PART V
Seeds and Stored Grains

Glenn F. Chappell II, Extension Agent, Agriculture, Prince George County,
D. Ames Herbert, Jr., Extension Entomologist
Sam McNeill, Assistant Extension Professor, Biosystems and Agriculture Engineering, University of Kentucky Research and Education Center

Managing stored grains and seed requires the use of various techniques to ensure the quality of the product entering the storage facility does not deteriorate over time. These techniques include: the use of sanitation, storing sound, dry grain, managing temperature and aeration, using chemical protectants, regular sampling, and the use of fumigation. Bin and storage facilities also play an important role in determining the quality of the stored grain. Storage facilities should be inspected regularly for deterioration of any type.

Proper storage moisture varies depending on type of seed, length of storage and storage conditions. Seed moisture content changes until equilibrium is established with the surrounding environment. The equilibrium moisture is different for each kind of seed. High oil content seeds (soybeans, peanuts, sunflowers) will not absorb as much moisture as seed with a high starch content (wheat, barley, corn, sorghum). Oil does not absorb water; therefore, in a seed with 40% oil the seed moisture will be concentrated in the other 60%. The time to reach equilibrium will vary from days to months depending on the kind of seed, humidity and temperature. When there are large differences in seed moisture and the surrounding environment the initial change is rapid and slows as equilibrium temperature/moisture is approached.

Over 60 species of insects infest stored grains. Lesser grain borer, rice weevils, maize weevils, cadelle beetles, flat grain beetles, rusty grain beetles, sawtoothed grain beetles, foreign grain beetles, mealworm beetles, red flour beetles, confused flour beetles, Indian meal moths, book lice and grain mites are considered the main pests. Of those listed, Indian meal moths are the most commonly encountered. Damage by stored grain insects can go unnoticed until the grain is removed from the storage facility. Regular monitoring will ensure that the quality of the grain will be maintained at the highest level possible. Scouting should not be limited to the field. A regular monitoring program should be continued until the grain leaves the storage facility.

Microorganisms are another important consideration when storing seeds or grain. The two major microorganisms involved in seed molds are aspergillus and penicillin. As molds develop in stored grains, temperatures rise resulting in “hot spots”. In these spots, temperatures can reach as high as 125^{o}F. Mold growth is retarded as temperatures increase; seed vigor and germination are also reduced with increased temperatures.

Bin facilities (bulk storage)

Bin facilities should be weather tight, rodent proof, steel, and on a moisture proof concrete base. Bins should be equipped with a perforated-floor aeration system and weather proof-roof vent. All bins should be inspected on a regular basis to guard against leaks and deterioration of any kind. Once filled, attempt to seal the bottom and sides of the bin so insects and rodents can only enter the top of the facility. Do not seal roof aeration exhaust or inlet vents except during fumigation so the top of the bin can be easily sampled and top dressings applied if necessary.

Sanitation

Before adding grain to a storage facility, make sure it is clean and free of old grain, trash and insects. Be sure the walls, ceiling, sills, ledges, floors and the ventilation system (under perforated floors, ducts and fan system) are clean. The area outside the bin should also be free of insects, weeds and grain products. Insects can breed and persist in these areas and infest new grain when placed in the bin. It is best to clean and treat bins at least two weeks prior to adding new grain.

Most insect infestations in stored grain originate in the immediate area of the storage facility. Area sanitation is important since many of the commonly stored grain pests can fly and may move from one bin to another.

Grain moisture

As a general rule, grain should be stored at no more than 12% moisture. Insects and fungi do not develop well in grain with moisture content of 12% or below. For seed to be stored for long periods of time, the maximum safe moisture content is about 2% below the safe storage moisture of the grain. Refer to Table 1 for recommended storage moistures for grains and seed at various storage temperatures. Seed can be stored for 3-5 years in sealed containers at 65–75°F if dried to 5 – 8% moisture. For longer storage periods under these conditions, seed should be dried to 2.5–5% moisture before placing in a sealed container. Seed moisture content can be increased as the temperature is reduced below 60°F. Avoid storing seed in environments that will expose them to high temperatures or humidity. Dry, cold storage is ideal; therefore, a freezer is excellent for seed storage.

