Stored-Grain Insect Management

Paul Fields and Noel White
Cereal Research Centre, Agriculture and Agri-Food Canada, Winnipeg, MB R3T 2M9
(pfields@em.agr.ca and nwhite@em.agr.ca)

Abstract

What are the problems?

The rusty grain beetle is the most common pest of stored grain on farms and elevators in Western Canada. When grain is harvested warm, or there is a warm fall as in 2001, large populations can build up quickly, causing grain heating and spoilage. The second most common insect is the red flour beetle. Like the rusty grain beetle, it only feeds on damaged kernels. In grain above 15% moisture content, mites, foreign grain beetle, booklice and moulds are common. Occasionally, the lesser grain borer, the rice weevil or the granary weevil, are found in stored grain.

What are the solutions?

There are three steps to dealing with stored-product insect pests: prevention, detection and control. Bins should be swept clean of grain residues and the interior surface treated with a contact insecticide such as malathion or diatomaceous earth. Dry grain has fewer problems in storage. Use aeration to reduce the grain temperature. Insects stop feeding and reproduction at 15EC and stop moving at 4EC. Early detection of insect problems makes control easier. Insects can be detected by sieving grain samples. Probe pitfall traps placed in the grain are an even more sensitive method of detection. In winter on the farm, aeration of grain will cause insects to die if grain is held for 8 wks at -5EC, 6 wks at -10EC, or 4 wks at -15EC. The contact insecticides registered for use on grain are diatomaceous earth, malathion and synergized pyrethrin. There are 2 fumigants registered for use in stored grain: aluminum phosphide and carbon dioxide. The use and sale of aluminum phosphide is restricted to licensed pesticide applicators. Carbon dioxide requires well sealed bins and grain temperatures above 20EC. Moving the grain with a pneumatic conveyor will also control insects.

For more detailed information; videos, images, insecticide labels and publications see: http://res2.agr.ca/winnipeg/stored.htm.

What are the Problems?

Moulds and mycotoxins

Moulds occur mainly as spores in the soil and on decaying plant material, contaminate grains and oilseeds with low numbers of spores during harvesting. Storage fungi are usually inactive at low grain-moisture levels. However, when the moisture is higher, as in tough, damp, or accidentally wetted grain, the mould spores germinate. Several species of *Aspergillus* and *Penicillium* are found on grains. Each fungal species requires a specific moisture and temperature level for germination and development and develops in a definite sequence. The first fungus to develop breaks down nutrients in the seed through its enzymatic activity and produces moisture, which allows other fungi to germinate in their turn.

Storage fungi on grains and oilseeds affect their quality by causing heating and spoilage, packing or caking, reduced germination, and production of off-odours and mycotoxins. Health hazards to humans and animals from the dust-like spores include “farmer’s lung” and allergies.

Mycotoxins are naturally-occurring fungal products which are poisonous when eaten or inhaled. These toxins occur in grain-based feeds, foods and dusts. *Aspergillus* and *Penicillium* moulds growing on stored

cereals will start producing mycotoxins after about eight weeks of favorable temperature and moisture conditions. Mycotoxins can occur anywhere in Canada where grain is stored.

Although highly toxic in the pure form, mycotoxins are usually present at low levels, usually at parts-per-million. These low concentrations are quickly detectable by modern test kits using the enzyme immunoassay principle. The health of farm animals can be impaired by mycotoxins in feed at the parts-per-million level or less, with livestock showing reduced productivity and increased mortality. Producers suspecting mycotoxin poisoning should save a sample of the feed, and consult their local veterinarian.

Mycotoxins usually develop when stored cereal grains become contaminated with *Aspergillus* and *Penicillium* moulds, following faulty storage or accidental dampening from seepage and condensation. In storage tests on damp grain, specific mycotoxins have been identified. Ochratoxin and citrinin are generally found in cereals contaminated with *Penicillium*, and sterigmatocystin is found during heavy growth of *Aspergillus versicolor*. The risk of these toxins forming at levels high enough to harm livestock depends on the particular crop:

- **$** low risk: oats, hard red spring wheat, medium-protein wheat, 2-row barley
- **$** moderate risk: corn, 6-row barley, hulless barley
- **$** high risk: amber durum wheat.

