

# Unit 4. Pest Management Options

## Learning Objectives

After studying this unit, the learner will be able to:

- Define Integrated Pest Management (IPM).
- Describe the advantages and disadvantages of fumigants.
- Evaluate several non-fumigant pest management methods for soil and stored commodities.
- Use several methods simultaneously or sequentially to solve a pest problem.

This unit describes the principles of Integrated Pest Management (IPM). It explains how you can use fumigation as one aspect of a well-planned IPM program. You will learn several advantages and disadvantages of fumigants. You will also learn several ways to manage pest and disease problems without fumigation. These “alternatives to fumigation” may be cultural, biological or chemical. By using a combination of methods, you may often achieve the best control.

## Terms to Know

**Action Threshold** – A pest population level that triggers a management response. Sampling and regular observation are necessary to assess threshold levels.

**Aeration** – *Fumigant application:* The process of replacing fumigant-containing air or water with fresh air and/or water that contains little or no fumigant. Aeration must follow all fumigation operations.

**Aeration** – *Grain storage.* The process of passing air through a stored product such as grain to regulate temperature and moisture content.

**Auger** – A grain transfer tool used to load and unload grain and other stored products.

**Binning** – Placing grain or another raw product into a storage bin.

**Biological Control** – The use of natural enemies (predators, parasites or pathogens) to control pests and pest populations.

**Cultivar** – An agriculturally derived plant variety with unique characteristics. For

example, there are several cultivars of corn. Each one has a unique flavor, color or pest resistance.

**Cultivation** – Plowing and/or tilling to loosen the soil, remove weeds, etc.

**Cultural Control** – A pest control method that involves changing one or more crop production practices (sanitation, cultivation, crop rotation, use of resistant plant varieties, etc.) to create an uninviting or unfavorable environment for pests.

**Cuticle** – The protective outer covering of an insect.

**Fines** – Broken kernels and pieces of small foreign material within a load of grain.

**Harborage** – Shelter, a home or refuge for an organism.

**Headspace** – The open area between the stored product and the ceiling of the storage facility.

**Herbicide** – A pesticide used to kill or alter the growth and development of plants.

**Hot Spot** – An area in stored grain that is much warmer (10°F or more) than the surrounding grain. A hot spot indicates that the grain has a higher than normal moisture content, possibly caused by insect or fungus activity.

**Insecticide** – A pesticide used to control or repel insects or to reduce the unwanted or harmful effects of insects.

**Integrated Pest Management** – A pest management system that uses all appropriate strategies to reduce pest populations.

**Multipurpose Fumigant** – A fumigant that controls more than one type of pest.

**Pathogen** – An organism that causes diseases.

**Pest Resistant Plant** – A plant variety or cultivar that can reduce the reproduction of a pest on it, thereby reducing pest damage. Sometimes resistance is 100 percent effective. This means that a resistant variety is immune to a disease. Usually, the resistance is only partially effective.

**Pest Tolerant Plant** – A plant variety or cultivar that can produce a similar yield and

quality whether a particular pest is present or not. By using tolerant cultivars, farmers can produce normal yields from crops in pest-infested fields.

**Pesticide Resistance** – The ability of an organism to tolerate a specific pesticide. There are levels of resistance. For example, some insects may be sensitive, weakly resistant or strongly resistant to a specific insecticide. Total resistance is immunity.

**Plenum** – An enclosure in which air or other gases are at a pressure greater than the atmospheric pressure outside the enclosure.

**Raised Bed** – An elevated planting surface also called a “ridged row” that is prepared by plowing and grading soil using cultivation equipment. Raised beds are separated by shallow ditches that improve drainage.

**Rodenticide** – Any substance used to control or repel rodents or to reduce the unwanted or harmful effects of rodents.

**Skinning** – Superficial injury, such as to the surface of a grain kernel during harvesting, transport and storage.

**Topdressing** – A material such as a pesticide applied to or mixed into the upper surface of grain or soil.

## IPM and Decision-Making

There are many ways to control pests of raw agricultural products and soil. Your job is to select the best method for the situation at hand. Pesticides and other control methods often provide good to excellent control temporarily. However, for consistent, reliable, long-term control, you will need to use Integrated Pest Management (IPM).

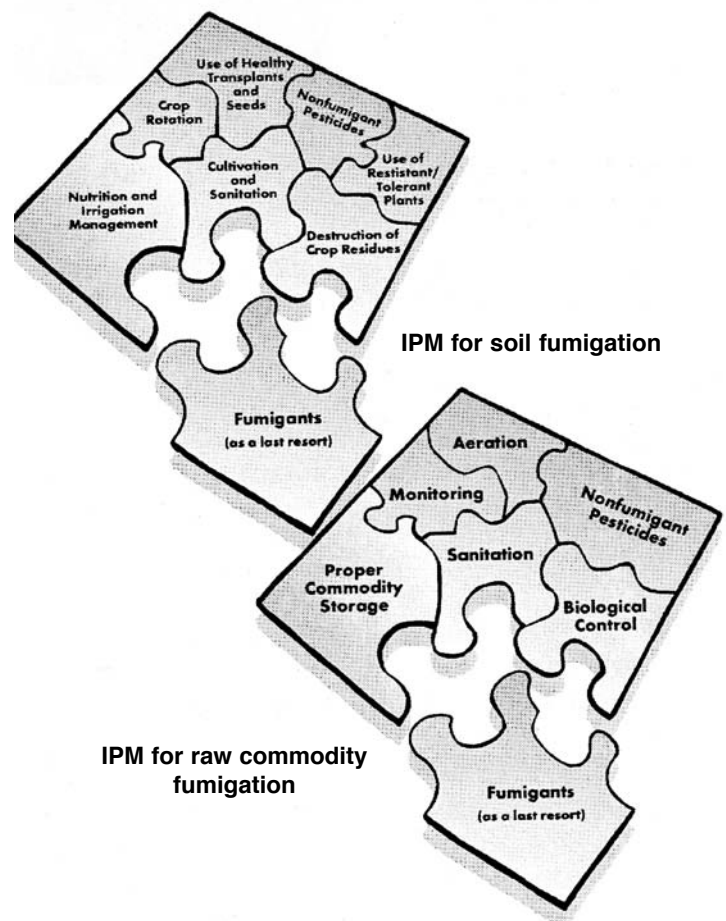
IPM is an ecological approach to pest control. It is based on the habitat and life cycle of the pest. It combines all of the most appropriate pest control strategies into a unified, site-specific plan. IPM plans may include both nonchemical and chemical management methods. IPM is dedicated to managing causes rather than simply treating symptoms. IPM balances the level of control needed with any associated risks. The goal of an IPM program is to reduce pest numbers to an acceptable level in a way that is practical, cost-effective and safe for people and the environment.

