Chapter 8

STORED WHEAT MANAGEMENT

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The majority of wheat harvested in Oklahoma is managed through a network of grain elevators from which it is either processed, exported or stored for periods ranging from 6 months to a year on average. About 20% of the wheat crop is stored on farm for 6 to 10 months after harvest. Grain is in its best condition at the point of harvest, but the impacts of harvesting, moving and storing will ultimately lower the quality and marketability of grain. The objective of stored grain management is to slow or deter this loss of quality so that grain can attain its highest potential market value. Much of the information below relates to grain storage in large commercial elevators, although all of the concepts and many of the procedures are transferable to smaller scale on-farm grain storage by the producer.

IPM and Safe Grain Storage

An integrated pest management (IPM) approach can be adopted for storage of wheat, just as it is being adopted for crop production. IPM of stored wheat requires the grain elevator or producer with on-farm storage to be knowledgeable about the pests of stored grain and to be well informed about the condition of the grain and the storage structures. The key to safe storage of grain is to store clean, dry grain in insect-free structures and to maintain grain temperatures as cool as possible. Such ideal conditions are difficult to achieve in Oklahoma and elsewhere. Wheat moisture content should be below 13% for safe storage. We are fortunate that the climate in Oklahoma facilitates proper drying in the field before harvest in most years. The practice of stored grain IPM integrates the use of preventive measures to avoid pest problems, monitoring insect levels and grain condition to aid in marketing and management decisions, cooling grain with aeration to slow infestation, and judicious use of effective chemical pesticides only when needed to avoid economic impacts due to infestation.

The Pests

Insect pests infesting stored wheat fall into one of two categories based on their feeding habits, either as internal feeders or external feeders. Internal feeders are those whose larvae feed inside grain kernels and bore holes through grain, such as the lesser grain borer and the rice weevil (Figs. 8.1 and 8.2). These two species are considered serious economic pests because they contribute to the grading factor of "insect damaged kernels" (IDK) which can lower the value of grain when sold. The lesser grain borer in particular should be considered the most serious pest of stored wheat in Oklahoma. External feeders are unable to penetrate the seed coat, either as adults or larvae, and make their living by feeding on broken kernels, grain dust, fungi and most forms of milled grain products (such as flour and feed). Although external feeders do not contribute to IDK, their presence in grain will trigger the designation of “infested” if two or more live specimens are found in a sample when grain is graded (discovery of dead insects does not result in the designation “infested”). One of the most common external grain feeders in Oklahoma is the rusty grain beetle (Fig. 8.3), which is relatively small compared to the next most common insect, the red flour beetle (Fig. 8.4). Other external grain feeders that may be encountered regularly are the sawtoothed grain beetle (Fig. 8.5), the hairy fungus beetle (Fig. 8.6), and the Indianmeal moth (Fig. 8.7). The worm-like larvae of the Indianmeal moth can cause problems when high populations deposit large amounts of silk on the top of grain that can block aeration and cause grain heating and molding. Not all insects in grain are pests, since all those mentioned above may be attacked and killed by various species of predators and parasites that may also occur in the grain. These natural enemies actually help to regulate and sometimes reduce populations of pest insects. If an unknown insect is found in grain the specimen should be directed to your local cooperative extension office for identification. Problems with non-insect pests can also occur in Oklahoma, but most are not as prevalent or persistent as those with insects. Some species of fungi (mold) can build up on high moisture grain and may cause problems with the production of mycotoxins. However, the hot, dry conditions in most Oklahoma wheat storage facilities preclude serious problems with fungi. Vertebrate pests such as birds, mice and rats pose a constant problem for most grain managers who must curb these pests for their grain consumption and contamination caused by hair, feces and urine in the commodity.

