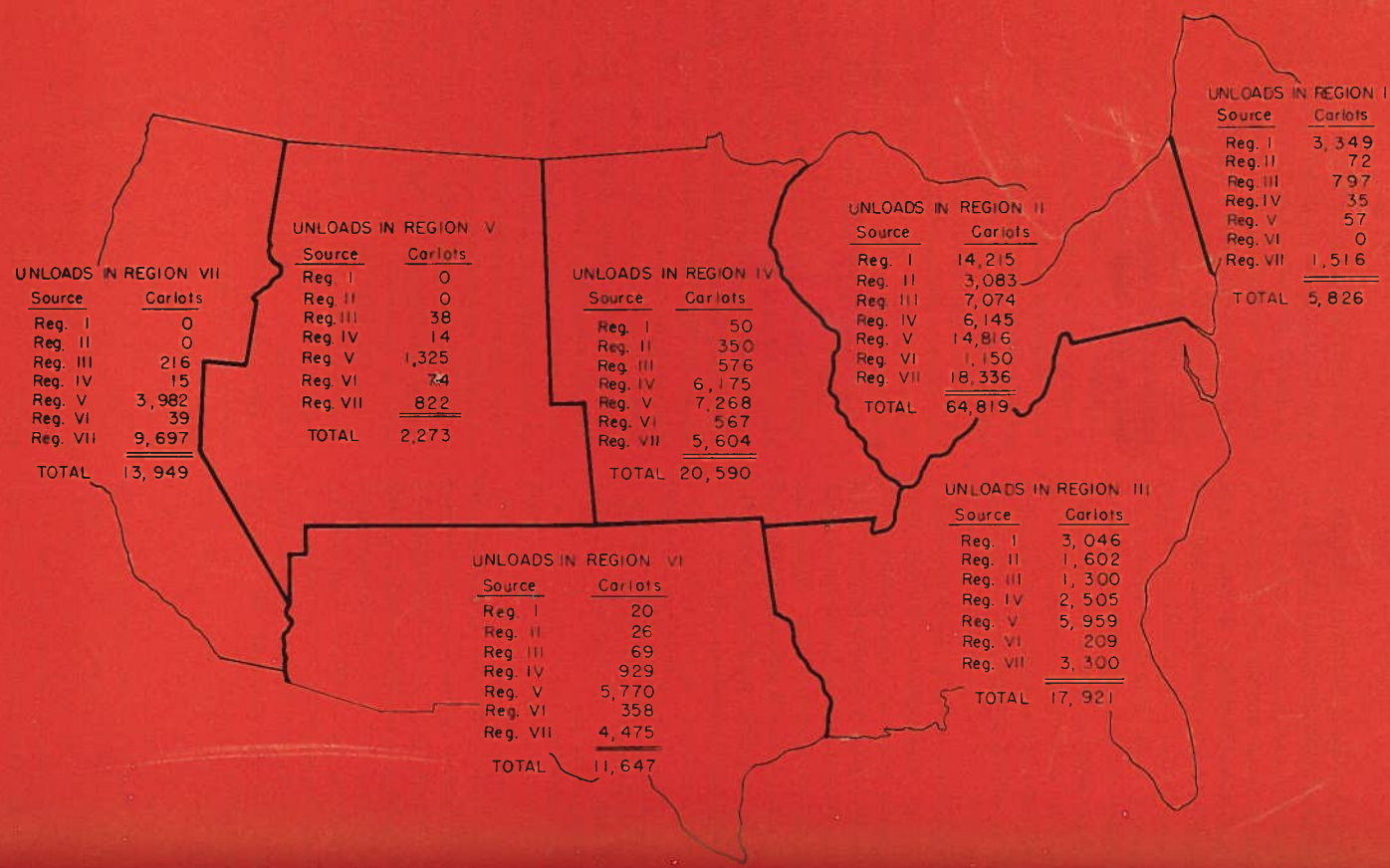

Carlot unloads of potatoes in 100 cities, 1949, showing source of potatoes by region and destination by region.

Control of Stored GRAIN INSECTS

IN THE NORTH CENTRAL STATES

Agricultural Experiment Station

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Contents

CONTROL OF *Stored Grain Insects* IN THE NORTH CENTRAL STATES[1]

RECENTLY there has been an increased awareness of the losses in stored grain due to insect activity and an increased demand on the part of the public for clean cereals and cereal products. It is both profitable and practical for producers and handlers of grain to utilize modern methods of insect control.

There are within the North Central States Region large reserves of grain in storage on the farm and in elevators. This varies from year to year but does amount to several billion bushels.

The longer the time that grain is held in storage, the greater is the likelihood for losses from insect infestation. Control and preventive methods and materials are presented in this publication. If properly used, they will largely prevent damage and the consequent deterioration of stored grain from insect attack.

INFLUENCE OF *Geographical Location*

THE NORTH CENTRAL States may be divided into three regions (figure 1) from the standpoint of damage from stored grain insects. In Region I, lower temperatures limit the period of insect activity to a few late summer months. As a result, insect populations do not increase as much as they do farther south. In Region II, insects are active in stored grains in bins during six to eight months of the year. In late fall and early winter, normal population increases give rise to tremendous numbers of these pests. In Region III, stored grain insects may be active during most of the year.

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[1] Manuscript prepared for North Central States Regional Technical Committee on Entomology by H. H. Walkden, Entomologist, Stored Products Insects Investigations, USDA; D. A. Wilbur, Entomologist, Kansas State College; Harold Gunderson, Extension Entomologist, Iowa State College.

