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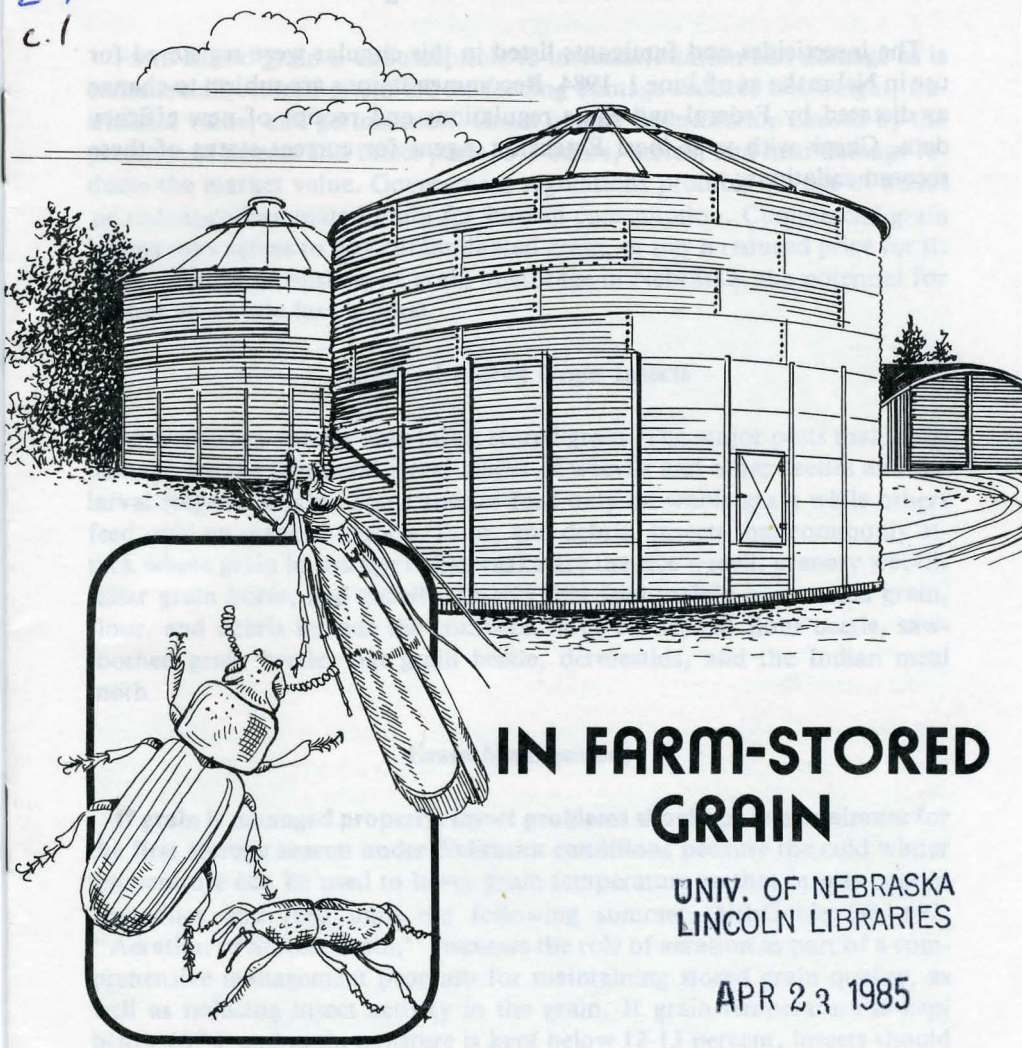
INSECT PREVENTION AND CONTROL



IN FARM-STORED GRAIN

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Issued in furtherance of Cooperative Extension work, Acts of May 8 and June 30, 1914, in cooperation with the U.S. Department of Agriculture. Leo E. Lucas, Director of Cooperative Extension Service, University of Nebraska, Institute of Agriculture and Natural Resources.

Recommendation Changes

The insecticides and fumigants listed in this circular were registered for use in Nebraska as of June 1, 1984. Recommendations are subject to change as dictated by Federal and State regulations and receipt of new efficacy data. Check with your local Extension Agent for current status of these recommendations.

