Pest Management For Grain Storage and Fumigation

Seed Treatment

-Pest Control- Grain Storage & Seed Treatment Facilities

September 2004

Montana Department Of Agriculture

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SECTION 1
PEST MANAGEMENT FOR GRAIN STORAGE AND FUMIGATION

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INTRODUCTION

Losses of grain in storage due to insects are the final components of the struggle to limit insect losses in agricultural production. These losses can exceed those incurred while growing the crop. Losses caused by insects include not only the direct consumption of kernels, but also include accumulations of frass, exuviae, webbing, and insect cadavers. High levels of this insect detritus may result in grain that is unfit for human consumption. Insect-induced changes in the storage environment may cause warm, moist 'hotspots' that are suitable for the development of storage fungi that cause further losses. Worldwide losses in stored products, caused by insects, have been estimated to be between five and ten percent. Heavier losses occurring in the tropics may reach 30%, and the net value of losses in storage in the United States has been placed at over $200 million annually.

Limiting insect infestation in grain storage must be a primary consideration beginning at the time of harvest. Economically speaking, storage insects and, to a lesser degree, fungi reduce the quality and value of grain, while losses due to rodents and birds are typically quite infrequent and minor. Infestation on-farm may further proliferate to devastating losses throughout the grain storage and marketing ecosystem. It is essential that on-farm storage should limit the infestation of grain from the onset of storage, to ensure the acceptance and marketability of grain in domestic and foreign channels. In Montana, the majority of grain storage is on-farm, a situation that is quite different from other major wheat-producing states

Cold Montana winters are an asset in the management of stored-product pests, but do not in any way guarantee that the stored product will be pest-free. While greater than thirty species of storage pests can attack grain stored in the northwest of the United States, seldom do more than a few species reach economic levels in Montana. This manual will help the producer storing grain on-farm and the commercial elevator operator become familiar with the available methods for managing these pests in Montana.

While several procedures to manage pests are used at storage facilities before storage, those that minimize pest invasion into storage structures include:

1. Cleaning bins, harvest and loading equipment prior to harvest and after bin emptying,
2. Applying "empty-bin" insecticides to the inside of the structures,
3. Sealing structures,
4. Cleaning up grain spills on the grounds,
5. Removing weeds close to structures.

Since higher moisture can encourage mold and insect development, additional management techniques also include:

1. Storing sufficiently dry wheat (less than 13%),
2. Aerating the stored grain with fans to cool the wheat thus slowing insect development,
3. Close monitoring of grain temperature and insect populations.

There are limited options for managing insects in the grain itself. Grain protectants are expensive, and thus used infrequently. In Montana, diatomaceous earth (Insecto®) can be used effectively for on-farm storage due to Montana's low ambient humidity and the relatively small sizes of bins in the state.

Diatomaceous earth (DE) is the remains of microscopic one-celled plants (diatoms) that lived in the oceans that once covered the western part of the United States and other parts of the world. Huge deposits were left behind when the water receded. The insecticidal quality of DE is due to the razor sharp edges of the diatom remains. As the insects crawl through treated grain and dusted bins, the DE comes contact with the insects and the sharp edges punctures the insects exoskeleton. The powdery DE then absorbs the body fluids causing death from dehydration.

Biological control agents, such as predatory and parasitic insects, have limited use in stored wheat management. This is mainly due to inadequate availability and restrictions on the presence of all live insects in the wheat when it is sold. Fumigants are a frequently-used type of insecticide for stored grain insects in Montana and include chloropicrin and phosphine. Chloropicrin has limited use in empty bins only. Phosphine is highly effective, remedial, relatively inexpensive, leaves no residual product, and when used correctly, is safe around workers and the environment. However, environmental factors and a revised label make the use of this product more exacting than in the past.

In general, warm grain temperatures at harvest and during storage, combined with grain moisture content of 12-13%, are favorable to growth of insect populations. Insect populations increase during the autumn, peak during late fall or early winter, with reproduction declining through the remainder of winter. The following spring, population growth resumes as the grain warms once again. However, very large bins do not cool down significantly over the winter, because of the thermal inertia of the large grain mass.

Wheat is tested and graded when it is sold. The price received for the grain is dependant upon the standards of the buyer. In the United States, government standards are set by the Grain Inspection, Packers and Stockyard Administration (GIPSA). Grain contaminated with high levels of insect-damaged-kernels (IDK), mycotoxins, pesticides, or commodities contaminated with animal or insect filth or fragments above established tolerances can be condemned.

Grain is assigned a U.S. Grade from No. 1 to 5. The premium grade is U.S. No. 1, and requires that a bushel of wheat weigh a minimum of 58 pounds and have less than two percent damaged kernels. There can also be no more than one live insect injurious to grain in a 1-kilogram sample (32.57 dry ounces). Some buyers set a no-live insect standard. Wheat that contains 32 or more insect-damaged-kernels (IDK) per 100 gram sample (3.5 dry ounces) is classified as sample grade and cannot be sold for human consumption. Sample-grade wheat is difficult to sell and will suffer a considerable price discount. Flour millers strive to minimize insect fragments in their finished product and thus have high quality standards for grain purchased. Millers will typically not accept grain with any live insects, and prefer grain with few or no insect-damaged-kernels (IDK) per sample. They may pay more for grain that meets these high quality standards.

For export contracts, some countries may specify a specific grain treatment to eliminate insect pests, whereas another country will not accept grain on which any pesticide was used. Much of the wheat stored on-farm in Montana will end up in an overseas market. All pest management decisions made for on-farm and commercial storage situations are based on minimizing discounts or penalties at the time of sale.

INSECT CLASSIFICATION AND IDENTIFICATION

Classification

All living things are classified into groups known as taxonomic groups. The highest level of all taxonomic groups is the kingdom. There are five kingdoms: (1) plant, (2) fungi, (3) bacteria, (4) protists (amoebas and algae), and (5) animal. Each kingdom is then further divided into increasingly smaller groups based on similarities.

Insects are classified into the animal kingdom. Using the honey bee (*Apis mellifera*) and humans (*Homo sapien*) as examples, the standard groups in a typical complete classification of this species are:

Taxonomic Level	Honey Bee	Humans
KINGDOM	Animal	Animal
PHYLUM	Arthropoda	Chordata
CLASS	Insecta	Mammals
ORDER	Hymenoptera	Primates
FAMILY	Apidae	Hominid
GENUS	*Apis*	*Homo*
SPECIES	*mellifera*	*sapien*

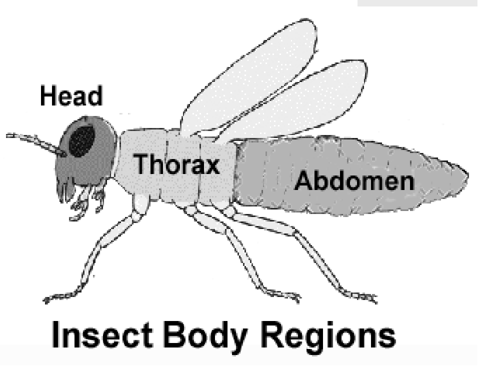
Of the 31 insect orders, there are 9 that contain most of the destructive insects.

1. Coleoptera – Beetles, weevils
2. Diptera – Flies, mosquitoes
3. Hemiptera – True bugs, assassin bugs, stink bugs, bed bugs, lygus bugs
4. Homoptera – Aphids, leafhoppers
5. Hymenoptera – Wasps, bees, ants, sawflies
6. Lepidoptera – Butterflies and moths
7. Orthoptera – Grasshoppers
8. Siphonaptera – Fleas
9. Thysanoptera - Thrips

Identification

All adult insects have two physical characteristics in common. They have three pairs of jointed legs, and they have three body regions -- the head, thorax, and abdomen (Figure 1.1).

Figure 1.1



Head - The head includes the antennae, eyes, and mouthparts. Antennae vary in size and shape and can aid in identifying some pest insects. Insects have compound eyes made up of many individual eyes. These compound eyes enable insects to detect motion, but they probably cannot see clear images. Mouthparts are also used to identify insects. The four general types of mouthparts are:

- Chewing - Cockroaches, ants, beetles, caterpillars, and grasshoppers,
- Piercing/sucking - stable flies, sucking lice, bed bugs, mosquitoes, true bugs, and aphids
- Sponging - flesh flies, blow flies, and house flies
- Siphoning - butterflies and moths

Thorax - The thorax contains the three pairs of legs and (if present) the wings. The various sizes, shapes, and textures of wings and the pattern of the veins are also used to identify insect species. The forewings take many forms. In the beetles, they are hard and shell-like; in the grasshoppers, they are leathery. The fore-wings of flies are membranous; those of true bugs are part membranous and part hardened.

Abdomen - The abdomen is usually composed of 11 segments, but 8 or fewer segments may be visible. Along each side of most of the segments are openings (called spiracles) through which the insect breathes. In some insects, the tip end of the abdomen has a tail-like appendage.

Insects, unlike some other types of animals, have no backbones. They have an outer supporting structure called an exoskeleton. Therefore they are called invertebrates. Organisms with an internal support structure (endoskeleton) which is characteristic of most large animals, are termed vertebrates.

Stored Grain Insects

In addition to obvious identifying characteristics, the feeding habits of storage insect pests are used to separate them into two classes: Primary pests and secondary invaders.

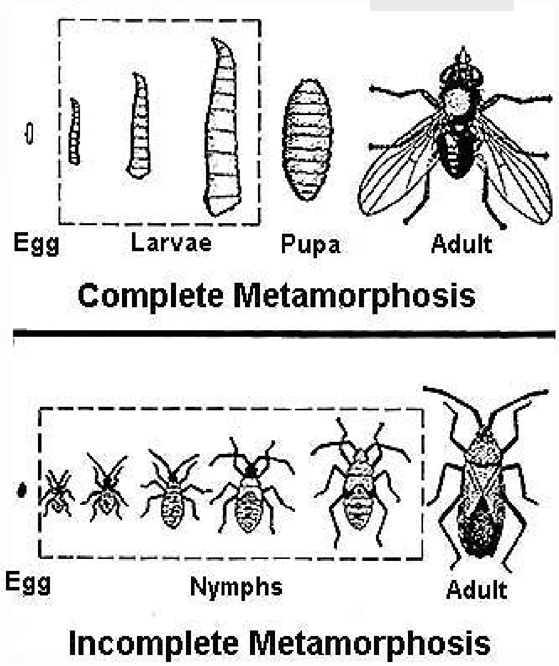
Primary pests are those that are capable of penetrating and infesting intact kernels of grain, and have immature stages that can readily develop within a kernel of grain.

Secondary invaders cannot infest sound grain but feed on broken kernels, debris, higher moisture weed seeds, and grain damaged by primary insect pests. In general, the immature stages of these species are found external to the grain. It is often thought that secondary invaders cannot initiate an infestation. This is untrue as in almost any storage situation there will be adequate amounts of broken grains and debris to support an infestation by secondary invaders. Moreover, secondary invaders contribute directly to grain spoilage after establishment, just as primary pests do. However, the most damaging insect types are those that feed within the kernel itself, causing insect-damaged-kernels (IDK). Wheat is discounted based on the number of insect-damaged-kernels (IDK) as well as the presence of live insects, and other grain quality factors, when samples are graded at the time of sale.

In Montana, almost all stored-grain insects are beetles and weevils in the Order Coleoptera. There are rare occurrences of moth pests (Lepidoptera). Members of seven other insect Orders are also found in grain storage throughout the world, but the major pests are still primarily from the Coleoptera and the Lepidoptera.

Insects from these two groups develop by complete metamorphosis; meaning they have (1) an egg stage, (2) multiple larval stages, (3) a pupal stage and , (4) the adult stage (Figure 1.2). Insects such as grass-hoppers and aphids pass through incomplete meta-morphosis with three stages: (1) egg, (2) nymph, and (3) adult. The immature stages resemble and feed on the same food as adults (Figure 1.2). By con-trast, larval and adult beetles that develop using complete metamorphosis feed on grain, while only the immature forms of the moth pests feed on the grain. Beetle pests are relatively common in Montana, even in unheated facilities, while moth pests are seldom able to overwinter in unheated facilities.

Figure 1.2



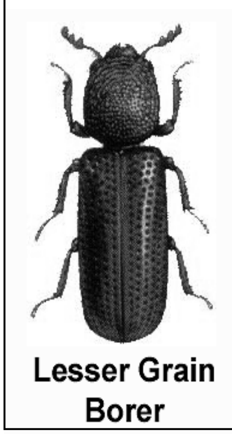
Before applying any treatment, it is a good practice to have pests positively identified by an expert. But with magnification, a little practice, and a good reference guide, it is possible to identify most stored product insects; especially in Montana where there are comparatively few species.

COMMONLY ENCOUNTERED STORED GRAIN INSECTS IN MONTANA

PRIMARY PESTS

Lesser Grain Borer - *Rhyzopertha dominica*

Figure 1.3



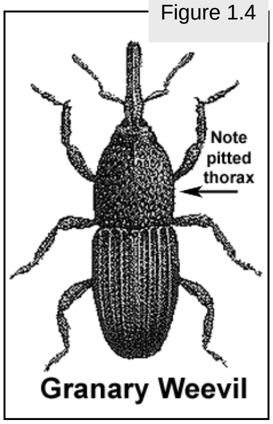
Although it is still relatively rare, the lesser grain borer has become the most com-monly encountered primary pest of stored grain in Montana. It is the most economically important primary pest of stored grain in the United States and is a strong flier that can tolerate high temperatures and dry grain (moisture content less than 12%). The adults of this species are readily distinguished by the "squared-off" appearance at the front of the body. Viewed from directly above, the cover of the thorax hides the head (Figure 1.3). The adults are less than 1/8 of an inch in length and range from reddish brown to dark brown. This species is a good flier, and adults are readily trapped in pheromone-baited traps at harvest. However, infestations are infrequent, when compared to the rate of capture for adults in these traps.

The lesser grain borer is a long-lived species and a female can lay up to 500 eggs. The eggs are deposited loosely among the kernels of grain and both the adults and the larvae can bore readily into, and out of, intact kernels. Adults and larvae have powerful jaws that are used to riddle the grain, creating large, irregular-shaped holes. Heavy infestation with lesser grain borers can be identified by a sweetish, musty odor in the storage. This odor is a result of the male-produced aggregation pheromone that has been demonstrated to be an effective lure for use in traps. This species is very capable of causing insect-damaged-kernels (IDK), which are important in quality assessment of samples. Weevils in stored grain also readily cause insect-damaged-kernels (IDK), but the larvae of these species remain within a single kernel.

Insecticide Resistance – The lesser grain borer has shown high resistance to malathion in wheat producing areas where it is more common. It is moderately tolerant of the insecticide chlorpyrifos-methyl (Reldan®), so this insect is not listed on the label. A light to moderate tolerance has been found to phosphine gas, once again in those areas where it is more commonly encountered.