Table 1. Suggested Maximum Safe Moisture Storage For Grain and Seed[1]

Seed	2 months	6 months	Grain and Seed Long-term Storage	Storage Temperature Should be Below °F
	Maximum Grain Moisture (%)			
Barley	—	13.4	11.9	77
Buckwheat	—	13.9	12.4	77
Corn, grain	14.8	14.0	12.4	77
Corn, grain	15.2	14.2	12.6	60
Corn, grain	17.7	15.5	13.9	40
Corn, ear[2]	—	20.0	—	50
Oats	—	12.8	11.4	77
Millet	—	10.0	9.0	70
Peanuts, unshelled	11.2	9.6	8.4	70
Peanuts, unshelled	12.0	10.3	8.9	50
Peanuts, shelled	8.8	7.7	6.7	70
Peanuts, shelled	9.1	8.1	7.2	50
Rye	—	13.9	12.3	77
Soybeans	15.8	12.0	9.7	77
Soybeans	16.1	12.4	10.1	60
Soybeans	16.5	12.9	10.4	40
Sunflowers, oil	—	9.6	8.6	77
Sunflowers, non-oil	—	10.0	9.0	77
Sorghum	14.7	13.5	12.4	90
Sorghum	15.2	14.0	13.0	60
Wheat, soft red winter	15.6	13.6	12.1	77
Wheat, soft red winter	15.8	14.0	12.4	70
Wheat, soft red winter	16.0	14.4	13.1	40
Alfalfa	—	—	7.8	73
KY bluegrass	—	—	11.3	73
Clover, red	—	—	9.1	73
Clover, white	—	—	8.7	73
Crown vetch	—	—	9.4	73
Tall fescue	—	—	12.1	73
Orchardgrass	—	—	11.0	73
Ryegrass	—	—	12.8	73
Timothy	—	—	12.5	73

[1] Safe storage depends on many factors such as temperature, humidity, kind and variety of seed, quality, damage, microorganisms, length and kind of storage. Stored grains and seed should be inspected frequently for changes in temperature and moisture as well as pest infestations.

[2] Ventilated cribs 6-8’ wide.

Temperature and aeration

A combination of low seed temperature and low moisture aid in insect control. Insect reproduction is reduced at temperatures below 60°F and as the moisture content of the seed is reduced. These conditions do not provide enough heat and water to meet the needs of the insects. Grains harvested and stored in the hottest part of the year have a greater chance of becoming infested, since insects reproduce rapidly at temperatures in the range of 60-90°F. Farm stored wheat, rye, barley or oats are more likely to have insect problems than corn or soybeans which are harvested during the cooler months of the year. Aeration during times of low outside temperature and humidity is suggested to reduce temperature and moisture. In the southern United States, it is recommended to maintain warm temperatures and low humidity until cooler temperatures arrive and then cool the grain to 55-65°F or lower as soon as possible. The amount of air required for good aeration is relatively low, but it should be at least 0.10 cubic foot per minute per bushel.

Resistance to Low Temperatures of Various Insects that Attack Stored Grain and Grain Products

	Days Exposure Required to Kill All Stages at[1]						
Insect	**0°-5°F**	**5°-10°F**	**10°-15°F**	**15°-20°F**	**20°-25°F**	**25°-30°F**	**30°-35°F**
Rice weevil	1	1	1	3	6	8	16
Granary weevil	1	3	—	14	33	46	73
Saw-toothed grain beetle	1	1	3	3	7	23	26
Confused flour beetle	1	1	1	1	5	12	17
Red flour beetle	1	1	1	1	5	8	17
Indian-meal moth	1	3	5	8	28	90	—
Mediterranean flour moth	1	3	4	7	24	116	—

[1] Storage of Cereal Grains and Their Products, J. A. Anderson and A. W. Alcock, American Association of Cereal Chemist, St. Paul, Minnesota, 1954.