Sanitation and Structural Maintenance

Maintaining storage structures that are clean and secure is the cornerstone of pest prevention in stored grain IPM. The primary sources of new infestations are from insects breeding in old grain from a previous storage season. Storage pests must have dried grain or grain debris in which to live and reproduce. Thus spilled grain, grain trash, or carry-over grain left in a bin represents breeding material for insects and a source of infestation on new grain. Since stored grain pests do not breed on wheat growing in the field, they do not come into storage facilities with the new crop when it is harvested and stored. However, most grain pests are good fliers and can move from bin to bin and farm to farm, and enter grain bins or silos through any number of small openings. Harvesting and transportation equipment must be cleaned prior to harvest because residues of old grain and grain pests can contaminate the new grain before reaching the bin. All empty bins, silos and flat storage structure should be cleaned of old grain before the new crop is stored. Prior to storage grain managers need to go inside round steel bins and flat storages and thoroughly sweep and vacuum old grain and debris from floors and side-walls. Grain fines and dust under aeration ducts and false floors should be vacuumed out annually. Concrete silos should be similarly cleaned if access is available, but minimally the old grain should be removed from these structures. Since it is impossible to clean every last bit of grain from empty bins, additional protection can be achieved by spaying the inside surfaces of bins with an appropriate residual insecticide or treating the entire structure with a registered fumigant (see below). If substantial carryover grain exists (from a previous crop year) it should be consolidated into one or more bins and monitored carefully or treated appropriately. <u>Never store new grain on top of old.</u> Loose grain around the outside of bins, and on floors in the basements and galleries of concrete houses, should be cleaned immediately after it is spilled. Volunteer wheat and other vegetation growing around bins should be removed because it can harbor insects and rodents. All grain-moving equipment, bin walls, roofs, doors and hatches should be in a good state of repair. Once a bin is full it is extremely difficult to perform repairs on load-out augers or conveyors. Holes in roofs can result in grain getting wet from rain water. Wet grain will sour readily and will support high levels of mold and insect infestation due to the moisture and the natural heating that occurs with mold growth. Roof vents should be screened to exclude birds and rodents. All bin doors and hatches need to be properly designed and in good working order so that grain is protected from rain and insect movement into the bin is restricted. Additionally, closures should be made as tight as possible so they can be properly sealed in the event of a fumigation treatment to the structure. Open-eave ventilation allows for easy access of insects. New bin construction should have no continuous eave vents, but rather install adequate roof ventilation. Older bins should be retro-fitted with roof vents and have all eave vents sealed.

Monitoring

Monitoring, also referred to as “scouting” when discussing field crop production, is very importing in IPM because it is the only way the manager can gain information about the commodity that will help him make control or management decisions. Once new grain is safely stored in a relatively insect-free structure it must be monitored regularly to see if pest problems, or the potential for pest problems, are developing. Four factors that should be monitored in stored grain are grain temperature, moisture content, grain quality and insect density. Grain moisture content should be measure and recorded when grain is stored. Grain should not be stored over 12% moisture content. High moisture grain will cause growth of molds with aflatoxin and will promote insect infestation. Temperature is important because cool grain, that less than 60^{o} F, will prevent excessive growth of insect populations, while increasingly higher temperatures indicate greater threat from pests because warm temperatures will allow populations to flourish. Large commercial storage structures, whether flat storage buildings, round steel bins or concrete silos, should be equipped with temperature monitoring cables that can provide the manager with a profile of grain temperatures throughout a grain mass. Temperature information is transmitted electronically from each thermocouple to a reading device that allows the user to record temperatures and thus keep records over time.

Whether grain temperatures are high (85°-95° F) or low (40°-50° F) at a given time, it is desirable to maintain fairly uniform temperatures throughout a grain mass to avoid "moisture migration" due to condensation at the interface between cool and warm grain. Changes in grain temperature from week to week or throughout a bin at a given time should be small (approximately 2°-3° F difference), which would reflect normal variation and changes with weather. When a thermocouple, or two or more closely situated thermocouples, read 5° to 10° F or higher than the others in a bin for two or more weeks the manager should suspect grain heating from some pest or moisture problem. Such grain temperature "warning signs" may lead the manager to turn the grain from one bin into another. Grain turning will break up hot spots, disrupt insect and mold growth and typically results in an overall cooling of the grain. Monitoring grain temperatures is also important to check the change in grain temperature during the course of aeration cooling (see below) or through passive seasonal cooling or warming. In the absence of temperature cables a grain manager can check grain temperatures directly by manual inspection. A protected mercury thermometer mounted on a probe can be inserted into grain, or an inspector can simply touch the grain with the hand and arm to determine if grain in the top 3-4 feet of the mass is at an appropriate temperature.