Granary weevil – *Sitophilus granarius*

Figure 1.4



This species is rarely encountered in Montana, and most records are from the eastern part of the State. The adult weevil can be readily identified by its long slender snout. Adults are less than 3/16 of an inch in length, and color varies from medium brown to black. The thorax is pitted with elongate depressions, and there are no wings under the wing covers, so the species is flightless (Figure 1.4). Closely related pests are the rice weevil, *Sitophilus oryzae,* from wheat, and the maize weevil, *Sitophilus zeamais,* from corn. These species infest these commodities in warmer and more humid climates than those found in Montana, and occur here only after the transportation of infested commodities. They can be readily identified by the presence of fully-developed wings, rounded depressions in the thorax, and by the commodity they were infesting.

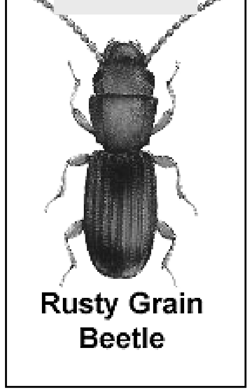
The granary weevil female chews a small hole in a kernel, into which she deposits an egg. The hole is sealed with a plug, and the egg hatches. The legless larva feeds within the kernel until pupation. The new adult emerges after the completion of metamorphosis. Each female can deposit between fifty and two hundred and fifty eggs, with development taking a month under warm conditions, and taking progressively longer as the grain cools.

In Montana, both the granary weevil and the lesser grain borer are thought to be unable to infest mature grain in the field because of a short window of opportunity and cool overnight temperatures. Field infestation is typically associated with warm humid climates, like in the tropics. Grain drying under these conditions may take quite some time, and the degree of field infestation is often correlated with the length of the period of exposure.

SECONDARY INVADERS

Rusty Grain Beetle - *Cryptolestes ferrugineus*

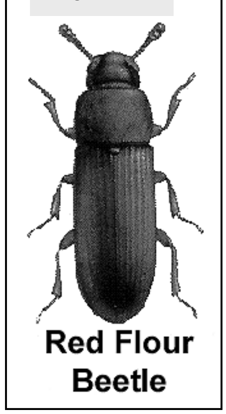
Figure 1.5



The rusty grain beetle is the most common external feeding grain insect in Montana. Eggs are deposited loosely between kernels and in the cracks or furrows on the grain surface. After hatching, larvae feed in the germ layer of the wheat kernel and also feed on broken kernels and grain dust. They are often found in large numbers, particularly through the winter, in the core of fine material that develops in the center of the grain mass. The adults are good fliers. Females can lay up to 400 eggs over a lifespan of up to nine months. These small insects (2 mm) are readily identified by their very long antennae (Figure 1.5).

Red Flour Beetle - *Tribolium castaneum*

Figure 1.6



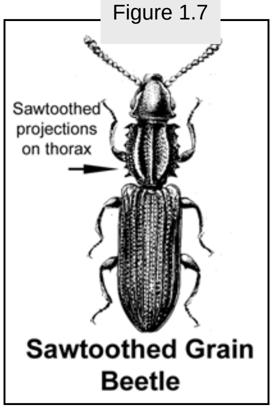
The red flour beetle is another external feeding insect found occasionally in Montana. It is seldom found in grain and is more often associated with milled products. The insects reproduce faster when some fine material is present in the stored grain especially if grain moisture is more than 12%.

Beetle populations grow very slowly and have difficulty reproducing on undamaged grain. Under optimal conditions females can lay up to 450 eggs over a lifespan that may be as long as eighteen months. The adults are good fliers.

A pungent, bad odor in the grain is a sign of a large infestation of red flour beetles. Red flour beetles have shown resistance to malathion and other protectant insecticides used on stored commodities. These elongate, shiny beetles have short, clubbed antennae (Figure 1.6).

Sawtoothed Grain Beetle – *Oryzaephilus surinamensis*

Figure 1.7



The sawtoothed grain beetle is a relatively uncommon insect in stored grain in Montana. It is more commonly associated with milled products. The larvae develop in flour, cereal products, and many other dried products. Eggs are deposited on cracks in the kernels and adults and larvae feed on damaged kernels, fines, and occasionally the germ of the intact grain. Adult females of this species may deposit up to 400 eggs over a lifespan that may be as long as two years. This species is readily identified by the saw-toothed-like projections on the sides of the adult thorax. This species is a good flier, but is most commonly associated with areas of high temperature and humidity.

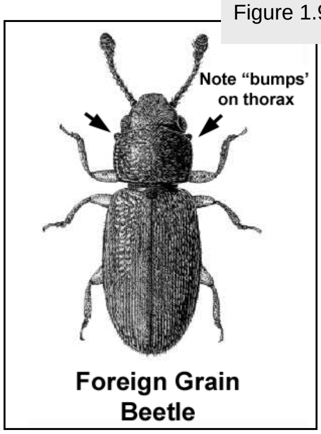
OTHER SECONDARY PESTS

Hairy Fungus Beetle - *Typhaea stercorea* and
Foreign Grain Beetle - *Ahasverus advena*

Figure 1.8

These species are thought to not feed readily on the grain itself, but on fungi that grow on high moisture grain, as well as on the surface of fine material and higher moisture weed seeds. Their presence is an indication of a higher moisture condition, and possibly moldy grain.

Figure 1.9



In Montana, adult beetles of these species fly into newly-stored wheat, where they feed on molds associated with the newly-stored grains, where females will deposit their eggs. The larvae will continue to actively feed on fungi and other fine material. However, these beetles are unlikely to damage stored grain and a population cannot survive the winter in Montana. Their presence in a bin indicates attraction to small amounts of moldy field grain in early storage. Well-managed grain will not remain infested with these beetles, particularly if the grain moisture content is maintained at less than 13% and the temperature declines.

Booklice - *Psocoptera*

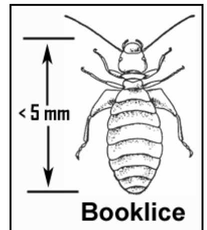
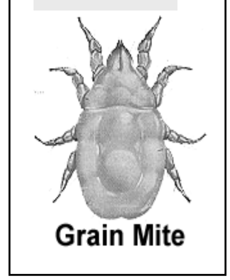


Figure 1.10

In Montana, these tiny insects are seldom found in very large numbers in properly stored wheat. They are not known to damage wheat significantly. Elevator operators and other buyers may require treatment for a very large number of booklice, but this is very unlikely to occur in a cool dry climate like Montana. The presence of booklice in a grain sample during grading should not result classification as “infested” grain.

Mites – *Acarina*

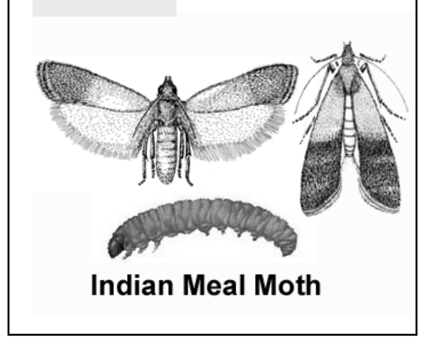
Figure 1.11



These minute organisms are not insects, but in the Class Arachnida (spider and ticks). They are rarely found in stored wheat and are not known to damage sound wheat significantly. However, they will feed on wheat germ, broken kernels or mold. Some mites are predators of insects and other mites. The presence of mites in a grain sample during grading should not result in the classification “infested” grain.

Indian Meal Moth - *Plodia interpunctella*

Figure 1.12



This short-lived moth is a serious pest that attacks stored grain and cereal products. It is capable of infesting any cereal grains or milled products, but is very rare in

Montana, due to low temperatures and low relative humidity.

Damage occurs when the larvae feed on kernels and spin massive amounts of silk over the grain surface. This webbing impedes air movement, which can cause grain heating and mold growth, and decreases fumigation effectiveness. Adult moths do not feed, and the females can deposit up to two hundred eggs on the commodity in a two-week lifespan.

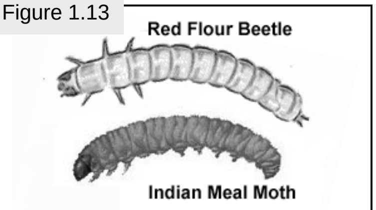


Figure 1.13 Differences Between Beetle and Moth Larvae

For identification purposes, it is important to note that moth larvae have three pairs of true legs, plus additional leg-like structures further down the abdomen. Beetle and weevil larvae are usually grub-like and legless, or have only three pairs of legs, all located close to the head (Figure 1.13).

Storage fungi

Any condition that increases moisture in stored grain can allow for the growth of storage fungi. Examples are condensation, leakage above the grain mass, or wheat harvested high in moisture (greater than 13%).

Mold production can decrease grain quality and support insect growth. Mold can spread over the kernel surfaces and result in caking near the surface. The mold itself produces heat and additional moisture, thus maintaining or increasing the relative humidity. This results in further mold growth.

Grain surface caking due to mold can decrease the effectiveness of fumigation and interfere with bin emptying. In Montana, large patches of moldy high moisture grain will often form at the peak of improperly stored wheat. The metabolic heat produced by these fungi create a 'hotspot' that allows for greater insect population growth over the winter.

CRITICAL IPM ISSUES

The integrated pest management (IPM) approach that protects stored grain includes:

- Sanitation
- Frequent monitoring
- Aeration
- Biological control
- Pesticide treatments

IPM techniques should be considered as tools in a toolbox; not all of them are needed every time, such as pesticides, but still need to be available.

SANITATION AND GRAIN LEVELING

The key to preventing insect infestations is to continually clean and properly maintain the storage structure. Stored grain insects breed readily in residual grain. They also live and feed on cracked grain, grain trash, or left over grain from previous crop. Both birds and rodents are also attracted to spilled grain. Rodents and pest insects find harborage and food in mature weeds surrounding the facility. The following are standard sanitation practices used for empty storage facilities.

- Clean harvest and transportation equipment before the harvest.
- Storage structures are emptied of old grain. Never store a new crop on top of old grain.
- Floors and walls inside empty bins are swept of old grain and debris.
- Weeds around the bins are removed.
- Remove spilled grain outside the storage structure.
- All grain handling equipment is repaired and kept in good condition before harvest.
- For additional protection, the inside and outside surfaces, foundations and floor of a storage facility should be treated with a residual insecticide, four to six weeks prior to harvest. This will kill any insects that were not removed during cleaning and those that migrate into the bin.

A serious problem for Montana producers is a tendency to overfill the bins, peaking the grain to the very top of the bin roof. The proper procedure is to fill the bins and level the surface of the grain at the top of the bin walls. This allows for a uniform dissipation of heat and moisture into a large airspace, which allows for the movement of warm moist air out of the storage structure (Figure 1.14).

Improper storage results in moisture wicking up the peaked grain and accumulating in the grain mass in this peak. Storage fungi can readily establish in this area, leading to spoilage, the development of hot-spots, and providing a very favorable environment for a large population of storage insects.

The process of leveling the grain requires the judicious use of the grain auger and a brief period of physical labor using a grain shovel. The level surface is well suited for monitoring with pitfall traps, and for the proper application of fumigants.

Figure 1.14

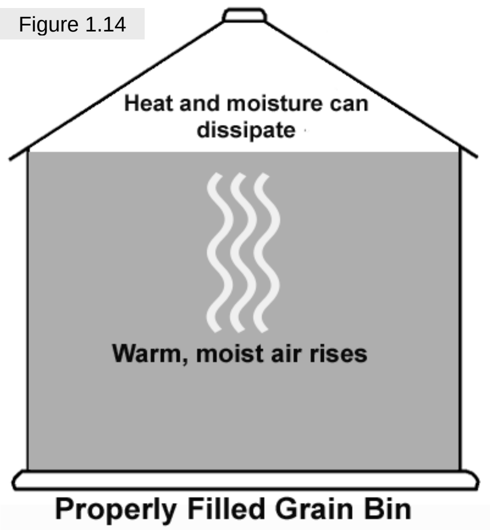
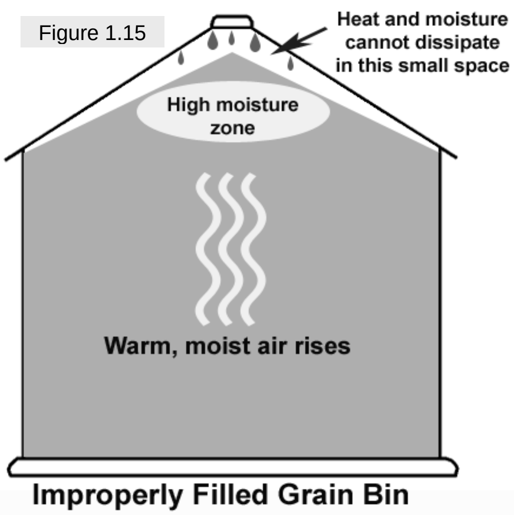


Figure 1.15



MONITORING

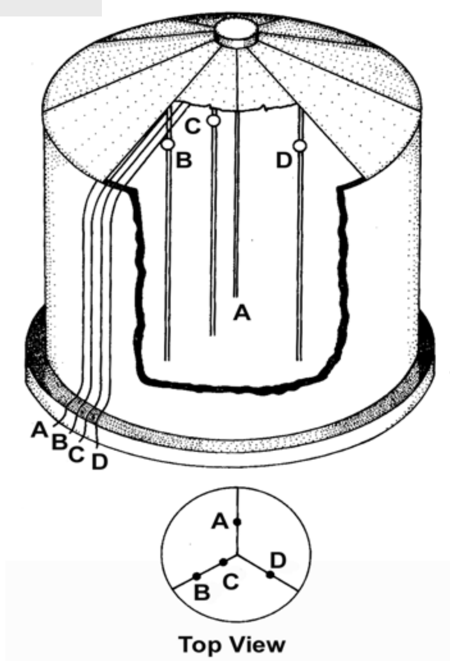
Pest monitoring is an important component in the IPM post-harvest practice for stored grain. Inspections should be done frequently, especially after first storage. Initially, grain is inspected for insects weekly until the baseline insect numbers are known. Then the grain is monitored every 2-3 weeks during throughout the autumn until the grain is cooled to 50-55°F or below, and monitored monthly for the remainder of the storage period.

Grain managers should carefully monitor the following:

- Grain quality
- Grain temperature
- Insects and insect density
- Hot spots
- mold growth
- Any “off odor”

Temperatures below 60°F prevent insect activities, while higher temperatures allow for increased insect growth and breeding. Many storage structures are equipped with temperature sensors that provide the temperature of the grain through the grain mass. The sensors are place on permanent cables that are suspended from the roof of the storage bin. Three are midway between the center and the wall, and one is very near the center (Figure 1.16).