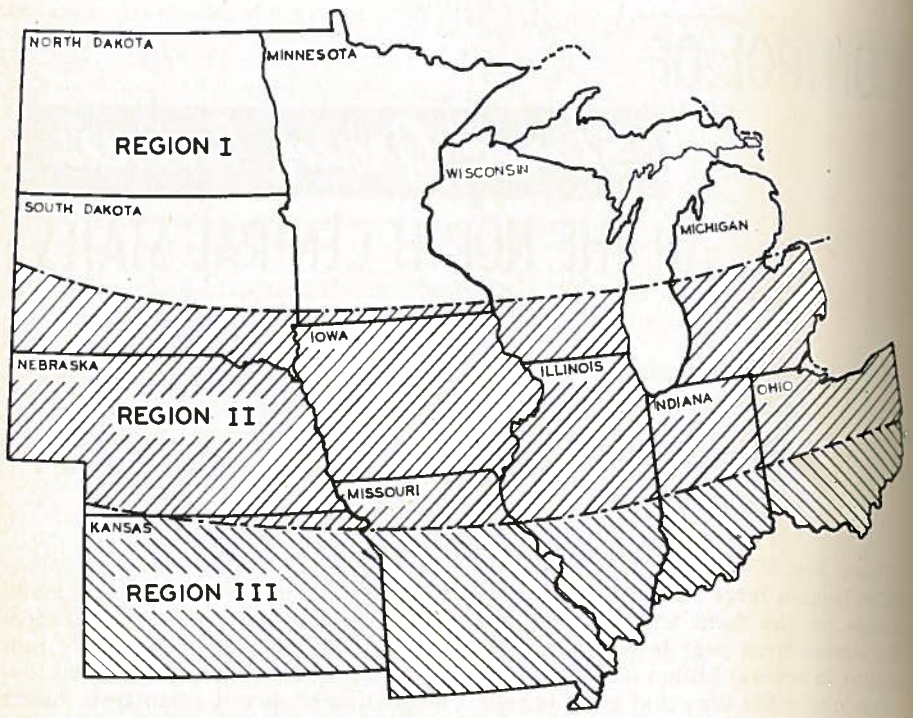


Fig. 1. Regional map of the North Central States, indicating relative hazard to farm-stored grain from insect attack: Region I, best adapted for safe farm storage for first season. Region II, insects troublesome in some years—frequent inspection and occasional fumigation necessary. Region III, insects troublesome every year—frequent inspection and fumigation necessary. The demarcations between regions are not sharp, but fade into one another.

TYPES OF *Damage*

THE FOLLOWING types of damage caused by grain-infesting insects may occur in the North Central states:

Loss in Weight and Food Value

Grain-infesting insects obtain food and water by eating the grain. The endosperm (starchy portion) of unbroken kernels may be consumed by adults and larvae of the granary weevil, rice weevil, and lesser grain borer; by larvae of Angoumois grain moth; under some circumstances by adults and larvae of confused and red flour beetles and cadelles; and by larvae of dermestids (figure 2).

Fig. 2. The rice weevils which emerged from these wheat kernels reduced the weight of the kernels by 24 per cent.

The germ may be consumed by the larvae of cadelles, Indian-meal moths, flat and rusty grain beetles, saw-toothed grain beetles, dermestids and confused and red flour beetles. Much of this damage occurs within the kernels and is not visible. Most farmers do not weigh the grain when it is placed in storage on the farm. They may be unaware of the extent to which this type of damage occurs in their grain. Damage to kernels from feeding may vary from slight injury to complete destruction. The amount of damage depends upon the kinds and numbers of insects present, the moisture and temperature of the grain, the length of time the grain is exposed to infestation, and the variety of grain.

Heating, with Resultant Caking and Spoilage

Grain-infesting insects frequently cause heating in small grains and shelled corn as a result of their feeding and other activities. Insect-caused heating, known as **dry grain heating,** may bring the temperature of the grain up to a maximum of 108°F. The warm air from the heating grain rises to the surface of the grain mass, carrying moisture with it. At the surface, the warm air is cooled and some of the moisture is deposited on the surface grain. Molds and fungi develop in the moist surface grain and caking and spoilage of the grain result (see cover).

Dry grain heating (insect-caused heating) develops in grain of less than 15 per cent moisture content. Dry grain heating should be distinguished from **wet grain heating,** which occurs only in grain of higher than approximately 15 per cent moisture. Wet grain heating results from the activity of yeasts, molds, fungi, and the respiration of the stored grain itself. In this kind of heating, the temperature of the grain may rise as high as 144°F. Insects cannot survive under conditions favorable for wet grain heating. Both dry grain heating and wet grain heating may develop simultaneously in different parts of the same bin.

Low Germination of Seed and Malt Grain

Lowered germination of seed and malt grain results from:

1. **Destruction of the germ** by the feeding activities of several species of insects. Cadelles, flat grain beetles, flour beetles, and Indian-meal moths are responsible for much of the germ destruction.
2. **Destruction of the endosperm.** Even though the germ may be undamaged the seedling lacks sufficient food to develop.
3. **Heating and high moisture.**

Filthy Grain

The presence of insects, particularly of the internal feeding types, implies the presence of filth, such as excrement, molted skins, disintegrated carcasses. Not all of this filth can be removed during the cleaning processes in the mill. Since grain is food, the Federal Food, Drug, and Cosmetic Act applies to interstate shipments of market grain. The law classes a food as adulterated if it contains filth. Also, a designation of "weevily" may be attached to the grade when samples, upon examination by official grain graders, are found to contain more insects than the United States grain-grading standards allow. Obnoxious odors imparted to grain by insects or webbing left on the grain also indicate the presence of filth.

Insect Fragments in Manufactured Products

The usual cleaning methods do not remove all of the internal feeding insects from grain which is to be processed into a cereal product. Internal feeding insects which are not removed are ground up during the milling process and the fragments are present in the finished product. These fragments may be detected by laboratory techniques. Here again, these insect fragments are classed as filth, and the Food, Drug, and Cosmetic Act will apply.

Sources of Insects WHICH INFEST NEWLY BINNED GRAIN

THE FOLLOWING constitute most of the important sources of infestation in stored grain.

Wooden Granaries and Cribs

Cracks, crevices, and cadelle burrows of wooden bins or other parts of the granary harbor grain-infesting insects (figure 3).