## Prevention

The first strategy of an IPM program is prevention. Prevention of pests in stored products relies on sanitation, proper storage and monitoring the condition of the commodity before and during storage. Prevention of soil pests depends on sanitation, crop rotation, cultivation practices and the health of the crop(s). Prevention may help you exclude pests or provide them with unsuitable living conditions. Stopping a pest problem before it occurs saves time and money.

## Sampling and Observation

IPM also relies on sampling and regular observation. Sampling and observation will help you determine if treatment is needed and/or if previous control measures were effective. Check commodity storage areas regularly. When sampling and observing stored products, check their physical condition. Look for signs of new infestations. Determine what pests are present, how many of each kind are in the area and how much damage they are causing. When sampling and observing crop fields, look at the above- and below-ground parts of plants. Check for



symptoms of disease or insect damage. Collect soil samples from fields to be planted. Submit them to a laboratory for a nematode assay – every year if possible.

## Thresholds

Use information from sampling and observation to make management decisions. Follow the action thresholds that indicate at what point pests need to be controlled.

Thresholds are the basis from IPM. “Damage thresholds” indicate how many pests must be present to cause a problem, such as economic damage or a safety threat. “Action thresholds” indicate the number of pests that must be present for a problem to be severe enough to warrant a control action. For example, the number of nematodes or nematode eggs in a soil sample is commonly used as an action threshold for soil fumigation. If the number in the sample exceeds the action threshold, the field needs treatment.

## Field/Product Histories

Knowing the history of a stored product or field is also useful when developing an IPM plan. For example, you can use the percentage of plants in a field killed by a particular soil-borne pathogen to determine when to apply a fumigant or other pesticide. If a soil-borne pathogen occurs at low levels one year, it can kill most of the plants in that field the next year if the field is not treated.

## When an Infestation Occurs

When an infestation does occur, identify the pest. Learn how it causes damage and when it is most vulnerable. Then, develop a control plan. Consider all appropriate control options. Your strategy should be economical and effective, while minimizing harm to people and the environment. Follow-up site inspections are critical. Did the control tactic work? Is re-treatment needed? Continue to monitor areas for long-term control.

Fumigation is only one option of an IPM program. Use it only as a last resort when nothing else works. For stored products, sanitation, proper grain storage and nonfumigant pesticides can often control pests without the help of fumigants. Control soil pathogens and pests with crop rotation, disease- or nematode-resistant varieties and nonfumigant pesticides.

Usually there is little you can do during the growing season to control soil pests. In some cases, you can apply nonfumigant pesticides when the crop is in the field. However, crop rotation, use of resistant plant varieties and fumigation must all be performed before the growing season starts. You cannot apply fumigants to fields that have already been planted because, in most cases, the process of injecting fumigant and the fumigant itself will injure the crop.

When deciding whether to fumigate stored products or soils, weigh these advantages and disadvantages.

## Advantages of Fumigants

- Depending on the specific situation and fumigant, fumigants are effective against insects, mites, diseases, nematodes, fungi, weeds and most other living things.
- Most fumigants are fast acting. They are the quickest way of controlling many pests.
- In some cases, they can provide total eradication.
- Human exposure is limited. Areas are evacuated during treatment and must be aerated before reentry.
- Most fumigants, when used properly, do not leave residues on surfaces.
- There are several ways to apply fumigants.
- They penetrate and treat spaces in soil and commodities like grain that cannot otherwise be reached.
- When treating raw products, you can apply them without disturbing the commodity.
- They usually are readily available.
- You can use some fumigants in or near food without leaving harmful residues, tastes or odors.

## Disadvantages of Fumigants

- They are highly toxic to most living things, including humans. Breathing even small amounts of some fumigants can be fatal.
- They may require special protective equipment, such as a self-contained breathing apparatus (SCBA) and gas detectors.

- They require highly trained applicators.
- They offer no residual control. Once an area, item or field is aerated, traces of fumigant do not remain to help control future pests.
- They must be confined in a tightly sealed area to be effective.
- Some may injure seeds and reduce germination. Others may leave toxic residues, tastes or odors if used incorrectly.
- Because they are fast acting, response to problems and emergencies must be quick. Spills, leaks and equipment failures usually call for immediate action.
- They usually require warm temperatures to be effective. Temperature requirements may be hard to meet, especially in the winter.
- Some are expensive.
- Some are corrosive.
- Some are flammable and explosive.
- Some fumigants are hard to remove from treated material.