Insect Prevention & Control in Farm-Stored Grain

Leroy L. Peters, Extension Entomologist

Farm-stored grain is as susceptible to insect infestation and damage as is commercially-stored grain. Direct feeding damage reduces test weight, nutritional value, and germination. Grain quality deterioration caused by the presence of insects and insect parts, off-odors, molds, and heat damage reduces the market value. Government regulations prohibit the use of insect or rodent-contaminated grain for human consumption. Commercial grain buyers may refuse to buy contaminated grain, or pay a reduced price for it. With millions of bushels of grain in storage in Nebraska, the potential for serious economic loss is great.

Kinds of Stored Grain Insects

Several insect species may infest stored grain. The major pests that cause damage are the adult and larval stages of weevils and other beetles and the larval stage of moths. Some species feed only on whole grain while others feed only on cracked kernels, flour, and debris. Insects that commonly attack whole grain in storage in Nebraska are the rice weevil, granary weevil, lesser grain borer, and cadelle. Insects that feed mainly on cracked grain, flour, and debris include the confused flour beetle, red flour beetle, saw-toothed grain beetle, flat grain beetle, dermestids, and the Indian meal moth.

Grain Management

If grain is managed properly, insect problems should be at a minimum for the first storage season under Nebraska conditions because the cold winter temperature can be used to lower grain temperature so that insects cannot reproduce and feed until the following summer. NebGuide G84-692, "Aeration of Stored Grain," discusses the role of aeration as part of a comprehensive management program for maintaining stored grain quality, as well as reducing insect activity in the grain. If grain temperature is kept below 60° F and grain moisture is kept below 12-13 percent, insects should not be a major problem in grain stored for more than one year.

Preventive Measures Before Storage

To keep grain free of insects, follow these steps:

1. Pest-proof bin.
2. Clean outside bin.
3. Clean inside bin.
4. Spray bin.
5. Clean harvesting and handling equipment.
6. Store clean grain.
7. Store dry grain.

Pest-Proof Bin

Repair all leaks and holes in bins. Keep roof vents shut except when aeration fans are being operated. Screen to prevent bird entry. Keep doors in flat storage buildings shut to keep birds and rodents out. All bins should have metal or concrete barriers around the exterior to prevent rodents from burrowing in. Tightly close aeration fan openings when the fan isn't in use. This will prevent rodent entry and reduce convection currents within the grain. Do not allow weeds and grass to grow up next to grain bins. The vegetation provides hiding places for rodents.

Clean Outside Bin

Clean up spilled grain from loading and unloading areas. This grain can be a source of insect infestation in the new grain. Remove junk piles, weeds, and tall grass from around the bin area.

Clean Inside Bins

Before putting new grain into a bin, clean the bin. **Never put new grain on top of old grain.** Use brooms, hoes, shovels, and vacuum cleaners to clean out all of the old grain, cracked kernels, and grain debris. Clean walls, ceiling, ledges, sills, and floors. Clean behind partitions, between walls, and clean out cracks and crevices. Remove and burn all sweepings and debris. Remove false floors and aeration ducts and remove debris. Grain dust and cracked grain under false floors provides an ideal growing area for flour beetles, dermestids, and Indian meal moth larvae.

Do not store grain near feed rooms, stables, or animal feeders. These areas often harbor insects which can infest the stored grain.

Spray Bin

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Do not store grain near feed rooms, stables, or animal feeders. These areas often harbor insects which can infest the stored grain.

Spray Bin

After the bin is thoroughly cleaned, spray all inside surfaces with premium-grade malathion or methoxychlor about two weeks before storing

grain. Be sure to spray removable doors, behind false partitions, under false floors, etc. Before putting grain into treated bins, sweep up and dispose of all dead insects on the bin floor to avoid contamination of clean grain.

Follow instructions on container label for dosage rates.

Use a compressed air sprayer or similar equipment and spray surfaces to the point of runoff. One gallon of diluted spray will cover about 750 to 1,000 square feet of surface. Exact coverage depends on whether it is a wood, metal, or concrete wall. A porous wood surface will require more spray than will a metal wall.

Caution—Premium grade malathion and methoxychlor are registered for use in storage bins for barley, corn, oats, rye, sorghum, and wheat, but not soybeans.

It is difficult, if not impossible, to clean under false floors or nonremovable air ducts in some bins. In such cases, remove as much of the grain debris as possible, then fumigate the empty bin with chloropicrin (a RESTRICTED USE PESTICIDE, to be applied only by EPA certified applicators). Before applying the fumigant, seal all openings to prevent escape of the gas. After 48 hours remove sealing material, open doors and vents, and allow the bin to air out for 8 hours before entering. The overall residual bin spray is still needed. Fumigation should help control insects in the hard-to-clean and spray aeration ducts. After the bin is aired out, sweep up and remove any additional dead insects before the bin is used.