Fig. 3. A corner of a wooden bin showing the accumulation of grain in the cracks between the wallboards and on the floor.

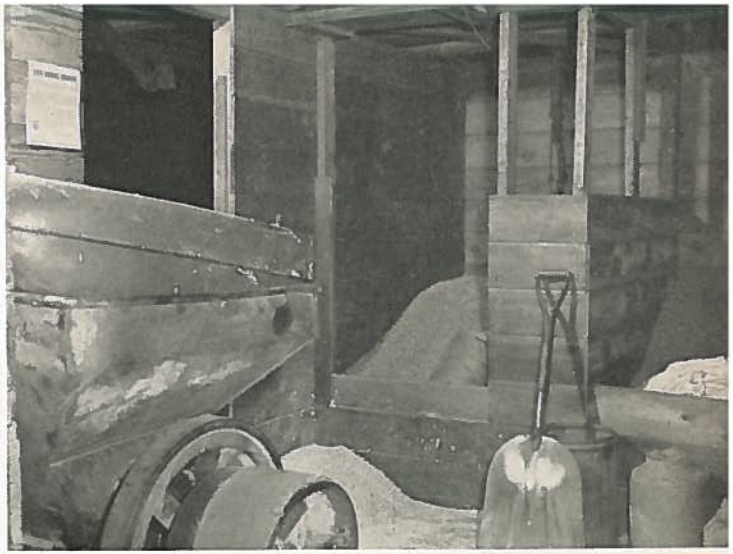


Fig. 4. A farm granary in which feed grain and ground feed are stored with market wheat. This practice enables insects in infested feed to move into the market grain.

Bins of Old Grain

Frequently new grain is dumped on top of old grain. The insects infesting the old grain move directly into the new. More frequently bins of old infested grain are adjacent to new grain and the insects migrate quickly to the new grain.

Feed Rooms or Bins or Other Stocks of Feed

All of the insects which attack stored grain may be found in feed rooms and feed bins. Often these insects can move readily to newly stored grain (figure 4).

Feed or Seed Brought to the Farm from Infested Sources

Stock and poultry feed may be infested. Frequently, screenings are available for scratch feed at local mills and elevators. These include much cracked grain, sweepings, and dust which are often infested with several kinds of stored grain insects. Seed wheat or other grains may also be brought to the farm in an infested condition (figure 5).

Accumulations of Waste Grain or Feed

Accumulations of waste grain or feed may be found in nearly every part of the farmstead. These include spillage,

Fig. 5. A wagon bed with a residue of infested grain housed in a granary driveway permits easy migration of stored grain pests into nearby bins of stored grain.

accumulations made by rodents, seepage through cracks in floors, grain trapped in double-walled construction, and piles of uncleaned grain and feed sacks. Accumulations are also found in implements like wagon and truck beds, self-feeders, combine hoppers, seeders, and grinders (figure 6).

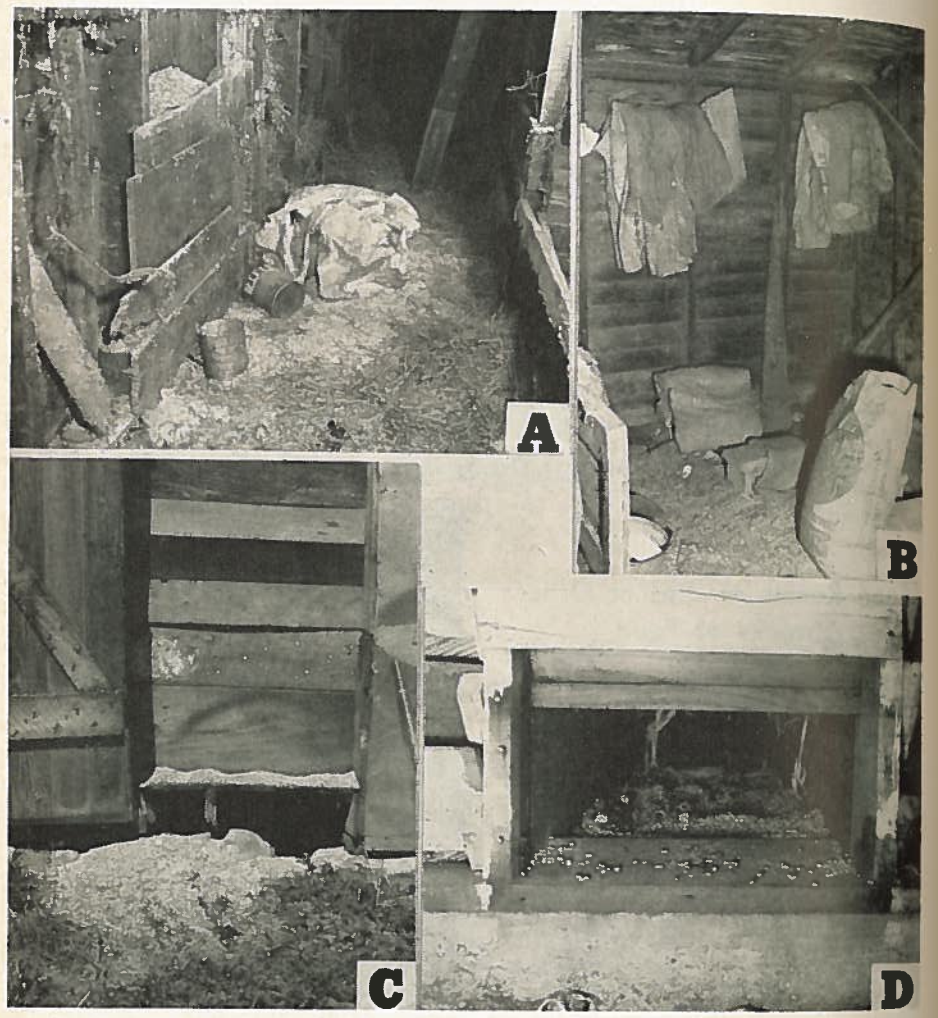


Fig. 6. Important sources of insect infestation in farm-stored grain:
A. A barn passageway littered with spilled grain, hay, and other debris.
B. Feed room in a granary showing accumulation of old feed and empty feed sacks.
C. A bin doorway showing accumulation of spilled grain on the doorsill, on the ground and underneath the bin.
D. A ventilation duct in a corn crib showing accumulation of waste corn.