Direct physical inspection of grain, as with remote sensing of grain temperature with cables, is an important monitoring activity because additional information for pest management decision-making can be gathered. Grain samples should be taken from several locations throughout a storage structure at monthly intervals to count the number and species of insects, if any are present, and to assess grain quality. Grain samples can be collected from standing grain using either a deep cup probe sampler (Fig. 8.8) or a long, spear-like grain trier (Fig. 8.9). Approximately two pounds of grain from each sampling point should be taken to make an assessment; as many samples as possible should be taken from each structure. Steel bins and flat storages allow access to the top of a grain mass where samples can be taken. <u>Take appropriate safety measures when entering a confined space such as a grain bin; do not work alone.</u> Concrete silos present problems for collecting grain samples, although samples from the bottom of the silo can be taken in most facilities by accessing grain at the hopper bottom and some silos are full enough to allow for deep cup or probe samples to be taken from the top.

Once a grain sample is obtained it should be sieved thoroughly to remove insects. Any insects found should be identified, counted and recorded to observe monthly trends. Presence of external feeding insects ("bran bugs" such as rusty grain beetle or red flour beetle) in dry, otherwise sound wheat is not cause for serious alarm during the storage period. However, the presence of two live bran bugs or other grain insects in a sample when the grain is inspected at the time of sale may result in the special grading category of "infested" being assigned to the load. If the grain-damaging lesser grain borers or rice weevils are found in a grain sample during storage the manager should conduct further inspection. One or more grain borers in more than one sample taken from a bin may signal the onset of a serious infestation that should be controlled by fumigation. Grain quality should be assessed from collected samples with the best methods available to the manager. Dampness, off-odor or moldy appearance are immediate signs of wet, deteriorating grain. Other quality factors to check are moisture content, test weight, dockage, and presence of IDK. Test weight and dockage information from in-bin grain samples will aid the manager in marketing decisions, while the presence of high moisture grain and any level of IDK can signal a pest problem. Consistent findings of grain damaging insects (borers and weevils) and IDK should be a trigger for a control action, such as fumigation (see below).

Insects can also be monitored using grain probe traps (Fig. 8.10). Probe traps should be inserted into the top of a grain mass and checked weekly or biweekly. Probe traps do not use attractants, but simply capture insects that are moving through the grain. Capture will depend on the species of insect, the total number of insects in the grain and the grain temperature. Numbers of insects caught in grain probe traps can not be easily converted into insect densities, such as the number of insects per bushel that can be determined from grain samples, but probe-trapped insects can inform the manager about the species present and population trends over time. It is possible to capture hundreds of non-grain damaging, external feeding insects in probe traps over a one to two week period in the summer without need for a control action provided that other indicators suggest the grain is in good condition. However, the capture of one or more grain damaging insects, particularly the lesser grain borer, is considered an “action threshold” should alert the manager toward further investigation and possible control.

Aeration

Aeration cooling, combined with grain monitoring using temperature cables, is the primary non-chemical grain management tool available to producers and grain elevator managers. Aeration fans should be used to cool grain with outside air once the average air temperature starts dropping below that of the average grain temperature. Cooling grain will not kill insects outright, but it will substantially slow their growth, feeding and reproduction (Fig. 8.11). For example, grain insects held at temperatures below 65° F will feed and grow very slowly, and their eggs will take months to hatch. OSU recommends that aeration fans at the base of bins be mounted to provide suction to draw cool air down (down-flow mode) through the grain mass from vents in the roof. Pressure aeration from the bottom (up-flow mode) is appropriate only if an adequate number of roof vents are installed to carry moisture out of the bin, which will minimize condensation under roofs and water damage to the top of the grain. Very large bins may require electric exhaust fans on roof vents to aide in moisture removal during up-flow aeration. Air flow rates of 0.1 or 0.2 cubic feet per minute per bushel (cfm/bu) are recommended for wheat at normal moisture contents and can be achieved by matching fan motor power with the depth of grain being aerated (Table 8.1). If higher moisture grain is being stored then flow rates approaching 0-.5 cfm/bu should be used.

In Oklahoma the most effective grain cooling by aeration occurs in the late summer and fall, when nighttime air temperatures fall to 50° F. During this time fans should be run at night and not during the day when air temperatures may still be in the 80s or 90s. Aeration fans need to be run on consecutive nights for several weeks in order to lower grain temperature uniformly through each bin. The number of accumulated aeration hours will depend on the type of grain being aerated, the depth of the grain in the bin and the airflow rates of the fans. Refer to OSU fact sheet xxxx for details on how to properly cool grain by aeration.

