90%, as compared with the control, and the related products did so to a lesser extent (Hell, 1988; Laborius, 1990b). Realistic field trails would be needed to assess the cost-effectiveness of these products and their effectiveness against infestations of mixed species.

Fumigation with phosphine was applied in a somewhat unorthodox way, soon after the appearance of larger grain borer in Togo, to disinfest rural stores. Polythene sheets were pulled over entire stores (as illustrated in Krall, 1984), apparently giving a satisfactory seal for at least 52hrs. Though technically successful, the method was clearly not suitable for extensive application, or for use by the farmers themselves. As noted by Hodges (1986), larger grain borer appears to be susceptible to fumigation in bulk stores in the normal way, though the effectiveness of such treatments has become an issue in relation to the international grain trade. Phosphine fumigation was shown to kill all stages of larger grain borer, including the eggs, when 'reasonably gas-tight conditions' were maintained for five days (Taylor and Harris, 1989); the authors recommended a minimum application rate of 1g phosphine per m^3 at 20°C, but noted that higher rates would normally be needed for control of *Sitophilus* spp. The efficiency of phosphine fumigation against the eggs of larger grain borer was confirmed by Hashem & Reichmuth (1989). Methyl bromide has also been shown to be an effective fumigant for this pest. An exposure time of 17hrs, with a concentration of 5mg/l at 30°C was required to kill the most tolerant stage, the pupa (Detmers, 1990).

Plant and mineral products

Concerns relating to the possibly damaging impact of synthetic pesticides on human health and the environment, as well as socio-economic obstacles encountered in the attempt to introduce pesticide use to otherwise traditional systems, have led to renewed interest in the use of alternative materials, traditional and novel, for the protection of grain. One of the most widespread traditional grain treatments reported from the larger grain borer's area of origin is the addition of lime, sprinkled on cobs at unspecified dosage (Anonymous, 1988a; Rodríguez, 1990b). More controlled tests of the application of lime indicate that it can indeed significantly reduce insect damage, including that caused by *P. truncatus*, at doses of 1% (Hoppe, 1986; Sánchez, 1987), 2% (Sánchez, 1987), 3% (Anonymous, 1988b) and 1lb/2m^2 (Espinal, 1986). In Honduras, lime was found to be more effective than malathion, though less so than pirimiphos methyl, and, combined with improved storage practices, gave a net economic advantage to farmers (Espinal, 1986).

Other traditional treatments prevalent in Africa include the addition of sand and ash, alone or in combination. Results of controlled trials of these products have usually been marginal or inconclusive (Cíntora, 1958; Golob *et al.*, 1983; Golob, 1988a) and sometimes large quantities of material are required in order to provide protection. For instance, at least 20% admixed sand and ash was required in a Tanzanian trial (Golob, 1988a), implying the need for considerable work, both to treat the grain initially and clean it before consumption. One more promising material identified in these trials was paddy husk ash (Golob, 1988) which, admixed at 5% (weight/weight), maintained grain weight loss as low as 3.7% after 8 months, compared with 31.8% in the control (Golob & Hanks, 1990).

One of the most active projects seeking to re-evaluate traditional materials and test new ones has been that at the Colegio de Postgraduados in Mexico, which has considered dusts of both mineral and vegetable origin (Anonymous, 1988a; Lagunes-Tejeda, 1989; Rodríguez, 1987; Rodríguez & Lagunes, 1990; Sánchez, 1987). Among 22 dusts evaluated initially, black 'tezontle' (petrified lava), at a dose of 0.1%, and ash from the volcano Chichonal (situated in the south-east of Mexico), at a dose of 0.5%, seemed to be the most effective treatments (Anonymous, 1988a; Rodríguez & Lagunes, 1990). Eight 'inert' dusts normally used as fillers in the formulation of commercial insecticides, mostly composed of different proportions of silica and calcium carbonate, were also tested for their own protectant properties. After six months, at an application rate of 1%, all products showed less damage than the control, but at 0.2% they provided no protection against larger grain borer (Sánchez, 1987).

In the first phase of the same project, 68 plant-derived dusts were tested, of which the best results were obtained with the root of 'cancerina' (*Hippocratea* sp.), the complete plant of castor (*Ricinus communis*) and the leaves of lavender (*Lavandula angustifolia*) all at a dose of 0.1% weight/weight (Rodríguez, 1987; Anonymous, 1988a). In addition, positive results have recently been obtained with nine more plants, amongst which appear once more the roots and leaves of *Hippocratea excelsa* and *R. communis*, as well as those of *Ribes ciliatum* and *Eupatorium odoratum*; higher mortality and lower emergence of the insect were the selection criteria (Rodríguez & Lagunes, 1990). Various of these materials, such as