granulosis virus of Indian meal moth is being patented. We have completed research on the efficacy and use of controlled atmospheres (high CO_2, low O_2) for control. In cooperation with engineers at the University of California, Davis, one of our scientists is investigating the use of extremes of heat and cold for control. Pheromones to disrupt mating of quarantined pests is also being investigated. Since some of these treatments do not afford extended protection it is quite possible that those treatments causing rapid kill (heat treatments) will be integrated with techniques providing control over extended periods (microbials). Thus programs providing immediate mortality along with extended protection might be devised.

Deterioration of Pirimiphos-Methyl and Chlorphyrifos-Methyl Residues on Stored Grains

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Data on the degradation of pirimiphos-methyl (PM) and chlorpyrifos-methyl (CM) on stored corn, wheat, oats, and rough rice were compiled from published literature. Data included various initial rates applied to grains, and residues monitored for different durations of time (6–24 months). A perusal of all studies indicated that the amount of residue of PM or CM on grain recovered 0–24 h after application was either greater or lesser than the amount originally applied to grain. Increased or decreased recovery of insecticide after treatment is attributable to improper application procedure resulting in non-uniform distribution of insecticide on kernels, loss of insecticide from exterior to interior of kernels or loss to neighboring kernels, and loss of residue during the extraction process. Comparisons could not be made between studies because the initial rates applied to grain were different. However, degradation data from each of the studies were fitted to an exponential decay model. The model was of the following form:

$$R_t = R_0 \exp^{-kt} \tag{1}$$

where R_t = residue at time t in future; R_0 = residue immediately ($t = 0$) after application of insecticide to grain; k = decay constant; and t = time in weeks. Models fitted to data within a study were used for comparing the influence of various factors (see below) affecting degradation. Half-life of PM or CM applied to grains was calculated for each study by rearranging eqn (1) as follows:

$$\text{Half-life} = \ln(2)/k \tag{2}$$

Degradation of PM residues on wheat of 16% moisture content was faster compared with degradation on wheat of 10, 12, or 14% moisture content. The

degradation curves for PM applied to corn and wheat at an initial rate of 10 ppm were similar. CM degradation on hulled and hull-less oats was similar. Aerating the grain did not decrease the rate of CM degradation, during the 16-week test period. Unlike malathion, PM and CM residues dissipate very slowly on high moisture grain (about 14% moisture content), with k across all studies ranging from 0·001 to 0·05. Half-lives of PM and CM varied with the value of k, which varied among studies. There was no information in literature on the effects of temperature on degradation of PM or CM on grains. However, field studies indicated that under normal storage conditions, these insecticides applied at a recommended rate of 6–8 ppm are relatively stable compared with malathion.

Bioassays with treated grain at regular intervals of time indicated that the residues of PM or CM were effective for 9 months in controlling adults of the rice weevils, red flour beetles, and saw-toothed grain beetles. However, adults of the lesser grain borer were able to survive and reproduce on PM- or CM-treated grain compared with the other insect species. Hairy fungus beetles survived on grain treated with PM; and adults present on treated grain required about three times the recommended dose to kill 50% of the exposed population. These findings suggest that adults of certain stored product insects may be naturally tolerant or have the potential for developing resistance to PM or CM.

PM and CM applied at 6–8 ppm are effective in suppressing insect infestations in stored grain for about a year. However, care should be taken during application to deliver the proper dose of insecticide evenly to the grain being loaded into storage. In addition, these two new organophosphates should be used to supplement and not substitute other non-chemical and chemical insect control tactics for managing insects in storage ecosystems.