If grain is peaked and contains a dense core of fine material near the top it will take much longer to aerate than normal and has the risk of moisture build-up at the peak. This peak and core of fines can be removed after the bin is full by running the unloading system to remove several 100s to 1000s of bushels. Unloading draws grain mostly from the top and center of the bin where the peak and fines exist, creating an inverted cone. This grain can then be added back into the top of the bin, perhaps mixed with cleaner grain, where it will have a lower density of fines and have less impact on aeration. “Coring” of grain bins to disperse fine material should be done by experienced grain mangers.

Automatic aeration controllers can be installed on fan motors that will turn fans on when the outdoor temperature goes below a given set point, and will turn the fans off when the outdoor temperature exceeds the set point. Controllers can also record the number of hours fans are turned on so that the progress of the cooling front can be estimated. Research indicates that automatic controllers may allow managers to begin grain cooling earlier and more effectively in the late summer or early fall copared to manually controlling fans. Winter aeration of grain in the cool months of November, December or January can be performed both night and day for several days in order to lower grain temperatures to a very cool and safe storage temperature. Very cool grain can often be maintained well into the next storage season. Implementation of proper grain cooling with aeration requires several economic and technical considerations by the manager. OSU publications E-912, F-7180 and No. 1100 should be consulted for details of proper grain aeration.

Chemical Prevention, Chemical Control and Alternatives

The cost-benefit analysis inherent in IPM requires that the cost of controls, such as application of pesticides, and costs of pest preventive measures, such as the electrical cost of cooling grain with aeration, must be outweighed by the return in value of the commodity that is protected. In stored grain it is sometimes difficult to determine if an expenditure for pest management will be cost-effective, especially if it is made several months before the grain is sold. Residual insecticide sprays for treating grain bins, and sprays for direct treatment of new crop grain while it is loaded into bins, are registered for use in Oklahoma. Two insecticides registered for applying directly to grain as long-term, residual protectants are malathion and chlorpyrifos methyl (Reldan®). Both of these materials have limited effectiveness for treating stored wheat in Oklahoma. Research has shown that many populations of stored grain insects have evolved resistance to malathion so that it has no toxic effect on these insects. Adding malathion to wheat at the time of storage probably provides no benefit for pest control and adds unwanted pesticide residue to a food commodity. Reldan, though still effective for many storage species, is not effective against the lesser grain borer, the most serious pest of Oklahoma wheat, and thus is no longer labeled for its control. Additionally, Reldan can breaks down chemically under the high temperature conditions (greater than 90^{o} F) of summer-stored wheat in Oklahoma. Use of residual grain protectants applied to an entire grain mass is typically limited to high value raw commodities that need protection during several months of storage and for which it is cost–effective to use such material. Top-dressing with a residual protectant, a practice in which the chemical is applied to the top several inches of grain, will save money and may control insects, but its effectiveness has been researched. The decision to use a residual insecticide on stored wheat is an important one that will require information about costs, benefits and risks.

Residual sprays can be effective and are recommended for treating empty grain storage structures in Oklahoma. As discussed above, steel bins, silos and flat storage structures should be empty and thoroughly cleaned prior to treatment. The residual spray serves to kill insects that are hiding in the structure that were not removed with the old grain by broom or vacuum-cleaning, and it should kill insects that enter the bin from outside. Thus a spray to the inside surface of a grain bin should act like a protective envelope around the grain. Four residual insecticides are registered for empty bin spray: malathion and chlorpyrifos methyl, the same two compounds discussed above as grain protectants, cyfluthrin (Tempo®) and methoxychlor. Cyfluthrin gives good control against lesser grain borer and other storage insects in Oklahoma, and is recommended over other registered products from residual protection of empty bins. Empty bins can also be fumigated with chlorpicrin, a type of “tear gas”, applied to the sub-floor area. Chlorpicrin is applied as a liquid and volatilizes to a gas over time. Empty bin treatment is the only registered use for chlorpicrin in Oklahoma; label instructions must be carefully followed.

Additional materials for controlling grain pests include diatomaceous earth (DE) and vapona pest strips (also referred to as dichlorvos of DVDP). DE is a natural dust composed of microscopic skeletons of diatoms (marine or freshwater algae) that is mined from the ground. DE is highly absorbent and it kills insects by absorbing the protective wax coating from their exoskeleton and causing the insect to dry out. DE is not toxic to people and is allowed in grain and many food items. DE is registered for complete admixture to grain masses as a protectant, but it has the drawback of decreasing test weight of the treated grain, which can result in a lowering of grade and price reduction. Targeted treatments with DE, such as application to empty bins, top-dressing and bottom-dressing, may be effective at protecting grain, but these methods have not been thoroughly tested.