Several practices should be followed when filling bins to permit even aeration of the grain mass. The upper surface of the grain mass should be level or slightly inverted to permit even aeration. The use of a grain spreader will help prevent the accumulation of fines (broken grain, weed seed, dust and debris) in the center when filling bins. If not spread evenly, this material will accumulate in the center of the bin preventing even aeration and providing an excellent environment for insects and fungi to develop.

Figure 1

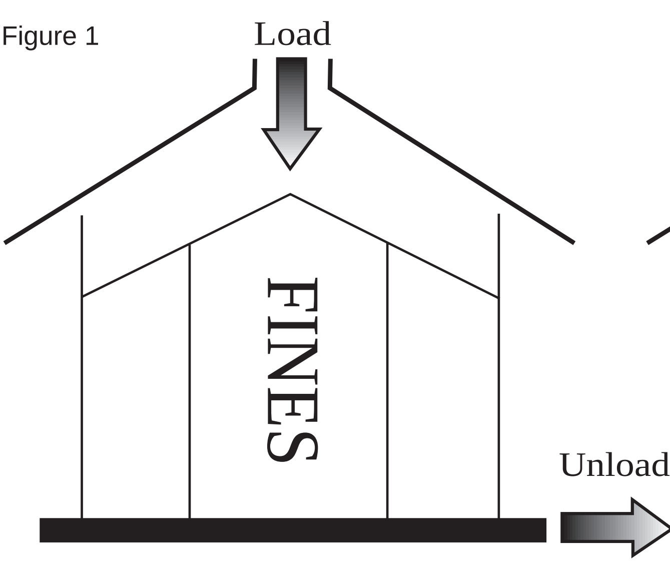
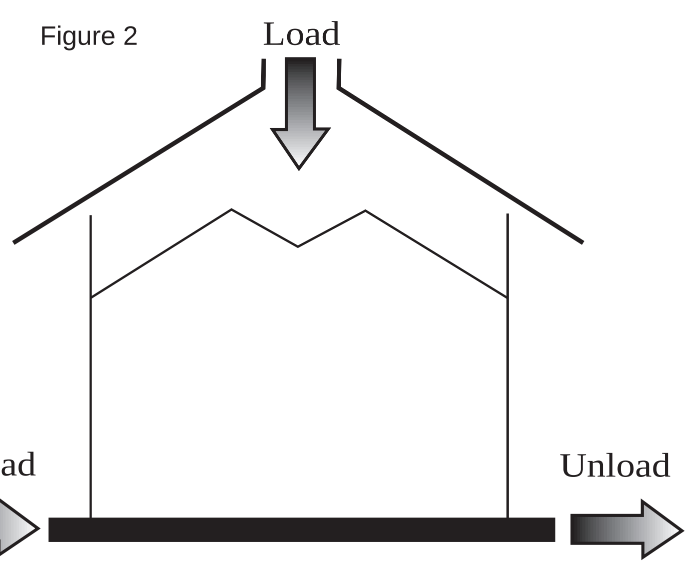


Figure 2



The accumulation of fines in the center of the bin can be greatly reduced by removing a portion of the grain mass after the facility is filled or several times during the loading process. Removing the core from the bottom with the centrally located unloading auger or conveyer will remove the column of fines and invert the peaked grain in the top of the tank (Figure 2). After this process is completed the grain can be left alone or leveled. This process called "coring" will increase aeration efficiency and reduce problems with insects, fungi and hotspots. For grain stored through the winter, aeration in the fall can deter moisture migration in the bin. Moisture migration is caused by differential temperatures in the grain mass resulting in convective flow of air through the grain. The convective flow of air can result in accumulating moisture condensation in the upper center of the grain mass. These factors will contribute to the development of molds and insects. Attempt to maintain grain temperature within 10˚F of the average outside air temperature. Depending on the year and the conditions several aeration events may be required to correct temperature differences. Aeration is very important in grain bins containing 2,000 bushels or more.