Although the aflatoxins are well-known contaminants of grains and oilseeds from tropical countries and the USA, surveys of Canadian stored crops indicate that these toxins are not present.

Mites

Mites are the smallest of the stored-product pests. They are common in grain stored at 14-17% moisture content but, because of their microscopic size, often go unnoticed. Mites, belonging to the same class as spiders and centipedes, are fragile creatures that are hard to see with the naked eye. Unlike an adult insect, which has a distinct head, thorax, abdomen, and six legs, an adult mite has a saclike body with eight legs; a larva has six legs. Mites are cold-hardy; most feed on broken grain, weed seeds, dockage, and moulds. They are therefore well adapted for infesting stored products. Some mites, such as the cannibal mite, feed on their own members, other mites, or insect eggs. They breed in tough and damp pockets of cereals and canola.

Insects

Rusty grain beetle. This beetle (Fig. 1) is the most serious pest of stored grain in most regions of Canada. It usually feeds on the germ (embryo) part of a whole seed. Heavy infestations cause grain to spoil and heat. The adult is a flat, rectangular, shiny, reddish-brown beetle, 0.2 cm long and has long, bead-shaped antennae that project forward in a V. It moves rapidly in warm grain and can fly when air temperature is above 23^{o}C. Eggs are laid in the crevices of kernels and in grain dust. The tiny larvae penetrate and feed on the germ of damaged kernels. Eggs become adults in wheat in about 21 days at 14.5% moisture content and 31^{o}C.

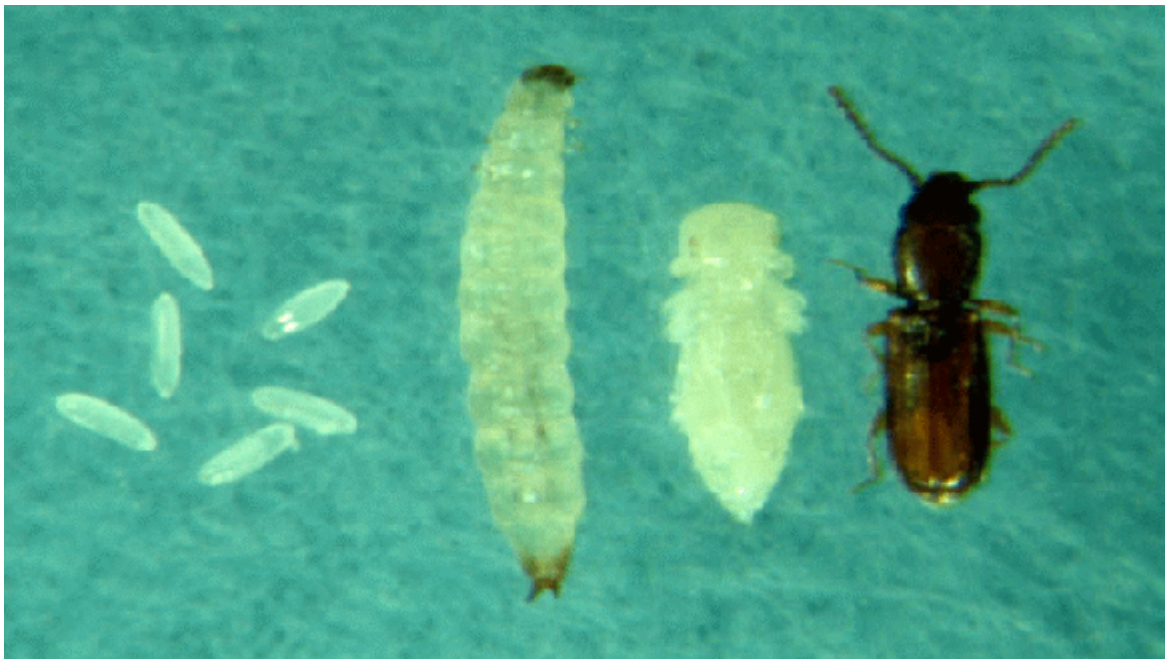


Figure 1. The rusty grain beetle, egg, larvae, pupae and adult.