Migration from Infested Sources

Several of the grain-infesting insects are capable of sustained flight. Studies have indicated that several species such as rice weevils, lesser grain borers, and flat grain beetles are in the air in abundance around infested granaries during the summer. Also, insects may be shaken off truckloads of grain.

Field Infestation

Studies have shown that field infestation of ripening wheat by stored grain insects does not normally occur in the North Central States Region. Angoumois grain moth and rice weevil infestations may occur in field corn in the southern portion of the area and be carried into storage at harvest.

PROTECTION OF *Grain on the Farm*

CONTROL of all these insects cannot be accomplished by *one* procedure alone. Cleanup of grain storage structures and the area around them, cleaning of all grain harvesting and handling equipment, and the use of chemicals for insect control are all important aspects of stored grain insect control.

Requirements for Grain Storage Structures

A variety of materials may be used in the construction of grain storage structures provided the structural design is adapted to the materials to be used (figure 7). The basic requirements are that the structures must:

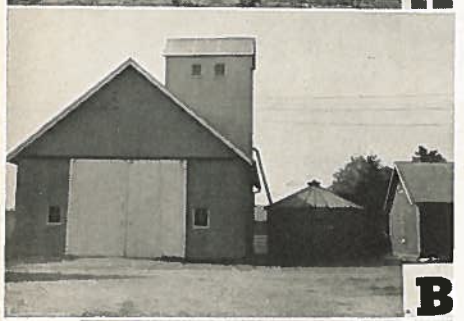
1. Hold the grain without loss of quantity.
2. Exclude rain, snow, and soil moisture.
3. Afford protection from rodents, birds, poultry, insects, objectionable odors, and theft of the grain.
4. Permit effective fumigation of small grains and shelled corn.
5. Provide reasonable safety from fire and wind damage.
6. Provide head room over binned grain for inspection and sampling.

Cleanup of Premises

In the North Central States, practically all infestations of stored small grains and corn occur after harvest rather than in the field. If these infestations are to be avoided, it is essential that the following sanitary procedures be observed:

1. **Separate the feed bins and feed rooms as far as possible from the structure where market grain is stored.** All grain-infesting insects are likely to be present in abundance in or near the feed rooms. Close proximity of feed rooms to bins of market grain facilitates migration of grain-infesting insects to the market grain. Feed rooms and feed bins are difficult to keep clean. This is particularly true when grinding facilities deposit layers of nutritious dust upon the surrounding areas.

2. **Avoid storing market grain in buildings that house animals or hay.**



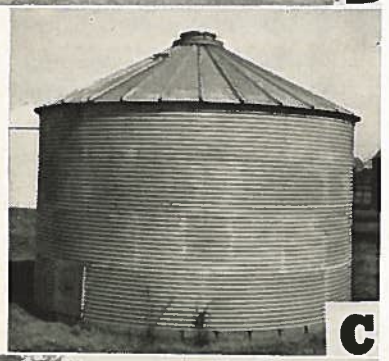


Fig. 7. A. A well constructed and maintained farm granary set on a tight concrete foundation. B. Farm elevators provide facilities for the efficient and economical handling of grain. C. Metal bins provide good grain storage if set on good foundation, and if the wall and the roof joints are tightly caulked. D. Bins in the dilapidated condition shown here are in common use. Such bins subject stored grain to all sorts of storage hazards.

Market grain stored in buildings or sheds occupied by animals or in buildings used as hay mows is more likely to become infested with insects than where grain is stored in separate buildings (figure 8). The heat given off by

Fig. 8. A combined livestock barn, hay barn and granary. Such structures prevent the natural, seasonal cooling of grain stored in them and permit activity of stored grain insects throughout most of the year.

the animals may prevent the seasonal cooling of the grain in the fall and enable insects to maintain activity throughout the winter. Mangers and feed boxes or troughs are frequently infested and thus constitute a continuous source of infestation. Large bulks of hay alongside or over grain bins and cribs serve as an insulation which prevents the reduction of infestation in the grain by low temperatures. Granary and rice weevils are particularly successful in surviving under such conditions.

3. **Clean up spilled grain, feed, and litter in and around the granary and other farm buildings to remove the supply of insects which infest the market grain.** In some cases it may be desirable to remove double-wall construction from bins, feed rooms, and other places behind which grain or feed can become lodged. Seal the foundations of the granary or bins so that spilled grain and feed do not lodge under the floor and in front of the bin doors.

Moisture Limits for Safe Storage

The drier the grain, the less deterioration will occur during storage. Grains differ in the permissible moisture content for safe storage. According to agricultural engineers, the median moisture limit for grains to be stored for a year or longer without loss of market grade is 13 per cent. The median moisture limit applies to a climate midway between the best and the worst of the region where the grain is stored. In a cold location (North Dakota) the limit may be 1 to 2 per cent above the median; in a warm location (Kansas) the limit is 1 to 2 per cent below the median.

Grain with high moisture content (above 14 per cent) is very favorable for insect development. The susceptibility of grain to insect attack decreases as the moisture content decreases, so that very dry grain (9 per cent moisture or lower) may be stored indefinitely without development of a serious insect infestation. Attempting to store grain of too high moisture content is almost certain to result in trouble.