Fumigants for raw products can be costly and dangerous. Always consider other pest control methods before fumigation. Fumigation should be your last resort. Use Integrated Pest Management (IPM) to select the best pest control method(s) for your situation. In this way, you may be able to reduce or avoid the need for fumigation.

## Pesticide Resistance

One of the biggest problems with pesticide use is “pesticide resistance.” Pesticide resistance develops when a group of pathogens or insects is able to tolerate doses of a specific pesticide that would kill a normal population of the same species. Surviving pests reproduce and pass their resistant traits to their offspring. Preventing resistance is of great importance for the pests of stored commodities. New laws and regulations have drastically reduced the number of insecticides approved for use against stored-product pests. As a pest control operator, you can protect the effectiveness of pesticides by:

- Using IPM
- Using alternative controls and nonchemical controls whenever possible
- Using pesticides only when necessary
- Avoiding repeated use of the same pesticide
- Doing a thorough job when applying a pesticide (do not leave behind pests that can develop resistance and reproduce)
- Fumigating only when nothing else works

## Alternatives to Fumigation

Many pests of raw commodities can be controlled without fumigants. The key is prevention. Prevention involves sanitation, proper grain storage and maintaining before and after it is placed into storage. In this way, you can keep pests away or reduce the number of pests that are able to develop. Other management strategies such as biological control, aeration, spot treatments, empty bin sprays, grain protectants, topdressing, pest strips and rodenticides help to reduce existing pest populations.

## Sanitation

The first step in preventing insect infestations is sanitation. By keeping bins and the areas around them clean, you can greatly reduce insect populations. Old grain and grain products provide food and habitat for insects. These residues can occur inside and around bins, in combines and in grain transfer equipment. Before storing fresh grain, clean the inside and outside of storage bins and buildings. Clean aeration ducts, augers and sidewalks. Use both a broom and vacuum. Dispose of all spilled or leftover grains and grain dust. Open the aeration ducts and augers to be sure they are clean. Clean bins immediately after they are emptied and again at least two to three weeks before adding grain. You should also clean bins before applying “empty bin sprays.” (See “Empty Bin Sprays” later in this unit). Always wear a dust mask when cleaning these and other storage areas. Mow regularly around bins to reduce harborage for rodents and insects.

## Proper Grain Storage

Harvesting grain does not end the danger of pests. You must also store it properly. Good grain storage can prevent infestation and the need for fumigation. In Arkansas, producers may store grain for a few weeks to a few years. The profitability of such storage depends on grain quality and marketing. Grain is usually

stored so that it can be sold when market prices are higher than they are during the harvest season.

## Grain Condition

The physical condition of grain when it is placed into storage influences its susceptibility to pests. Only high-quality, undamaged grain with a low moisture content can be stored successfully for long periods. Never mix new grain with old grain in storage.

## Drying Grain Before Storage

Grain is dried to prevent spoilage and to deter insect infestation. Most small grains are dried to 12 to 13 percent moisture. The moisture level may be 1 to 2 percent higher if the producer plans to hold the grain during the cooler part of the year only.

Drying methods may influence grain quality. High-speed, high-temperature drying produces more stress-cracked corn than low-temperature drying. Kernels with stress cracks break readily during handling. Broken kernels are more likely to spoil.

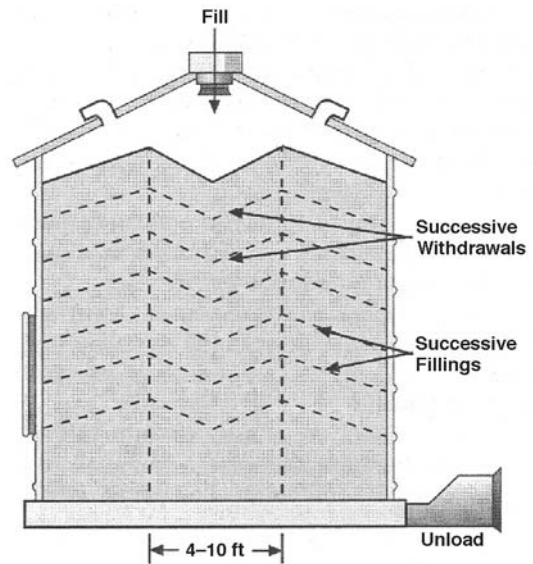
**Table 4-1. Maximum moisture contents for safe aerated grain storage in Arkansas.**

Grain Type and Storage Time	Maximum Moisture Content for Safe Storage (% wet basis)
<b>Shelled corn and sorghum</b>	
Sold as #2 grain by spring	14-15
Stored 6 to 12 months	13-14
Stored more than 1 year	12-13
<b>Wheat, oats, and barley</b>	
Stored up to 6 months	12-13
Stored 6 to 12 months	11-12
Stored more than 1 year	10-11

## Broken Kernels and Fines

Many insects that infest stored grain are not able to penetrate the seed coat of unbroken kernels. These pests depend on the presence of broken kernels and foreign material called "fines." Broken kernels are also more likely to spoil and mold than are unbroken kernels. Fines decrease the airflow from aeration fans. This can increase aeration time up to 50 percent. Fines

also tend to accumulate in the center of the bin. Fines hold moisture, further increasing the chance of insect and mold damage. This is especially true when fines are concentrated in certain parts of the storage.



