Although radiation has been used successfully to control insects in large-scale grain handling facilities, larger grain borer can usually be satisfactorily controlled in such circumstances by more conventional methods, especially fumigation. It therefore seems unlikely that control of this pest would normally justify the considerable investment involved in grain irradiation technology.

Hermetic storage in metal drums is known to provide good control of all storage insects, including larger grain borer (Giles & Leon, 1974), but the high initial cost of the drums in some areas and the tendency for people to use them for other purposes, limits their use in rural grain storage. Plastic bags provide a cheaper alternative but insects tend to perforate the bags, even if the grain inside is fumigated initially (Giles & Leon, 1974). More recently it has been suggested that multi-layer films could improve the perforation resistance of bags and that such materials, suitably fabricated, could be used to provide airtight containers within traditional structures (Troude, 1988). Although this technology may well have applications in commercial packaging (Fleurat-Lessard & Serrano, 1990), the technical and economic obstacles to its use in rural storage seem considerable.

Biological control

In recent years there has been an explosion of interest in the possibility of using biological control against larger grain borer. Classical biological control, involving the permanent establishment of introduced natural enemies, would have the advantage of requiring little or no change in storage practices on the part of farmers and therefore minimal intervention from extension services. This would circumvent two frequently encountered limitations on the introduction of other non-traditional technologies (Markham, 1990). Even if an inundative approach proved necessary (involving, for instance, yearly application of a pathogen), this approach would still have the advantage of avoiding toxic pesticide residues on food and would reduce the risk of inducing resistance in the pest population. The search for appropriate natural enemies and methods for their application was declared a priority for coordinated international action at a meeting in Arusha, Tanzania, in 1988 (Anonymous, 1988b). This effort has been sustained through specially-targeted meetings held in Cotonou, Benin, in 1989 (Markham & Herren, 1990) and Lomé, Togo, in 1990 (proceedings in preparation).

The first indication that larger grain borer might be subject to control by natural enemies came from identification records of the histerid, *T. nigrescens*, in association with the pest in maize samples from Mexico (Haines, 1981). This observation led researchers at the Natural Resources Institute (NRI) to begin laboratory studies of the predatory ability of *T. nigrescens* (Rees, 1985 & 1987). The search for biological control agents began in earnest in 1984 with the establishment by the Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) of a project involving comparative field studies in Africa (Tanzania and Togo) and Central America (Costa Rica), supported by laboratory studies in Europe (Boeye *et al.*, 1988; Laborius *et al*,; 1989; Laborius, 1990a). Studies already cited, showing that losses were higher in Tanzania (Keil, 1988) and Togo (Pantenius, 1987 & 1988) than in Costa Rica, formed part of this initiative (Laborius, 1990a).

Among insect natural enemies, two pteromalids, *A. calandrae* and *Choetospila elegans* (Westwood), were found to attack larger grain borer in Costa Rica. These parasitoids could slow pest population increase in cage trials and in laboratory studies achieved a high rate of parasitism if infested grains were spread out so as to expose them fully to the parasite (Böye, 1988; Boeye, 1990). However, these species were already known as parasitoids of various storage pests, with a wide distribution, including Africa. Two predators, *Calliodis* sp. and *T. nigrescens*, were encountered attacking larger grain borer in Costa Rica, but not in Africa (Böye, 1988; Boeye *et al.*, 1988). *Calliodis* sp., an anthocorid, showed some promising characteristics but only occurred late in the storage season and was not considered further for introduction to Africa, partly on the grounds of its comparative fragility and inability to survive without hosts in the desiccating conditions of grain stores (Boeye, 1990). *T. nigrescens*, in contrast, was able to survive for at least three months on maize without prey (Leliveldt & Laborius, 1990). This predator has subsequently been shown to be able to feed to a limited extent, though not to reproduce, on a variety of stored products (Laborius, report to coordination meeting in Lomé, Togo, 1990).

Laboratory studies initiated at NRI showed that *T. nigrescens* is a voracious predator of *P. truncatus*, capable of suppressing laboratory populations of the pest, both alone and with other storage pests, on shelled maize and on cobs (Rees, 1985, 1987, 1990b, 1991). The histerid larvae consumed up to 3.5 prey larvae per day, consuming some 60 prey to complete their development (Rees, 1985). Similar results were obtained in laboratory studies in Germany, though higher consumption rates (averaging 5.7 eggs or 4.9 larvae per adult predator per 24 hours) were observed when predators foraged in continuous darkness (Leliveldt & Laborius, 1990). Some feeding and reproduction on storage pests other than larger grain borer was observed: *T. nigrescens* could reproduce on *Sitophilus oryzae* (Linnaeus) (Leliveldt, 1990), *R. dominica* (Leliveldt, 1990; Rees, 1991), *Dinoderus minutus* (Fabricius)(Rees, 1991) and *T. castaneum* (Rees, 1987), causing various degrees of suppression of their population growth. Among the bostrichids, *T. nigrescens* controlled *D. minutus* and *P. truncatus* more effectively than the smaller *R. dominica* (Rees, 1991). A reduction in the number of progeny of *Oryzaephilus surinamensis* (Linnaeus), *Cryptolestes ferrugineus* (Stephens) and *Carpophilus dimidiatus* (Fabricius) was also observed (Leliveldt, 1990). The lack of strict specificity, and even a tendency to cannibalism, on the part of this histerid has been seen as a favorable characteristic, helping to ensure the predator's survival during periods of scarcity of larger grain borer (Leliveldt & Laborius, 1990).

Although not prey-specific, *T . nigrescens* appears to be well adapted, behaviorally and morphologically, to locate larger grain borer infestations (Rees, 1990b). *T. nigrescens* is attracted from a distance by the pest's aggregation pheromone (Böye, 1988; Schulz & Laborius, 1987) and, within bulks of grain, responds to the frass of, or grain infested by, the larger grain borer (Rees, 1990b). In field studies, the incidence of the two species was found to be closely correlated, both when trapping in stores (Böye, 1988; Laborius *et al.*, 1989) and using flight traps (Rees, 1990b). Studies to test the ability of *T. nigrescens* to feed on a range of stored commodities and beneficial insects were completed in parallel with cage trials in Togo during 1990 (Laborius, reports to coordination meeting in Lomé, Togo, 1990) and small-scale field releases of the predator began in early 1991.

Comparative studies of microorganisms pathogenic to *P. truncatus* in Tanzania and Central America were also made (Boeye *et al.*, 1988; Laborius, 1990a). Seven out of 23 fungal isolates and two out of 14 bacterial isolates from Central America were found to be somewhat pathogenic to larger grain borer; the diversity of fungal pathogens was lower in samples from both Mexico and Tanzania (Burde, 1988). Unfortunately, the most pathogenic fungi were *Aspergillus* spp. whose use as control agents in rural maize stores can be discounted in view of the danger of toxic meta-bolites. Two more promising fungal isolates (*Beauveria bassiana* and *Metarrhizium anisopliae*) were obtained from non-storage insects (Burde, 1988). Two isolates of the bacterium *Bacillus thuringiensis* have been tested in Mexico, though detailed results are not reported (Ibarra & de León, 1989).