How to Avoid High Moisture Content in Small Grains for Farm Storage

1. Delay harvest until the crop is dry.
2. Use weed killers during the growing period where necessary to avoid harvesting weedy grain.
3. Avoid combining too early or too late in the day when atmospheric moisture makes the grain tough.
4. Combine around low spots or other unripe parts of the field and cut them later.
5. If it is necessary to harvest an occasional load of wet grain, spread it out in the granary driveway, or leave it in the truck bed to dry. Remember that only a part of a load of wet grain is all that is necessary to start a large bin toward spoilage.
6. Run the grain over a screen on a hot, dry, windy day.
7. Place a vapor barrier such as hot asphalt or water- and vapor-proof paper on concrete floors.
8. Stop up all openings or leaks which might permit entrance of moisture.
9. Bind or windrow grain which must be harvested before it is sufficiently dry for safe storage and let it dry in the field.

Cleaning and Drying Grain

Harvest and store only clean dry small grains or shelled corn. If weather is such that damp grain is put into storage, heating, molding, and spoiling will occur. Fungus beetles and grain mites infest grain with high moisture content. If the condition is discovered soon after it starts, the grain may be dried artificially or run over a screen on a dry windy day to reduce the moisture content of the grain and to remove many of the insects and dockage (cracked grain, weed seeds, etc.).

An improperly adjusted blower used to transfer grain will create more dockage and cracked kernels. Excessive dockage in wheat and cracked kernels and foreign material in shelled corn prevent rapid cooling and effective fumigation. Grain that has been binned for a year with light insect infestation and normal amounts of cracked grain and foreign material frequently becomes packed. This condition promotes insect activity and sharply reduces the

effectiveness of fumigation. Such grain should be run over a gravity screen to remove the fine material and most of the free living insects before fumigation is attempted.

Maintaining Cool Grain Temperatures

The temperature of the grain will depend largely upon the climate of the region in which it is stored, provided the moisture content is within safe storage limits and the grain is kept free of insect infestation. Most of the stored grain insects do not lay eggs at 60°F. or lower.

When insects become concentrated in stored small grain or shelled corn, the heat and moisture created by their body processes result in dry grain heating. Although the resulting damage does not usually extend more than two feet below the surface, the entire grain mass can be contaminated with the musty or decayed surface grain when the bin is emptied, so that it is graded "sample," and must be offered for sale at a discount.

Storage of grain in a separate building will result in the seasonal cooling of the grain in the fall. Air drainage through the building on cold nights hastens cooling. It was pointed out earlier that grain storage in well insulated buildings where high temperatures are maintained by animals or by quantities of hay should be avoided. These precautions are more essential in the southern part of the North Central States Region than in the northern portion.

By painting the outside walls and roofs of metal bins with white paint, stored grain can be maintained several degrees cooler than that stored in unpainted bins (figure 9). The explanation is the reflection of part of the heat rays of the sun.

Placing vertical ventilating tubes in bins at filling time will also accelerate cooling of the grain in the fall. Such devices will, however, hasten warming of the grain in the spring. Hence, if grain is to be stored through a second summer or longer, the ventilating tubes should be capped during the warm months of the year.

The size of the storage unit also has an influence on the rate at which temperature changes occur. In general, the larger the bulk of grain, the slower will be the rate of temperature fluctuation in the grain mass.

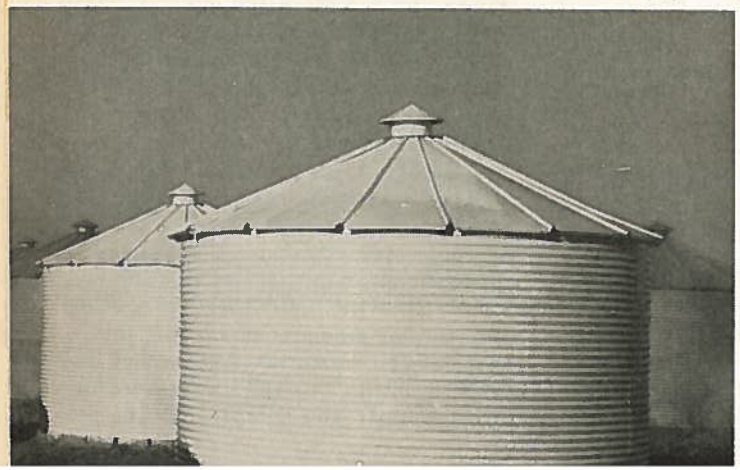


Fig. 9. Metal bins with walls and roofs painted white maintain grain temperatures several degrees lower than that of grain stored in unpainted metal bins.

Cleanup and Spraying of Storage Facilities

1. **Granary and cribs.** After the old grain has all been removed and the building has been swept clean, the ceiling, walls, and floor of each bin should be sprayed with a recommended insecticide (table 1). If there are spaces under the floors, these should be sprayed also. Any old grain that cannot be removed from the granary should be fumigated before the new grain is binned, if there is evidence of infestation.

Table 1. Spray Formulas and Rates of Application for Treating Walls and Floors of Storage Bins, or Parts of Elevators

Material	Mixture	Rate of application per 1000 square feet of surface
	per cent	gallons
DDT	2.5	2
Methoxychlor	2.5	2
TDE	2.5	2
Pyrethrins*	0.5	2
Allethrin*	0.5	2

* Synergized pyrethrins and synergized allethrin spray formulas are available. Insufficient evidence is at hand to determine the rates at which these mixtures may be substituted for 0.5 per cent emulsions of pyrethrins and allethrin. If used, follow manufacturer's recommendations.

For maximum effectiveness residual sprays should be applied at least two to four weeks before the new grain is binned. This allows time for cadelles and other grain-infesting insects to emerge from holes and cracks in the walls and to walk over the sprayed surfaces, thereby coming into contact with the insecticide.

2. **Feed rooms and other farm buildings.** Liberal application of residual sprays (table 1) about the farmstead at the time of the granary or crib cleanup will aid in preventing insect buildup and migrations. In spraying the feed room, feed stocks should be protected by a canvas cover during the process of spraying.

Protective Powders

A powder composed of pyrethrins and piperonyl butoxide in an inert organic carrier may be applied to newly harvested wheat to prevent insect infestation (table 2). These powders are intended to prevent infestation, and not to control one already established.

