Fumigants

In This Chapter

Chapter 1: FUMIGANTS

Learning Objectives:

← List the three most widely used fumigants in the agriculture industry and the most widely used fumigant for stored grain in Minnesota.

← Know which fumigant must never be applied while wearing gloves.

← List three financial factors to consider before fumigating.

← Demonstrate knowledge of the Federal Grain Inspection Service guidelines for determining if stored grain is infested.

"Today's fumigants are similar to the infamous "mustard" gases used on the allies in World War I . . ."

What Are Fumigants?

Fumigants are insecticides in the form of gases that are slightly heavier than air and have the ability to spread to all areas of a sealed structure. Because they are highly toxic and can seep into the smallest of cracks and crevices, they have become a popular solution to insect infestations in stored grain. But their ability to move quite easily throughout the grain mass also poses a problem of seepage from the bin or storage building. This seepage poses three major problems for the fumigator.

- First, without enough fumigant inside the structure, the pest may not be killed.
- Second, loss of the fumigant to the outside of the structure means a loss of a fairly expensive pesticide.
- Third, the ability of fumigants to move through the smallest of cracks, also means that they may move along electrical conduits, pipes, augers, and other passageways into adjacent buildings where they may harm and quite easily kill animals and people.

Today's fumigants are similar to the infamous "mustard" gases used on the allies in World War I, so it is no surprise that they are considered Restricted Use Pesticides (RUPs). In the past, to use fumigants in the state of Minnesota, a farmer needed a Private Pesticide Applicator Certificate. Minnesota is now requiring that private pesticide applicators have a fumigation endorsement on the certificate in order to use fumigants.

WWI Soldier with mask

When commodity prices drop, Minnesota farmers become increasingly drawn to on-farm storage of their grains in an attempt to wait out the

soft markets. With increased storage comes the increased chance of insect infestation. Rather than dumping infested products and facing dockage on top of already low prices, farmers may turn to fumigants for stored grain. Concerns have been raised by farmers, regulators, and the general public about the possible increase in fumigant usage, because the use of fumigants, coupled with lack of previous application experience, may lead to unnecessary tragedies involving these highly toxic chemicals.

The recommendations for fumigation training and an endorsement on the private pesticide applicator certificate were developed by the Pesticide Applicator Education and Examination Review Board (PAEERB) in 1998. This advisory board is made up of farmers, representatives of the agriculture industries, Minnesota Department of Agriculture and the University of Minnesota Extension Service employees. The goal of the PAEERB is to create common sense recommendations for pesticide education and training in Minnesota.

"Chloropicrin can only be used for fumigating empty bins and storage buildings"

The recommendations of the board were approved by the Commissioner of Agriculture to enhance the training for fumigants. The Minnesota Department of Agriculture, which is the state lead agency for pesticide licensing and regulatory compliance, worked in cooperation with the University of Minnesota Extension Service to develop this manual and the Private Fumigation Endorsement Exam. This manual and the closed-book exam were implemented on March 1, 2001, with the main purpose of increasing awareness of the dangers and benefits inherent with the use of these hazardous chemicals.

There are three chemical fumigants registered for use in the State of Minnesota: chloropicrin, methyl bromide, and phosphine.

Chloropicrin

Chloropicrin is a fumigant that comes packaged in a liquid form and turns into a gas as it is exposed to air. For years, chloropicrin was very popular because the residues left behind on the kernels of grain would continue to kill infesting insects long after the fumigation was completed. Although this was a positive aspect of chloropicrin, it also was its undoing as a stored grain fumigant. The residues left behind after a fumigation with chloropicrin tended to stay on the grain. Sometimes these residues continued on through the processing chain and into the final product, such as flour or bread, in concentrations that were too high for safe usage. Because of this, ***chloropicrin is no longer registered for use in the United States on stored grains***.

In stored grain systems, chloropicrin can only be used for fumigating empty bins and storage buildings, and it is particularly effective for use in the subfloor plenum of ***empty*** bins (bins which have full-floor aeration). However, aeration ducts and full-floor aeration systems can also be effectively fumi-

gated with phosphine, which can be used on stored grain as well. In other words, it may not be cost-effective to buy the protective clothing and other safety devices required to apply chloropicrin, as well as purchasing chloropicrin itself, when it has such a limited use.