Empty bin sprays

Empty bin sprays are recommended for summer stored grain, difficult to clean bins or when there is a history of insect problems. After bins have been properly cleaned and inspected and prior to adding new grain, spray the empty bin with a labeled insecticide. Spray to run-off the inside surface, and as much of the outside including the nearby ground surfaces, aeration ducts, and grain handling equipment, as possible. Sprays should be concentrated on cracks, crevices and areas difficult to clean. Applications should be made at least two weeks prior to adding new grain. Allow 24 hours for sprays to dry. These sprays provide a barrier for insects that may be attracted to the storage facilities and also provide control of the insects not removed during the cleaning operation.

Bacillus thuringiensis grain products

Bacillus thuringiensis (Bt) is a biological insecticide that has activity on some moth larvae. This insecticide has been genetically engineered into many of the grain crops currently produced in the United States. In many of these newer engineered crops, the *Bt* gene is expressed in the grain as well as other parts of the plant thus providing the grain with protection from larval feeding. Although no research has been conducted to determine the effectiveness of *Bt* grains in storage, protection should be equal to or superior to the *Bt* products available for stored product treatments. The expression of the *Bt* toxin in every grain should provide a level of protection greater than any *Bt* topical, bin or grain treatment. Until research has been conducted to determine the effectiveness of the *Bt* gene under storage conditions, sample grain regularly. *Bt* products will not control weevils or other beetles.

Chemical grain protectents

A grain protectant may be added when the bin is being filled to guard against insect damage. Protectants may also be added to the upper surface of the grain in the bin to protect against damage from moths and other insects entering the top of the storage facility. Protectants will not eliminate existing infestations. Protectants are recommended if grain is going to be stored for extended periods, in flat structures, under circumstances that favor pest development, or in facilities with a history of insect damage. The combination of high grain moisture and high temperatures will shorten the residual life of grain protectants. Use only labeled products at the approved rates and check with your miller or buyer before using an insecticide on stored products.

Top dressing and pest strips

It may be necessary to mix an insecticide with the top 4 inches of the grain to deal with an infestation of primarily moths. Moths tend to attack the upper surface of the grain mass. The Indian meal moth is the most common insect to attack stored grain and, unfortunately, it already has resistance to some insecticides.

Resin strips (dichorvos or DDVP) may also be hung in the air space in the top of the bin to help control adult moths. For this treatment to be effective, the top of the bin must be temporarily sealed including the roof vent. Aeration will disrupt this treatment. Remember to open the roof vent before aerating.

Insect Sampling

Bins should be inspected on a regular basis for insects, hot spots, mold growth or any "off odor." As a general guideline, bins should be sampled twice a month under warm conditions and once a month under cool conditions. Regular inspections will reduce the chances of pests becoming established. Take all necessary safety precautions. Bins should be easily accessible and all unloading equipment should be turned off. Be aware of any pesticides applied to the grain, undissipated fumigants, bridged grain, grain dusts, and high temperatures. WORKING IN TEAMS IS THE BEST POLICY WITH AT LEAST ONE PERSON ON THE OUTSIDE OF THE STORAGE FACILITY.

Samplers should be alert for:
• Off odors
• Crusting
• Temperature differences > 10˚F
• Visible water vapor
• Sprouting grain
• Exterior bin conditions and signs
• Uneven snow melt or frosting
• Condensation
• Discoloration
• Fecal matter (birds, rodent and insect)
• Birds (insect feeders)

Use a probe (Figure 4) or scoop to collect the samples. Take five to ten, one-pint samples from various areas over the grain surface. Using a compartmentalized grain trier will allow the sampler to determine differences in grain moisture, insect populations, temperature and grain quality at different depths in the grain mass. Label samples so problem areas within the bin can be identified. Sampling at different depths will greatly increase the chances of finding trouble spots before a large area of grain is damaged.