Table 2. Protective Powder for Application to Uninfested Wheat as It Is Put into Bins

Formulation	To be used on	Rate of application per 1000 bushels
		pounds
Pyrethrins, 0.08 per cent* Piperonyl butoxide, 1.1 per cent Inert organic carrier, 98.82 per cent	Wheat, U. S. standard grades	75

* Other formulas of synergized pyrethrin powders, or sprays, may soon be available. If used, follow manufacturer's recommendations.

Protective powders have certain advantages:

1. They are applied before damage has been done.

2. They are the only means of protecting wheat stored in bins too loose for effective fumigation.

3. They are not dangerous to apply and may be applied by anyone available, young or old, without skill.

4. They are effective with one application through the first season of storage.

5. They do not adversely affect germination.

Protective powders are easily applied to wheat by farmers at any of the following places or times:

1. In the combine hopper.

2. As the wheat pours out of the combine hopper into the truck bed (figure 10).

3. Over the top of the wheat in the truck at the granary.

Fig. 10. Applying a protective powder to wheat as it flows from the combine hopper to the truck.

4. As the truck bed is emptied into the lifter hopper.

5. As the wheat is elevated to the bin.

Fumigation

In gas-tight bins, fumigation at proper dosages and under usual conditions should kill insects present in the grain, but it will not prevent reinfestation. However, one or two properly applied and timely fumigations per year should provide good insect control. (See table 3 for dosage schedules.)

In some sections the use of carbon bisulfide as grain fumigant persists. Carbon bisulfide is highly explosive and insurance companies cancel policies on properties where it is used.

Fumigated grain can be fed within three or four days after fumigation if it is run out of the bin and stirred in the air to hasten final evaporation of the fumigant. No taste or odor is left when evaporation is complete.

How to Fumigate

For the successful fumigation of farm-stored grain it is necessary to create and maintain a uniform distribution of the fumigant throughout the grain mass long enough to kill insects both inside and outside the kernels. Most wooden farm granaries are loosely constructed and open at the top, a condition which permits rapid escape of the fumigant gases. For this reason, more fumigant is required for wooden farm bins than for concrete or steel structures in order to overcome the leakage.

Table 3. Fumigants for Grain Stored in Farm Bins*

Fumigant	Dosage per 1000 bushels		
	Wheat	Shelled corn	Sorghum grain
	gallons		
STEEL BINS			
Carbon tetrachloride—carbon disulfide (80-20)	2	5	6
Ethylene dichloride—carbon tetrachloride (75-25)	4	6	8
WOODEN BINS			
Carbon tetrachloride—carbon bisulfide (80-20)	4	6	8
Ethylene dichloride—carbon tetrachloride (75-25)	8	8	10

* There are many other suitable liquid mixtures available. Use according to manufacturer's directions.

1. **Break or remove any crust of grain before applying fumigant.**
2. **Level the grain.** The top surface of the grain should be at least six inches below the top of the bin.
3. **Fumigate when there is little or no air movement.**
4. **Apply the fumigant as a coarse spray evenly over the surface of the grain** (figure 11). If a severe infestation is known to exist near the edges, or elsewhere in the bin, apply a heavier dosage above such places.
5. **Apply the fumigant from the outside of the bin.** Under no circumstances should the operator enter the bin until 24 hours after the fumigant has been applied.

CAUTION: All chemicals used in grain fumigation are poisonous to human beings and animals. In handling them, the operator should take all necessary precautions and follow all directions given on manufactured products. Care should be taken not to breathe the vapors or spill the liquid fumigants on the skin or clothing. If a number of bins are to be fumigated, the operator should wear an approved full-face gas mask equipped with an approved black canister labeled "for organic vapors." The canister should be replaced with a fresh one after 30 minutes' exposure to the fumes of the fumigant.

For small operations, a garden sprayer is suitable. When using a garden sprayer, enlarge the opening in the spray disc with an eight-penny nail, or remove the spray nozzle and substitute one made of a ¼-inch pipe 6 inches long, with the nozzle end flattened.

For larger operations, a power pump which will take fumigant directly from the barrel is desirable. All pump fittings should be of bronze to resist the corrosive action of fumigants. Hose and gaskets should be of plastic or synthetic rubber which are not affected by the fumigant.

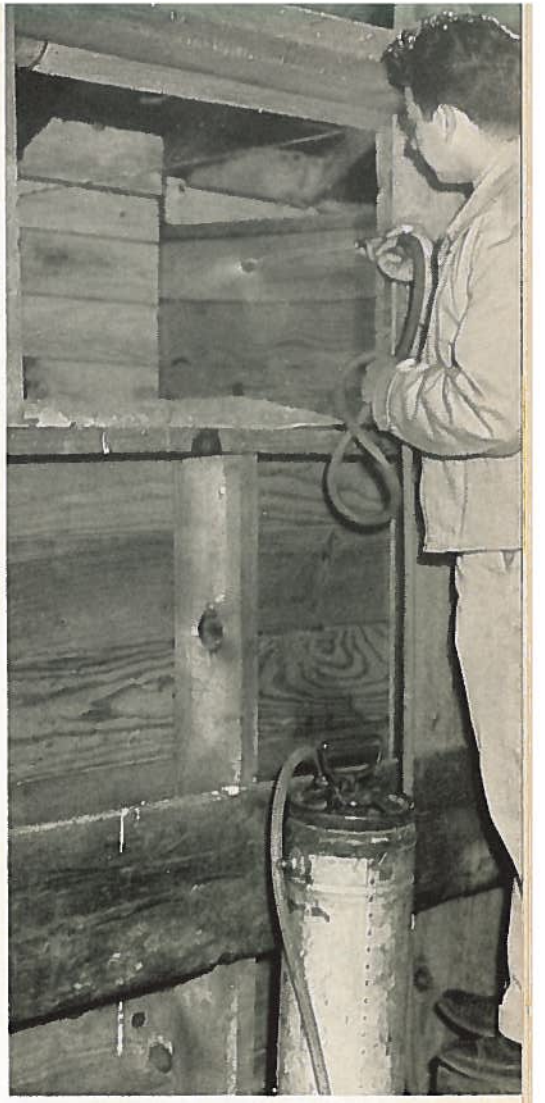


Fig. 11. Applying fumigant as a coarse spray, from the outside of the bin, using a 3-gallon sprayer with enlarged spray disc orifice.

