Grain protectant chemicals[1]: present status and future trends

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Abstract

After a brief introduction this paper presents several key market and biological constraints on the development and usage of protectant chemicals. These are: costs of protectant development; regulatory requirements; consumer preference for residue-free foodstuffs; increasing resistance of pests to protectants; and rapid degradation of organophosphate protectants currently in use. The potential of the pyrethroids for use in grain protection in the United States is then assessed. Finally, the likely future role of protectants in integrated pest management is discussed.

Introduction

For many years, insect pests in stored grains were controlled primarily by the direct application of a protectant chemical as the grain was loaded into storage. The application rate was sufficient to give residual control for most if not all of the usual storage period. This preventative approach for insect pest management was favoured for a variety of reasons, including simplicity of application, the vulnerability of the crop during the initial months of storage, the difficulty of adequately sampling large storage bins to determine the extent of insect infestations, and the requirements of the various marketing channels for stored grains. Supplemental control during the storage season was accomplished primarily by a fumigation which would kill existing populations but give no residual protection. Non-chemical controls such as sanitation and aeration played a relatively minor role as compared with the chemical inputs.

In recent years several protectants have been lost to the post-harvest market, either by regulatory action or through the development of insecticidal resistance in the important pest species. The successful development and refinement of integrated pest management (IPM) programs in field crops have sparked new research on stored grain ecosystems. Some scientists are questioning the necessity of protectants as a part of a modern IPM program, and are advocating alternative control methods such as biological control, aeration, sanitation, increased monitoring and sampling, etc. The fact that residues are on food, regardless of the actual amount of these residues, is becoming less and less acceptable to consumers. I will identify and discuss several issues that will affect the continued use of protectant chemicals for insect pest management in stored grains. Although these concerns and issues reflect current conditions in the United States, they are applicable to stored grain systems world-wide.

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[1] Mention of a chemical does not constitute a recommendation or endorsement by the U.S. Department of Agriculture.

Market and Biological Constraints for Protectants

Developmental expense

The increasing costs of developing and marketing new insecticides in the United States and other developed countries will certainly limit the availability of new protectants. It will be difficult for a registrant to recover the developmental costs of a stored-product protectant. A chemical registered for field crops can be used several times during the growing season. These field chemicals may be applied several times during the growing season. These field chemicals may be applied several times during the growing season on vast areas. This is in contrast to a protectant that can be used once on crops loaded into a confined storage structure. Also, raw grain is a relatively low-value commodity. Farmers, elevator managers, and others responsible for grain management will not purchase and use a protectant if costs are prohibitive.

Regulatory requirements

The requirements of regulatory agencies such as the U.S. Environmental Protection Agency (EPA) and similar organisations in other countries add to the developmental costs of new products. Rodgers (1993) references a publication in 1989 which estimated the registration costs of bringing a compound to market in the U.S. at 20 million dollars. The extensive data requirements and documentation in the various phases of the registration process comprise a significant portion of the developmental costs. Currently, only two companies in the United States market protectant chemicals for stored grains. Other agricultural chemical companies may enter the protectant market if they perceive an acceptable profit; however, future replacements for existing products will be limited at best.

Consumer preferences

Consumers in the United States are expressing concerns regarding potential health risks associated with long-term dietary exposure to chemical pesticides used in agricultural pest management. Pesticide residues in food are identified as a major safety concern (Beall et al. 1991). Children are viewed as especially vulnerable to any adverse effects caused by exposure to pesticide residues. In 1990, the EPA rejected an Emergency Use Petition (EUP) from the States of Georgia, Florida, and Alabama for pirimiphos-methyl on stored peanuts, partly because 'the agency's acute dietary exposure analysis indicates that its use on peanuts would significantly increase dietary expoures of children, resulting in inadequate dietary Margins of exposure (MOE) for a subtantial portion of this testing on effects of pesticide residues on specific target groups such as children, registration costs will undoubtedly increase. In an attempt to satisfy consumers, grain processor could conceivably specify residue-free grain as a condition of purchase. If this were to become a widespread practice, protectant usage would undoubtedly diminish.

Protectant resistance

The development of insecticide resistance will affect future use of protectants. Malathion resistance has been extensively documented for a number of agricultural systems world-wide, including stored products. malathion will not be re-registered as a grain protectant in the United States. Once it is removed from the market, the organophosphates chlorpyrifos-methyl and pirimiphos-methyl will be the only protectants registered in the United States. There are several recent reports of chlorpyrifos-methyl resistance in the lesser grain borer, *Rhyzopertha dominica*, collected from field storages in Oklahoma. This major insect pest of stored wheat has been removed from the chlorpyrifos-methyl label. Subramanyam et al. (1989) found low levels of chlorpyrifos-methyl resistance in sawtoothed grain beetle, *Oryzaephilus surinamensus*, strains collected from stored barley in Minnesota. Zettler (1991) reported chlorpyrifos-methyl resistance in red flour beetle, *Tribolium castaneum*, and confused flour beetle, *Tribolium confusum*, strains collected from flour mills. Wienzeryl and Porter (1990) found a single strain of hairy fungus beetle, *Typhea stercorea*, to be resistant to pirimiphos-methyl. There are currently no published reports of multi-strain resistance in a major pest species. Isolated incidents of resistant strains of other pest species have been reported for pirimiphos-methyl by Halliday et al. (1988), Arthur et al. (1988), and Summer et al. (1988).