Red flour beetle. This pest (Fig. 2) develops on stored grains and oilseeds on farms and in primary elevators throughout the Prairie Provinces and most of Canada. The adult is reddish brown and 0.4 cm long. Larvae and adults feed on broken kernels. Complete development from egg to adult occurs in about 28 days under optimal conditions of 31°C and 15% moisture content. Slower development occurs at moisture contents as low as 8%. Adults fly in warm weather or may be blown by the wind into farmhouses or other buildings.

Figure 2. The red flour beetle, adult pupae, larvae and eggs.

Other insects. There are several other insects that are found in stored grain in Western Canada. The foreign grain beetle feed on storage moulds. The rice weevil and the lesser grain borer are found occasionally in Western Canada. They are serious pests in the USA and are able to attack intact kernels. The Indian meal moth is found on corn, sunflower seeds and processed cereal products. The adult moth does not cause damage, however severe damage is done by the larvae.

What are the Solutions?

1. Prevention

Moulds
To prevent storage mould activity, give particular attention to the moisture and temperature of the bulk at binning, especially in unaerated bins. Monitor bulk temperatures at 1- or 2-week intervals. Dry high-moisture and cool high-temperature grains or oilseeds by aeration. Use spreaders to disperse dockage throughout the bulk: small, broken, and shriveled kernels; weed seeds; chaff; and straw. Remember that the increased bulk density in the bin reduces the rate of forced airflow through the bulk. Remove windblown snow before it melts and provides a focus for mould development. To control heating or spoilage in progress, move the bulk to cool it and break up high-moisture pockets. Alternatively, aerate or dry the bulk. Have someone with you when climbing into or onto granaries. Wear a dust mask to prevent inhalation of mould spores either when breaking up a mouldy crust within a bin or when handling spoiled grains or oilseeds.

Mites
Mite infestations can be prevented and or controlled by the following procedures:
- Keep the moisture content of cereal grain below 12% and that of canola below 8%.
- Transfer the grain or oilseed to an empty bin to break up moist pockets, or chill cereal grain at 15 to16% moisture content with forced air during winter.