**Withdrawals during filling remove most fines from the core of fine material**

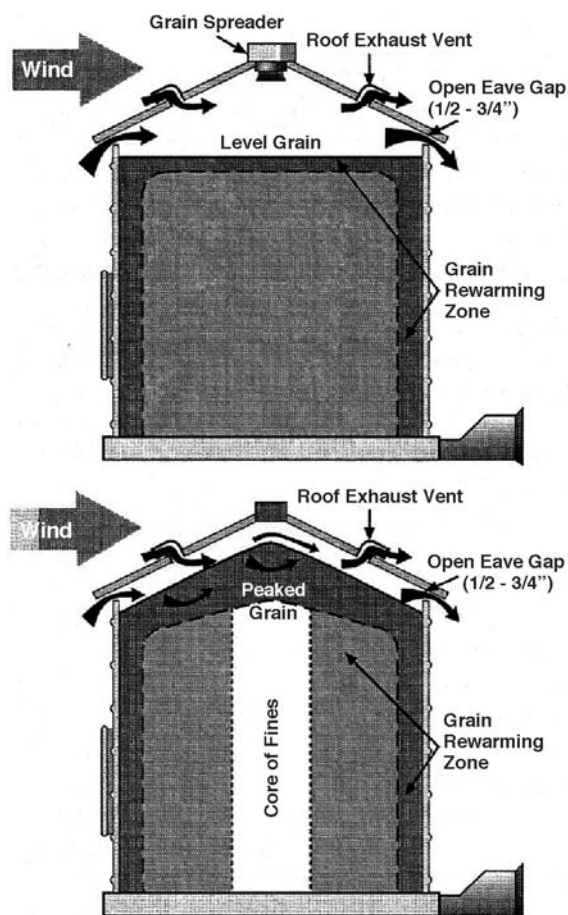
## Grain Cleaning

Cleaning grain before "binning" is the best way to minimize problems with fines. Rotary screen and aspiration cleaners work best. Rotary screen cleaners use a rotating screen to remove fines and foreign material from the grain as it is transferred to a dryer or storage bin. Avoid using perforated or screened sections in the auger. These usually do a poor job of cleaning the grain. They may even reduce grain quality by "skinning" or causing superficial damage to the kernels.

If you cannot clean the grain ahead of time, remove fines during bin loading. When grain is loaded into the center of a round bin, most of the fine material will collect in a center "core" under the spout. Eliminate this problem in one of two ways. First, try using a grain spreader. Grain spreaders distribute fines and grain evenly throughout the bin. This method retains the fines, which may have value as animal food. However, they tend to pack the grain, reducing airflow within the load. You can also remove the core of fine material periodically as the bin is filled. To do this, remove the grain from the bottom of the center core. Mix it with other grain and put it back in the bin.

## Peaked Grain

Peaks occur at the top of a grain pile just below the loading spout. There are several problems with leaving grain peaked in a bin. First, it is impossible to achieve uniform aeration. This is because air moves toward the nearest open areas, the sides, leaving the center core unaerated. (See "Aeration" later in this unit for more information on how it affects stored grain.) Second, when grain is loaded without a spreader, the fines tend to accumulate in the center under the spout. Fines are particularly prone to insect and fungal attack. They are also difficult to aerate. (See "Broken Kernels and Fines" earlier in this unit for more information on how they affect stored grain.) In addition, it is very difficult to enter a bin to sample the grain or to apply a topdressing if the grain is peaked and filled to the top of the bin. It is easier to walk on level grain than on sloped grain. There may also be insufficient headspace. Be sure to level the surface of stored grain so that it is not peaked.



Peaked grain vs. level grain surface in storage bins.

## Storage Facilities and Packaging

Grain should always be stored in a steel bin. Be sure the bin is weather-tight, rodent-proof, and mounted on a moisture-proof concrete base. It should have a grain spreader, a perforated floor aeration system, an adequate fan and a weather- and rodent-proof roof vent. Caulk the seams of older bins and inspect them annually for moisture leaks. Buildings used to store other types of commodities should be dry and designed to exclude rodents, birds and flying insects. There should also be a minimum of harborage for pests. Move or eliminate unnecessary equipment, wood, rocks and other popular pest hideouts in and around storage facilities.

## Storage Time

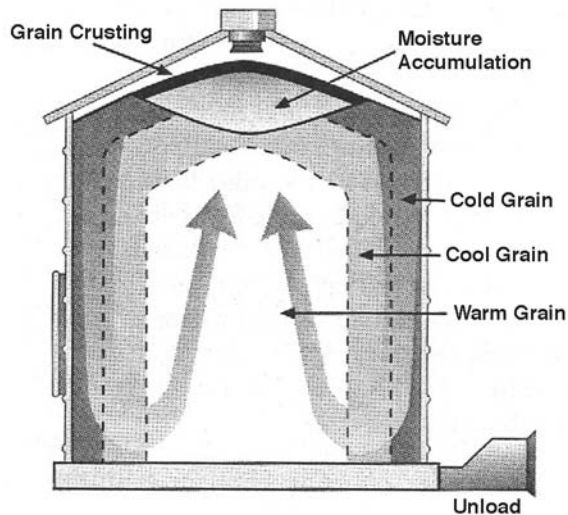
Storage pest problems tend to be seasonal. Grains harvested and stored in the heat of the summer are more susceptible to pests than grains harvested in the fall when temperatures are cooler. As a rule, the longer a commodity is stored at 60°F to 90°F, the greater the chance of pest problems. If a producer needs to store a commodity for more than one year, or if conditions are more likely to be favorable to pests, he or she should increase monitoring and pest prevention efforts.