Figure 1.16



Information is transmitted for each thermocouple to a reading device that helps grain managers record temperature over time. More than a five-degree rise (>5^0 F) recorded by one of the thermocouples over a two-week period indicates a pest or moisture problem exists in that location. Monitoring also detects changes in grain temperature during aeration or seasonal temperature fluctuations. Temperature of the stored grain in bins without temperature monitoring devices can be monitored by a thermometer mounted on a probe and inserted into the grain mass, or simply by inserting one's arm into the top layer of the grain mass.

Frequent grain sampling from several locations throughout the storage structure provides grain managers with the status of insects and grain quality. Initial sampling should be done at least weekly until the history of the grain has been

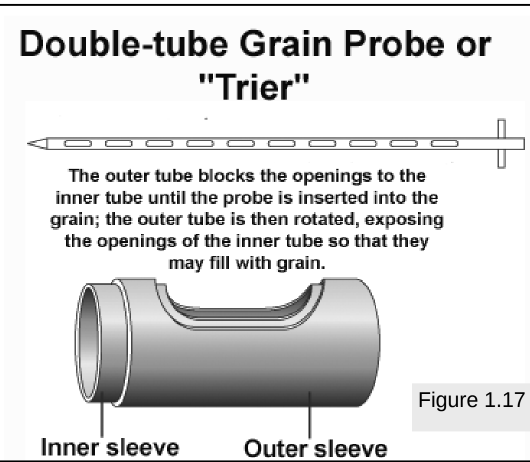


Figure 1.17

clarified. In many warmer locations, samples are collected from standing grain using either a deep bin cup or a grain trier (Figure 1.17).

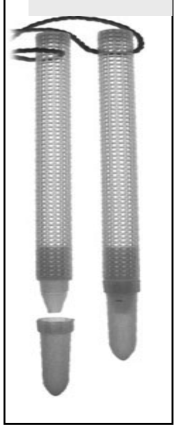


Figure 1.18

An alternative that works quite well is to use pitfall probe traps that remain in the grain (Figure 1.18). These traps are placed just below the grain surface or probed into the grain. With Montana's, comparatively low insect numbers, these traps can be serviced weekly to readily provide similar information to sampling. Note that the traps are more sensitive than sampling, so the numbers will appear greater than from sampling.

Nonetheless, the basic approach remains the same. Numbers and species of insects are recorded to assess a monthly pattern. The presence of insects in dry whole grain is an indication of future economic loss (in terms of live insects at time of sale). The presence of IDK-causing insects will result in discounts at the time of sale. A moldy appearance, dampness, off-odor, presence of IDK, and high moisture levels can also indicate insect problems. Consistent findings of internal feeders and IDK call for fumigation to protect grain value.

AERATION

Aeration is used to dry and cool newly-stored grain. It is also used to prevent moisture migration when ambient temperatures drop below that of the grain temperature.

Moisture migration occurs when outdoor temperatures decline during the fall and winter. Grain and air temperatures near the bin walls also drop. The insulating characteristics of grain prevent temperatures in the center of the grain mass from falling as rapidly. Cooling air near the bin wall makes this air more denser (heavier), and it settles toward the bin floor. At the same time, warmer air near the center of the bin floor is less dense (lighter). This air, which is displaced by the cooler air, rises through the center of the bin, absorbing small amounts of moisture from the surrounding grain as it rises. Grain near the top of the grain mass, like that near the outer walls, is cooler than the rising air. As the warm air rises through the cooer grain and is cooled by it, moisture condenses from the air onto the grain. This moisture migration produces wetting and crusting of surface grain (Figure 1.19).

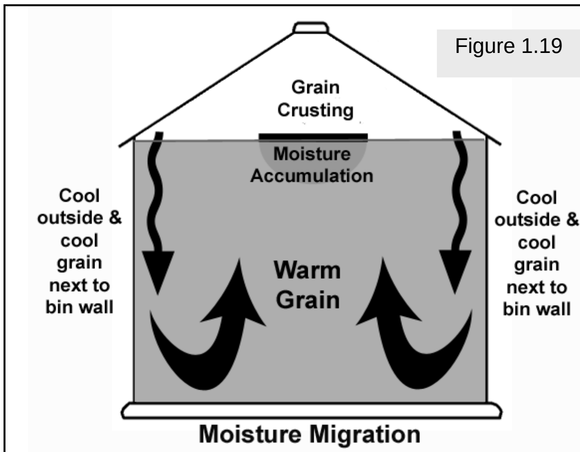


Figure 1.19

Prevention of moisture migration by maintaining a uniform temperature throughout the grain mass greatly reduces the possibility of mold development as well as insect feeding and reproduction. Aeration will not kill insects, but will slow their growth and development. Aerated bins contain lower insect populations than non-aerated bins through the winter, thus aeration greatly reduces the requirement for fumigation. In Montana, running aeration fans continuously for up to one week, and then running them only at night will rapidly cool grain stored to temperatures that inhibit insect feeding and reproduction in smaller bins.

Aeration fans at the base of the bin move cool air through the mass, with warm air exhausting through vents in the roof. Airflow rates of 0.1 to 0.5
17. cfm/bu are historically recommended for wheat at normal moisture levels. However, higher airflow, night aeration is most effective during late summer and fall, when the air temperature is below 60°F. In Montana, the nighttime air temperatures conducive for cooling occur from the time of first storage onwards. The number of aeration hours required to cool the grain to less than 50°F depends on the volume of wheat, the depth of the grain in the bin, airflow rates, and the difference between grain and ambient air temperatures.

Automatic controllers turn the aeration fans on when the ambient air temperature drops a set interval (5° F for example) below the grain temperature to cool the grain. The controllers turn the fan off when the air temperature exceeds the set point.

BIOLOGICAL CONTROL

There are a number of insect predators and parasitic wasps that attack insect pests of stored grain. All are effective if used in overwhelming numbers. However, biologicals are generally not used because the Food and Drug Administration (FDA) and food processors do not accept live insects or insect parts in raw grain. This inudative approach is simply the addition of very large numbers of beneficial insects.

Biological agents have limited commercial availability and are cost prohibitive, except perhaps for organic production. Specific species that attack the different groups of pests are listed below. It is important to note that there are limited numbers of naturally occurring biological control agents:

<u>Primary Pests</u>

Parasitic wasp of grain
- *Anisopteromalus calandrae*
- *Choetospila elegans*
- *Lariophagus distinguendus*

Predaceous mites
Warehouse pirate bug - *Xylocoris flavipes*

<u>Secondary Pests</u>

Predaceous mites
Warehouse pirate bug - *Xylocoris flavipes*

<u>Indianmeal moth</u>

Habrobracon hebetor
Predaceous mites
Trichogramma pretiosum
Warehouse pirate bug - *Xylocoris flavipes*

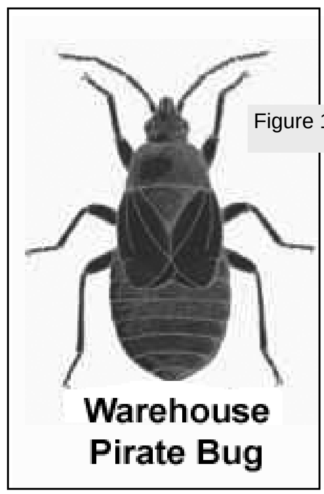


Figure 1.20

INSECTICIDE TREATMENTS

Empty bin treatments include residual insecticides applied in and around the fan, aeration ducts, auger, door openings, and hatch covers, or fumigants, before bins are filled at harvest. Commercial facilities must comply with the Occupational Safety and Health Administration (OSHA) bin entry permits. Following are pesticides available for treating empty bins:

Insecticides Labeled for Use as Empty Bin Treatments		
Active Ingredient (a.i.)	**Example Brands**	**Comments / Usage**
Cyfluthrin	Tempo Sc Ultra Premise Spray®	Most effective residual as compared with malathion and chloripyrifos-methyl.
Diatomaceous earth (DE)	Insecto, Protect-it®	Excellent empty bin treatment. Special grade required for grain use. Must use DE labeled for grain.
Malathion	Malathion	No longer recommended for empty grain bins because of high insect resistance and rapid degradation in warm, relatively moist grain.
Chlorpyrifos-methyl + deltamethrin	Storcide II ®	Can only be applied from outside of bin and sprayed downward into bin.
Chloropicrin	Chlor-o-pic®	Empty bin fumigant, under false floor, aeration tubes, and tunnels.
Methyl bromide	Brom-o-gas®, others	Empty bin fumigant; seldom used.
Phosphine	Phostoxin®, others	Empty bin fumigant.

Grain protectants are insecticides applied directly onto grain going into the storage or already in storage. Grain protectants do not kill insects inside the kernels. Following are insecticides labeled as protectants.

In Montana, the use of protectants should be limited to high-value commodities that need protection during storage for several months, and for which it is cost effective to use them. For direct application on wheat at first storage, there are limited circumstances where the use of a protectant is necessary.

Liquid Insecticides Labeled for Use as Grain Protectants		
Active Ingredient	**Example Brands**	**Comments**
Malathion	Malathion 5EC	Existing stocks are available but label has been withdrawn. Most stored grain insects are resistant.
DDVP	Vapona®	Also as strips. Used in the head space against Indianmeal moth.
Methoprene	Gentrol, Diacon II®	Kills developing insects only, slow kill of larvae, no kill of adults though causes sterility. High cost and must use other products before sale. Newly marketed.
Chlorpyrifos-methyl + deltamethrin	Storcide II ®	Applied as a coarse spray to the grain stream as it is moved into the bin.
Pyrethrins	Pyrenone®	Expensive, short residual life.

Dust Insecticides Labeled for Use as Grain Protectants		
Active Ingredient	**Example Brands**	**Comments**
Malathion	Big 6 Grain Protector®, Agrisolutions 6% Malathion Grain Dust	Top-dress treatment. Insects are resistant in many areas. Millers resist purchasing grain with strong malathion odor.
Diatomaceous earth (DE)	Protect-It™, Insecto®	Can lower the test weight of grain and is expensive if it is applied to entire grain mass, so is best applied to empty bins and to the top and bottom layers of the grain mass.

FUMIGANTS

Properly conducted fumigation will stop insect infestation and grain degradation from getting progressively worse. When fumigation is effectively conducted in late fall, pest populations can be drastically reduced.

Fumigation is recommended if:

- Grain samples reveal the presence of insect-damaged-kernals (IDK).
- Samples or traps capture harmful insects (lesser grain borer, granary weevil).
- Trapping or sampling indicates that a population of secondary pests like the rusty grain beetle is expanding rapidly.

Fumigants registered for use are phosphine, either released from aluminum or magnesium phosphide or directly as a gas, methyl bromide, and chloropicrin (used for empty bin treatment only). Tablets or pellets of aluminum or magnesium phosphide are sold under Weevilcide®, Fumitoxin®, and Phostoxin® trade names. Phosphine gas mixed with carbon dioxide is sold in gas cylinders as ECO_2-Fume®. Methyl bromide is expensive, difficult to use properly on raw grain, kills the germ, and is not recommended for stored grain, especially seed wheat. In addition, methyl bromide use is being phased out due to its status as an ozone depleter under the Montreal protocol.

The phosphide pellets or tablets release phosphine gas as they are exposed to moisture in the air. In a large storage facility, phosphide pellets or tablets are often added to infested grain as it is moved from one silo to another silo, bin, railcar, or truck.

NOTE: The treatment of mobile units must be in isolation as per label standards and the units can not be moved until the fumigation is over and the residue has been properly aerated!

For fixed facilities with a significant infestation, pellets or tablets are probed deeply into the mass and also similarly distributed near the top surface. The released gas is more effectively distributed through the mass using an air-circulation system known as closed-loop fumigation (CLF). For an effective fumigation, the facility must be well sealed to prevent gas leakage to maintain a high enough dosage for sufficient time to kill all life stages of the infesting insects. This requirement to prevent leaks is now a label requirement for the use of phosphine products.

In Montana, phosphine can only be sold to and used by pesticide applicators that are certified in its use.

Phosphine is used because it has good cost-benefit factors, is safe for workers when used properly, is environmentally safe, has no residue, is highly effective, and is remedial when large insect populations are found. Phosphine can be corrosive to copper and precious metals, such as those found in electronic equipment (computers, aeration fan motors, etc.), which limits its use in buildings.

Fumigation is more effective when sanitation, grain leveling, removal of fines, and thorough bin sealing has been done in advance. It is essential that the level of phosphine remain adequate (greater than 200 ppm) for as long as possible, with a minimum of 100 hours recommended to kill all life stages of the pest insects at optimal temperatures.

Many of the regulations stressed in this manual were recently established. The label and applicators manual are considered part of the revised label, and the label requirements are far more stringent than for the previous label and includes:

- a stricter restricted use statement requiring the physical presence of a certified applicator when the product is used,
- a requirement that two trained applicators be present whenever fumigation or gas monitoring requires work or reentry within confined spaces which reinforces the common sense approach that fumigators should always work in pairs,
- language that fumigant use must be in strict accordance with the label.

In addition, certified applicators must:

- ensure that the fumigated facility is secure and placarded before leaving.,
- be physically present and responsible for all workers when the fumigation exposure is complete,
- ensure that the structure is opened for aeration.

The certified applicator is also responsible for the monitoring of exposure levels during the application, fumigation, and aeration process. For this reason, the new label has strict sealing guidelines to prevent exposure to phosphine gas escaping from leaky storage structures. The new label also sets on maximum dosage levels and gives recommended dosage ranges for specific applications, whereas the preceding label only set minimum and maximum dosage levels.

Also, the entire label must be physically present when the product is used, and if an incident with adverse effects on human health or the environment occurs, the product registrant must be informed.

There are also requirements for weatherproof placarding, with name of the applicator and the product EPA registration number affixed.

There are requirements for the reporting of product theft to local police, and for DOT transportation labels when the product is transported.

FUMIGATION MANAGEMENT PLAN

A fumigation management plan (FMP) must be prepared by the certified applicator for each structure to be fumigated (See Appendix 1 and 2). This plan is designed to ensure a safe and effective fumigation, and must fully characterize the area to be fumigated, and include all appropriate monitoring and notification requirements. The development of a fumigation management plan is quite involved so we will spend some time on this.

In order to develop an effective Fumigation Management Plan, the following procedures need to be followed:

- The certified applicator must inspect the structure and surroundings to determine suitability for fumigation. If sealing is required, review records to determine if structural changes may have resulted in new potential leaks.
- Seal all leaks and test the seal, plus monitor phosphine levels in adjacent occupied buildings to ensure safety.
- Review existing Fumigation Management Plans, Material Data Safety Sheets, the label/applicator's manual, and safety procedures before fumigating.
- Develop procedures and safety measures for other workers that will be in and around the fumigation area during application and aeration.
- Develop a monitoring plan that confirms that workers and bystanders are not exposed to levels above the allowed limits during application, fumigation, and aeration. This monitoring plan must also demonstrate that nearby residents are not exposed to unacceptable levels, as well. The levels for exposure are an 8 hour time-weighted average of 0.3 ppm or a 15 minute time-weighted short term exposure limit of 1.0 ppm.
- Develop a procedure with local authorities to notify nearby residents in the event of an emergency.
- Confirm the placement of placards to secure all entrances to any structure under fumigation.
- Ensure that the required safety and monitoring equipment and adequate manpower is available to conduct a safe fumigation. More recent respiratory

protection guidelines for workers and certified applicators, require the use of monitoring equipment to establish airborne concentrations. Between 0 and 0.3 ppm, no respiratory protection is required. At concentrations from 0.3-15 ppm, a NIOSH/MSHA approved full – face canister respirator is required (Figure 1.21). If the phosphine concentration is above 15 ppm or if it is not known, a self-contained breathing apparatus (SCBA) is required (Figure 1.22).