Clean Harvesting and Handling Equipment

Thoroughly clean combines and other harvesting equipment of any old grain that might be left in the machine from last harvest. This grain could contain insects that would start a new infestation in the newly harvested grain. Also clean grain wagons, trucks, augers, dryers, and other handling equipment.

Store Clean Grain

Grain containing weed seeds, cracked kernels, and other dockage will tend to become infested with insects sooner than will sound, clean grain. Moisture, temperature, and grain dust or dockage interact to provide conditions favorable for insect reproduction and survival. Presence of grain dust or dockage permits some of the grain beetles to survive and reproduce at extremely low temperatures. Adjust the combine to produce a minimum of cracked kernels while still removing the maximum amount of dockage.

Store Dry Grain

Don't store grain with high moisture content. Use your moisture meter or take a sample to your elevator and have the moisture content checked. Safe

moisture content of grain depends upon how long the grain will be in storage and temperature of the grain (Tables 1 and 2).

Table 1. Maximum moisture content of grain for safe storage, provided grain is properly aerated.

Storage period	Grain: Corn, sorghum	Grain: Soybeans	Grain: Small grains
	%		
Over winter[a/]	15.5	14	—
1 Year	14.0	12	13
2-3 Years	13.0	—	—

a/ Assumes unloading or further drying before summer.

Table 2. Effect of grain temperature and moisture on maximum number of days of safe storage time[a/] of shelled corn.

Grain Temperature (F)	Grain Moisture (%): 15	20	25
75	116	12	4
65	207	21	8
55	337	35	12
45	725	75	27
35	1,140	118	42

a/ Assumes that aeration is used to maintain constant grain temperature.

Insects may obtain moisture from the air, grain, or **metabolic water from breakdown of starches.** Their activity also produces heat which can lead to further reduction in grain quality by grain respiration and mold growth.

Preventive Measures After Storage

Once clean, dry, good-quality grain is placed in storage, follow these steps to maintain it as a pest-free, good-quality product.

1. Cool grain after drying.
2. Use grain protectant.
3. Treat grain surface.
4. Follow recommended aeration schedule.
5. Inspect grain regularly.

Cool Grain

If the temperature of the grain and the insects in the grain is reduced to 60° F or lower, most insects stop feeding and reproducing. Cool winter temperatures can be effectively used to cool the grain mass in a bin, making the grain unfavorable for insect development and reducing grain damage. Use aeration fans to reduce the temperature of the grain to 35° F. Grain cooled to 35° F should not become warm enough for insect damage until the following summer. Aeration system management is necessary to maintain uniform temperature throughout the grain during seasonal temperature variations and to minimize the potential for convection currents and resulting moisture deposition.

As temperature of the grain increases, insects are able to reproduce in grain of lower moisture content. Stored grain insects require more time at low temperatures and less time at high temperatures to complete their life cycle. For every species of stored grain insects there is a minimum constant temperature threshold below which development ceases. Most species of stored grain insects do not multiply fast enough to become a pest until the temperature is 5 to 9° F above the minimum temperature requirement. There is also a 5 to 7° F temperature range at which the rate of population increase is greatest. The minimum temperature range varies from 50 to 79° F with optimum temperature range of 60-99° F.

Death of insects at low temperature can be due to freezing, starvation, or old age. Some stored grain insects can withstand temperatures below freezing for a few days.

Grain Protectants

Dry, insect-free small grain or shelled corn can be protected from most insect damage by using liquid or dust formulations of malathion as a grain protectant. Apply the insecticide to the grain stream as it comes out of the combine if grain is dry, or as it is being elevated into the bin. Forcing heated air through grain treated with malathion will reduce the effectiveness of the malathion. When using heat, dry the grain first, then apply the malathion after the grain has cooled.

After binning is completed, level the grain. If the grain has to be fumigated later, the low spots will collect most of the fumigant, while the high spots will not be fumigated. Leave at least 6 inches of space between the top of the leveled grain surface and the top of the bin wall so that the fumigant will not "spill over" the sides.

Follow instructions on container label for dosage rates.