## Aeration

Proper aeration can control insects in many ways. Aeration is the movement of air through grain to regulate moisture and temperature. By preventing moisture from building up and moving through a commodity, aeration helps to limit mold growth. This, in turn, reduces the food supply for fungus-feeding insects. Aeration also controls "hot spots." Hot spots are sites that are much warmer (10°F or more) than the grain in the rest of the storage bin. These areas indicate that the grain has a higher than normal moisture content and may harbor insects or fungi.

Aeration procedures are the same for all types of stored grains. In the fall, aerate to lower the grain temperature below 60°F. At this temperature, most insect and mold activity will decrease. In the fall, winter and spring, aerate to control moisture migration and to create a uniform temperature throughout the grain

mass. If you plan to store grain through the summer, you may need to aerate to control moisture during this season as well. However, most grain is sold before summer to make room for the next crop.



**Example of moisture migration in grain stored several months without aeration.**

## Biological Control

Biological control is the use of natural enemies (predators, parasites or pathogens) by humans to control pests and pest populations. These natural enemies, also called biocontrol agents, can sometimes reduce the number of pests in raw commodities. Predatory or parasitic insects are the most common biocontrol agents used to control insect pests of raw commodities.

Unfortunately, it may be difficult to effectively use biological control in an IPM program. This is because beneficial insects require some host insects to become established. It is difficult to keep these pest insects from reaching damaging levels. Stay informed about new developments in biocontrol that may help prevent infestation.

## Non-Fumigant Pesticides

### Empty Bin Sprays

Another management strategy is to coat empty bins with insecticidal sprays. These pesticides will kill eggs and insects missed during cleaning. Treat bins as soon as they are clean. Try to delay treatment until the weather is

warm and the insects are active. Insecticides are most effective at this time. If treatment occurs more than three months before the bin will be filled, repeat the application at least two weeks before storing the grain. Apply the spray to as many surfaces as possible. Be sure to hit all joints, seams, cracks, ledges and corners. Spray the ceiling, walls and floor to runoff. Spray beneath the bin and its supports. Treat the outside surfaces in a similar fashion. Then apply the insecticide in a six-foot border around the outside foundation. For increased protection, treat harvesting equipment, elevators, augers, trucks and wagons. Be sure these items are thoroughly cleaned. Insecticides will kill most insects emerging from cracks and crevices.

Unfortunately, empty bin sprays do not work for every type of storage bin. More and more producers are using metal bins with perforated floors. These floors aid in grain drying and aeration. They also permit broken grain and grain dust to gather in the subfloor plenum. This is an ideal area for insects to thrive. Additionally, subfloors are often difficult to remove. It may be difficult to inspect, clean or apply insecticides under them. In these cases, fumigation may be your only practical method of pest control.

## Grain Protectants

You can prevent or reduce insects by applying insecticides directly to the grain. These "grain protectants" are usually applied as grain is moved into storage. Grain protectants are intended to protect the grain, not to eradicate an existing infestation. For eradication, use a fumigant.

If a producer plans to hold grain for more than one month and the grain temperature is likely to be above 60°F, treat the grain with a protectant. To apply liquid protectants, use a gravity drip, compressed air or wipe-on applicator to apply the insecticide as the grain is augered or elevated into the bin. Mixing of the insecticide and the grain will occur during the bin-filling process. Use the auger diameter, angle and speed as well as the type of grain to determine the application rate.

Grain protectants are also formulated as dusts. You can apply dusts to grain in trucks before transfer. Spread the dust evenly over the surface of the grain and mix it in with a shovel. Complete mixing will occur as the grain is loaded into the bin.

Unfortunately, insecticides tend to break down faster in areas with high temperatures and moisture. If the moisture level of grain is greater than 13 percent and its temperature exceeds 90°F, a treatment may last for only a couple of weeks. When treating warm grain, be sure to aerate and cool it as soon as possible after it is introduced into the bin. Aeration will not remove the insecticide from the grain.

Most grain protectants are not registered for use on all types of grain. Be sure that you use the correct insecticide for the product you intend to treat. Consider all types of registered protectants including synthetic pesticides, naturally produced toxins, abrasives and growth regulators.

## Topdressing

Some areas of a grain bin, such as the headspace at the top, are likely to remain hot and humid. These conditions cause some grain protectants to break down quickly at the grain surface. The headspace is also the area where reinfestation tends to recur after fumigation. This is because chemical protectants break down more quickly, and the moisture content of the grain in this area makes it more favorable to insect pests. Treat the surface of the grain beneath the headspace with an insecticide registered as a topdress treatment. Both sprays and dusts work well. Mix half of the treatment with the upper 3 to 6 inches of grain. Be sure the grain is dry and less than 90°F. The bin should be insect-tight below the treated surface. Once the insecticide is in place, do not disturb the treated surface. It acts as a protective barrier over the entire load of grain. Topdressings can be especially useful against moths, such as the Indianmeal moth, that tend to stay near the grain surface.

*NOTE: Topdressings will kill insects on the surface and in the upper few inches of grain. They can also prevent new insects from entering the grain load from the top surface. However, they will not control existing infestations deeper in the bin.*

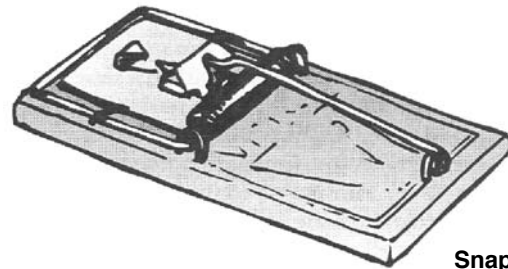
## Pest Strips

You can also hang resin strips in the headspace in the top of the bin to help control adult moths. Use one strip per 1,000 cubic feet of air space. Replace them once every three

months. For resin strips to be effective, you must temporarily seal the top of the bin, including the roof vent. Aeration will prevent this treatment from working.