- Application of fumigant material and post-fumigation aerations must be by two persons, with at least one person being a certified applicator. The second individual may be a worker under the direct supervision of the certified applicator, and the certified applicator is responsible for the safety of this worker.

Figure 1.21

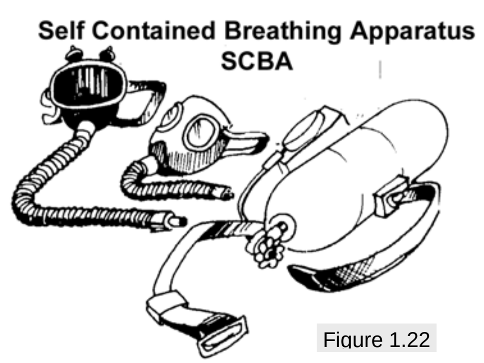


Figure 1.22

GAS DETECTION AND MONITORING DEVICES

Revised labels for fumigants require the use of sensitive gas monitoring devices during fumigant application and before warning placards can be removed from fumigated storages. Devices that provide adequate sensitivity include gas detector tubes and matching pumps manufactured by Auer, Draeger, Matheson Kitagawa, MSA, and Sensidyne.

Figure 1.23

Detector tubes are sealed glass tubes filled with a specific reactive solid. Both ends of a tube are broken off just before use, and one end is attached to a calibrated pump. Available pumps use a bellows, bulb, or piston-type syringe to draw a precise volume of air through the detector tube (Figure 1.23). Discoloration of the solid material within the tube indicates fumigant presence, and the gas concentration, can be read directly from the scale on the glass tube. A reading of 2 ppm is shown in Figure 1.24. Although tubes and pumps manufactured by different companies may be very similar, accurate readings require matching detector tubes and pumps from the same manufacturer. **Do not mix separate brands of equipment.**

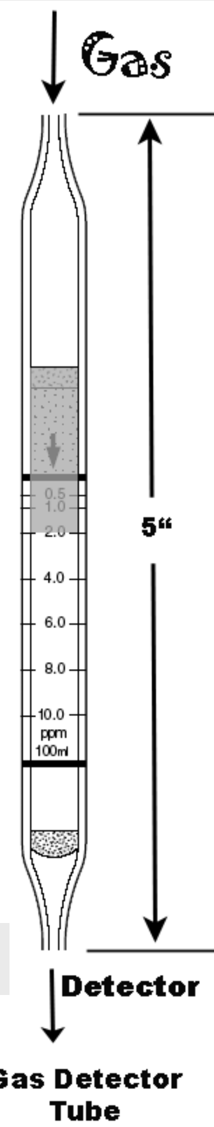


Figure 1.24

Detector tubes are specific for a single fumigant. Auer, Draeger, Matheson-Kitagawa, MSA, and Sensidyne manufacture detectors that offer adequate sensitivity for label-required monitoring of hydrogen phosphide and methyl bromide.

Resistance Management Issues

Grain storage facilities lend themselves to the development of insecticide resistance by virtue of the enclosed, protected structures, limited immigration and emigration of insects, and the repeated use of the same chemicals without rotation between chemical classes and modes of action. Of particular concern are the organophosphate and pyrethroid protectants.

The same fumigant, phosphine, is used with no rotation with other chemical classes. Methyl bromide is to be phased out entirely in 2005, leaving phosphine as the only registered fumigant for application directly to stored wheat.

Resistance to phosphine can occur in locations where it is used frequently, but thus far there have been no real control failures in Montana. Investigation of unsuccessful fumigation has shown that improper application has been the cause of the reduced efficacy in every circumstance scrutinized. However, proper use of phosphine is essential to prevent resistance development, including correct bin sealing and dosage to maintain phosphine concentration at high levels for a sufficient amount of time. As stated above, these are now label requirements, and will ensure that improper application does not speed the development of resistance through exposure to a less than optimal concentration, or by shortening of the exposure interval.

Consumer Education Issues

Pesticide residues are an ever-growing concern to consumers, and many of the grain protectants can be detected in the final milled product. However, phosphine fumigant does not leave any residues once the grain is ventilated.

Insect fragments and parts, rodent and bird droppings and hairs are all undesirable components in foodstuffs. The standard for the acceptable amount of insect fragments and/or animal droppings in a milled product is regulated by the Food and Drug Administration (FDA). Flour mills will not accept grain with live insects or animal droppings, and strive to strictly limit the amount of insect fragments. Millers also note that these fragments are not just of pest insects, but of beneficial (e.g., predators, parasites) insects as well, thus limiting their use.

Consumers are largely unaware of the balance between the use of pesticides and those standards that pertain to fragment and animal dropping in grain. Perhaps a critical education issue is to stress that good storage practices limit the use of pesticides to prevent contamination of foodstuff by either the pesticide residue or unacceptable levels of the end products from infestation.

As a related issue, the Food and Agriculture Organization and the World Health Organization have established the Codex Alimentarius, which sets international residue limits. Insect-infested grain is not acceptable, and only those pesticides that are on the Codex can be exported unless accepted by the receiving country. Given that most of Montana's wheat is exported, this further limits insecticides that can be used on stored grain. For example, the product Storicide® contains cyfluthrin as one of its active ingredients, but since there is no Codex Maximum Residue Limit (MRL) for this chemical, wheat destined for export cannot be treated with the product.

Appendix 1

PREPARATION OF A FUMIGATION MANAGEMENT PLAN (FMP)

The following are the required parts in creating a Fumigation Management Plan

- Purpose
- A Checklist Guide
- Preliminary Planning and Preparation
- Personnel
- Monitoring
- Sealing Procedures
- Application Procedures and Fumigation Period
- Post-Application Operations

FUMIGATION MANAGEMENT PLAN

The certified applicator is responsible for working with the owners and/or responsible employees of the site to be fumigated to develop a Fumigation Management Plan (FMP). The FMP is intended to ensure a safety and effective fumigation. The FMP must address characterization of the site, and include appropriate monitoring and notification requirements, consistent with, but not limited to, the following:

1. Inspect the site to determine its suitability for fumigation.
2. When sealing is required, consult previous records for any changes to the structure, seal leaks, and monitor any occupied adjacent buildings to ensure safety.
3. Prior to each fumigation, review any existing FMP, Material Safety Data Sheets (MSDS), Applicators Manual and other relevant safety procedures with company officials and appropriate employees.
4. Consult company officials in the development of procedures and appropriate safety measures for nearby workers that will be in and around the area during application and aeration.
5. Consult with company officials to develop an appropriate monitoring plan that will confirm that nearby workers and bystanders are not exposed to levels above the allowed limits during application/aeration. This plan must also demonstrate that nearby residents will not be exposed to concentrations above the allowable limits.
6. Consult with company officials to develop procedures for local authorities to notify nearby residents in the event of an emergency.
7. Confirm the placement of placards to secure entrance into any area under fumigation.
8. Confirm the required safety equipment is in place and the necessary manpower is available to complete a safety effective fumigation.

These factors should be considered in putting a FMP together. It is important to note that some plans will be more comprehensive than others. All plans should reflect the experience and expertise of the applicator and circumstances at and around the site.

In addition to the plan, the applicator must **read the entire label** and follow its directions carefully. If the applicator has any questions about the development of a FMP, contact the product manufacturer for further assistance.

THE FMP AND RELATED DOCUMENTATION, INCLUDING MONITORING RECORDS, MUST BE MAINTAINED FOR A MINIMUM OF 2 YEARS.

GUIDANCE FOR PREPARATION OF A FUMIGATION MANAGEMENT PLAN

PURPOSE

A Fumigation Management Plan (FMP) is an organized, written description of the required steps involved to help ensure a safe, legal, and effective fumigation. It will also assist you and others in complying with pesticide product label requirements. The guidance that follows is designed to help assist you in addressing all the necessary factors involved in preparing for and fumigating a site.

This guidance is intended to help you organize any fumigation that you might perform PRIOR TO ACTUAL TREATMENT. It is meant to be somewhat prescriptive, yet flexible enough to allow the experience and expertise of the fumigator to make changes based on circumstances which may exist in the field. By following a step-by-step procedure, yet allowing for flexibility, safe and effective fumigation can be performed. Before any fumigation begins, carefully read and review the label and the Applicator's Manual.

This information must also be given to the appropriate company officials (supervisors, foreman, safety officer, etc.) in charge of the site. Preparation is the key to any successful fumigation. If the type of fumigation that you are to perform is not listed in this Guidance Document you will want to construct a similar set of procedures. Finally, before any fumigation begins you must be familiar with and comply with all applicable state and local laws. The success and future of fumigation are not only dependent on your ability to do your job but also by carefully following all rules, regulations, and procedures required by governmental agencies.

A CHECKLIST GUIDE FOR A FUMIGATION MANAGEMENT PLAN

This checklist is provided to help you take into account factors that must be addressed prior to performing all fumigations. It emphasizes safety steps to protect people and property. The checklist is general in nature and cannot be expected to apply to all types of fumigation situations. It is to be used as a guide to prepare the required plan. Each item must be considered, however, it is understood that each fumigation is different and not all items will be necessary for each fumigation site.

PRELIMINARY PLANNING AND PREPARATION

1. What is the purpose of the fumigation?
   - ☐ Elimination of insect infestation?
   - ☐ Elimination of rodent infestation?
   - ☐ Plant pest quarantine?

2. Determine the type of fumigation, for example
   - ☐ Space; tarp, mill, warehouse, food plant.
   - ☐ Vehicle; railcar, truck, van, container.
   - ☐ Commodity; raw agricultural or processed foods.
   - ☐ Grain; vertical silo, farm storage, flat storage.
   - ☐ Vessels; ship or barge. In addition to the Applicator's Manual, read the U.S. Coast Guard Regulations 46CFR 147A.

3. Fully acquaint yourself with the site and commodity to be fumigated, including:
   - ☐ What is he general structure layout, construction (materials, design, age, maintenance) of the structure?
   - ☐ What are fire or combustibility hazards?
   - ☐ Are there any connecting structures and escape routes, above and below ground, and other unique hazards or structure characteristics?

- Plan and prepare with the owner/operator/person in charge.
- Draw or have a drawing or sketch of structure to be fumigated, delineating features, hazards, and other structural issues.
- How many and what is the identification of persons who routinely enter the area to be fumigated (i.e. Employees, visitors, customers, etc.)?
- What is the specific commodity to be fumigated, its mode of storage, and its condition?
- What is the previous treatment history of the commodity, if available?
- What is the accessibility of utility service connections?
- Where is the nearest telephone or other means of communication? Mark the location of these items on the drawing/sketch.
- Where are emergency shut-off stations for electricity water and gas? Mark the location of these items on the drawing/sketch.
- Make note of current emergency telephone numbers of local Health, Fire, Police, Hospital, and Physician responders.
- What are the names and phone numbers (both day and night) of appropriate company officials.
- Check, mark and prepare the points of fumigation application locations if the job involves entry into the structure for fumigation.
- Review all labeling.
- What are exposure time considerations?

4. What is the fumigant to be used?
   - What is the minimum fumigation period, as defined and described by the label use directions?
   - How much down time is required to be available?
   - What are the aeration requirements?
   - What are the cleanup requirements, including dry or wet deactivation methods, equipment, and personnel needs ,if necessary?

6. What are the measured and recorded commodity temperatures and moistures?
   - Cubic footage or other appropriate space/location calculations.
   - Structure sealing capability and methods.
   - Label recommendations
   - Temperature, humidity, wind
   - Commodity/space volume
   - Past history of fumigation of structure
   - Exposure time
   - Determination of dosage

PERSONNEL

1. Confirm in writing that all personnel in and around the area to be fumigated have been notified prior to application of the fumigant. Consider using a checklist each one initials indicating they have been notified.

- Instruct all fumigation personnel about the hazards that may be encountered.
- Instruct all fumigation personnel about the selection of personal protection equipment (PPE) and devices, including detection equipment.
- Confirm that all personnel are aware of and know how to proceed in case of an emergency situation.
- Instruct all personnel on how to report any accident and/or incidents related to fumigant exposure.
- Provide a telephone number for emergency response reporting.

- Instruct all personnel to report to proper authorities any theft of fumigant and/or equipment related to fumigation.
- Establish a meeting area or rally point for all personnel in case of emergency.

MONITORING

1. Safety. Monitoring must be conducted in areas to prevent excessive exposure and to determine where exposure may occur.

- Document where monitoring will occur.
- Keep a log or manual of monitoring records for each fumigation site. This log must, at a minimum, must contain the timing, number of readings taken and level of concentrations found in each location.
- When monitoring log records document that there is no phosphine present above the safe levels, subsequent monitoring is not routinely required. However, spot checks should be made occasionally, especially if conditions significantly change.
- Monitoring must be conducted during aeration and corrective action taken if gas levels exceed the allowed levels in an area where bystanders and/or nearby residents may be exposed.

2. Efficacy

- Gas readings should be taken from within the fumigated structure to insure proper gas concentrations. If the phosphine levels have fallen below the targeted level the fumigators, following proper entry procedures, may re-enter the structure and add additional product.
- Document readings.

NOTIFICATION

- Confirm that all local authorities (fire departments, police departments, etc.) have been notified as per label instructions, local ordinances if applicable, or instructions of the client.
- Prepare written procedure ("Emergency Response Plan") which contains explicit instructions, names, and telephone numbers so as to be able to notify local authorities if phosphine levels are exceeded in an area that could be dangerous to bystanders.

SEALING PROCEDURES

- Sealing must be complete.
- If the site has been fumigated before, review the previous FMP for previous sealing information.
- Make sure that construction/remodeling has not changed the building.
- Warning placards must be placed on every possible entrance to the fumigation site.

APPLICATION PROCEDURES & FUMIGATION PERIOD

- Plan carefully and apply all fumigants in accordance with the registrants label requirements.
- When entering into the area under fumigation, always work with two or more people under the direct supervision of a certified applicator wearing appropriate respirators.
- Apply fumigant from the outside where appropriate.
- Provide watchmen when a fumigation site cannot otherwise be made secure from entry by unauthorized persons.
- When entering structures, always follow OSHA rules for confined spaces.
- Document that the receiver of in-transit fumigation has been notified and is trained to receive commodity under fumigation.