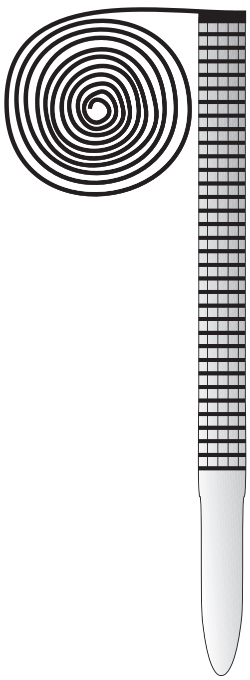


Figure 3. Probe Trap

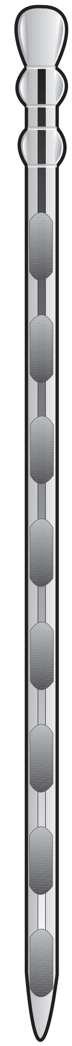


Figure 4. Grain Trier

Grain temperature should be determined as soon as possible after the sample is taken to achieve the most accurate results. Temperature differences in the range 10 - 15˚F indicate a potential problem. Usually aeration will correct the temperature difference. After corrective measures are taken, further sampling is suggested to ensure the problem has been corrected.

When sampling for insects in cool grain, samples should be warmed. Warming will increase the activity of the insects allowing the sampler to easily spot the pests and determine if the insects are alive. Individual samples can be placed in labeled plastic bags to guard against contamination. Each sample should be placed on a sieve, which will hold the grain while allowing the pieces (fines), insects and small debris to pass through. If insects are present, save them for identification, estimate the abundance and determine the distribution. Pest identification is crucial when selecting a control measure. For example, several species of insects feed on fungi. Their presence indicates a moisture problem. Control of the insects with pesticides can be achieved without correcting the primary problem.

Another method of sampling involves using a grain probe trap. (Figure 3) This trap consists of a perforated plastic tube with a funnel collector on the bottom. Traps are inserted in the grain mass and marked with colored string which allows them to be retrieved. Traps are retrieved after 24 hours and are more efficient than probing and sieving for beetles, but they do not adequately detect moth larvae.

Trouble spots can also be identified using a metal rod. Insert the rod into the grain and allow it to remain for about 10 minutes. Hot spots can be detected by running your hand down the rod after removing it from the grain. If temperature differences are sensed, investigate these areas further to determine the reason for the difference in grain temperature.

Accurate records should be kept so changes over time can be detected. Records can be used to refine a management strategy for your individual operation.

Generally, it is suggested to treat grain to control insects:

If Wheat, Rye, or Triticale have one live insect per quart sample

If Corn, Sorghum, Barley, Oats or Soybeans, have one live weevil or five other insects per quart sample

If these thresholds are exceeded, fumigation is suggested. However, if temperatures are below manufacturer suggested levels, fumigation should be delayed. Fumigation effectiveness is greatly reduced under cool conditions. For conditions that do not favor fumigation, the grain mass should be cooled to below 60˚F if possible. At temperatures below 60˚F, insects are for the most part inactive. When temperatures permit, fumigation should be considered.

Primary grain insects

Primary grain insects refer to a group of insects that attacks whole, undamaged grain. The immature stages of these insects occur on the inside of the grain where detection is more difficult. The damage from these insects results in an Insect Damaged Kernels (IDK) sample grade classification. Examples of primary insects include the rice weevils, bean weevils and lesser grain borer.

Secondary grain insects

This group refers to a complex of insects that feeds on fragments of grain and cereals. They can also be referred to as bran bugs. They include various grain moths, mites, psocids and various beetles. Examples of secondary insects include flour beetles, sawtoothed grain beetles, rusty grain beetles and Indian meal moths.

Fumigation

Fumigation should be conducted only by trained, experienced, registered applicators. If insects are found above the suggested thresholds, fumigation is suggested. The goal of fumigation is to maintain a toxic concentration of gas long enough to kill the target pest population. The toxic gasses penetrate into cracks, crevices, the commodity and the facility treated. Fumigants provide no residual protection. Fumigants come in several forms and formulations. All label instructions and precautions should be read and carefully followed.

Fumigant selection should be based on the following factors: pest susceptibility, volatility, penetrability, corrosiveness, safety, flammability, residues, odors, application method, required equipment, and economics. There are two products labeled for treating stored products – methyl bromide and phosphine producing materials such as magnesium phosphide and aluminum phosphide.