## Rodenticides

Rodents harm stored grain by eating it and contaminating it with feces and saliva. There are many rodenticides registered for the control of rats, mice and other rodents. Before using rodenticides, fumigants or nonfumigants, to control vertebrate pests, develop an IPM program. Include prevention through structural exclusion and sanitation, sampling, and nonchemical controls such as snap traps. These methods may reduce or eliminate the need for rodenticides.



Snap trap

When pesticides are necessary, try nonfumigant rodenticides first. Choose between anticoagulants and nonanticoagulants. Anticoagulants cause death by internal bleeding. These chemicals are normally placed with baits in bait stations. Nonanticoagulants cause death by stopping the heart, damaging the intestines or liver or by attacking the central nervous system. These chemicals act quickly and rodents are usually less resistant to them. However, rodents are more likely to reject nonanticoagulants as food. You may need to prebait with untreated food to encourage consumption.

If control with nonfumigant rodenticides is poor, it is usually due to:

- Insufficient or low-quality bait
- Low numbers of bait stations
- Failure to treat the entire infested area
- Invasion from untreated areas such as outside a structure
- Poor placement of the stations

- Other foods being more readily available
- Pesticide resistance

When possible, pinpoint the problem and correct it before resorting to fumigation.

## Fumigation

Sanitation, proper grain storage, aeration and nonfumigant pesticides can go a long way toward preventing or reducing pests in stored grain and other raw products. For some situations, however, fumigation may be the only answer. Fumigants control pests by diffusing through the spaces between grain kernels as well

as into the kernels themselves. They often work better than nonfumigant pesticides because they can penetrate into places that are not accessible with insecticide sprays or dusts. They can also kill all stages in an insect's life cycle.

Before using a fumigant to control pests in stored grain and other raw products, make sure you need it. Monitor pest populations throughout the storage period. Do not hold grain or other raw products in storage for longer than necessary. Use all possible cultural and non-fumigant chemical controls to maintain pest populations below damaging levels. Before you decide to fumigate, make sure that pest populations are high enough to warrant fumigation.

## Test Your Knowledge

### Q. What is Integrated Pest Management (IPM)?

- A. IPM is an ecological approach to pest control. It is based on the habitat and life cycle of the pest. It combines all appropriate pest control strategies, including nonchemical and chemical management methods. IPM is dedicated to removing causes rather than simply treating symptoms. Prevention is key. IPM balances the level of control needed with any associated risks. The goal of an IPM program is to reduce pest numbers to an acceptable level in a way that is practical, cost-effective and safe for people and the environment.

### Q. How does fumigation fit into an IPM program?

- A. Fumigation is only one part of an IPM program. Because it is specialized, very toxic and often expensive, fumigation is usually the last resort to a pest problem.

### Q. Why is regular observation of stored grain and field crops important in effective pest management programs?

- A. Sampling and regular observation allows you to check for pests in an area to determine what pests are present, how many of each kind are in the area and how much damage they are causing. Sampling and observation will help you determine if treatment is needed and/or if previous control measures were effective.

### Q. List some of the advantages of fumigants.

- A.
1. They are effective against insects, mites, diseases, nematodes, fungi, weeds and most other living things.
  2. Most are fast acting.
  3. They are capable of providing total eradication.
  4. Human exposure is limited.
  5. Most fumigants, when used properly, do not leave residues on surfaces.
  6. There are several ways to apply fumigants.
  7. They penetrate and treat hard-to-reach areas.
  8. You can apply them without disturbing the commodity.

9. They are usually readily available.
10. You can use some fumigants in or near food without leaving harmful residues, tastes or odors.

### Q. List some problems with fumigants.

- A.
1. They are highly toxic to most living things.
  2. They require special protective equipment.
  3. They require highly trained applicators.
  4. They offer no residual control.
  5. They must be confined in a tightly sealed area to be effective.
  6. Some may injure seeds and reduce germination. Others may leave toxic residues, tastes or odors.
  7. Response to problems and emergencies must be quick.
  8. Temperature requirements may be hard to meet.
  9. Some are expensive.
  10. Some are corrosive.
  11. Some are flammable and explosive.
  12. Some fumigants are hard to remove from treated material.

### Q. How can you prevent pesticide resistance?

- A. As a pest control operator, you can protect the effectiveness of pesticides by:
- Using IPM
  - Using alternative controls and nonchemical controls whenever possible
  - Using pesticides only when necessary
  - Avoiding repeated use of the same pesticide
  - Doing a thorough job when applying a pesticide (do not leave behind pests that can build up resistance and reproduce)
  - Fumigating only when nothing else works.

### Q. How often should you clean grain storage bins to prevent insect infestations?

- A. Clean bins immediately after they are emptied and again at least two to three weeks before adding grain. Before storing fresh

grain, clean the inside and outside of storage bins and buildings. You should also clean bins before applying “empty bin sprays.”

**Q. Name several things you can do to reduce stored grain’s susceptibility to insects and disease.**

- A.
1. Clean and dry the grain before placing it into bins.
  2. Always store grain in a steel bin that is weather-tight, rodent-proof and mounted on a moisture-proof concrete base.
  3. Remove as much fine material as possible or spread out the fines throughout the load.
  4. Level the surface of the grain so that it is not peaked.
  5. When possible, store the grain in the fall when temperatures are cooler.