Keep these facts in mind:

- **Chloropicrin is a restricted use pesticide that is highly toxic to all living organisms-*especially the applicator*!** As with all pesticides, and especially fumigants, any application of chloropicrin must be completed exactly as its label indicates.
- Chloropicrin is an intense lacrimator or "tear gas," which can severely irritate the eyes and throat in concentrations as low as 1.0 part per million (ppm). Breathing chloropicrin fumes, even for a very short period of time, can lead to severe lung injury and death. **It is absolutely necessary that applicators wear canister respirators (gas masks) or self-contained breathing apparatus (SCBA) during application and for any reentry into the structure before complete aeration has taken place.**
- Since chloropicrin can cause severe injury when it comes into contact with skin, it is the **only fumigant** that requires full-body protective clothing.
- Because of toxicity and residues, chloropicrin is not recommended for fumigating empty grain storage facilities in Minnesota.

Protective clothing needed for chloropicrin application.

Methyl Bromide

Methyl bromide is the only chemical fumigant that comes packaged as a compressed gas. Unlike phosphine and chloropicrin, which do not become gaseous and kill insects until they have come into contact with air, methyl bromide becomes effective immediately upon leaving the bottle. It is also colorless, odorless, and tasteless, so it cannot be detected without measuring devices specifically designed for methyl bromide. Combine these facts with its high toxicity as a respiratory poison (methyl bromide requires only 24 hours to thoroughly fumigate a structure) and rapid dispersion in the air, and it is no wonder that methyl bromide is such a silent and deadly compound. While it is still legal and registered for private application, due to its deadly nature and costly required protective gear, ***farmers should leave methyl bromide application to professional fumigators.*** However, it has another drawback that will first limit and then curtail its usage as a fumigant in stored grain.

Because methyl bromide depletes the protective ozone layer in the upper atmosphere, the federal government has banned its importation and production as of January 1, 2005, with a 25% reduction in importation and production as of January 1, 2001. This means that even as this manual goes into production, the anticipated removal of methyl bromide from the agricultural

industries has driven its price up dramatically, just as the banning of freon drove its price out of the reach of most consumers. Methyl bromide will still be available for several years by hiring a professional fumigator, but the rising prices will make it an unwise alternative to other fumigants. If methyl bromide is to be used safely, these factors must be kept in mind:

- **A self-contained breathing apparatus must be worn** if the applicator or any other person is inside the area to be fumigated, or in any building close by, where the methyl bromide concentration exceeds 5 parts per million (ppm).
- Canister-type gas masks are not effective against methyl bromide.
- **No gloves, wristwatches, or jewelry!** Applicators of methyl bromide must wear loose fitting clothing and shoes because if the gas gets trapped against the skin, severe burning will take place.
- As with all pesticides, methyl bromide's label must be completely read, understood, and followed exactly for the fumigation to be both safe and effective.
- Methyl bromide comes packaged as a compressed gas in canisters. Every precaution should be taken with methyl bromide canisters that would be taken with any other compressed gas.
- Because of toxicity, the phase-out of its availability, and the required respiratory protection, methyl bromide should be left to professional fumigators, if it is used at all.

Methyl bromide delivery tanks

Phosphine

Phosphine, which is produced under various trade names such as Phostoxin, Phosfume, Fumitoxin, Gastoxin, Detia, Phostek, Weevilcide, and others, is another name for hydrogen phosphide gas. Phosphine is produced when the compounds aluminum phosphide and magnesium

Applicator wearing an air pack (SCBA) and using a piston-type gas detection device.

phosphide, are exposed to the air. Like methyl bromide, phosphine is an odorless and colorless gas. But the byproduct of the reaction between aluminum or magnesium phosphide and air produces an odor that smells like garlic. **If you can't smell a garlic odor, there still may be enough phosphine in the air to seriously injure or even KILL you!** While phosphine is considered less toxic than other chemical fumigants currently registered, exposure to the gas can lead to serious illness or even death at concentrations as low as 0.3 parts per million (ppm).

