from India and Sri Lanka (de Geus 1973; Sivasubramanian *et al.* 1981). In sub-Saharan Africa, local PR sources have only been tested in a few places, notably in Malawi (Appleton 1994), where field data from tea plots in the Thyolo area showed positive responses after two years of application of Tundulu PR (Appleton 1994).

### Organic wastes from plantation crops.

Plantation crops commonly produce large amounts of organic residues and some of these 'wastes' could be used to enhance the performance of agrominerals. For example, research in Brazil has shown that residues from the sugar industry can be used as substrate for growing microorganisms that partially solubilize unreactive phosphate rock (Cerezine *et al.* 1988). The utilization of sugary wastes from sugar cane and pineapple operations should be investigated for their potential to enhance the solubilization of phosphate rock and various K-silicates.

### 6.3 Pasture

Large parts of sub-Saharan Africa consist of natural grassland, and extensive cattle grazing on savanna land is common. There are only few areas where extensive grazing on improved grass-legume mixes is practiced, mostly in areas with more temperate climates. There are even fewer pasture schemes with intensive management in Africa. Fertilization of pastures is rarely done in sub-Saharan Africa, largely for economic reasons. Most research on phosphate rocks and liming materials in Africa is done to increase production of annual food crops. Research efforts on intensive pasture management in Africa and elsewhere concentrate on improvement of the grass-legume mixes and the introduction or maintenance of nitrogen fixing legumes.

In some parts of the world, the move to improve pastures includes the use of phosphate rocks. For example, in tropical Australia the need for P fertilization for intensive pasture management has been the focus of a major national research initiative: 'The role for reactive phosphate rock fertilisers for pasture in Australia' (Bolland *et al.* 1997; Sale *et al.* 1997; Simpson *et al.* 1997). The results of this research on direct application of cost-saving rock fertilizers for pasture are published in a book (Sale *et al.* 1997) and a special issue of the Australian Journal of Experimental Agriculture (Vol. 37, No. 8: 845-1098). Sale *et al.* (1997) conclude that under conditions of low pH, high rainfall and certain soil conditions, reactive phosphate rock is an effective P fertilizer in the short- or medium-term for permanent pasture.

Hedley and Bolan (1997) summarized the results of similar research on directly applied reactive phosphate rock in New Zealand. Here, the tests included partially acidulated phosphate rocks (PAPR). Experiments on volcanic soils illustrate the high agronomic effectiveness of PAPR on ryegrass-white clover permanent pasture (Rajan 1987b).

In Latin America, most of the directly applied PR fertilizers are used for improved pastures, especially in Brazil and Colombia (Appleton 1994). Best responses were obtained by applying both N and P sources. Steady yield increases over time have been found on Brazilian oxisols when applying the otherwise unreactive PR from Araxa (Leon *et al.* 1986). In East Africa, an example of base fertilization on pasture using phosphate rock comes from northwestern Kenya. Phosphate rock fines from the 'hard phosphates' of the Busumbu PR deposit in eastern Uganda were applied directly on pastures in the 1950s (Atkinson and Hale 1993; Mathers 1994).

Magnesium deficiencies have been identified in pastures on infertile acid soils of subtropical China. Here, correction with magnesium sources resulted in significant yield increases in subterranean clover (Michalk and Zhi-Kai 1992). Magnesium deficiencies of pasture soils can be addressed through the use of local Mg rock sources, specifically finely ground dolomitic limestone or calcined magnesite. In New Zealand some of the Mg inputs for pasture come from the addition of the Mg-rich silicate rocks dunite and serpentinite, and from superphosphate fertilizers (Chittenden *et al.* 1967). In some cases, fertilizers with micronutrient additions (for example Mo) are introduced in order to improve the composition of the grass-legume pasture.

The fertilization for intensive pasture production in sub-Saharan Africa is largely a function of costs. Small-scale farmers who cannot afford fertilizers for annual food crops are unlikely to use fertilizers or agrominerals for intensive pasture fertilization. Promising new directions include the use of low-cost locally available phosphate rocks to enhance fodder crop production near the cattle pens of zero-grazing farms and in phospho-composting systems (Odongo 2002).