When to Fumigate

The problem of conserving farm-stored grain from insect attack varies in different parts of the United States. In the southern portion of the North Central States Region, insect problems

are more acute than in Region I where the temperature of stored grain rarely rises high enough to permit development of dangerous insect populations (figure 1).

In Region I, fumigation during the first season of storage on the farm may not be necessary but it is good insurance. In Regions II and III farm-stored small grains should be given a protective fumigation within six weeks after they are put in the bin unless protective powders have been used. One annual fumigation will probably be sufficient. However, farm-stored grains should be inspected at monthly intervals during the summer months to determine the need for an additional control fumigation. Small grains to be stored for a second year or longer should be fumigated annually in mid-August.

In Region III, corn that is to be stored for an additional year or longer should be shelled as soon as the moisture content of the kernels is low enough for safe storage, preferably before the middle of May. All shelled corn should be cleaned before binning, since corn free from grain dust and broken kernels is less attractive to insects than uncleaned grain. Clean grain can be fumigated more effectively. An annual protective fumigation between late summer and early fall is necessary in shelled corn which is to be stored for a year or longer.

Shelled corn has been stored for three years in the North Central States region without appreciable deterioration or loss from insect attack, when the requirements for safe storage were observed.

Surface Treatments for Shelled Corn

In the central and northern parts of the region, the most troublesome insect in shelled corn is the Indian-meal moth whose larvae feed mostly on the surface layer. If the top layer of corn is sprayed with a white mineral oil (see table 4) applied at the rate of 2 quarts per 100 square feet of surface grain in June and August, very good protection from this pest will result.

Table 4. Oil Sprays for Surface Treatment of Shelled Corn in Bins*

Specifications	Dosage rate
Unsulfonated, technically white or refined mineral oil, 100 to 200 seconds viscosity (Saybolt 100° F.), free of objectionable odors	2 quarts per 100 square feet of surface grain

* Brands found satisfactory in bin tests were: Standard Oil of Indiana, Renown Engine, Texaco 519 Corvus Oil, Texaco 522, Texaco 1519, Diamond Paraffine, Skelly Skeltone, Conoco, Redind extra light, Pale Paraffine, Socony S/V Prorex Oil D, and Shell S.I.C.O.

Inspection of Farm-Stored Grain

Inspect grain in farm storage at monthly intervals during the summer and fall months throughout the period of storage. A standard grain probe is a convenient sampler. Empty the probe into a section of eave trough from which the grain can be handled to locate hot spots and screened to determine the kinds and numbers of insects present (figure 12). Take the temperature of the grain in the bin by fastening a thermometer to a stick and thrusting it into the grain. If a thermometer is not available, thrust an iron rod or pipe, or a hoe handle vertically into the grain. If upon removal, it is warm to the touch, the grain is heating. When hot spots are detected, determine the cause immediately by taking samples from the affected portion of the grain. Sift the samples through window screening into a shallow pan or other container to sieve out the insects. If you find insects, fumigate the grain immediately. Otherwise look for some other cause of heating, such as high moisture.

Fig. 12. Inspection of grain in farm storage, showing the grain probe or trier, the eave-trough for receiving the samples, and the pans for screening the insects.

What Is a Dangerous Level of Insect Infestation?

This can be determined by screening through a 10- to 12-mesh screen samples taken from the center or surface grain. The presence of granary weevil, rice weevil, or lesser grain borer adults indicates a need for immediate fumigation. The presence of five or more other species of grain insects per 1-quart sample (1,000 grams) also indicates a need for immediate fumigation.

Turning and Cleaning

Free-living insect infestations in stored small grains and shelled corn may be appreciably lowered by turning and cleaning, especially if a bin has "hot spots" due to high moisture, caking, or intense insect activity. However, fumigate the grain after turning and cleaning to kill the immature forms of insects which feed within the kernels. If equipment is available, turn grain in cold weather to lower the temperature.

SUMMARY OF THE *Program for Protection* OF GRAIN IN FARM STORAGE

1. Store grain in a well constructed, isolated granary.
2. Store the grain in as dry a condition as possible.
3. Remove all old grain from bins and any grain and feed accumulations from other buildings on the farmstead to prevent a buildup of insect populations.
4. Apply residual spray to the ceilings, walls, and floors of the granary or crib and other buildings at least two weeks before grain or feed is to be stored.
5. Fumigate all old grain which cannot be removed from the granary before new grain is binned.
6. Apply protective powders to newly harvested wheat.
7. Fumigate unprotected small grains within six weeks after harvest.
8. Inspect grain at frequent intervals to discover insect infestations or heating.
9. Fumigate the binned grain a second time if infestations develop.

PROTECTION OF *Grain in Elevators*

Sanitation of Premises

INSECT INFESTATION in elevators may come from two sources. Some insects occur in incoming grain, or they may spread into clean grain from residual sources within the elevator. Good housekeeping practices in the elevator will do much to eliminate this latter source of infestation (figure 13). Sweep out and remove all dust and accumulation of grain from gallery and headhouse floors, flat space under the eaves, tunnels, around edges of bins or structural members; clean elevator boots, legs, heads, horizontal screw conveyors, and spouting. Remove and dispose of tailovers.