POST-APPLICATION OPERATIONS

- Provide watchmen when you cannot secure the fumigation site from entry by unauthorized persons during the aeration process.
- Ventilate and aerate in accordance with structural limitations.
- Turn on ventilating or aerating fans where appropriate.
- Use a suitable gas detector before reentry to determine fumigant concentration.
- Keep written records of monitoring to document completion of aeration.
- Consider temperature when aerating.
- Insure aeration is complete before moving vehicle into public roads.
- Remove warning placards when aeration is complete.
- Inform business/client that employees/other persons may return to work or otherwise be allowed to reenter.

Appendix 2

FUMIGATION MANAGEMENT PLAN – A Template

The purpose of this Fumigation Management Plan is to assist ___________________________________ ____in _____________________________, Montana to ensure the safety of their employees, community and the environment. It is also designed to ensure an effective fumigation and to assist the company in meeting phosphine label requirements.

Owner/Manager of Responsibility

Name:		
Address:		
Day Telephone Number: ( )	Night Telephone Number: ( )	E-mail:

Certified Applicator in Charge

Name:		
Address:		
Day Telephone Number: ( )	Night Telephone Number: ( )	E-mail:

Emergency Telephone Numbers

Local Police:	Local Fire Department:	Sheriff's Office:
Local Hospital:	Fumigant Manufacturer:	
Chemtrec: 1-800-424-9300	U. S. Poison Control Center: 1-800-222-1222	Montana Department of Agriculture: (406) 444-3144

Month/Day / Year	
/ /	Date of Site Inspection or referred to previous FMP of: _______/_____/______ Month Day Year
/ /	Date of consultation with facility officials in developing FMP & worker safety plant
/ /	Date of consultation with facility officials in developing monitoring plan
/ /	Date of consultation with facility officials in procedures for notifying local authorities to notify nearby residents in the event of an emergency.
/ /	Date of consultation with facility officials in placement of placards
/ /	Date of consultation with facility officials in having required safety equipment

The following information **supports** the concept of the Fumigant Management Plan (FMP).

Reason for Fumigation - pest(s), buyer requirements, etc.

____

____

____

Type of Fumigation: silo, warehouse, corrugated steel, etc.

____

____

____

____

Previous fumigation history.

____

____

____

____

____

Location of nearest telephone: May refer to facility diagram with telephone marked:

____

Emergency electrical, gas and water shut-off stations: May refer to facility diagram with telephone marked.

Electrical:____

Gas:____

Water:____

Other:____

Site(s) to be Fumigated:

Indicate below or refer to attached diagram of facility. Use number to reference site.

Site(s)	Volume of Treated Area	Temp. of Commodity	Moisture of Commodity	Dosage	Fumigation Time
1.					
2.					
3.					
4.					
5.					
6.					
7.					
8.					
9.					
10.					
11.					
12.					
13.					
14.					
15.					

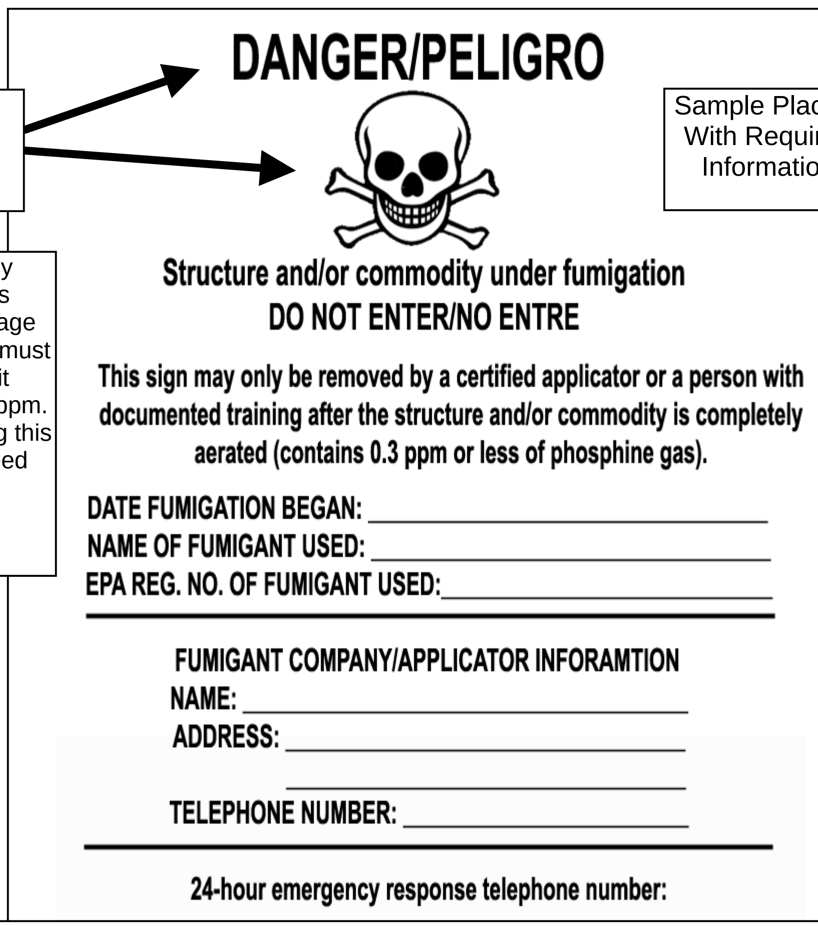
Remarks:

Sites to Placard: List below or indicate on attached diagram	
1.	
2.	
3.	
4.	
5.	
6.	
7.	
8.	
9.	
10.	
11.	
12.	
13.	
14.	
15.	
Remarks:	

Danger/Peligro & Skull/Crossbones should be in Red!

Sample Placard With Required Information

NOTE: If incompletely aerated commodity is transferred to new storage structure, new structure must also be placarded if it contains more than 0.3 ppm. Workers exposure during this transfer must not exceed allowable limits.



All entrances into a fumigated structure must be placarded. Where possible, placards should be placed in advance of the fumigation to keep unauthorized persons away. Do not remove placards until the treated commodity is aerated down to 0.3 ppm phosphine or less.

Sites to be monitored: List below or indicate on attached diagram		
Site(s)	**Date**	**Phosphine Reading**
1.		
2.		
3.		
4.		
5.		
6.		
7.		
8.		
9.		
10.		
11.		
12.		
13.		
14.		
15.		
Remarks:		

Site, Wind Speed & Direction, Date and Reading for samples taken at property line

Site(s)	Wind Speed	Wind direction	Date	Phosphine Reading
1.				
2.				
3.				
4.				
5.				
6.				
7.				
8.				
9.				
10.				
11.				
12.				
13.				
14.				
15.				
Remarks:				

Site(s) and date cleared of phosphine: List below or indicate on attached diagram		
Site	**Date Cleared**	**Phosphine Reading**
1.		
2.		
3.		
4.		
5.		
6.		
7.		
8.		
9.		
10.		
11.		
12.		
13.		
14.		
15.		
Remarks:		

Name of Persons Fumigating:		
Name	**Certified or Trained**	**Certification Number If Certified**
Bud Tuggley (Example)	*Certified*	*12345-12*
Payne N. Diaz (Example)	Trained	

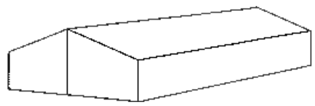
Appendix 3

APPLICATION PROCEDURES

A Fumigation Management Plan (FMP) must be devised for application, aeration and disposal of the fumigant so as to keep to a minimum any exposures to hydrogen phosphide and to help assure adequate control of the insect pests.

The following instructions are intended to provide general guidelines for typical fumigations. These instructions are not intended to cover every type of situation nor are they meant to be restrictive. Other procedures may be used if they are safe, effective and consistent with the properties of aluminum phosphide products.

FLAT STORAGES



Treatment of these types of storages often requires considerable physical effort. Therefore, sufficient manpower should be available to complete the work rapidly enough to prevent excessive exposure to hydrogen phosphide gas. Open the flasks containing the pellets outside the storage, conduct fumigations during cooler periods, and employ other work practices to minimize exposures. It is likely that respiratory protection will be required during application of fumigant to flat storages.

- Inspect the site to determine its suitability for fumigation.
- Determine if the structure is in an area where leakage during fumigation or aeration would adversely effect nearby workers or bystanders if concentrations were above the permitted exposure levels.
- Develop an appropriate Fumigation Management Plan. (Refer to FMP guidelines.)
- Consult previous records for any changes to the structure. Seal vents, cracks and other sources of leaks.
- Apply tablets or pellets by surface application, shallow probing, deep probing or uniform addition as the bin is filled. Storages requiring more than 24 hours to fill should not be treated by addition of fumigant to the commodity stream as large quantities of hydrogen phosphide may escape before the bin is completely sealed.

  Probes should be inserted vertically at intervals along the length and width of the flat storage. Pellets or tablets may be dropped into the probe at intervals as it is withdrawn. Surface application may be used if the bin can be made sufficiently gas tight to contain the fumigant gas long enough for it to penetrate the commodity. In this instance, it is advisable to place about 25 percent of the dosage in the floor level aeration ducts. Check the ducts prior to addition of phosphine product to make sure that they contain no liquid water.
- Placement of plastic tarp over the surface of the commodity is often advisable, particularly if the overhead of the storage cannot be well sealed.
- Lock all entrances to the storage and post fumigation warning placards.

VERTICAL STORAGES

Concrete upright bins and other silos in which grain can be rapidly transferred.

- Inspect the site to determine its suitability for fumigation.
- Determine if the structure is in an area where leakage during fumigation or aeration would expose nearby workers or bystanders to concentrations above the permitted levels.
- Develop an appropriate Fumigation Management Plan. (Refer to FMP guidelines.)
- Consult previous records for any changes to the structure. Close openings and seal cracks to make the structure as airtight as possible. Prior to the fumigation, seal the vents near the bin top which connect to adjacent bins.

- Pellets or tablets may be applied continuously by hand or by an automatic dispenser on the headhouse/gallery belt or into the fill opening as the commodity is loaded into the bin. An automatic dispenser may also be used to add phosphine product into the commodity stream in the up leg of the elevator.
- Seal the bin deck openings after the fumigation has been completed.
- Bins requiring more than 24 hours to fill should not be fumigated by continuous addition into the commodity stream. These bins may be fumigated by probing, surface application, or other appropriate means. Exposure periods should be lengthened to allow for diffusion of gas to all parts of the bin if phosphine product has not been applied uniformly throughout the commodity mass.
- Place warning placards on the discharge gate and on all entrances.

This extensive set of guidelines is intended to provide for a safe and effective fumigation. Although the regulations are substantial, there are entirely appropriate, given the toxicity and volatility of this restricted use product. Now, to some final comments on other issues relevant to pests, insecticides, and stored commodities.

SPRAY ON GRAIN PROTECTANTS

Grain can be treated in several ways as it is moved (augered) into storage or transferred from bin to bin. Many grain handlers use commercially available spray units that deliver an insecticide solution to grain as it flows into an auger, conveyor belt, or similar grain transfer equipment. Its successful use does require knowledge of the delivery rate of the auger, a value easily computed by determining the time required to move a known quantity of grain into storage.

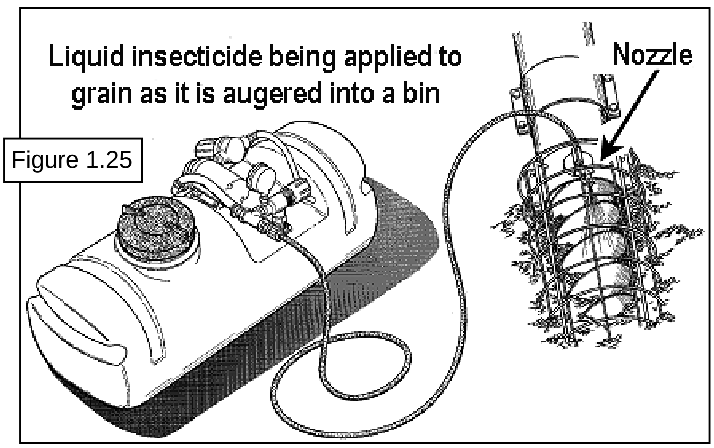


Figure 1.25

Spray-delivered under constant pressure may provide a more uniform delivery rate than homemade gravity flow applicators. The uniformity of coverage for each kernel required for effective insecticide activity allows for some flexibility in application methods. Research has shown that it is not necessary to obtain uniform coverage of all kernels; it is important that an insecticide be applied at a consistent rate throughout all grain layers. To deliver the desired insecticide rate, it is usually best to apply the treatment as near as practical to the grain's destination. This minimizes the amount of insecticide left on grain moving equipment and maximizes the deposit remaining on the grain. A coarse spray application such as that provided by a flooding nozzle produces maximum deposits on grain and minimum losses to aerosol grain dusts (Figure 1.25).

Appendix 4

Grain Storage Mathematics

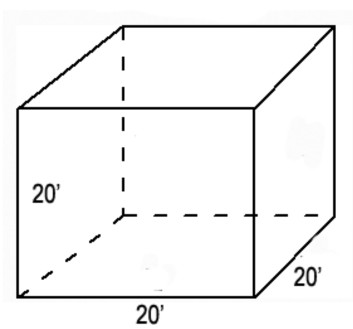
The recommended rates, or doses, listed on fumigant labels are more often based on the volume of the structure rather than the quantity of grain to be fumigated. This is especially true of hydrogen phosphide (Phostoxin®) as it is a mobile gas and will penetrate to all parts of the storage structure. Therefore, dosage must be based upon the total volume of the space being treated and not on the amount of commodity it contains. The same amount of Phostoxin is required to treat a 30,000 bushel silo whether it is empty or full of grain unless, of course, the surface of the commodity is sealed off by a tarpaulin.

It is critical, then, that you correctly determine a structure's volume or, to a lesser degree, the volume of grain before you begin a fumigation If you use too little fumigant for a given volume, you may not achieve the desired level of pest control; too much fumigant is wasteful and may even damage the treated commodity.

Grain storage units may be rectangular, cylindrical, cone shaped or trapezoidal. When calculating cfm/bu, the number of bushels in the structure must be known. Calculate the amount of grain stored by using these formulas, either singly or in combinations, to estimate total bushels stored.

In simple terms, the volume (or cubic content) of a structure is equal to the structure's area times its height The area is determined by multiplying the length by the width.

SQUARE STRUCTURES



The volume of a square or rectangle is calculated by the following formula:

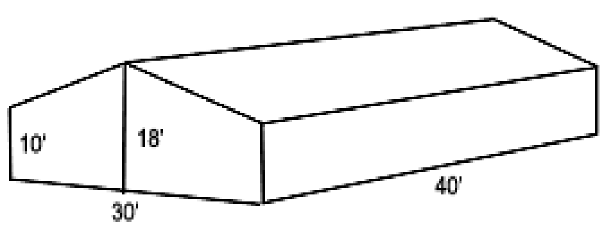
Area = Height x Length x Width

For this example, the volume of this square is 8,000 cubic feet (ft^3)

20 feet x20 feet x20 feet = 8,000 cubic feet

In actual practice, calculating volume is usually more involved, because most structures are irregular and have peaked or gable roofs.