Surface Treatment

Treat all the leveled grain surface with malathion liquid or dust grain protectant. The "topdressing" acts as a barrier, preventing insects from entering the grain mass and from feeding on the surface grain. Each time the surface grain is disturbed, such as when probing for moisture or insect samples, the barrier is broken. Retreat disturbed areas with grain protectant.

Indian meal moths are one of the major insect pests in Nebraska farm-stored grain.

The adult is a moth about one-third to one-half inch long. The tips of the wings are dark red or brown, with the basal one-third light gray. Full-grown larvae are about half an inch long, dirty white, sometimes with a pinkish or greenish tinge, and a dark brown head.

The larvae prefer to feed on cracked or broken seeds, or weed seeds, but will feed on the germ of whole kernels. The larvae feed only in the upper portion of the grain mass unlike the other stored grain insects that may feed in the grain throughout the bin. The top 1-2 inches of the grain is often webbed together by Indian meal moth larvae. Where the infestation is severe, a crust of webbing and trash will be very obvious. This crust hinders fumigant penetration, protects the larvae from contacting the grain protectant "topdressing," and reduces the effectiveness of aeration fans. Remove the crust and damaged grain before treatment or before the grain bin is emptied.

If Indian meal moths have been a problem in the past, use a "top-dress" of *Bacillus thuringiensis* (Dipel, SOK-BT), since these insects are resistant to malathion. *Bacillus thuringiensis* does not control weevils and beetles, therefore, malathion is still recommended for the bulk of the grain.

Follow instructions on container label for dosage rates.

Caution—Premium grade malathion is registered for use on stored barley, corn, oats, rye, sorghum, and wheat, but not on stored soybeans. *Bacillus thuringiensis* is registered for use on stored grains and soybeans and is exempt from tolerance restrictions. Grain treated with malathion or *Bacilus thuringiensis* as recommended can safely be fed or sold at any time after treating.

Another aid in the control of Indian meal moths is the use of Vapona® resin strips hung in the bin overspace. Vapona resin strips are thin, plastic strips impregnated with the insecticide dichlorvos. When these strips are hung in a closed area, they give off vapor that kills insects. To be successful with these strips, the area to be protected must be closed without ventilation because air exchange reduces the vapor concentration to the point that it will no longer kill insects.

The strips will control Indian meal moths in tight storage areas if they are hung above the grain with one strip for each 1,000 cubic feet of air space

over the grain. The strips must be hung before moths begin to emerge in the spring. Strips will last up to four months. If strips are used, check grain once each month for a buildup of insects. Replace strips if live pests are seen.

Aeration

Develop and follow an aeration schedule in bins with false floors or aeration ducts. The purpose of aeration is to maintain uniform temperature and moisture conditions throughout the grain mass, prevent localized hot spot development, and cool existing or developing hot spots. Proper aeration will be of considerable value in reducing insect and other pest problems in the grain.

Inspect Grain

Inspect grain regularly. If an infestation is detected early, insects can be controlled before they cause extensive damage. There are minimum acceptable levels of damage and contamination.

Check the grain for heating and off-odors once a week. Use a sharp pointed stick or rod and determine if hard, compacted areas are developing. Probe samples of the grain do not have to be taken each week. In the winter, when the grain is cooler, take probe samples of the grain every 4 to 6 weeks. During warmer months, take probe samples of the grain every 1 to 2 weeks. Buy or borrow a grain probe from your local grain buyer.

During cold weather, insects will congregate near the center of the grain mass where it is warmest, so sample the center of the grain mass thoroughly during the winter. Use the aeration system to minimize temperature variations within the bin. During warm weather, infestations usually begin near the surface, so pay special attention to that area during the summer.

Follow a systematic procedure when taking probe samples. Empty each sample into a grain sampling tray or section of eavestrough long enough to accommodate the grain probe. Sift the samples through a 10 to 12 mesh per inch screen and examine for insects.

When first entering the bin, insert the probe horizontally 2 to 4 inches under the grain surface in the center of the bin before the grain surface is disturbed. Collect the sample and examine for insects. Take additional surface samples around the sides of the bin. Then probe from the top to the bottom of the grain mass. Extensions may have to be attached to the probe so that it can penetrate to the bin floor.

In round bins, start the deep probes at the center, then probe around the wall. Insert the probe about one foot from the outer wall. Make surface and deep probes at the north, west, south, and east sides of the bin. Examine each sample for insects. In extremely large bins, samples may have to be taken at more locations, no farther apart than every 20 feet around the wall.

Bins with diameter of more than 40 feet should also be sampled more than once near the center.