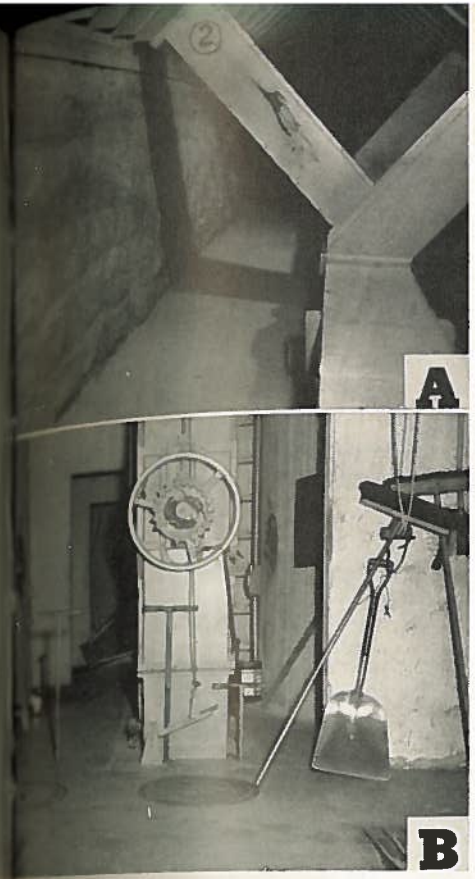


Fig. 13. A. Conveyor tunnel in an elevator showing cemented floor and plastered rock walls, thus eliminating insect harborages and facilitating cleaning. B. View of the work floor of a modern concrete country or line elevator where good housekeeping is a routine practice.

Cleanup of Elevator Bins

Use self-emptying hoppers in all bins, or manually remove all grain in flat-bottomed bins after each emptying.

Once a year before harvest time clean and spray all crib and balloon frame bins (table 1). Apply insecticide sprays during summer months to walls and floors of tunnels, gallery, and headhouse (table 1).

Fumigation

To supplement good housekeeping, fumigate elevator legs and screw conveyors whenever insects are seen in those locations with a so-called "spot" fumigant (table 5). If the elevator is generally infested, fumigate the whole structure when empty. If the management is inexperienced with fumigation, a professional fumigator should be consulted.

All wheat that is to be stored longer than one month should be fumigated within a week after it is received, regardless of how free of insects it appears to be. Other small grains and shelled corn in elevator storage in all parts of the region should be inspected and fumigated as needed (table 6).

How to Apply Fumigants

Apply liquid fumigants to small grains or shelled corn with an automatic applicator just as the grain enters the bin, and fill the bin as rapidly as possible. If applying fumigant by hand, add the proper amount to the last 100 bushels of each 1,000-bushel draft en-

Table 5. Spot Fumigants for Use in Elevator Legs, Screw Conveyors, Boots, and Pits*

Fumigant	Dosage rate
Ethylene dichloride—carbon tetrachloride (75-25)	Boots: 1½ pints to ½ gallon, depending on size
Carbon tetrachloride—ethylene dichloride—ethylene dibromide (60-35-5)	Screw conveyors: 4 ounces per foot

* There are many acceptable spot fumigants available on the market. Use according to manufacturer's recommendations.

Table 6. Fumigants for Use on Grain in Elevators

Fumigant	Dosage rate per 1000 bushels: 80° F. or above	70° to 80°	Below 70°
CONCRETE OR STEEL ELEVATOR BINS		pounds	
Calcium cyanide	10	10	15
Chloropicrin	2	2½	3
		gallons	
Carbon tetrachloride—carbon bisulfide (80-20)	2	2½	3
Ethylene dichloride—carbon tetrachloride (75-25)	4	5	6
WOODEN ELEVATOR BINS		pounds	
Calcium cyanide	20	20	30
Chloropicrin	4	5	6
		gallons	
Carbon tetrachloride—carbon disulfide (80-20)	4	5	6
Ethylene dichloride—carbon tetrachloride (75-25)	8	10	12

tering the bin. On warm clean grain, apply the whole amount of fumigant for a bin evenly over the top surface of the bin-load. When chloropicrin or calcium cyanide is used, apply it continuously to the grain stream as the bin is filled, using specially designed applicators.

How to Treat Surface Infestations in Grain

Occasionally the Indian-meal moth infests elevator bins, but most of the damage is done in the top layers. Close all bin openings and spray fumigants into the space above the load (table 7).

Table 7. Fumigants for the Control of Surface Infestation of the Indian-Meal Moth in Grain Stored in Elevators

Fumigant	Dosage rate per 1000 cubic feet of unfilled bin space
Chloropicrin Methyl bromide—chloropicrin (80-20) Methyl bromide—ethylene dibromide (80-20)	½ to 2 pounds, depending on tightness of the structure

Dangerous Levels of Insect Infestation

Grain should be sampled as it is being run from the bin with an automatic sampling device or with a pelican sampler (figure 14). Fumigate if **any** weevil adults are found in wheat or if an average of five or more other adult insects per quart sample is found in either small grains or shelled corn.

Fig. 14. Sampling elevator grain with a pelican sampler.

Control of Moisture

High moisture grain is attractive to insects, promotes mold growth, and may induce heating. If grain is to be held in elevator storage for any length of time, avoid that above safe moisture levels, or dry it artificially.

Temperature Control

Insects are not active in grain if the temperature is below 50°F. If grain is cooled by turning in cold weather, any buildup of infestation can be delayed as long as the temperature of the grain remains low. In the northern half of the region, low temperatures will persist until the middle of the summer season.

PROTECTION OF *Grain in Transit*

Cleanup of Cars

RAILWAY CARS are often infested with stored grain insects which are breeding in waste grain or feed accumulated behind end and side linings, or which are hidden in cracks in the linings. Before loading, cars should be swept clean and a spray applied to the floor and all side walls[2] (table 1).

Fumigation

Satisfactory fumigation of bulk grain in freight cars is now possible by using forced circulation. Such fumigation is limited to commercial fumigators or operators handling a large number of cars. Details can be obtained from the Stored Products Insects Investigations, USDA, Washington 25, D. C.

[2] It has been reported that empty cars intended for flour shipments have been successfully treated with aerosols. Insufficient data are at hand to recommend this procedure for empty cars at this time.

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