PEAKED STRUCTURES



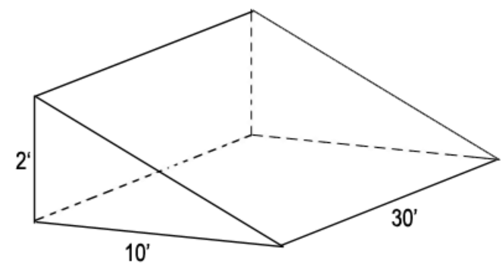
From this diagram, you immediately determine that the structure is 40 feet long and 30 feet wide. However, the height is different at different points along the roof. In order to calculate the volume of the structure, you must first determine the average height. The easiest way to do this is to take the average of the wall height (10′) and the height at the peak (18′). The average height of this structure in is:

$$\text{Average Height} = \frac{\text{Wall height + Peak height}}{2} \quad \frac{10' + 18'}{2} = \frac{28'}{2} = 14'$$

Now we can calculate the volume as: Length x Width x Average Height or; 40′ x 30′ x 14′ = 16,800 ft^3

TRIANGULAR PRISMS

The area of a triangle is: ½ base x height. In the case of triangular prisms, the volume is the area of one trianglar side times the length.



In this example, the area of one triangular side is:

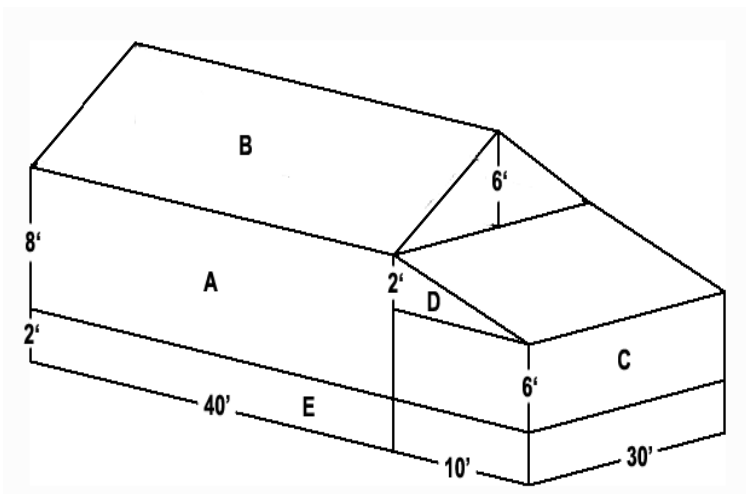
½ x 10′ x 2′ = 10′

The volume of this triangular prism is:

10′ x 30′ = 300 ft^3

IRREGULARLY SHAPED STRUCTURES

The following is a complex structure but the volume of this structure can be easily computed.



First is to "divide" the structure into three main parts: the main room with its attic (A + B), the lean-to with its attic (C + D), and the crawl space (E). Use the procedure for Peaked Structures to first determine the average height of the main room with its attic, and then use this average height to determine the volume. Likewise, use the procedures to calculate the volume of rectangles and triangular prisms to calculate the volume of the lean-to with its attic. You can calculate the volume of the crawl space as you would to calculate the volume of a rectangle. The total volume of the structure is the sum of the volumes of the three "divisions"

A and B

$$\text{Average Height} = \frac{\text{Wall height + Peak height}}{2} \quad \frac{8' + 14'}{2} = \frac{22'}{2} = 11'$$

Length x Width x Average Height or; 30′ x 40′ x 11′ = **13,200 ft^3**

C and D

C = Length x Width x Height. 30′ x 10′ x 6′ = **1,800 ft^3**

D = (½ Base x Height) x Length. (½ x 10′ x 2′) x 30′ = 10′ x 30′ = **300 ft^3**

E

E = Length x Width x Height. 50′ x 30′ x 2′ = **3,000 ft^3**

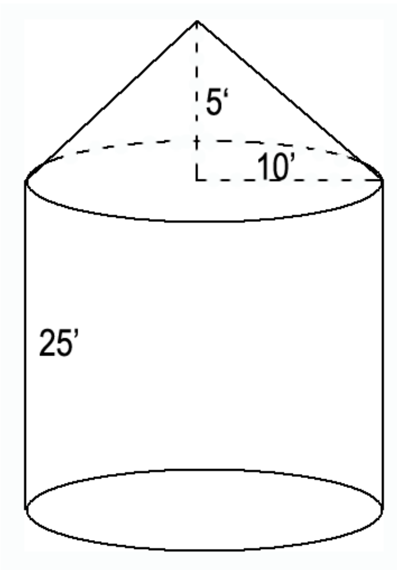
TOTAL STRUCTURE VOLUME = (A and B) + (C and D) + E

= 13,200 ft^3 + (1,800 ft^3 +300 ft^3) + 3,000 ft^3 = 18,300 ft^3

CYLINDERS AND CONES (GRAIN BINS)

The above examples represent fairly simple structures. Many buildings have overhanging eaves, chimneys, and dormers that add to the overall volume. If a building is covered by a tarp during a fumigation, be certain to account for the space between the tarp and the structure (e.g., when the tarp envelops a porch) when calculating the total volume to be fumigated. While the task of calculating the volume may take longer in such cases, the basic methods of calculation are the same as in the examples here.

Now let's look at a structure that is not rectangular. If you wish to fumigate an empty grain bin, how do you determine the volume of the bin?



This is a simplified drawing of a grain bin. Remember, the bin is a cylinder (like a big tin can) with a conical (funnel-shaped) cap.

The volume of a cylinder = $3.1416 \, x \, r^2 \, x \, h$

The volume of a cone = $\frac{3.1416 \, x \, r^2 \, x \, h}{3}$

Where r is equal to the radius and h is equal to the height of the cylinder and height of the cone respectively.

The number 3.1416 is a constant.

The volume of the cylinder = $3.1416 \, x \, 10^2 \, x \, 25$

= $3.1416 \, x \, 100 \, x \, 25$

= $7{,}854 \text{ ft}^3$

The volume of the cap or cone = $\frac{3.1416 \, x \, 10^2 \, x \, 5}{3} = \frac{1{,}570.8}{3}$

= 523.6 ft^3

VOLUME OF THE TOTAL STRUCTURE = $7{,}854 \text{ ft}^3 + 523.6 \text{ ft}^3 = 8{,}377.6 \text{ ft}^3$

Appendix 5

Useful Information

1. Average Bushel Weights and Seeds Per Pound

Crop	Bushel weight (lbs.)	Seeds Per Pound
Barley	48	13,600
Corn	56	1,450
Oat	32	12,700
Rye	56	18,080
Soybean	60	2,500
Sunflower, oilseed	27	6,000
Wheat	60	12,000

2. Useful Conversions

Unit of Measure	Multiply by (x)	To Find
Acres	0.405	Hectares
	43,560	Square feet (ft^2)
	4840	Square yards
Bushels (dry)	1.244	Cubic feet (ft^3)
	2150	Cubic inches
	35.24	liters
	4	pecks
	32	quarts
Cubic Foot (ft^3)	0.804	Bushels
	25.714	Quarts (dry)
	29.922	Quarts (liquid)
	1728	Cubic inches
	7.481	Gallons
Gallons	128	Ounces (liquid)
	231	Cubic inches
	0.1337	Cubic feet (ft^3)
	3785	Cubic centimeters
	3.785	Liters
Hectares	2.47	Acres
Inch	2.54	Centimeters
Kilogram	2205	Pounds
	35.274	Ounces (dry)
Liter	33.81	Ounces (fluid)
	0.264	Gallons
	61.025	Cubic inches
Ounce	28.349	Grams (avoirdupois*)
	1.805	Cubic inches
Pound	16	Ounces
	453.59	Grams
Square foot	144	Square inches
Square yard	9	Square feet (ft^2)
Ton (short)	907.185	Kilograms
* Avoirdupois means there are 16 ounces in a pound		
Reference: Penn State Agronomy Guide 2004		

Appendix 6

Placarding Of Fumigated Areas And Sample Placard

All entrances to the fumigated structure must be placarded. Placards must be made of substantial material that can be expected to withstand adverse weather conditions and must bear the wording as follows:

1. The signal words DANGER/PELIGRO and the SKULL AND CROSSBONES symbol in red.
2. The statement "Structure and/or commodity under fumigation, DO NOT ENTER/NO ENTRE".
3. The statement, "This sign may only be removed by a certified applicator or a person with Documented training after the structure and/or commodity is completely aerated (contains 0.3 ppm or less of phosphine gas). If incompletely aerated commodity is transferred to a new storage structure, the new structure must also be placarded if it contains more than 0.3 ppm. Workers exposure during this transfer must not exceed allowable limits.
4. The date the fumigation begins.
5. Name and EPA registration number of fumigant used.
6. Name, address and telephone number of the Fumigation Company and/or applicator.
7. A 24-hour emergency response telephone number.

All entrances into a fumigated structure must be placarded. Where possible, placards should be placed in advance of the fumigation to keep unauthorized persons away. For railroad hopper cars, placards must be placed on both sides of the car near the ladders and next to the top hatches into which the fumigant is introduced.

Do not remove placards until the treated commodity is aerated down to 0.3 ppm phosphine or less. To determine whether aeration is complete, each fumigated structure or vehicle must be monitored and shown to contain 0.3 ppm or less phosphine gas in the air space around and, if feasible, in the mass of the commodity.

DANGER/PELIGRO

Structure and/or commodity under fumigation

DO NOT ENTER/NO ENTRE

This sign may only be removed by a certified applicator or a person with documented training after the structure and/or commodity is completely aerated (contains 0.3 ppm or less of phosphine gas).

DATE FUMIGATION BEGAN: ______________________________

NAME OF FUMIGANT USED: ______________________________

EPA REG. NO. OF FUMIGANT USED: ________________________

FUMIGANT COMPANY/APPLICATOR INFORAMTION

NAME: __________________________________

ADDRESS: ______________________________

____

TELEPHONE NUMBER: ______________________

24-hour emergency response telephone number:

____

SECTION 2
SEED TREATMENT

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HISTORY OF SEED TREATMENTS

Seeds carry a crop's genetic material that is needed for good crop growth. Seeds also contain lots of energy which is attractive to soil-borne diseases and insects. Protecting a crop from seed-attacking pests can result in quick seedling emergence that produces even crop growth, better quality yields, and increased economic return.

For thousands of years, farmers have continuously fought plant diseases and insect pests. Through a combination of accident, and trial and error, early farmers developed many methods to protect their crops, and crop seeds. To reduce the incidence of stinking smut in wheat (common bunt), Egyptian and Roman farmers dipped the cereal seeds in onion brine before sowing. In ancient Greece, wine and crushed cypress leaves were mixed together to control insects in stored grain. The Greeks had unknowingly produced hydrogen cyanide gas, an effective fumigant.

In 1670, a ship carrying wheat grain sank off the English coast near the town of Bristol. Nearby farmers were able to retrieve and plant some of the grain. The crop that resulted was remarkably free of "smut", whereas most of the fields planted with grain that had not been soaked in seawater showed heavy smut infestation. Over the next 100 years, many methods were used to treat wheat seed. Salt, lye and urine were applied to wheat seed to determine if they could reduce the amount of smut that developed.

In 1807, a liquid solution of copper sulfate was used to slow smut spore germination. However, this compound is a general biocide that kills everything including many germinating seeds. In 1895, the chemical formaldehyde was suggested as a seed treatment. While it gained in popularity due to its effectiveness and low cost, it was neither pleasant nor safe to use for the person treating the seed.

In the 1920s, copper carbonate dust began to replace copper sulfate dips because it was more convenient and safer for the seed. Also, the advent of the organic mercury compounds in the 1920s started a new era in seed treatment. This resulted in the multiple contact and systemic fungicides now available for seed treatment. Although safety concerns have led to the banning of mercury compounds, the newer contact and systemic fungicides allow for a more precise matching of seed treatments to specific needs.

Into the 1930s, organic mercury seed treatments achieved great success against a number of seed-borne diseases. These mercury-based treatments were abandoned in 1970 due to the risk of accidental mercury poisoning. After World War II, a variety of useful non-systemic, organic chemical fungicides and insecticides were developed. Beginning in the 1960s and 1970s, several families of systemic organic chemical seed treatments were produced. In the 1980s and 1990s, researchers developed the first biological seed treatments using bacterial pathogens as to control seedling diseases.

WHAT IS A SEED TREATMENT?

Seed treatments are chemical or biological substances that are applied to seeds or vegetative reproductive parts. The purpose being to prevent/control infection by disease-causing organisms, insects, or other pests.

Seed treatment pesticides include:

- Bactericides (to control bacteria)
- Fungicides (to control fungi)
- Insecticides (to control insects)

Most seed treatments are applied to true seeds; ripened ovules with a pericarp (seed coat) that surrounds an embryo. These seeds include barley, wheat, or soybeans. However, some seed treatments can be applied to vegetative reproductive materials, such as bulbs or tubers (such as potato seed pieces).

In Montana, seed treatments are mainly fungicidal in nature. Fungicidal seed treatments are used for three reasons: (1) to control **soil-borne** fungal disease organisms (pathogens) in the soil that cause seed rots, damping-off, seedling blights and root rot; (2) to control fungal pathogens that are **external** or **surface-borne** on the seed, such as those that cause covered smuts of barley and oats, and common bunt of wheat; and (3) to control internally **seed-borne** fungal pathogens such as the loose smuts of wheat and barley (Figure 2-1).

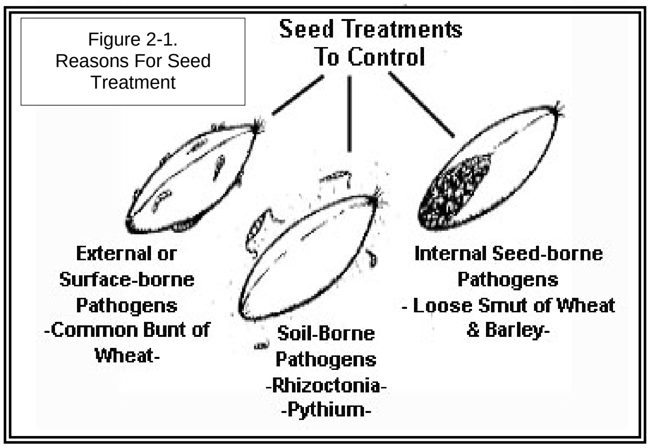


Figure 2-1. Reasons For Seed Treatment

Most fungicidal seed treatments do not control bacterial pathogens and most will not control all types of fungal diseases, so it is important to carefully choose the treatment that provides the best control of the disease organisms present on the seed or potentially present in the soil.