There are several advantages and disadvantages to using phosphine for the fumigation of stored grain. When used properly, phosphine can produce almost a complete kill of stored grain pests. But to achieve this kill, phosphine needs between 3 to 10 days of contact with the contaminated grain, depending on the temperature and humidity. There is some debate as to why phosphine requires an extended exposure period to be effective. One idea is the slow rate at which phosphine penetrates into the grain kernel and kills internal feeders (insects that burrow into the grain kernel and either live and feed there or lay their eggs inside). Another belief is that phosphine can only kill one or more of the life stages of an insect (egg, pupa, larva, adult, etc.) and that phosphine must be in contact with the insect until this life stage is reached.

Another advantage to using phosphine is the slow rate at which aluminum and magnesium phosphide, generally packaged as pellets or tablets, react with air to produce hydrogen phosphide gas or phosphine. If phosphine gas is produced too quickly, the density of the gas can quickly reach levels where it may spontaneously combust in an explosion or fire. The formulations of aluminum and magnesium phosphide were developed to slow the chemical process of phosphide turning into hydrogen phosphide gas. These formulations usually provide enough time for the applicator working in a smaller bin or building to make the application and exit the structure before the phosphine has reached toxic levels. **Remember that every fumigation is different, and air quality must be monitored at all times!**

Because chloropicrin and methyl bromide use is strongly discouraged, this manual will focus almost completely on phosphine, its application, and safety in handling.

The Need for Fumigants

The most important step that must be taken before fumigating stored grain is to be absolutely certain that the insects in the grain are harmful to the quality of the grain and your ability to sell the grain. Many insects that find their way into storage from the field are either not harmful to the grain and will leave on

their own or are helpful insects that may eat or kill harmful insects. Since choosing to fumigate is not only expensive but also potentially dangerous, it is very important to be able to identify the insect and be sure that there is an infestation.

It is important to correctly identify the insect or insects because insects differ in their behavior. These differences in insect behavior require different management strategies to effectively control the infestation. It is a difficult task even for experts to identify stored grain insects, primarily because these insects are very small (1/16 to ˘ inch long) and look quite similar to each other.

Most insects found in stored grain can be divided into three categories:

- ***Primary Pests*** (internal feeders) – insects that lay their eggs in or on the grain and the larvae develop inside the kernels
- ***Secondary Pests*** (external feeders) – insects that develop and feed outside the grain kernels or feed within cracked or damaged kernels
- ***Surface-feeding Caterpillars*** – caterpillars that feed in stored grain and primarily feed on the outside of the grain mass (usually the grain surface but also on the bottom of the mass just above perforated drying floors or aeration ducts)

1. **Granary weevil** is never found breeding in the field. It occurs only in places where grain is stored. A polished, chestnut-brown or blackish beetle, it is very similar in size and appearance to the rice weevil. However, it has no yellow markings on the back and has no hind wings, distinguishing it from the rice weevil. Adult beetles live about 7 to 8 months. The life history is like that of the rice weevil.

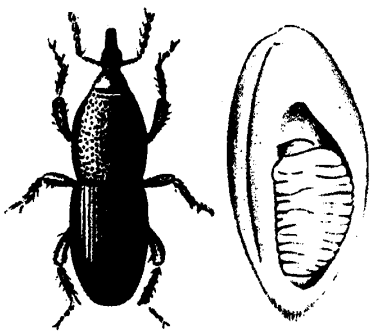
2. **Sawtoothed grain beetle** has a thorax with 6 saw-tooth projections on each side. It is often found in flour mills and warehouses. This species, together with the red flour beetle, causes major damage to stored grains and processed cereals. Adult beetles may live for more than 3 years, though the average is 8 months. Females lay from 45 to 285 eggs, dropping them loosely in grain or in a crack in the kernel itself. The small, white eggs hatchin 3 to 5 days, and the larvae move about and feed freely. Larvae mature in about 2 weeks in the summer and construct “nests” of small grains and fragments stuck together with a sticky secretion. In this cell the larva changes to the pupal stage for about a week, emerging in the adult form.