**Q. What technique can you use to maintain ideal moisture levels and temperatures within a load of stored grain?**

A. Aeration.

**Q. Why is it important to keep stored grain cool and dry when applying insecticides?**

A. Insecticides tend to break down faster in areas with high temperatures and moisture.

**Q. True or False: Topdressing will kill insects throughout a load of grain.**

A. False.

# Pathogens and Pests in Soil

## Alternatives to Fumigation

There are several methods and tools you can use to control pests and pathogens in soil besides fumigation. These include a variety of cultural controls methods and nonfumigant pesticides.

## Cultural Control Methods

Cultural control methods are some of the most effective nonchemical ways to control soil pests. Cultural practices include crop rotation, use of resistant plant varieties, destruction of crop residues, use of healthy transplants and seeds, cultivation practices, nutrition and irrigation management and sanitation. When properly used, these tactics reduce the need for or improve the effectiveness of fumigation and nonfumigant pesticides. Cultural practices are also often less expensive.

## Crop Rotation

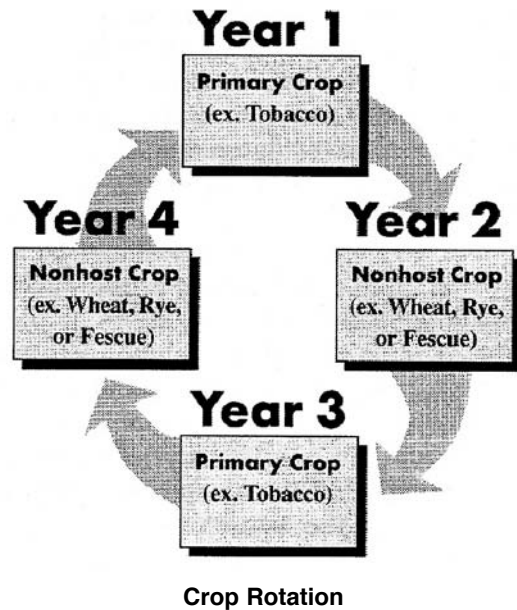
Crop rotation is one of the most important cultural controls for managing soil-borne pathogens, nematodes, insects and weeds. Crop rotation works like this:

**Year 1** – A primary crop (tobacco, corn, etc.) is planted in a given field.

**Year 2** – A secondary crop (rye, fescue, etc.) that does not support soil-borne pests of the primary crop is planted in the same field. Without the primary crop to attack, soil-borne pest numbers will drop. Secondary crops are often called “non-host crops.”

**Year 3** – The primary crop is replanted. Because a secondary crop was planted in the field for one year, fewer pests will be present to damage the primary crop.

For example, tobacco is often rotated with wheat, rye or fescue. Many of the nematodes and pathogens that commonly attack tobacco (cyst and root-knot nematodes, and diseases such as black shank, bacterial wilt and black root rot) cannot reproduce or reproduce poorly on wheat, rye or fescue. Thus, during rotation, populations of these pests fall. When tobacco is replanted, pest problems are fewer.



Longer rotations (when a secondary crop is planted for three or more years before a primary crop is replanted) are best. However, even a two-year rotation with a resistant or nonhost crop is better than planting the primary crop year after year in the same field.

## Resistant and Tolerant Plant Varieties

Many crops have varieties or cultivars that are “resistant” or “tolerant” to soil-borne pests. Resistant plant varieties reduce the ability of a pest to reproduce in or on that variety, thereby reducing the damage that the pest causes. Tolerant plant varieties, on the other hand, do not affect the reproduction of soil-borne pests. Instead, these plants are able to produce a similar yield and quality whether a particular pest is present or not. By using tolerant cultivars, farmers can produce normal yields from crops in pest-infested fields. Resistant and tolerant cultivars are often rotated with a nonhost crop. You can also combine resistant and tolerant plant varieties with other cultural practices, contact pesticides or fumigants to manage soil-borne pests.

## Destruction of Crop Residues

After harvest, fields usually contain a lot of leftover plant material. These residues act as food and habitat for soil-borne pests. Crop residues can sustain pests long after the crop is gone. Populations may even build up and carry over

into the next planting season. Destruction of crop residues after harvest eliminates this food source. Pest populations are unable to persist.

Destruction of crop residues is important for managing diseases on many crops, including tobacco. For example, the roots and other parts of tobacco plants are often still alive long after harvest. This living plant material provides food and shelter for soil-borne pathogens and nematodes. Insects can feed on leaves that remain on the plant or regrowth that forms from the stalks and roots. To discourage pest populations, it is important to kill the plants by turning the crop with a plow to expose the roots to the sun and wind. After the plants are dead, cut up debris into small pieces that will rot quickly. Incorporate these pieces into the soil. Plant a cover crop to reduce soil erosion.

Although cultivation is the most common way to eliminate crop residues, other methods are available as well. One option is to feed aboveground parts of some crops (like peanut vines) to livestock. Either allow the animals to graze the field after harvest or bale the vines for feeding elsewhere. In other situations, you can burn or compost crop residues.

## Healthy Transplants and Seeds

Using healthy transplants and seeds reduces the chance that a new soil pathogen will be introduced into a field. If a pathogen already exists in the field, many of the healthy plants and seeds have a good chance of avoiding infection. Even when the healthy plants or seeds become infected, the delay in onset of the disease (resulting from the amount of time it takes for the pathogen to find the host) often limits the amount of disease and ultimate damage. Many companies guarantee their seeds and transplants to be free of disease and pests. Be sure to purchase your seed and transplants from reputable vendors.

