Integrated Pest Management of Stored Grain Insects: Current Status and Future Concerns

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Integrated pest management (IPM) has always been an important consideration in the management of stored grain insect pests. However, with continued depressed commodity prices, loss of treatment products, recent and impending legislative actions, and changes in consumer attitudes IPM has taken on an even greater significance. Of major importance in an integrated pest management program are the components that seek to prevent the establishment and build-up of insect pest populations. Before examining these components, however, it is important to first have a good understanding of the identification, biology and behavior of the major insect pests associated with stored grain.

Stored Grain Insect Pests

Insect pests associated with stored grain can be divided into three major groups based on their importance, biology, and feeding behavior. These groups are commonly referred to as the primary insect pests, secondary insect pests, and miscellaneous insect pests. While a precise identification of a specific insect may not be necessary, it is critical that the insect be identified as belonging to one of these three groups in order to determine effective treatment options.

Primary Insect Pests

Primary insect pests include those insects considered to be the most damaging pests of stored grain. These pests cause the most damage because they develop within the whole grain kernel. Examples of primary insect pests include the rice weevil, granary weevil, and maize weevil. All of these weevils are similar in appearance and have similar life cycles.

Adult weevils are reddish-brown to black, elongated, hard-shelled beetles that have a characteristic long snout or beak. Adults may vary slightly in size but are typically 2.5 mm in length. Like all beetles, adult weevils have chewing mouthparts. However, adult weevil feeding is usually not considered to be of major importance in stored grain. The main damage from weevils results from the feeding activity of the larva. Adult female weevils chew a tiny hole in the whole kernel and then deposit a single egg in the opening. The female then seals the hole with a gelatinous covering. Upon hatching, the larva feeds internally within the kernel. Pupation also occurs within the kernel. Following pupation, the adult chews an emergence hole through the hollowed-out kernel. The entire life cycle can be completed in about 4 weeks under ideal conditions. Depending on the species, adult weevils can live up to 8 months during which time females may lay up to 400 eggs.
Secondary Insect Pests

Secondary insect pests do not cause as much damage to stored grain as the primary pests. However, their presence and feeding damage can be a major concern. Unlike the primary pests, the secondary insect pests feed and develop outside of the whole grain kernel. In fact, most of these secondary pests depend on the presence of cracked and broken kernels for their development. Examples of secondary pests include the red flour beetle, confused flour beetle, flat grain beetle, sawtoothed grain beetle, and Indian meal moth.

Red flour beetles are difficult to distinguish from confused flour beetles. Adults of both species are shiny, flattened, elongate, reddish-brown beetles that are about 4 mm in length. Female beetles cover their eggs with a sticky secretion, gluing the eggs to the sides of grain bins, sacks, boxes, or other objects or containers. These eggs hatch into larvae in about 5 to 12 days. Both the adult and larval stages actively feed on cracked and broken grain kernels. The entire life cycle can be completed in about 6 weeks under ideal conditions.

The flat grain beetle is one of the smallest beetles found in stored grain. Adults are flattened, reddish-brown beetles that are less than 2 mm in length and have elongate antennae that are about two-thirds as long as their body. Both the adults and larvae feed on cracked, broken, or injured grain kernels, with the larval stage having a particular fondness for the germ. Under ideal conditions the entire life cycle can be completed in about 5 weeks.

The sawtoothed grain beetle closely resembles the red flour beetle in color and appearance but is slightly smaller in size. This beetle gets its common name from the six, sawtoothed projections that occur on each side of its thorax. Like the other secondary beetles, both the adult and larval stage of the sawtoothed grain beetle actively feed on cracked and broken grain kernels. The entire life cycle can be completed in about 4 weeks. Adult beetles can live up to 10 months during which time females may lay up to 300 eggs.

Adult Indian meal moths have a wing span of almost 20 mm and are easily identified by the markings on their forewings, which are reddish-brown with a copper luster on the outer two-thirds but whitish-gray on the inner third. Female moths lay approximately 100 to 300 eggs that hatch into larvae in about 2 to 4 days. Damage is done entirely by the larvae which produce a silken webbing that they deposit over the grain. Indian meal moth larvae will typically only be found in the top few inches of the grain mass. Under ideal conditions the entire life cycle can be completed in about 6 to 8 weeks.

Miscellaneous Insect Pests

A number of other pests can, at times, be associated with stored grain. These miscellaneous pests include the foreign grain beetle, fungus beetles, psocids, and mites. These pests are fungus feeders that do not feed directly on clean, high quality grain. As a result, their presence indicates a serious moisture-related problem associated with the stored grain.
An effective integrated pest management program for stored grain has many important components. Among these are sanitation, empty grain bin treatments, grain cleaning, the use of grain protectants, temperature and moisture management, and insect monitoring.

Sanitation

In many respects, sanitation is the most important component to a successful pest management program for stored grain. In fact, many leading authorities and experts have suggested that sanitation efforts could constitute 80% of an overall effective pest management program. Sanitation efforts include techniques for both the removal of the pests themselves as well as the pests habitat in an effort to prevent the establishment of damaging pest populations. Sanitation will also enhance any further or subsequent control measures that may have to be implemented, such as fumigation.