3. **Red flour beetle** is an important pest of ground cereal products. The last few segments of the antennae are abruptly larger than the preceding ones. Unlike the confused flour beetle, this insect is a strong flier. Feeding and breeding habits of the two are alike and the larvae are very similar. Females may live a year or more and lay about 400 to 500 eggs, dropping them in raw

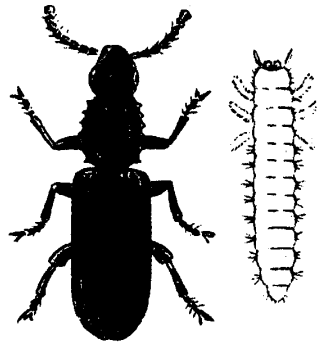
Picture sheet No. 1

PRINCIPAL STORED GRAIN INSECTS

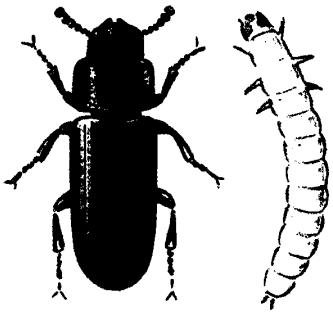
For safe and effective use of insecticides, always identify the problem correctly.



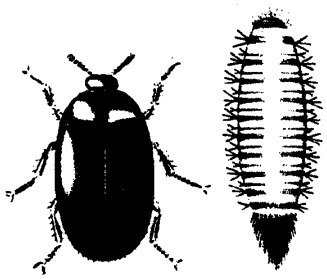
1. Granary weevil



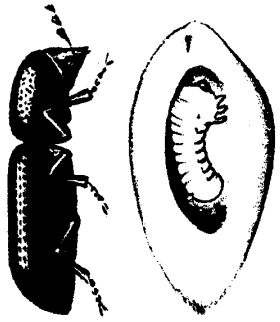
2. Saw-toothed grain beetle



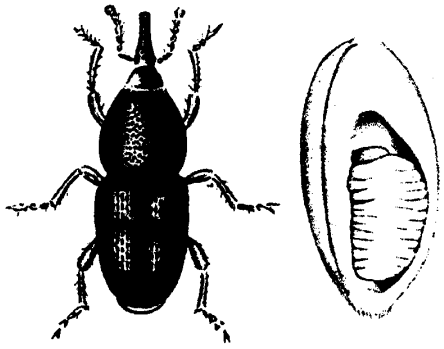
3. Red flour beetle



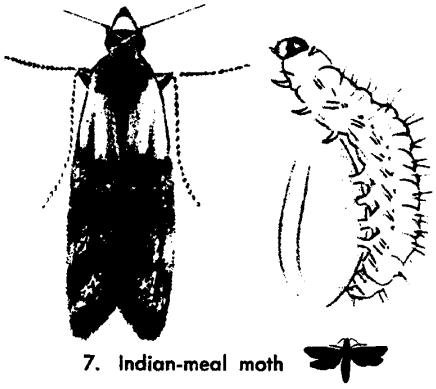
4. Larger cabinet beetle



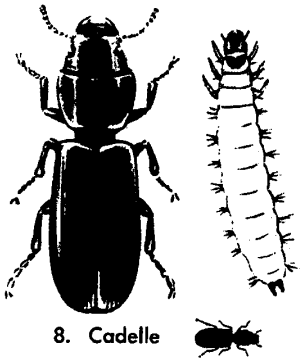
5. Lesser grain borer



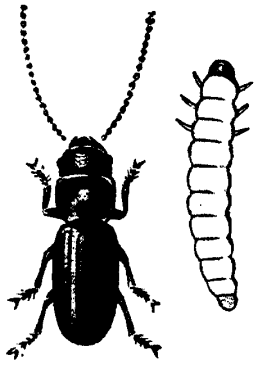
6. Rice weevil



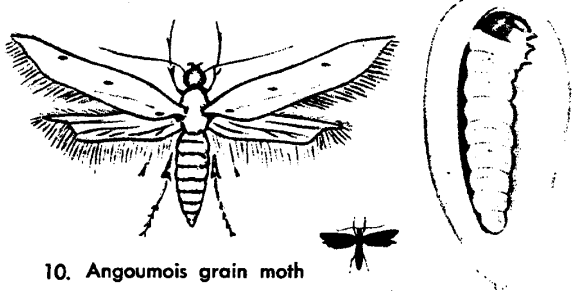
7. Indian-meal moth



8. Cadelle



9. Flat grain beetle



10. Angoumois grain moth

Some of these stored grain insects are also KITCHEN PESTS.