In regards to the seed industry, the terms “grain” and “seed” have different meanings. Grain is untreated seed that is used for human consumption and can legally be marketed as such. Grain becomes seed when a seed treatment pesticide is applied to it. The seed treatment then makes the seed unfit to legally enter the grain market and be consumed by humans.

Because they are not intended for pest control, seed-applied growth regulators, micronutrients, and nitrogen-fixing inoculants such *Rhizobium* and *Bradyrhizobium* are not included in this manual. Also, treatments designed to protect stored food or feed grain are considered grain treatments rather than seed treatments.

BENEFITS AND RISKS OF SEED TREATMENTS

Seed treatments are used on many crops to control a variety of soil-borne, seed-borne, and surface-borne pests.

Although seed treatments have important benefits, they also pose certain risks:

- Accidental pesticide exposure of workers who produce or apply seed treatments.
- Contamination of the food supply by accidental mixing of treated seed with food or feed grain.
- Accidental contamination of the environment by improper handling of treated seeds or pesticides used to treat seeds.

While there are risks associated with seed treatments, it is important to note that these risks can be reduced through proper training and proper use of seed treatment pesticides.

PRINCIPLES OF SEED PEST MANAGEMENT

In agriculture, a pest is any living organism that competes with humans for food or fiber. The control of a particular pest is considered only when it is suspected that economic damage will occur. The amount of loss in yield or quality then justifies the cost of applied control measures. Seed is therefore chemically treated in anticipation of economic damage. While seed treatment pesticides are applied to control diseases and pests that reduce yields and lower food/feed quality, it is only one step in a series of disease and insect control practices called Integrated Pest Management or IPM.

INTEGRATED PEST MANAGEMENT

Effective seed pest management should not rely upon any one method of control, but should be based on a combination of pest control strategies. The coordinated use of multiple tactics is called integrated pest management or IPM.

IPM uses a combination of cultural practices, host resistance, biological control, and chemical control methods to simultaneously:

- minimize economic losses due to pests,
- avoid development of new pest biotypes that overcome pesticides or host resistance,
- minimize negative effects on the environment,
- avoid pesticide residues in the food supply.

An IPM plan should identify important pests, determine pest management options, and blend together various management options to achieve the goals listed above. In order to use seed treatments effectively, it is important to understand the purposes of seed treatment, alternatives or additions to seed treatments, and the various advantages and disadvantages of seed treatments.

PURPOSES OF SEED TREATMENT

Eradication of Seed-borne Pathogens. Seed-borne, pathogens may occur on the surface of seed, hidden in cracks or crevices of the seed coat, or as infections deep inside the intact seed. Since some pathogens may not survive in soil or in crop residue and are dependent on the seed-borne phase for survival between crops. An example is the fungus that causes loose smut of wheat.

Even if a pathogen can survive in soil or residue, being seed-borne may allow it to get a head start resulting in more severe disease. Also, seed-borne pathogens may be transported to new localities in seed shipments.

Seed treatments can often be used to eradicate pathogens that occur on or in the seed. The choice of seed treatment may be dictated by whether the pathogen is borne externally or internally. For example, both systemic and non-systemic (contact) fungicides can eliminate surface contamination of wheat seed by spores of the common bunt fungus. However, the fungus causing loose smut in wheat is borne within the seed embryo and can only be controlled with systemic fungicides.

Protection of Seeds and Seedlings. Both insects and disease pathogens can decimate germinating seeds and young plants, which are relatively tender and lack food reserves to recover from injuries. For chronic diseases like leaf spots and root rots, the earlier the infection takes place, the greater will be the damage.

Seed treatments can protect the seed and seedling from attack by certain insects and diseases. Non-systemic fungicides or insecticides form a chemical barrier over the surface of the germinating seed and protects the developing seedlings from chewing insects like wire-worms or soil-borne diseases like damping-off.

Systemic seed treatments can protect aboveground parts from sucking insects like aphids or air-borne diseases like rust. Systemic fungicides and biological seed treatments can also protect young plants from infection by root rot. Although the duration of protection may be limited, this infection delay can reduce the losses.

ALTERNATIVES/ADDITIONS TO SEED TREATMENT

Usually, seed treatments are not the only available method to control a particular pest. Seed treatments should be compared to other pest control measures for cost, efficacy, safety, etc. Since a single pest control method may not provide sufficient control, seed treatments can often be supplemented with other control measures to achieve satisfactory results.

Biological control. Biological control is the use of natural predators or antagonists to suppress pests. For example, Kodiak® consists of the bacterium (*Bacillus subtilis)* that provides protection against rhizoctonia, fusarium, alternaria and other disease organisms that attack root systems**.**

Broadcast sprays. Broadcast sprays can provide control later in the season when seed treatments have dissipated.

Certified seed. The Montana State University Seed Lab checks seed for the presence of barley strip mosaic virus only.

Crop rotation. Crop rotation reduces populations of many insects and disease pathogens that survive in soil or crop residue. Seed treatments may be less necessary where crop rotation is practiced.

Fertility management. Lack of micronutrients such as chloride and excess of major nutrients like nitrogen can favor certain diseases. Maintaining balanced fertility can reduce disease pressure.

Heat treatment. Hot water treatment can be used to rid seeds of certain seed-borne pathogens while leaving the seed viable. For example, the fungus that causes downy mildew can be eradicated by soaking seed at 122°F for 25 minutes. This treatment will also eliminate the bacteria that cause black rot. Soon after treatment, the seed must be cooled in cold water for several minutes and then dried. If water is too cool, the seed-borne pathogens will not be killed. If the water is too hot, the seed may be injured or killed. Because it is tricky, hot water treatment has limited use.

Planting date. Planting date affects the severity of some root rots, certain insects and some insect-borne viruses. The classic example is Hessian fly on wheat, which is more likely to occur with early planting. Take-all root rot of wheat and barley yellow dwarf are diseases that can be affected by planting date.

Variety resistance. Variety resistance may be available for certain pests. Examples include Hessian fly on wheat, phytophthora fungi on alfalfa and powdery mildew on wheat. Seed treatments may be unnecessary when high varietal resistance is available. However, seed treatments may be an important supplement when resistance is weak.

Volunteer control. Many insects and diseases use volunteer crop plants and weeds as a reservoir, or "green bridge." Elimination of the green bridge at least one month prior to seeding significantly reduces the damage due to root diseases, especially *Rhizoctonia*, and may increase yield.

ADVANTAGES OF SEED TREATMENTS

- **Seed-borne pathogens are vulnerable.** The seed-borne phase is the weak link in the life cycle for many disease pathogens. Using seed treatments to eradicate seed-borne pathogens is often very effective for disease control.
- **Precision targeting.** Because chemicals are applied directly to seeds, seed treatments are not subject to spray drift.
- **Optimum timing.** Seeds and seedlings are more vulnerable to diseases and insects than adult plants. Applying treatments to seeds allows pesticides to be present when needed most.
- **Low dose**. Relatively small amounts of pesticides are used in seed treatments compared to other broadcast sprays. This reduces the cost and the potential environmental impact. It also reduces the probability of chemical residues in harvested grain.
- **Easy to apply.** Seed treatments are relatively easy and cheap to apply compared to broadcast sprays.

DISADVANTAGES OF SEED TREATMENTS

- **Accidental poisoning.** Hungry livestock and birds have been known to consume spilled treated seed. Young children may find and eat treated seed that has been stored improperly.
- **Cropping restrictions.** Just like other pesticides, some seed treatments may have significant grazing or rotation crop restrictions.
- **Limited dose capacity.** The amount of pesticide that can be applied is limited by how much will actually stick to the seed.
- **Limited duration of protection.** The duration of protection is often short due to the relatively small amount of chemical applied to the seed, dilution of the chemical as the plant grows, and breakdown of the chemical.
- **Limited shelf life of treated seed.** Producing excess treated seed is undesirable because the shelf life of treated seed may be limited. Surplus treated seed cannot be sold for grain.
- **Phytotoxicity**. Pesticide injury to plants is called phytotoxicity. Since modern day seed treatments tend to be low in toxicity and applied at low rates, they may have little environmental impact. A few seed treatments are partly phytotoxic when applied at high rates. Lower germination or stunting may occur if application rates are not carefully controlled. Cracked, sprouted, and scuffed seeds may be particularly susceptible to toxic effects. A few seed treatments may reduce the length of the sprout and, therefore, affect the choice of planting depth.
- **Worker exposure.** When inhaled, some products such as those containing thiram, can cause

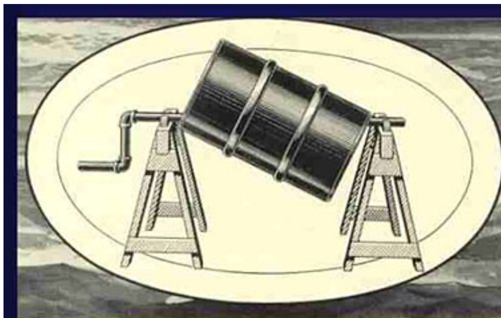
irritation of the respiratory system and mucous membranes. The use of a NIOSH-approved respirator is required when using products containing thiram.

PLANNING FOR SEED TREATMENTS

Careful planning, evaluation, and implementation are necessary for an effective seed treatment program. Listed below are the basics involved in the selection and use of chemicals, machinery available for treating seed, the expected results, and legal and hazardous aspects of their use:

- Analyze why you need to treat your seed. What are your objectives; what disease(s) or insect(s) do you want to manage; what specific conditions do you want to correct?
- Become familiar with the chemical(s) you are using or expect to use. You should know the following about the chemical.
    - Mode of action.
    - Toxicity class or LD_{50}.
    - Antidote or practical statement of treatment.
    - Physical hazards, such as flammability and corrosiveness, etc.
    - Relative safety to seed (phytotoxicity).

  Both a pesticide's label and its accompanying Material Data Safety Sheet (MSDS) can provide most of this information.
- Understand the basic working principles of your seed-treating equipment. Know how to properly calibrate, maintain, and clean it.
- Be aware of the legal results of seed treatment and understand the applicable laws and regulations related to chemical treatment, using machinery, disposing of wastes from the treatment operation, labeling treated seed, etc.
- Evaluate the results of your management program by using comparative damage ratings, production data, etc. In most cases, it is difficult, to do an adequate evaluation without leaving untreated checks to use as a basis for comparison. The results should be recorded for future reference.



Rotary duster (1930's) made from a 30 gallon steel oil drum. A baffle board was placed inside to help mix the seed. Construction cost was $1.25

SEED AND SEEDLING PESTS

Pesticide labels often list the specific type of insects, pathogens, or general pest groups that are controlled by the seed treatment. Understanding the different types of pests, their life cycles, where they attack, and when they attack will help in selecting the proper seed treatment(s).

While seed treatments are often a very important pest management tool, it is best to develop a long-term plan involving many pest management practices. The use of seed treatments, resistant varieties, crop rotations, residue/volunteer plant control, and are just a few management variables that can influence disease and insect problems. It is important to consider all the management options available for recurring pest problems.

The availability of new pesticide formulations complements the products that have been used by agricultural producers for many years. This has resulted in a much greater choice of available seed treatments than in the past. Before selecting a product, any one who is treating seed should determine which diseases and/or insects have been recurring problems in their location. They should also have a rudimentary understanding of the development of seed and seedling pest.

PLANT DISEASE DEVELOPMENT

Organisms that cause plant disease are called **pathogens**. Pathogens include: fungi, bacteria, viruses, nematodes, phytoplasmas, protozoa, and some parasitic plants. Plant diseases can also be caused by nonliving, or abiotic agents, like air pollutants, nutrient imbalances, and various environmental factors.

Plant disease occurs when a **susceptible host** and a disease-causing or **virulent pathogen** meet in a **favorable environment**. The relationship of theses three parts is called a "**disease triangle"** and can be manipulated to help manage disease problems. (Figure 2-2).

If one or more of these factors do not occur, then the potential for plant disease is small. For example, if host plants are resistant or widely spaced, the amount

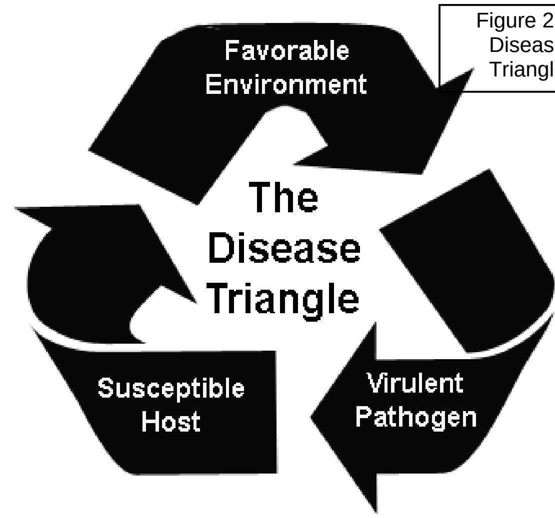


Figure 2-2. Disease Triangle

of disease will be small or zero! But if host plants are susceptible, at a susceptible stage of growth, or densely planted, the potential for disease is great. Correspondingly, if the pathogen is abundant or more virulent, the potential for disease is also greater. Likewise, the more favorable the environmental conditions that help the pathogen or that reduce host resistance, the greater the potential for disease.

During infection, most plants produce **symptoms**. Symptoms are the **plant's expression of disease**. Some symptoms are easily seen such as wilting, visible lesions, yellowing, abnormal growth, mosaics, and root rots, whereas others, such as shriveled seed or reduced seed quality, may not be noticed until the crop is harvested.

Signs of infectious plant diseases are the physical; evidence of the actual **pathogen** itself. Some signs of a pathogen are visible with an unaided eye. For example, mushrooms are evidence of fungal mats or mycelium. Rusts pustules are evidence of fungal spores. Other signs, such as, asexual spores (conidia), internal mycelium, bacterial ooze, or virus particles require the use of a hand lens or a microscope to be visible.

With every plant disease there is a distinct chain of events that leads to the development of plant disease and reproduction of the pathogen. This chain of events is called the **disease cycle.** The primary events in the disease cycle are:

- Inoculation – Arrival of a pathogen on a host.
- Penetration - Invasion of a plant by a pathogen.

♦ Infection and colonization – Establishment, growth and reproduction of a pathogen within a plant.
♦ Dispersal of the pathogen – Movement of pathogens from one host to another.
♦ Survival of the pathogen in the absence of the host. Also known as over-wintering or over-summering.

Inoculation. When a pathogen comes in contact with the host, it is called inoculation. For disease to develop, the pathogen must arrive on the host, invade tissue, and begin to grow and establish a parasitic relationship with the host.

Penetration. Pathogens penetrate host tissues in various ways. Spores of many fungi get inside the plant by growing through natural plant openings called **stomata** (Figure 2-3).