One of the most important rules regarding the management of stored grain pests is that new grain should never be placed on top of existing grain in storage. As a result, all old grain and debris should be thoroughly removed from the bin and all grain handling equipment (i.e. combines, wagons, trucks, augers, etc.) and aeration fans should be thoroughly cleaned prior to harvesting and storing new grain.

Insects can also enter bins through gaps, cracks, holes, or other similar entry points. Therefore, prior to harvest, a careful inspection should be made of the storage facility and any likely entry points should be caulked or sealed appropriately. Likewise, the roof of the bin should be carefully checked for any possible moisture leaks that could lead to increased pest-related problems. Finally, all old spilled grain and debris should be removed from around the outside of the storage facility. In addition, all vegetation growing within 10 feet of the bin or storage facility should be removed and the area periodically inspected throughout the warm weather months for subsequent regrowth.

Empty Bin Treatments

After the empty bin or storage facility has been cleaned, the inside walls and floors should be treated with a residual insecticide. These same insecticides can also be used to treat the outside base of the storage facility, the outside walls up to 15 feet above the base, and the soil around the facility. Insecticide products currently approved for this use include methoxychlor, cyfluthrin (i.e. Tempo™), and chlorpyrifos-methyl (i.e. Reldan®; only for bins that will contain barley, rice, oats, sorghum, or wheat). Malathion is an insecticide that has also been traditionally used as an empty bin treatment. Unfortunately, malathion is not being reregistered for use on stored grain. Any existing carry-over malathion that still has stored grain listed on its label can still legally be used as an empty bin treatment. However, use of any malathion that does not list stored grain on its label would constitute an illegal application.

Sanitation and treatment of the area beneath the perforated floor is of critical importance, especially if grain is expected to remain in storage for at least a year. If this area can not be
adequately cleaned or treated with a residual insecticide, it should be fumigated prior to adding any new grain. Products approved for fumigating empty grain bins include aluminum phosphide and chloropicrin.

Grain Cleaning

Another important IPM component that is often overlooked is cleaning grain prior to storage. Grain cleaning can be a valuable management tool since unclean grain has the potential to cause a variety of storage problems. First, uncleaned grain has the potential to reduce airflow and prevent uniform aeration. This could lead to uneven cooling and drying and the formation of hot spots within the grain mass. Uncleaned grain also increases the potential for spoilage since broken kernels, weed seeds, and other crop debris often spoil at moisture levels generally considered safe for whole grain. The formation of explosive aerosol dusts is also a major concern of uncleaned grain. In addition, fine material also contributes directly or indirectly to many insect problems since many secondary insect pests depend on this fine material for food, survival, and reproduction. Finally, clean grain will also increase the effectiveness of the treatment should the grain need to be fumigated at a later date.

Grain Protectants

It is widely recommended that a grain protectant be applied to grain that is expected to remain in storage for at least a year. Grain protectants are insecticides that work as contact poisons to kill insects as they crawl about or feed on the treated grain. These products are generally applied to grain as it is being augered, loaded, or turned into storage facilities. A consistent rate of application is important when applying grain protectants to ensure even distribution throughout the grain mass.

Products currently approved as grain protectants include pirimiphos-methyl (i.e. Actellic®; for corn and sorghum), chlorpyrifos-methyl (i.e. Reldan®; for barley, oats, sorghum, and wheat), methoprene, diatomaceous earth, products containing the bacterial agent *Bacillus thuringiensis*, and synergized pyrethrins. Existing carry-over stocks of malathion that still have stored grain listed on their label can also be used as a grain protectant. It is also important to know the limitations of these various grain protectants. For example, pirimiphos-methyl, chlorpyrifos-methyl, diatomaceous earth, and malathion can provide protection against most stored grain insect pests while *Bacillus thuringiensis* is only effective against the larval stage of the Indian meal moth. Methoprene is an insect growth regulator that interferes with the growth and development of immature stages of insects but will not control adult insects already present in the grain. Finally, synergized pyrethrins can only be expected to provide short-term residual protection and are therefore mainly useful as surface sprays or aerosols against Indian meal moths or other pests on the grain surface.

Grain protectants can be applied to the entire grain mass as it is being placed into storage. However, due to concerns about the potential development of resistance to protectants such as Actellic®, Reldan®, and malathion, current recommendations have changed and now state that these products should only be applied to the top 10 feet and the bottom 10 feet of the grain mass. Some grain protectants may be applied as a surface treatment to the grain mass already in storage.
to control surface feeding insects such as the Indian meal moth. These treatments are commonly referred to as top-dress or cap-off applications and are most effective if incorporated into the top few inches of the leveled-off grain mass.

Temperature and moisture factors are also of critical importance in the application of grain protectants. For example, protectants should not be applied before high-temperature drying or when temperatures drop below 40 degrees F since these temperatures will inhibit or limit the residual effectiveness of the protectant. As far as moisture is concerned, protectants applied to 13% moisture grain will have a greater residual life than protectants applied to 15% or greater moisture grain.