The sawtoothed grain beetle, red flour beetle, larger cabinet beetle, and Indian meal moth develop in flour, cake mixes, corn meal, breakfast foods, and similar products. The Angoumois grain moth infests popcorn.

Prepared by Extension Entomologists of the North Central States in cooperation with the Federal Extension Service, U. S. Department of Agriculture

and processed cereals and grains. Larvae are wiry in appearance, about 3/16 inches in lenght, and whitish, tinged with yellow. Development from egg to adult is about 4 weeks.

4. **Cabinet beetles** belong to a large family that includes insects that attack animal products such as hides and wool rugs. Those we are concerned with feed mostly on grain products. A generation can be completed in 5 weeks. Larvae are hairy.

5. **Lesser grain borer** is found in flour as well as in stored grain. The beetle is a strong flier, and both adults and larvae cause serious damage, attacking a variety of grains. This species is uncommon.

6. **Rice weevil** is the most destructive pest of stored grain in the world. It is a small reddish-brown beetle, about 1/8 inches in length, with four light-yellowish spots on the back. Adults fly. Adults live 4 to 5 months, and females lay about 300 to 400 eggs in holes bored in kernels of grain. Larvae hatch inside the kernel and mature there. The period from egg to adult may be as short as 26 days.

7. **Indian meal moth** breeds freely in ear corn and other feeds of all kinds around the farm and flies to bins of shelled corn or other grains where larvae may completely web over the surface. Female moths lay about 200 eggs singly or in groups on foodstuff. Caterpillars are dirty white with sometimes a greenish or pinkish tint. Moths are about 1/2 inch in length. The period from egg to adult is about 4 weeks.

8. **Cadelle** sometimes burrow into the woodwork or empty bins as larvae and remain dormant until fresh grain is stored. A seemingly clean bin may hold thousands of the insects. The cadelle is one of the longest-lived of the insects that attack stored grain; many adults live for more than a year and some for 2 years. Females lay about 1,000 eggs which hatch in 7 to 10 days into white larvae with black heads and two black points at the end of their bodies. Period of development from egg to adult is at least 70 days.

9. **Flat grain beetle** prefers grain that has been damaged and cannot survive in sound grain. Small white eggs are placed in crevices of the grain or dropped loosely. When fully grown, larvae may form cocoons to which food particles stick. Development from egg to adult may be as short as 5 weeks but is usually about 9 weeks.

10. **Angoumois grain moth** flies to fields of ripening corn and wheat as they are nearing maturity and females lay eggs on the wheat heads or corn kernels. Between crops the adults breed in grain in storage. Females lay about 40 eggs, one egg per kernel. Larvae hatching from the eggs bore into the kernels, where they develop.

Descriptive information prepared by entomologists at Iowa State University.

Pm 463-1 | October 1975 Cooperative Extension Service, Iowa State University of Science and Technology, Ames, Iowa.

Primary Pests

- The Weevils – rice weevil, maize weevil, and granary weevil
- The Lesser Grain Borer
- The Angoumois Grain Moth

The most common primary pests found in stored grain are the weevils-**rice weevil, maize weevil, and granary weevil**. Weevils are a unique and recognizable group of stored grain insects. Adults are small (1/16 to 1/8 inch long) but identifiable because the head bears a prolonged snout. After the adults mate, females lay eggs on or in whole kernels. The small, white, legless, and wrinkled larvae feed and complete their development inside the kernels. After development, adults emerge from the kernels and repeat the process, damaging a vast majority of the grain kernels in storage.

Another primary pest found in stored grain is the **lesser grain borer**. Unlike the weevils, the lesser grain borer's head points downward and not forward and does not have a snout. Both the weevils and the lesser grain borer can be found anywhere in the bin or storage building.

The third type of primary pest is the **Angoumois grain moth**. While this moth is less common in the northern parts of the U.S., it is occasionally found in stored grain and farmers should be aware of its existence. This moth lays its eggs on grain kernels and the larvae bore into kernels and feed there. Infestation by the Angoumois grain moth may occur in the field before harvest, but most of the damage occurs while the grain is in storage. Infestations in storage occur mostly at the top of the grain mass.