Residue degradation

Organophosphate compounds used as grain protectants tend to degrade rapidly when commodity temperature and moisture content are evelated (Desmarchelier and Bengston 1979; Samson et al. 1987, 1988; Snelson 1987). Arthur et al. (1991) showed that after two months chlorpyrifos-methyl degradation on maize stored at 30.0 and 37.5°C was approximately 68 and 88% of the measured deposition after application (Table 1). Another test with wheat (Arthur et al. 1992) showed loss rates of approximately 49 and 68% after two months on wheat stored at 30 and 35°C (Table 2). This increased degradation at higher temperatures limits the effectiveness of organophosphate protectants in hot humid climates, particularly where there is an extended storage period before the onset of cooler weather.

New Protectant Chemicals

Developmental research in the United States on new grain protectants has focused on pyrethroids as replacements for malathion. Unlike organophosphates, pyrethriods do not break down at high temperatures and moisture contents, and may be more efficacious than organophosphates as protectants for grains stored during warm weather. Pyrethroids synergised with piperonyl butoxide and applied alone or in combination with organophosphates have been used in control programs in Australia for several years. However, no pyrethroids are currently labelled in the United States for use on stored grain. Because market conditions and potential regulatory actions may limit the use of piperonyl butoxide, any registrations for pyrethroids probably will not include the synergist.

An ideal pyethroid protectant would be applied at a dosage that is both economical and efficacious toward the major pest species of that particular commodity. Species variability is a potential problem with some pyrethroids. Studies indicate that application rates of bioresmethrin and resmethrin (Arthur 1992), deltamethrin (Arthur 1994), and cyfluthrin (Arthur, unpublished data) that control the lesser grain borer do not control the rice weevil. Combination treatment of these individual pyrethroids plus an organophosphate will kill both species. A mixture seems to be a logical approach because of the susceptibility of the lesser grain borer to pyrethroids. Also, a mixture may be desirable for economic considerations.

Table 1. Chlorpyrifos-methyl residue (ppm, x ± SEM) on corn stored at two temperatures and three moisture contents (m.c.) and sampled at bimonthly intervals (residue at application was 4.9 5± 0.67 ppm).

Month of storage	11.4% m.c.	12.4%m.c.	14.4% m.c.
		30°C	
2	1.90 ± 0.08	1.70 ± 0.16	1.65 ± 0.11
4	1.28 ± 0.08	0.14 ± 0.05	0.70 ± 0.05
6	0.80 ± 0.09	0.74 ± 0.07	0.52 ± 0.03
8	0.59 ± 0.07	0.55 ± 0.06	0.44 ± 0.05
10	0.47 ± 0.04	0.40 ± 0.06	0.26 ± 0.02
		37.50°C	
2	1.29 ± 0.05	0.94 ± 0.05	0.78 ± 0.03
4	0.65 ± 0.22	0.80 ± 0.19	0.48 ± 0.09
6	0.50 ± 0.05	0.40 ± 0.04	0.26 ± 0.02
8	0.56 ± 0.05	0.47 ± 0.02	0.37 ± 0.02
10	0.25 ± 0.02	0.18 ± 0.03	0.11 ± 0.02

Table 2. Chlorpyrifos-methyl residue (ppm, x ± SEM) on wheat stored at two temperatures and three moisture contents (m.c.) and sampled at bimonthly intervals during storage (residue at application was 4.39 ± 0.47 ppm)

Month of storage	11.4% m.c.	12.4%m.c.	14.4% m.c.
		30°C	
2	1.98 ± 0.33	2.77 ± 0.63	1.91 ± 0.27
4	1.88 ± 0.41	1.83 ± 0.39	1.00 ± 0.26
6	0.98 ± 0.16	1.22 ± 0.22	0.62 ± 0.09
8	1.16 ± 0.31	0.91 ± 0.23	0.60 ± 0.10
10	0.48 ± 0.08	0.69 ± 0.14	0.23 ± 0.07
		35°C	
2	1.63 ± 0.32	1.35 ± 0.11	1.19 ± 0.16
4	1.48 ± 0.34	1.14 ± 0.13	0.65 ± 0.09
6	0.74 ± 0.19	0.49 ± 0.06	0.30 ± 0.05
8	0.70 ± 0.15	0.41 ± 0.09	0.19 ± 0.04
10	0.31 ± 0.07	0.27 ± 0.02	0.11 ± 0.03

Future Trends

Integrated pest management (IPM) systems for stored grains in the United States will become increasingly important. Such systems will integrate physical controls such as sanitation and aeration into traditional chemical control programs. There will be a continual reduction in protectant chemicals, as compounds are removed from the market due to regulatory action or loss of efficacy. There will be increased market pressures to maintain grain quality during storage, while minimising the use of protectants to avoid residue problems.

Protectant chemicals may become less important than alternative controls such as sanitation, biological control, aeration, monitoring, etc. However, they should remain part of the total control package for stored grains, particularly in those geographic regions where initial storage conditions preclude the use of environmental controls. Pyrethroids are the most promising compounds for new tests. Routine applications of protectants may be necessary for some management situations, and complete elimination from the postharvest system could eventually cause serious economic losses from reduced grain quality.

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