In flat storage bins, sample grain in the center and around the walls. Take samples no farther than 20 feet apart. Take surface probes first, then probe from the top to bottom, examining each sample for insects. Always retreat surface with topdressing of grain protectant after disturbing the grain.

If you find considerable damage and/or insects in the probe samples and cannot identify the insects, show them to your county agent or elevator manager for positive identification. If one granary weevil, one rice weevil, or one lesser grain borer, or as many as five insects of other species such as flour beetles and saw-toothed grain beetles are found per quart sample of grain, fumigation of the grain is necessary to prevent further insect damage. Grain temperature should be above 65° F for the fumigant to be effective.

New methods of detecting stored grain insects by the use of specially-designed traps and chemical attractants are being developed. These traps show promise in detecting developing pest problems before they become serious problems. They appear to be relatively easy to use and economical.

If Insects Are Found—Fumigate

It is usually less expensive, more effective, and safer to have the fumigation done by a commercial fumigation company than to attempt to do it yourself. Consider the cost of application on a per unit volume basis. The cost should include the necessary safety and application equipment, as well as the cost of the fumigant. The time and labor expense should also be considered.

Flat storage structures and large round bins present special problems in maintaining the fumigant in place long enough to cause an effective kill. Recirculating the fumigant is a technique often used by commercial applicators in these structures to make the distribution of the fumigant more uniform throughout the grain. This is accomplished by attaching a return duct between the overhead space above the grain surface and the fan on the aeration duct. Depending on the direction of the air movement, the fumigant can be drawn or pushed through the grain and then directed back to the grain by a return duct. The fumigant is generally recirculated for a time estimated to produce two or more air changes within the stored commodity. Grain may be fumigated effectively at greater depths when bins are equipped with recirculating equipment.

Applicators must be EPA certified to apply most fumigants, since most fumigants are restricted-use pesticides.

Bin Preparation for Fumigation

Seal all cracks and openings to prevent fumigant leakage. If the bin has

many openings that cannot be sealed to prevent fumigant leakage, it's doubtful that the fumigation will be effective.

Circular storage structures constructed from the corrugated metal strips and quonsets and other rectangular buildings constructed of corrugated and flat metal bolted together are usually the most gastight. Caulking the seams at the time of construction improves the tightness of these bins.

Wood structures are the most difficult to fumigate because such structures are porous and allow an excessive amount of fumigant to escape. For this reason, fumigant dosage recommendations for wooden bins are usually twice the amount recommended for metal bins. Follow container label recommendations. It may be necessary in some cases to cover the wooden structure with a gastight tarpaulin to retain the fumigant for a sufficient length of time.

Before applying the fumigant, spray the outside of the bin with a residual spray of premium grade malathion or methoxychlor to kill those insects forced out of the bin by the fumigant. These insects could quickly reinfest the grain after the fumigant disappears. Also clean up and dispose of any waste grain outside the bin for the same reason. Fumigants do not have residual properties, so as soon as they are exhausted, the grain can be quickly reinfested from outside sources.

Fumigant Selection

All fumigants are poisons and are toxic to humans and other warm-blooded animals, as well as to insects and other pests. Certain fumigants are highly flammable and corrosive. Some will leave undesirable residues if not used correctly. Some will injure seed germination and affect milling quality if improperly used. Fumigants are most effective when the air is calm and grain temperature is 65° F or above.

Fumigants are available in liquid, gas, and solid formulations. However, they all must become a gas to be effective as a fumigant.

Liquid fumigants—Formulations of liquids usually contain a mixture of two or more compounds. Liquids commonly used in farm fumigant mixtures are combinations of carbon tetrachloride with carbon disulfide, or ethylene dichloride. Do not use carbon disulfide alone because it is extremely explosive and flammable.

Liquid fumigants are usually applied to the grain surface. Because they are heavier than air, they settle to the bottom of the grain mass. Chloropicrin (tear gas) or sulfur dioxide are sometimes added to these mixtures as warning agents.

Gaseous fumigants—Methyl bromide is usually released from pressurized containers into the area and commodity to be fumigated.

Control with methyl bromide is improved by using recirculation systems. Gaseous fumigants are extremely hazardous and require special equipment and precautions for handling. Applications should be done only by experienced persons equipped to use these materials.

