H. excelsa, have been used in rural and commercial storage in various regions of Mexico (Anonymous, 1988a).

Other plant products, such as the dry seed of *Crotalaria juncea* and leaves of *Melia azedarach*, *Azadirachta indica* and *Tephrosia vogalii*, have been tried at 5% (weight/weight), as well as an aqueous extract of pyrethrum at 1%, but all were found to be ineffective for control of the larger grain borer after 32 or 40 weeks of storage. Even though some of these treatments showed significantly less damage than the control, their effectiveness varied from one year to the next and was lower than that provided by synthetic pyrethroids (Golob & Hanks, 1990). Two more detailed laboratory studies considered the action of *Crotalaria ochroleuca* on the larger grain borer. Five and 10% of milled *C. ochroleuca* seeds mixed with the insect's diet reduced larval growth and slowed development (Schulleri, 1989). In another study 5.0% whole seeds had the same effect as 0.5% admixed milled seed (Nielsen, 1986). In neither study was an acute toxic effect of this plant on *P. truncatus* observed. When three plants used locally in Costa Rica as grain protectants were tested, none showed a toxic effect on larger grain borer, but one (leaves of *Gliricidia sepium*) showed significant repellency (Boeye, 1988 & 1990).

Unfortunately, few of these studies report on the toxicological implications of the admixed products. In the case of most of the mineral dusts the deleterious effects on the insect arise mainly from the physical characteristics of the products, such as a tendency to abrade the cuticle and cause desiccation, or, in larger quantities, simply to form a barrier to insect penetration. No acute toxic effect on mammals would be anticipated, but such products may irritate mucous membranes. Some of the plants mentioned, on the other hand, are known to be significantly toxic to mammals, as in the case of *R. communis*. It would surely be a mistake to assume that plant products, in general, cannot leave toxic residues on the grain stored with them.

Physical control measures

Traditionally, the exposure of cobs and grain to the heat and smoke from cooking fires and to sunlight has been used as means of both drying grain and directly discouraging insects, both in Africa and the New World tropics. In general, larger grain borer seems more resistant to these strategies than most other storage insects (Golob & Hodges, 1982; Hodges *et al.*, 1983a).

However, in a more recent study in Togo, Pantenius (1988) showed that regular smoking can discourage even *P. truncatus* damage.

McFarlane (1989) explored the thermal tolerances of larger grain borer in more detail and showed that a total kill could be achieved by exposing infested grain to 50°C in an oven for one hour or by exposure to simulated solar radiation in a solar cabinet for 2-3 hours. The tests suggested that direct exposure to sunlight (without a cabinet) would not achieve the critical temperature for disinfestation, though some pest reduction might be achieved. As the author remarks, further trials are needed to confirm the conclusions under real tropical conditions, particularly to ensure that excessive temperatures, which might adversely affect the germination rate, are not reached.

A series of studies has been carried out in Mexico regarding the effects of various kinds of radiation on larger grain borer. Exposure to 5krad (at 2.7krad/min.) from a ^{60}Co gamma ray source resulted in a total kill of *P. truncatus* within 28 days of exposure; increasing the total dose to 50krad and 100krad (applied at the same rate) shortened the time to achieve a complete kill to 15 and 12 days, respectively (Adem *et al.*, 1979). Increasing the dose rate (for the same total dose) had little effect (Adem *et al.*, 1979 & 1987). *P. truncatus* was considerably less sensitive to accelerated electrons than to gamma rays (Adem *et al.*, 1987). Exposure to a 15krad dose of gamma rays produced 100% mortality within 15 days; in the meantime, only 3.3% of irradiated females laid eggs and only 1.5% of these eggs hatched (Ramírez & Ramos, 1980). Deleterious effects of exposure to laser light were also reported in a series of experiments. Exposure of *P. truncatus* adults without grain to doses of 120J or above resulted in the population dying out completely within 180 days, but if the insects were exposed within grain a proportion of the population survived beyond this time (Ramos, 1983). Differing effects on larval development rate and mortality with different exposures are described by Ramos *et al.* (1983 & 1984) and in the thesis of Calcáneo (1979). Prolonged exposure to an uniform magnetic field also had negative effects on the larger grain borer; after 90 days, higher mortality, weak cocoon formation and a lengthening of the life cycle were observed (Urbán, 1982). Exposure to a 250W infra-red lamp achieved a total kill of *P. truncatus* adults in only 38 seconds; the simultaneous application of a magnetic field reduced the necessary time to 36.7sec at 1kgauss and 27.5 at 3kgauss (Urbán *et al.*, 1982). Presumably the heating involved in such treatments would be likely to reduce the viability of the grain at the same time as disinfesting it.