"Both the weevils and the lesser grain borer can be found anywhere in the bin or storage building."

Secondary Pests

- Saw-Toothed Grain Beetle
- Red Flour Beetle and Confused Flour Beetle
- Flat Grain Beetle and Rusty Grain Beetle
- Merchant Grain Beetle
- Foreign Grain Beetle

Often called "bran bugs," secondary pests are those insects that develop and feed outside the grain kernel or inside cracked or damaged kernels. These beetles range in size from 1/16 to ˘ inch long, and the adults of most species are red-brown to black with the forewings hardened to form a "shell" over the body. Their larvae are cylindrical and cream-colored with three pairs of legs near the head; some species have fine hairs.

Like the weevils, secondary pests may be anywhere in the grain mass. They feed on bits and fragments of several different grains. Their population usually increases when and where there is a large amount of broken kernels

(fine material) or fungal growth on moist grain. So it is very important to monitor grain moisture before storage, aerate or dry to acceptable moisture levels, and clean the grain to remove any fines before storage, especially if the grain is to be stored for an extended period of time.

Surface-Feeding Caterpillars

¥ *Indianmeal Moth*

Most caterpillars that feed on stored grain live in the outer portions of the grain mass. These caterpillars are cream-colored and about ° inch long when mature. They have three pairs of true legs near the head and five pairs of "false legs" (prolegs) on the abdomen. The caterpillars produce fine, silken webbing as they move about near the grain surface. Mature larvae grow within a silky cocoon. Adult moths fly and mate in the bin headspace where they may be seen resting on the bin walls and roof.

"[Indianmeal Moth] larvae may web over the grain surface completely, preventing proper aeration or fumigation."

The *Indianmeal moth* is the most common surface-feeding caterpillar. The larvae may web over the grain surface completely, preventing proper aeration or fumigation. When this happens, it is important to rake all webbing off the surface of the grain, and probe down into the grain as many times as possible with a stick, pole, or handle, to break up any webbing below the surface. The adult Indianmeal moth has a wingspan of about ∫ inch; the outer half of each front wing is red-brown or copper-colored. Although these surface-feeding caterpillars live primarily on the outside of the grain mass, Malathion resistance seems to be increasing, and topdressing the grain with Malathion is proving to be ineffective on most populations.

It is important to note that almost all of the problems with stored grain insects can be avoided by proper grain handling and management. Chapter 2 of this manual covers the basics of grain handling in Minnesota. For more information on infestations of most stored grain pests, their identification, and models of infestations that are dependant upon moisture, grain type, length of storage time, and temperature, download the free Internet program from Kansas State University called "Stored Grain Advisor." (See appendix for more information).

Remember, it is always cost effective to take the time for wise grain handling practices, especially if not doing so could require costly fumigation and potentially putting your life in danger.

Grain Inspection Packers and Stockyards Administration Standards

The Federal Grain Inspection Service (FGIS), now known as the Grain Inspection Packers and Stockyards Administration (GIPSA), has standards that determine whether or not there is an "infestation." If the grain that has been sampled is determined to be infested, often grain elevators will not take delivery of the grain or they will label it as "sample grade," which will lower the price significantly. Sometimes it becomes almost impossible to sell "sample grade" grain, especially if the market price for grain that is in good condition is quite low. At such a time, the farmer will have to locate a local market for the grain to be sold as feed. But in those times when market prices are high, elevator operators may work with the farmer to move the grain on the open market.

It is important to keep in mind that some elevators will have even more strict standards than those of the GIPSA, so the federal standards are an important place to start. Before grain is hauled to the elevator, it is a good idea to talk to your local elevator manager about the standards they maintain for insects in grain. There are scientific ways of sampling the grain to ensure that the samples accurately reflect the insect population within the bin or storage building. But the sampling that will determine whether you can sell the grain is the one done at the elevator. To make sure the elevator sample will match the on-farm sample, ask the elevator manager how a recommended sampling should be done. Most farmers do not own a grain probe and will have to borrow one from the local elevator. The manager can assist in describing the best way to probe the grain. Here are some very key pieces of information that must be relayed to the manager:

- Size of the bin in bushels
- Type of the grain to be sampled
- Height and diameter of the bin

The GIPSA standards are determined by kilogram (1 kilogram = 2.2 pounds) samples that are averaged to see how many live insects are present per kilogram.