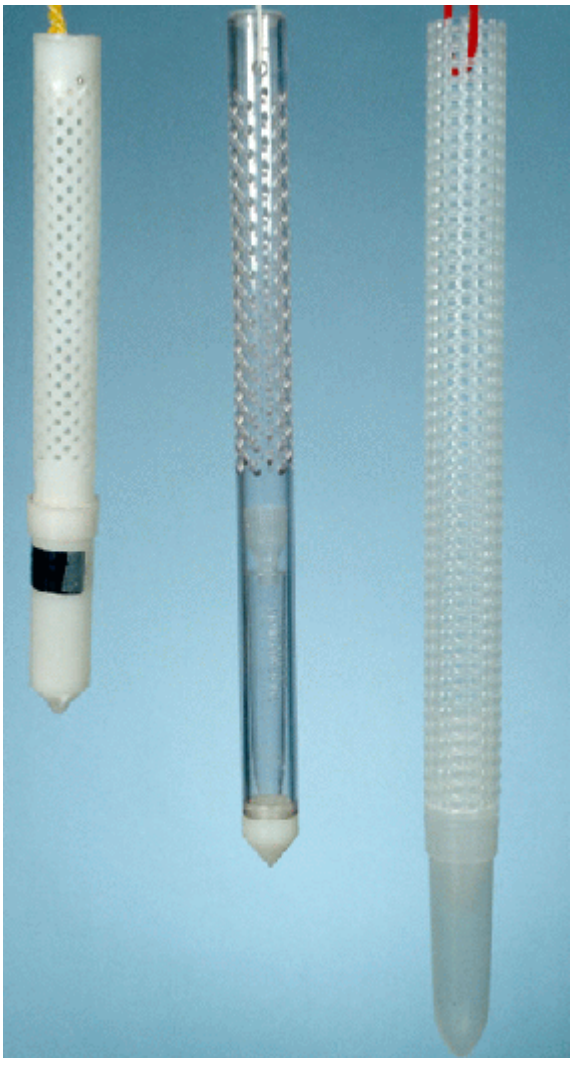
Insects
To prevent and control infestations we need to know where and when insects occur. Surveys have shown that most empty granaries are infested with low numbers of insects and mites. Animal feeds, trucks, and farm machinery are other sources of insect infestations. Some insects can fly as well as walk, which increases their ability to infest stored crops. Take the following measures before the crop is harvested to prevent infestation and spoilage during storage.
- Keep dockage to a minimum by controlling weeds in the growing crop; insects do not multiply extensively in stored crops that contain low amounts of dockage.
- Clean granaries, preferably with a vacuum cleaner; burn or bury the sweepings.
- Repair and weatherproof granaries before filling with grains or oilseeds.
- Do not allow waste grain or feed to accumulate either inside or outside storage structures.
- Eliminate grass and weeds around granaries.
- Do not store crops in bins next to animal feeds that are likely to be infested.
- Spray the walls and floor of empty granaries with an approved insecticide about 1 week before crop storage.
- Examine grains and oilseeds that have been binned tough every 2 weeks: (1) push your hand into the surface at various points to feel for warmth or crusts; and (2) insert a metal rod into the bulk to test for heating at various depths; after at least 15 min, preferably 60 min, withdraw the metal rod and test for warmth on the wrist or palm of the hand.
- Store new grains or oilseeds only in clean, empty bins. Bins that contain old grain might be infested.
- Try and sell for feed your high-moisture grains first.
- Remember that cool, dry grains or oilseeds seldom spoil.

2. Detection

Inspect grain and oilseed stocks regularly to detect the first signs of infestation or spoilage. Sample bulks every 2 weeks to check for insects and heating. To detect insects, warm the sampled grain or oilseed in a screened funnel for several hours. Insects and mites move away from the gradually drying grain and heat and fall into a collecting bottle

Another way to check for insects in cereals is to screen surface samples using a No. 10 sieve (2.0-mm aperture). For the smaller canola seeds use a No. 20 sieve (0.85-mm aperture). Use a sampling probe to obtain deep samples. Warm the siftings for a few minutes and then examine them for insect movement. Check grains and oilseeds for heating by feeling the bulk's surface and a metal pipe after it has been inserted for 1 h within the bulk.

To check for mites, sift grain or oilseed samples through a No. 20 or 30 mesh sieve (0.595-mm aperture). Warm the dust and screening to room temperature and examine them through a magnifying glass. Large numbers of mites in siftings look like clumps of moving dust. Smaller numbers that look like specks of dust are hard to see.



Traps

Insect-detection devices used to trap insects consist of probes, or plastic tubes perforated with small holes that exclude grain kernels but allow insects to drop into, but not to escape from, the trap (Fig. 3). Traps are generally not used in oilseeds where insects are usually not a problem.

As a monitoring device, traps can detect infestations early so that producers or elevator managers can act before the grain has deteriorated to the point at which serious losses occur. Traps can be used in granaries, elevators, rail cars, and ships to monitor grain at all stages of storage and transport. Push traps into the centre of a grain mass where insects generally accumulate because of warmth and higher moisture. Leave them for about 1 week (adult insects of some cold-hardy species continue to be captured down to 10^0C) and remove by pulling on an attached rope. Take care to identify captured insects because grain-feeding pests require chemical control measures, whereas fungus-feeding insects indicate the grain is going out of condition and should be moved into another bin or dried.