Solid fumigants—Solid pellets, tablets, or packets containing aluminum phosphide or magnesium phosphide can be used to fumigate farm-stored grain. These fumigants are activated by moisture in the air and release highly toxic phosphine gas. This material is extremely dangerous if improperly used, so should be applied only by experienced applicators who are thoroughly familiar with proper use of the material. Do not pour or spill water on these materials.

Volume Calculation

To determine the amount of fumigant required, you must know how many bushels of grain are in the bin. There are several ways of determining volume of a grain mass. The following formulas are simple to use.

Bushels of grain in a square or rectangular bin: Bushels = 0.8 x length (ft) x width (ft) x average depth of grain (ft)

Bushels of grain in a round bin: Bushels = 0.6283 x diameter^2 (ft) x average depth (ft)

Fumigant Dosage

Fumigants are sold under various trade names. Ingredients are listed on the container label. Follow the label instructions and recommendations.

How To Use Fumigants

Always use the recommended dosage of an approved fumigant for the type of grain and bin you are treating.

Make a special effort to make the grain bin airtight. Level the grain surface to insure even penetration of the fumigant throughout the grain mass.

Place signs at all entrances warning that the bin is being fumigated and listing the fumigant used and the name, address, and telephone number of a responsible person to contact in case of emergency.

Apply liquid fumigants evenly to the entire surface as a coarse spray. Use a hand-type compressed air sprayer, bucket pump, or powered pump. The pump should have brass fittings and a plastic or plastic-lined hose, because some of the fumigants are corrosive.

Stay on the outside of the bin.

When fumigating large volumes of grain, use power equipment.

Diaphragm or brass gear pumps may be used and driven by a small motor or tractor power take-off. Use a nozzle that disperses the liquid in an even pattern as a coarse spray.

Farm bins with the grain mass deeper than 10-12 feet may require the use of both liquid and aluminum phosphide for best results because liquid fumigants settle to the bottom quickly. The grain in the top 2 to 3 feet may not be exposed to the fumigant long enough to obtain good control. The proper dose of aluminum phosphide could be probed into the top 2 to 3 feet of grain, and then the required dosage of liquid fumigant applied. This procedure provides good fumigant coverage both at the top and bottom of the grain mass.

In all cases, close and lock the bin immediately after applying the fumigant. Keep closed for at least 72 hours.

The bin may be opened and aired out after 72 hours and grain may be fed or placed in market channels after the grain is completely aired. Stay out of fumigated bins until they are completely aired out. Topdressing the grain surface after complete aeration with malathion and *Bacillus thuringiensis* will prevent insect reinfestation.

Cautions

All fumigants are dangerous if improperly used. Follow the cautions listed on the container label and use only in strict accordance with label directions.

Wear a gas mask with full face piece and proper canister approved by the U. S. Bureau of Mines and National Institute of Occupational Safety and Health for use with the particular fumigant you will be using. Gas masks of this type will not protect the user against heavy fumigant concentrations in bins where oxygen has been replaced by the fumigant. The effective life of a gas mask canister is limited. Keep an accurate account of the time that a canister is used and replace it after 30 minutes of continuous or intermittent exposure to fumigants.

Avoid spilling fumigant on the skin, clothing, or shoes. Remove fumigant-wetted clothing or shoes at once and wash the skin thoroughly with soap and water.

Never fumigate a bin by yourself. Have someone else around to help if you get into trouble. The helper must also be properly fitted with a gas mask. Have a code so that you can communicate with each other. Make sure gas and electrical connections are turned off. Have available the telephone numbers of the police and fire departments, hospital, physician, and rescue squad.

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Summary

Grain is food—protect it from insect damage and contamination. Insect damage can be reduced in stored grain by:

1. Cleaning bins, harvesting, and hauling equipment.
2. Cleaning outside of bins.
3. Spraying bin walls and floors.
4. Storing dry, clean grain.
5. Cooling grain after drying.
6. Using grain protectants.
7. Topdressing grain surface.
8. Following recommended aeration schedule.
9. Inspecting grain regularly.
10. Fumigating if needed.

Additional References

Several NebGuides are available at your County Extension Office with additional information on stored grain management.

G79-461 — Controlling Rats
G79-479 — Controlling House Mice
G80-516 — Burrowing Rodent Control With Gas Cartridges
G81-580 — Starlings and Their Control
G82-624 — Bait Stations for Controlling Rats and Mice
G83-656 — Rodent Proof Construction—Structural
G78-418 — Checking Condition of Stored Grains
G84-692 — Aeration of Stored Grain

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