Phosphine fumigants

Phosphine has no adverse affects on seed germination when applied according to label directions and at labeled rates. Phosphine does react with certain metals such as copper, brass, bronze, gold and silver. Reactions result in discoloration and corrosion. This is a problem with electrical and mechanical systems that utilize these metals. This problem apparently only occurs when there are high concentrations of phosphine in combination with high humidity and temperature.

If the liberation of hydrogen phosphide occurs in a confined area an explosion or fire may result. Aluminum phosphide has been formulated with ammonium carbamate or aluminum stearate and calcium oxide to control the release and lower the combustibility. In addition to controlling the reaction, formulations that contain ammonium carbamate release a garlic odor that serves as a warning odor. The time required for phosphine release is shorter under warm, humid conditions and longer under cool and dry conditions. Since the gas diffuses through the grain rapidly, structures must be sealed properly, especially under cooler conditions.

Methyl bromide fumigants

Under most conditions, fumigation with methyl bromide will not harm germination. However, high doses (generally used for insects) for more than 24 hours coupled with temperatures above 85˚F and moisture greater than 12% can negatively impact seed germination. Methyl bromide does not harm electronic equipment and wiring, requires less time to kill insects when compared to phosphine but does give certain products containing sulfur, rubber (foam and sponge rubber also), feathers, hairs, and cinder blocks an odor. For other products affected by the methyl bromide refer to the product label. When using methyl bromide at temperatures below 60˚F, the dosage of the fumigant should be increased to compensate for the cooler conditions.

Methyl bromide is 3.27 times heavier than air, causing it to fall when released. Because of the density of the fumigant, grain leveling is important. Unleveled grain results in the fumigant settling to low areas in the grain resulting in poor fumigation of the peaked grain. Recirculation is often used to ensure even distribution of the fumigant.

Methyl bromide comes in small cans or can be obtained in large cylinders. Small cans require special puncture type openers to release the gas. The cans are generally used where small structures and transportation containers require fumigation. Cylinders are primarily used for larger facilities. The cylinders are connected to the bin facility with brass fittings and polyethylene tubing. The end of the tubing is usually placed in the headspace of the bin with a plastic pan or tray under the end of the tube to catch any moisture. The amount of fumigant required is determined based on the size of the structure and environmental conditions present. The cylinder is placed on a set of scales and the weight determined. The valve is opened and then closed once the proper amount of the fumigant has been released.

Grain storage space, capacities and weights

Bushels of grain can be determined either on a weight basis or on a volume basis. Grain test weight can be used to convert from one to the other.

Volume bushels

1.0 bushel shelled grain = 1.25 cubic feet
1.0 cubic foot = 0.8 bushel shelled grain

1.0 bushel ear corn = 2. 5 cubic feet
1.0 cubic foot = 0.4 bushel ear corn

2.0 bushels of ear corn = 1.0 bushel of shelled corn

Bin Storage capacity in bushels
(approximate)

Rectangular bins = length x width x height x 0.8 bu.
Round bins = Diameter2 x height x 0.628 bu.

Weight of Grain Per Bushel at Various Moisture Levels

	Corn		Soybeans	
Moisture %	**Shelled lbs.**	**Ear lbs.**	**Harvest Moisture %**	**Lbs. Grain to Make 60 lbs. Bu at 14%**
10.0	52.6	62.5	10.0	57.6
12.0	53.8	64.7	11.0	58.2
14.0	55.0	66.9	12.0	58.8
15.5	56.0	68.4	13.0	59.4
18.0	57.7	71.3	14.0	60.0
20.0	59.1	74.0	15.0	60.6
22.0	60.6	76.8	16.0	61.2
24.0	62.2	79.8	17.0	61.8
26.0	63.9	82.8	18.0	62.4
28.0	65.7	85.6	19.0	63.0
30.0	67.6	88.5	20.0	63.6
32.0	69.6	91.4	21.0	64.2
34.0	71.7	94.3	22.0	64.8

References

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Stored Product Management. Oklahoma Cooperative Extension Service Circulation Number E-912.