Figure 3. Plastic traps that catch insect once placed in store.

Temperature

The most common and readily available method of monitoring for spoilage is to measure temperatures throughout the bulk with permanently or temporarily installed electrical sensors. One such system

consists of a cable and a hand-held, battery-operated monitor. The cable hangs down the centre of the bin with temperature points every 1.2 m and down the outside of the bin with the connector at eye level. The monitor is plugged into the connector and the bulk temperatures are read off and recorded.

Measuring temperatures regularly throughout the bulk during aeration can locate the cooling front. Turn the fan off when the bulk temperature is cooled to the outside temperature and turn it on again when the outside temperature drops about 5^0C below the bulk temperature.

When grain spoils from the growth of moulds or insects, oxygen is consumed while heat, carbon dioxide, and water are produced. The heat can cause the temperature of spoiling grain to rise. Thus in an unventilated bulk, temperature measurements may be useful in detecting deterioration. But difficulties arise in using and interpreting temperature results.

- Temperatures of large grain or oilseed bulks change slowly. For example at the centre of a 6-m diameter bin the temperature can be highest in winter and lowest in summer.
- When a small pocket of grain spoils, the temperature at the centre of the pocket may reach 65^0C whereas only 50 cm away the grain may be 10^0C. To detect small pockets, temperatures must be measured at many points or at least where spoilage is most probable.
- Low bulk temperatures do not necessarily indicate safe storage conditions. At -5^0C, some moulds can begin to grow slowly; above 10^0C both moulds and mites can flourish. Most insects, however, require bulk temperatures above 20^0C to reproduce rapidly.
- Bulk temperatures above outside air temperatures do not necessarily indicate the occurrence of spoilage. Straight-grade crops can be harvested and placed into storage in excellent condition at warm temperatures. But, when the crop is harvested and stored on a hot day, insects flying in from outside and those from the walls and floor debris in an unclean bin may start an infestation by multiplying rapidly. Such grain should be cooled by turning or by aeration to prevent insects from breeding. If the crops are stored dry in large, unventilated storage the temperatures near the centre can remain relatively high throughout the cold winter.

Carbon dioxide concentration

A second method of detecting active spoilage caused by either moulds or insects is to measure the concentration of carbon dioxide (CO_2) in the intergranular air. The usual biological deterioration process occurring in stored grain and oilseeds consumes oxygen and produces carbon dioxide. The concentration of CO_2 in outside air is about 0.03-0.04% (300-400 ppm). Concentrations above this level in a bin indicate that biological activity (moulds, insects, mites, or grain respiration) is causing the stored crop to deteriorate.

As CO_2 usually spreads into the surrounding bulk, gas sampling points need not be right in the spoilage pockets. But it is preferable to sample at locations where spoilage usually occurs, such as at the centre of the bulk about 1-2 m below the top surface.

Air samples can be withdrawn through small-diameter plastic tubes temporarily or permanently located within the bulk, using a hand pump, syringe, or electric pump. The concentration of the CO_2 can be measured with an electronic detector.

A less expensive alternative is to use gas-analyzer tubes, which change colour according to the amount of CO_2 passed through them. The tubes can only be used once. Tubes cost approximately $5.00 each (in 2000) and can be obtained from most safety equipment outlets.

3. Control

Moulds
Mouldy grain should be cooled and dried to below 14% moisture content. However, mycotoxins will remain in the grain and can reduce growth of livestock.

Mites
Turning grain will kill most mites and drying the grain will prevent reinfestation.