Vapona pest strips are registered for hanging in the headspace of grain bins. A chemical pesticide is given off from the strips as a vapor. Pest strips are effective at killing adult moths and most adults of grain beetles. Strips are less effective at killing immature stages of grain insects, particularly eggs and pupae. The experiences of several grain managers suggests that if fresh vapona strips are continually hung in the headspace of a full concrete silo (with a small headspace) the adult population of moths is suppressed and subsequent larval infestation and webbing is reduced. Hanging vapona strips in larger headspaces of big steel bins and flat storages may be less effective because of the large volume of air in which the vapona becomes diluted.

Fumigation to kill insects and stop infestations is recommended when insect populations reach undesirably high levels or if grain damage is unacceptable. For example, a grain manager my chose to fumigate if grain samples reveal the presence of IDK and probe traps or other monitoring activities detect lesser grain borers. Fumigation in this case will stop infestation and grain degradation from getting worse, and will allow the manager to then either blend the damaged grain to reduce total IDK or take other action. However, many commercial grain elevators will fumigate grain just before it is sold, whether grain-damaging insects or IDK are present or not, to ensure that no live insects are present when the grain is evaluated by the buyer. Such one-time fumigations are usually cost-effective for the manager because discounts for grain that is infested with external feeders are avoided. Similarly, many managers keeping grain through the fall and winter will opt for a fumigation at the end of the summer to suppress insect populations. When fumigations are effectively conducted in August or September, and then are followed by fall and winter aeration to cool the grain, pest populations can be greatly reduced.

Fumigants registered for use on stored wheat in Oklahoma are phosphine gas generated from either aluminum or magnesium phosphide, and methyl bromide. Methyl bromide is rarely used on raw grain because it is expensive and it is so strong it can easily kill the germ of kernels. The fumigant of choice for stored wheat is aluminum phosphide in the form of pellets or tablets (Fig. 8.11), which is sold under various trade. Alluminum phosphide is potentially very dangerous if improperly used or handled. Strict safety guidelines are in place to protect those applying phosphine and those working in areas where phosphine is being used. <u>OSU recommends that fumigations be conducted by certified applicators who have received specific training in grain fumigation and fumigation safety.</u>

Aluminum phosphide pellets or tablets generate phosphine gas after they are exposed to moisture in the air. In concrete silos aluminum phosphide pellets are added to infested grain as the grain is moved into one silo after being in another silo, bin or truck. For infested grain that can't easily be moved or turned, such as in large steel bins or flat storages, pellets or tablets are probed as deeply into the mass as possible, and also distributed on or near the top surface. Phosphine gas is as light as air and moves easily through grain and out of leaks in structures just as smoke would move. Since small amounts of gas are being released from each pellet or tablet it is important that these point sources be well-distributed throughout a grain mass. However, since the gas has a tendency to move passively upward with convection currents, a larger distribution of pellets in the bottom of a mass is recommended.

For steel bins or flat storages, in which the pellets can not be probed evenly through the mass or concentrated safely in the bottom, a re-circulation system known as closed-loop fumigation (CLF; see OSU publication no. E-912) can be installed. CLF utilizes a combination of a samll, low-power centrifugal blower commected between suction and pressure manifolds with PVC pipe. A PVC suction pipe draws phosphine gas from the bin headspace above the grain mass and re-circulates it into the aeration system at the base of the bin. Gas then rises through the grain mass from bottom to top and achieves a uniform distribution. CLF seems ideal for leaky bins that would otherwise lose excessive phosphine before insect control is achieved, because a large proportion of gas that rises into the headspace is re-circulated through the suction pipe rather than leaking through roof openings.

Phosphine gas requires up to a week to kill eggs, larvae, pupae and adults of grain insect pests when grain is warm. Effective fumigation treatment requires that enough pellets or tablets are distributed to generate an adequate level of gas, that grain moisture and temperature be optimum for gas generation and that leaks in a structure be minimized so that gas can be held on the grain for the required time. Leaky bins and silos contribute to most of the fumigation failures in Oklahoma stored wheat. Many steel bins and flat storages have numerous leaks in walls and roofs and would not meet the minimum levels of gas-tightness for a good fumigation treatment. Concrete silos have potential for being low-leak structures, but they can easily lose substantial amounts of gas before kill is achieved if inter-vents between silos and outside vents at the top of the silo are not sealed during fumigation. Phosphine fumigation is a technical operation that should be undertaken only by skilled professionals. Ineffective fumigation can lead to poor insect control, and in the long run may result in resistance to phosphine developing in our pest populations.