**Temperature and Moisture Management**

The importance of temperature and moisture management in preserving grain quality and minimizing insect-related problems cannot be overstated. It is crucial that the grain mass be reduced to 50 degrees F or less and 12% to 13% or less moisture as soon as possible after storage. Reducing the grain mass to these levels will slow insect development and will limit both mold growth and the possible formation of hot spots. As stated earlier, reducing the grain mass to these temperature and moisture levels will also prolong the effectiveness of any grain protectant that may have been applied.

**Insect Monitoring**

The final component of an integrated pest management program is insect monitoring. Any time that grain will remain in storage at or above 50 degrees F, it should be inspected or monitored every 2 weeks for insect activity. A number of insect monitoring devices are available for use such as deep bin probes and sectioned grain triers. Samples should be taken from several depths and locations, paying particular attention to the grain surface and the central core. Particular attention should also be paid to areas of the grain mass that exhibit high temperature or moisture readings.

Insects collected from the grain mass should be identified before any control measures are implemented. As stated earlier, while identifying insects to the exact species is not critical, it is important to determine if the insects are primary pests, secondary pests, or miscellaneous pests in order to determine what options will be effective in controlling the specific insect problem.

If primary pests, such as the rice weevil, are detected in the grain the options are somewhat limited. If immediate control is desired or required the only option available is fumigation of the entire grain mass. Fumigation is the only treatment option that will penetrate the kernel to kill weevil larvae developing within the kernel. The product of choice for grain fumigation is aluminum phosphide. In Iowa, grain fumigation can only be done by Commercial Pesticide Applicators certified in Category 7C – Fumigation or by Private Pesticide Applicators who have been certified in Category 7C – Fumigation. If immediate control is not desired or required and the grain can be moved to an empty bin, treating the grain with a grain protectant as it is being transferred can be a viable option. The grain protectant will not immediately kill the weevil larvae developing within the kernels, but will eventually provide control as the weevils progress.
through their life cycle. The time required for this option to provide control will be dependent upon grain temperature and moisture levels.

The presence of red flour beetles, sawtoothed grain beetles, or other secondary beetles indicates the presence of excessive grain dusts, cracked kernels, or grain debris. These insects can be distributed throughout the grain mass or may be localized because of a collection of fine material, such as in the core of the bin. If secondary beetles are confined to the central core, simply removing one or two loads to remove the core may eliminate the problem. Control may also be achieved by simply running the grain through a cleaner or aspirator while moving the grain from one bin to another. This will not only remove the cracked kernels and fine material, but the insects as well. For further protection, a grain protectant can also be applied while moving the grain. Fumigation is also an option for the control of secondary beetles.

Indian meal moths are typically restricted to the top few inches of the grain mass. Therefore, if these secondary pests are the only concern simply removing the top 3 to 6 inches of the grain mass may be all that will be required. If removal of the infested grain is not feasible, incorporating an approved grain protectant into the top 6 inches of the grain mass will eliminate the problem. As with the other stored grain pests, fumigation is also an option for the control of Indian meal moths.

If foreign grain beetles, mold mites, or other miscellaneous pests are the only pests present it is a sure bet that moldy, out-of-condition grain exists somewhere within the grain mass. Therefore, pulling grain out of the center of the bin, cleaning the remainder of the grain mass as it is being moved, and properly drying and cooling the grain should provide an environment unsuitable for the continued survival of these pests.

Future Concerns

There are several key issues that may impact the management of stored grain insects in the upcoming years. These concerns relate to continued product availability, the development of alternative control measures or techniques, and changing producer and consumer demands.

Malathion was an inexpensive, widely used empty bin spray and grain protectant that was voluntarily discontinued. While other products are still available for this purpose, the loss of malathion will have a significant impact. In addition, actions resulting from the implementation of the Food Quality Protection Act and from EPA mandated product reregistration may also have a serious impact on other products used in the management of stored grain insects. There also appears to be a lack of new product development for stored grain, both in terms of grain protectants and fumigants.

The loss or lack of treatment products will necessitate a greater emphasis being placed on the development and use of alternative control measures in the upcoming years. Alternative controls currently being investigated for stored grain include the use of cylinderized phosphine gas, an on-site phosphine generator, and a combination method incorporating heat, carbon dioxide, and phosphine gas. The use of controlled atmospheres such as carbon dioxide, nitrogen, heating, and chilling are also be investigated. While all of these alternative approaches have been
successfully used on perishable goods or in food processing plants, flour mills, and museums their use on stored grain appears questionable.

Producer and consumer demands will also be a key issue in the upcoming years. Producers will continue to demand effective and economical stored grain management programs even in the absence of treatment products or alternative control measures. In addition, producers of organically grown or alternative crops will also demand effective and economical management programs that may need to be totally nonchemical in nature. Finally, consumers will continue to focus on issues related to food safety, worker safety, and occupational and residential safety.

In examining these future issues and concerns is it readily apparent that prevention will be the most important consideration to the future management of stored grain insects. This points out the continued importance of integrated pest management since prevention, and in particular nonchemical prevention, is the basis for the development of any successful IPM program for stored grain insects.