Insects
Cold. The ideal temperature for stored product insect growth and reproduction is from 25 to 331C. The lower the grain temperature, the slower the insect populations increase. Aerating the grain immediately after harvest, so that the grain is cooled, will significantly reduce insect infestations. At 151C, the stored product insects stop laying eggs and development stops. At lower temperatures, insects will die. Although some species are quite cold-hardy and able to acclimatize themselves to falling temperatures in the winter, it is possible to kill them if the temperature gets low enough.

In Western Canada, the most realistic use of low temperature thermal disinfestation occurs in the winter when ambient temperatures can be extremely low. Running an aeration fan at these low temperatures will purge the storage bin with cold air. Grain in bins over 6 metres in diameter will not cool sufficiently without aeration to control some insects. Keep the temperatures at one of the following levels for the designated times: -51C for 8 weeks, or -101C for 6 weeks or -151C for 4 weeks.

Malathion.
Malathion is toxic to insects, however, it is effective only if it comes in direct contact with the pests. Malathion will not penetrate piles of grain or dust on floors. It is therefore most often used as an empty-bin treatment to control carry-over infestations or reduce insect entry into the bin.

Malathion is used either as a preventive insecticide or for controlling established infestations. Malathion can be applied to the walls, ceiling and floor of empty bins. A 1% malathion spray remains active for only a couple of days on concrete; up to six months on wood or steel.

Although it is not usually recommended, it is still legal to treat grain with malathion at 8 parts per million concentration. As a grain treatment, malathion is applied at the time the grain is stored. Either liquid insecticide is sprayed on the grain, or dust composed of treated wheat flour is mixed with the grain at rates dependent on its flow through the auger. Treated grain should neither be sold for at least 7 days, nor used for feed for 60 days after treatment.

Oilseeds absorb contact insecticides such as malathion. Controlling insect infestations with malathion is therefore not possible with canola or flax. Insect infestations in oilseeds are related to the presence of cereal dockage since oilseeds are not nutritionally adequate for insects.

Diatomaceous earth.
Control of rusty grain beetle can be achieved by using a nontoxic dust made from phrehistoric, diatoms. When rusty grain beetles come in contact with this dust, the waxy covering on their skin is absorbed, leaving them prone to dehydration and death. The product is applied to grain as it is augured into the bin, and is most effective when applied to dry grain at harvest. Control can take up to five or six weeks.

Phosphine.
Prepared tablets and pellets release phosphine gas when they come in contact with humid air. Phosphine gas is toxic to insects. When insects are exposed to this type of an atmosphere for sufficient time, all stages of development (eggs, larvae, pupae and adults) are killed. Phosphine does not change or impair

the commodity in any way, and does not leave residues which could be hazardous to the consumer. However, it is still extremely toxic to humans as a gas.

Fumigation must take place in a bin that can be tightly sealed. Once the exposure time has ended, the grain must be aerated and the bin checked for residual phosphine gas before entering. The use and sale of aluminum phosphide is restricted to licensed pesticide applicators possessing a stored agricultural products license. In Manitoba, this requires the successful completion of two courses, Pesticides and Stored Agricultural Products. These correspondence courses are available from Assiniboine Community College, Brandon Manitoba.

Carbon dioxide.
Insects, like humans, require oxygen for respiration. With carbon dioxide fumigation, much of the oxygen in the storage bin is replaced with carbon dioxide, thus suffocating and dehydrating the insects. Carbon dioxide also chemically poisons insects by producing toxic chemicals in their blood. To be effective, the elevated carbon dioxide atmosphere must be maintained until all of the insects die. The required exposure time depends on the percentage of carbon dioxide and the temperature of the grain.
Controlled atmosphere storage or carbon dioxide fumigation is most practical for long-term storage and should be used only with dry grain. It is also more effective at high temperatures.

Pneumatic grain-handling equipment.
Most free-living adult and larvae insect pests are killed during bin unloading by using a “grain-vac.” Insects are killed by abrasive contact and impact as the grain and insects are moved through the discharge tube. Better control is achieved when there is a 90^0 bend in the tube; this causes more contact of insects with the sidewalls of the tube.