Many other materials and practices are registered for use in killing stored grain pests, but they are not considered here because they are either not widely used or are considered ineffective or inappropriate for most stored wheat situations in Oklahoma. The reader is directed to OSU publication E-912 for information of numerous grain management techniques. Research is ongoing at OSU, at USDA laboratories and at other institutions worldwide to find safe and effective alternatives to chemical pesticides and to develop pest management methods the grain industry can use to reduce loss of grain quality with minimal input and cost. Much of IPM in stored grain involves application of common sense once the manager has a good understanding of the pests and the commodity being managed. Grain managers should be motivated to maintain a disciplined watch over their grain while it is in storage because it represents a substantial financial investment for them and their customers that must be preserved.

<u>Related publications and Web-sites:</u>

OSU Circular Number E-912, "Stored Product Management"

OSU Extension Fact Sheet No. 1100, "Maintaining Quality of Stored Grain by Aeration"

OSU Extension Fact Sheet No. F-7189, "Stored-Grain Management in Oklahoma"

Other OSU pubs?

Purdue Website

USDA ARS GMPRC site, with Paul Flinn's expert system.

Natural Resources Institute (U.K.) website for stored product management tutorial

Ag. Canada site (Paul Fields?)

Australia CSIRO website?

Table 8.1.

Approximate aeration fan horsepower required per 100 bushels of wheat.[1]

	Cfm/bu[2]		
Grain Depth (ft)	½	¼	1/10
15	.47	.11	.04
20	.79	.20	.05
25	1.26	.30	.07
30	1.92	.45	.08
35	2.79	.65	.01
40	3.68	.87	.14
45	5.16	1.16	.16
50	6.33	1.34	.19
60	9.55	2.06	.28
70		2.82	.39
80		3.64	.50
90		4.95	.66
100			.79
110			1.04
120			1.27

[1] Total horsepower for all fans on a single bin.

[2] Air flow rate in cubic feet per minute per bushel of wheat.

Figure Legends

Fig. 8.1. The lesser grain borer, an internal grain feeder, is the most serious insect pest of stored wheat in Oklahoma because it causes insect damaged kernels (IDK). Adults bore holes directly into grain kernels. Larvae develop inside kernels and new adults chew holes to the outside.

Fig. 8.2. The rice weevil, and internal grain feeder, is less common than lesser grain borer in Oklahoma, but also causes IDK.

Fig. 8.3. The rusty grain beetle is one of the most common insects infesting Oklahoma stored wheat. These tiny beetles are rust-red in color, very flat, with long antennae and they feed on grain dust and cracked kernels.

Fig. 8.4. The red flour beetle is also common in stored wheat, but like the rusty grain beetle, this insect feeds only on dust and broken kernels. This beetle is rust-red in color and has an oval, round-topped body shape.

Fig. 8.5. The sawtoothed grain beetle has a flat body and is recognized by the saw-like projections form the side of the body

Fig. 8. 6. The foreign grain beetle is a tiny beetle with clubbed antennae and a two-tone brown color. This beetles feeds on mold and grain dust, and flies into grain bins at certain times of the year.

Fig. 8.7. The Indianmeal moth adult has red coloration on the back part of its wings and white on the front. Larvae are creme-colored, worm-like caterpillars approximately ½ inch long when fully grown. Large numbers of larvae sometimes build up near the end of summer and lay down copious silk on the top of grain masses and cause heating.

Fig. 8.8. A deep-cup grain probe sampler can be used to take a sample from different depths and locations in a grain bin.

Fig. 8.9. A grain trier for collecting a grain sample can obtain a grain sample from the top 5 feet of a grain bin or truck.

Fig. 8.10. A grain probe trap for catching insects that walk through the grain. Insects fall through the holes, into the hollow shaft and are trapped in the tip at the bottom.

Fig. 8.11. Growth of grain insect populations with and without aeration cooling. ET=economic threshold, the point at which spending money on a control procedure will save money by controlling the pest; EIL=economic injury level, the point at which expenditure for control would not be realized by return after selling the grain.

Fig. 8.12. Tablets of aluminum phosphide being handled prior to application in a grain bin. These tablets slowly react with moisture in the air to give off phosphine gas, the poison that kills insects. Phosphine and other insecticides should be sued only be certified pesticide applicators.