GIPSA Standards for designation as *Infested* – Insect density per kilogram of grain

Wheat, Rye, Triticale

- Two or more live insects that are injurious to grain

Corn, Barley, Oats, Sorghum, Soybeans

- More than one live weevil, or
- One live weevil plus five or more other live pests insects, or
- No live weevils, but ten or more live pest insects injurious to stored grain

For example, six probe-samples are taken of wheat, and the total weight of all the samples is nine pounds. In the six probe samples, five insects that injure stored grain are found. Here is how to determine if there is an infestation:

9 pounds of sample divided by 2.2, to determine the sample in kilograms:

9 lbs. of wheat / 2.2 kg. per pound = 4.09 kg. of wheat

In the 4.09 kg. of wheat there are 5 live insects.

4.09 kg. of wheat / 5 (live injurious insects) = .82 insects per kilogram

In other words, in this example .82 insects were found per kilogram of wheat, and the limit per kilogram is two or more, so this sample would be determined "Not infested." This does not mean that the grain will remain uninfested if left in storage, but simply that it is not now infested. In this case, it may be a good idea to clean the grain on the farm and market it as soon as possible, or notify the elevator of the situation so that they can clean the grain and make appropriate storage arrangements.

Helpful Hints:

- **WHAT'S THAT SMELL?** — Grain that is going out of condition, or has gone out of condition due to insect infestation, usually (but not always) has a sharp acrid odor that is different from rotting or damp grain. The effect this odor has on the back of the throat may be similar to that of musty wet hay when inhaled. Certainly any strange odor should be thoroughly investigated to find its origin.

- **THE BUCKET TEST** — Peering inside a bin may not always give a farmer a chance to spot insects. Although no diagnosis of an infestation can be made without a proper sampling, a good place to start would be a bucket test. Quickly shovel the first foot or two off of a spot on the top of the grain mass and scoop a large bucketful of grain out of the hole. Remove this bucket to the outside of the bin where the lighting is better and inspect the grain closely for insects and insect damaged kernels.

Food and Drug Administration Regulations for Insect-Damaged Grain

Another important concern to keep in mind for the marketing of grain is insect-damaged kernels. If no live insects are found in any grain samples but there is evidence that there have been insects in the grain, strict (FDA) regulations will determine whether or not a sample will get a "sample grade" designation. For example, if there are 32 or more insect damaged kernels of wheat per 100 grams (0.22 lbs.), the wheat is considered "sample grade." The absence of insects in the grain and the lack of evidence that there is insect damage to the kernels but not enough to be knocked down to "sample grade" does not mean that you as a farmer are in the clear. When kernel damage does take place, test weights will be reduced and dockage will be automatic. Again, if there is evidence that there is insect damage to some of the stored grain, a consultation with the local grain elevator is in order before the grain is shipped.

Is Fumigating Cost Effective?

In the second section of this manual, there will be an in-depth description of the handling, use, safety precautions, and safety equipment needed for effective fumigations. Before those things are tackled, and after an infestation is determined and the insects identified, the farmer must sit down, sharpen a pencil, and crunch some numbers. Consideration must be given to whether or not fumigating is the best and most economical solution, since fumigants are expensive and costly safety equipment is mandatory. Also, a significant amount of time is involved not only in fumigating, but in being trained and getting certified to fumigate as well, not to mention the possible safety risks involved in fumigating.

What will fumigating cost?

Each of these questions must be answered completely before you consider fumigating:

- Can the grain be sold with these insects in it?
- What price will I get? Will it be "sample grade?"
- How much money will be lost if the grain is sold out of condition?
- How much does it cost to buy enough fumigant to handle the infestation?
- How long will it take to become trained and licensed to buy and use fumigants?
- What is the cost of a canister gas mask and a self-contained breathing apparatus (SCBA)?
- How much does it cost to hire a professional fumigator?
- How comfortable am I in working with highly toxic, *even deadly*, chemical fumigants?

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