## Cultivation Practices

Certain cultivation practices can also reduce problems caused by soil-borne pests. These include:

- Planting into raised beds
- Deep plowing
- Increasing the amount of organic matter in soil



**Raised beds**

Planting into raised beds can enhance root growth, improve aeration and encourage soil drainage. These improved growing conditions help plants to develop more quickly. They may also slow the spread of pathogens that like wet soil conditions. Deep plowing works because some common soil-borne pathogens live primarily near the soil surface. Plowing buries these pathogens deeper in the soil profile, increasing the distance they must move to infect a new crop. Increasing organic matter can improve pest control by enabling the natural enemies of soil-borne pests to build up. Higher levels of organic matter improve the ability of these organisms to persist at levels high enough to reduce the populations of soil-borne pests.

## Nutrition and Irrigation Management

Healthy plants can often resist soil pathogens. Fertilize and add organic matter as recommended for the crop. Maintain a soil pH that is favorable to the crop. Irrigate when necessary. Proper irrigation can maintain a soil environment that is less favorable for some pathogens. Conditions that are too wet or too dry can stress the plants and allow pest populations to flourish.

## Sanitation

Whenever possible, clean farm implements before using them in a different field. Nematodes, insects and diseases live in the soil left on equipment. They can spread from

infested to healthy fields by “catching a ride” on vehicles and farm equipment.

## Nonfumigant Pesticides

Cultural practices can go a long way toward preventing or reducing soil-borne pests. However, sometimes you will need to use pesticides to prevent serious damage to crops. Fumigants are not always the best choice when it is necessary to use a pesticide. Nonfumigant pesticides usually control soil insects and some root and stem diseases better than fumigants. Nonfumigant pesticides also provide good to excellent control of nematodes and weeds in some cases. In addition, many nonfumigant fungicides, insecticides and herbicides can be used during the growing season, while fumigants cannot.

Nonfumigant pesticides are usually formulated as liquids or granules and applied directly to the soil or to the crop. In many cases, if you apply chemicals to the soil surface, you will need to incorporate them into the soil immediately after application.

## Fumigation

For some situations, fumigation may be the only answer. Some farmers have limited amounts of land. They may not have enough room to rotate crops. With no rotation, disease and nematodes can be difficult to manage

without pesticides. Pest-resistant crop varieties are not always effective or available. Biological and nonfumigant chemicals may not provide the same level of pest control as fumigants do for the specific pest(s) causing the problem. In fact, fumigants tend to provide better control of nematodes and soil-borne bacteria than do nonfumigant pesticides.

Before using a soil fumigant (or any pesticide), be sure you need it. If you suspect a nematode problem, take soil and/or root samples. Send them to a lab for analysis. Look for soil insects or evidence of their damage. Determine whether nematode or insect numbers are above the action threshold(s). Keep track of weed infestations and the number of plants in each field killed by a disease over time.

Some fumigants, called “multipurpose fumigants,” control more than one soil problem (for example, bacteria, nematodes, insects, and weeds). Others control only a single type of pest. Use a multipurpose fumigant when plant-parasitic nematodes are present in a field and you observe a high percentage of disease in the field during the previous season. For example, you may need to use a multipurpose fumigant in a tobacco field with root-knot or tobacco cyst nematodes if 5 percent of the plants died in previous years due to bacterial wilt.

Above all, be sure you are using soil fumigation as a last resort.

## Test Your Knowledge

**Q. Name several cultural control methods you can use to control pests and disease in soil.**

- A. Crop rotation, use of resistant plant varieties, destruction of crop residues, use of healthy transplants and seeds, cultivation practices, nutrition and irrigation management and sanitation.

**Q. Describe how crop rotation works.**

- A. 1. Year 1 – A primary crop (tobacco, corn, etc.) is planted in a given field.  
2. Year 2 – A secondary crop (rye, fescue, etc.) that does not support soil-borne pests of the primary crop is planted in the same field. Without the primary crop to attack, soil-borne pest numbers will drop.  
3. Year 3 – The primary crop is replanted. Because a secondary crop was planted in the field for one year, fewer pests will be present to damage the primary crop.

**Q. How do crop residues encourage pest and disease populations to flourish?**

- A. After harvest, bits of plant material left in a field act as food and habitat for soil-borne pests. Crop residues can sustain pests long after the crop is gone. Populations may even build up and carry over into the next planting season.

**Q. What kinds of cultivation practices can reduce soil-borne pests?**

- A. Planting into raised beds, deep plowing and increasing organic matter in soil.

**Q. Name three nonchemical ways you can enhance crop growth and help plants to resist soil pathogens.**

- A. 1. Utilize resistant and tolerant plant varieties.  
2. Destroy crop residue after harvest.  
3. Use healthy transplants and seed.  
4. Practice proper plant nutrition and irrigation management.

**Q. In general, what types of soil-borne pests are best controlled by fumigation?**

- A. Plant-parasitic nematodes and soil-borne bacteria and fungi.

**Q. When should you use a multipurpose fumigant?**

- A. When several soil-borne pests are present in a field at damaging levels. This situation is often indicated by a high percentage of disease in the field the previous season. Fumigation will help ensure proper control for subsequent seasons.

**Q. True or False. Fumigant pesticides are always the best choice for controlling soil-borne pests.**

- A. False. You can control many pests and pest problems by
- Rotating crops
  - Using resistant/tolerant plant varieties
  - Destroying crop residues
  - Using healthy transplants
  - Practicing good sanitation, cultivation practices and nutrition and irrigation management
  - Using nonfumigant pesticides