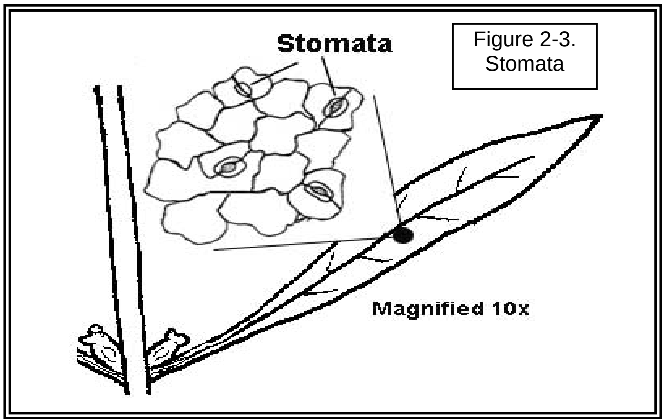


Figure 2-3. Stomata

Some fungal spores produce "infection pegs" that can penetrate the leaf surface directly (Figure 2-4). By contrast, most bacteria gain entry into the plant through insect vectors while feeding. Other bacteria penetrate through microscopic injuries resulting from wounding or rubbing of plants.

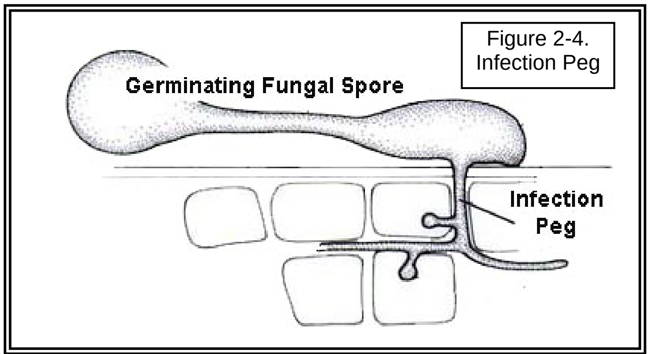


Figure 2-4. Infection Peg

Some pathogens penetrate plant surfaces but do not cause disease. This is because an incompatible host-pathogen relationship develops. A resistant plant may respond to penetration by undergoing bio-chemical and physiological changes that either kill the pathogen or prevent its entry and spread throughout the host. For a disease to develop, a relationship must be established so that a pathogen can continue to grow and colonize host tissues.

Infection. As the pathogen continues to grow, or infect, in the host plant, symptoms will begin to appear at a certain time after penetration, depending on the particular pathogen and host involved. Many biochemical and physiological changes have usually occurred in the plant before symptoms develop. **Visible symptoms are the responses of the plant to disease processes that are the result of a pathogen and occur over time.** The time between inoculation and symptom development is know as the **incubation period**. After the incubation period, the pathogen may produce reproductive structures (signs) such as fungal spores, bacterial ooze and viral particles that aid in the pathogen's dispersal or spread to other susceptible hosts.

Dispersal. Some pathogens have the ability to spread only a few inches whereas others can be transported for many miles. Pathogens are usually spread by wind, water, soil, in plant parts, or by a vector.

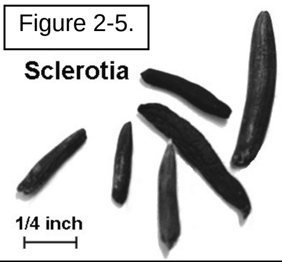
- **Wind.** Tiny fungal spores are well adapted to travel by air currents. Spores of rust fungi have been detected at altitudes of 33,000 feet and can be blown for distances of 2,400 miles on turbulent air currents. The spores of other fungi, such as those that cause damping-off, are carried only a few inches by water-saturated soils, mists or spattering rain.
- **Water.** Fungal-infested debris and bacterial-infested soil can be transported by rainwater from infested fields into disease-free fields. Irrigation water may carry spores to new locations and cause disease outbreaks. Other pathogens spread in water as swimming spores called zoospores. This group of pathogens includes soil-inhabiting fungi that include pythium seed rot (damping-off) and phytophthora root rot.
- **On Plant Material.** Many pathogens are spread by infected transplants, cuttings, seed and plant litter. Infected seed is responsible for many disease outbreaks, and the use of contaminated seed has

been responsible for introducing plant pathogens into new areas. The smut fungi that cause serious grain losses, generally overwinter as spores on contaminated seed and plant debris.

- **By Vectors.** Insects, nematodes, fungi, and animals are important agents that transport pathogens from one place to another. Many of the disease-causing fungi and viruses are spread from diseased to healthy plants by insect vectors. Some viruses reproduce in their insect vectors thereby making management difficult.

Survival. The survival of a pathogen between cropping seasons and its effective dispersal to uninfected plants are crucial aspects of the plant disease cycle. If either of these is prevented, the disease will not occur (the disease triangle). Most pathogens possess mechanisms to survive periods between crops or periods where environmental conditions are less than favorable.

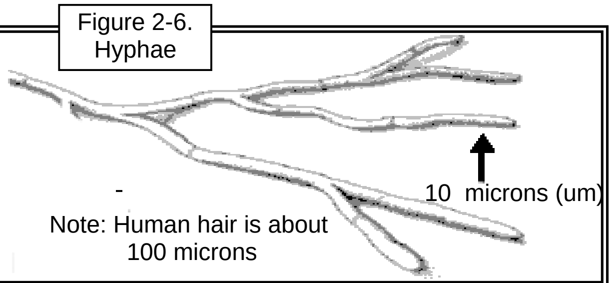
Figure 2-5.
Sclerotia



Fungi affecting annual plants such as cereal grains usually survive the winter or summer as mycelium in infected plant debris, resting spores,or as sclerotia (Figure 2-5). Sclerotia are compact masses of hyphae (Figure 2-6), usually with a darkened outer shell, that resemble small mouse droppings.

Some fungal plant pathogens are soil inhabitants; they are able to survive indefinitely on dead plant matter. These include common seed pathogens such as pythium, fusarium and rhizoctonia.

Figure 2-6.
Hyphae



FUNGAL DISEASES

Fungi (singular = fungus) are small thread-like organisms composed of tiny filaments called hyphae (Figure 2-6). Individual hyphae are composed of strands of simple cells so small that they cannot be seed without a microscope. The tangled mass of intertwined hyphae is collectively called mycelium.

These numerous and diffuse mycelial threads then spread within the food source (soil, organic litter or wood) and are able to extract nutrients from this host.

Most fungi use nonliving plant or animal material for nutrients and serve an important role in recycling organic matter in the environment. However, there is a small group of fungi that obtain their nutrition from living plants, resulting in plant disease. Such fungi are considered pathogens, and they are the most common and destructive of all infectious plant diseases.

Most fungi produce “seed-like” microscopic spores that are often spread from one plant to another by wind, rain, insects, seeds, farm equipment, and runoff water or soil. The spores land on a susceptible host and germinate. The hyphae then forms an infection peg that penetrates the host surface directly, through natural openings (stomata) or through wounds.

Some disease- causing fungi, like those that cause leaf spots and blights, cannot survive in the soil for long periods and can be effectively managed through cultivation and crop rotation. However, other fungi, such as most root and stem rot pathogens, are soil inhabitants and survive well despite efforts to “starve” them out through crop rotation. Seed treatments can be used to control or suppress many of these seed-borne and soil-borne, fungal diseases.

In Montana, major fungal pathogens of small grains include:

- Smut Diseases
  - Loose Smut of Wheat and Barley
  - Covered Smut of Barley and Oats
  - Loose Smut of Oats
- Dwarf Bunt of Winter Wheat
- Barley Strip
- Common Bunt of Wheat
- Common Root Rot
- Dry Seed Decay

- Fusarium Crown Rot
- Net Blotch of Barley
- Pythium Seedling Rot (Damping Off)
- Rhizoctonia Root Rot
- Scab – Fusarium and Seed-borne
- Take-all

Smut Diseases. Up until the 20th century, smut dis-eases were second only to the rusts as the cause of serious losses in cereal grains. Today, total losses to smuts are low, but serious localized losses can occur. Unlike the rusts, which attack the stems and leaves of cereal crops, smuts do damage by attacking the grain kernels. The reduction in yield caused by the smuts is easily observed as the grain kernels are replaced by teliospores, black, sooty spore masses of the smut fungi. Kernels that do develop may be covered with these dark, oily spores and are, therefore reduced in quality.

Loose Smuts of Wheat and Barley[5,8] Loose smut (Figure 2-7) infects wheat and barley and is caused by the path-ogens *Ustilago tritici* and *Ustilago. nuda*. This disease is characterized by the development of teliospores in the head that are initially surrounded by a very thin membrane. This membrane later breaks

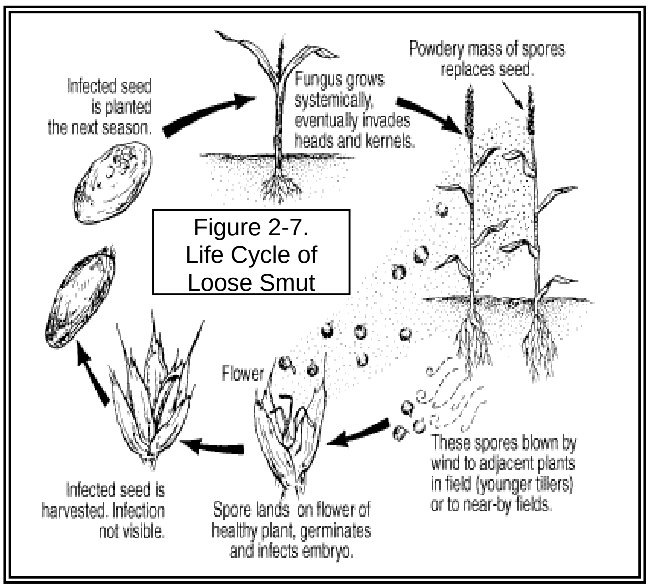


Figure 2-7. Life Cycle of Loose Smut

down soon after teliospore formation. The spores can then be wind-blown to nearby healthy plants during flowering. Teliospores land on the stigma of an open flower, germinate, and the infection hyphae penetrate into the developing seed. It survives from one growing season to the next as mycelium in the embryo of a seed. While this mycelium does not harm the embryo, it does serve as a source of inoculum to infect the seedling when the seed germinates. Because of the internal nature of the seed-borne inoculum, control of loose smut was limited to the hot water treatment prior to the development of systemic fungicides. The develop-ment of the fungus inside the new kernel makes contact fungicides ineffective for control. Carboxin was the first to be developed for control of loose smut, but today several of the sterol-inhibiting (DMI) fungicides also provide control.

Effective systemic fungicides include those containing the active ingredient (a.i.) tebuconzole or metalaxyl (Raxil®) or those containing carboxin (Vitavax® or Enhance®). Dividend® (difenoconazole/metalaxyl) does not control loose smut in barley, but provides effective control in wheat. If low levels of loose smut occur in grain to be saved for seed, that seed should be treated with an appropriate systemic fungicide.

Covered Smut of Barley and Oats[5,8] This disease of barley and oats is caused by *Ustilago hordei*. Kernels and glumes of infected plants are replaced by teliospores that are surrounded by an intact membrane. Hence the name "covered smut". This membrane breaks down during the harvest operation to spread the teliospores to nearby healthy grain and onto the soil surface. While covered smut can be soil-borne, infection of new seedlings is primarily from seed-borne inoculum Most seed treatment fungicides, even non-systemic fungicides, provide excellent control of this disease.

Loose Smut of Oats[8] Unlike most loose smuts, loose smut of oats (*Ustilago avenae*) can be con-trolled by either a systemic or protective seed treatment. While generally not serious in Montana, a few isolated oat fields experience loose smut each year. Seed treatment is recommended if seed from infected fields will be saved for future planting.

Dwarf Bunt of Winter Wheat[8] Dwarf bunt (*Tilletia controversa*) is mainly a soil-borne disease of winter wheat. It can develop wherever snow exists for prolonged periods on unfrozen ground. Depending upon temperature, the infection process requires anywhere from 35 to 105 days for completion. In the past, available seed treatments have been ineffective in controlling this smut, and use of resistant varieties or very late seeding have been the main controls used. However, Dividend® (difenoconazole-metalaxyl) provides complete control of dwarf bunt when used at the highest recommended rate. This fungicide has expanded the number of varieties available to Montana grain producers in affected areas.

Barley Stripe [8] This disease occurs only on barley and is caused by *Pyrenophora graminea*. Inoculum is seed-borne, usually as mycelium within the "husk" tissue of the barley seed. Infection of the seed occurs the previous growing season when conidia are blown from sporulating areas on infected leaves into the head where the new seed is developing. Infected plants show brown linear lesions in the developing seedling leaves. Plants are stunted, and developing leaves become tattered as the leaves are whipped by the wind. Heads on infected plants often are lodged in the leaf sheath and only partially emerge. Grain in such heads is greatly shriveled and often discolored brown. Control of barley stripe became possible with the advent of the sterol-inhibiting (DMI) fungicides with imazalil providing complete control.

Common Bunt [8] Common bunt is characterized by the formation of "bunt balls" in the heads of infected plants. When crushed, these bunt balls release thousands of dark teliospores that appear black in mass. They also smell of rotting fish which is why common bunt is also called "**stinking smut**." When the teliospores are released from the bunt balls during harvest, they contaminate healthy seed or fall on the soil where they can survive for 10 years or more. Infection occurs from seed-borne or soil-borne teliospores near the soil surface. Cool temperatures during seed germ-ination favor teliospore germination and infection of the seedling. While the seed-borne inoculum of common bunt is fairly easy to control with seed treatment, it is the soil-borne phase that is more difficult to control. Systemic fungicides are very effective against both the seed-borne and soil-borne inocula.

While this diseases is no longer is a serious production problem, about two percent of Montana's wheat may carry background levels of this pathogen. Without seed treatments, the disease again could become an economic problem. Late planted winter wheat is most prone to infection. With the exception of imazalil (Flo-Pro IMZ® or Double R®), a number of protective and systemic materials provide good control.

Common Root Rot [5,8] The common root rot of wheat and barley is caused primarily by the soil-borne fungus *Cochliobolus sativus*. It gets its name because this pathogen is commonly found in most small grain fields. Other fungi, such as *Fusarium* or *Pythium*, may follow initial infection and increase the severity of the disease. These secondary infections are infrequent and often are associated with unusual conditions such as excessive rainfall or high soil temperatures. This disease is sometimes confused with dryland root rot since it often shows up when conditions are dry. This disease is also commonly associated with fusarium crown rot.

Infection occurs from the thick-walled conidia that survive on plant debris. The main symptoms of common root rot are dark brown lesions on the subcrown internode and on crown tissue. The subcrown internode is that part of the plant just above the seed, but below where crown roots emerge. However, the lesions rarely extend above the soil surface as they do with dryland root rot caused by *Fusarium* spp. Infected plants usually have fewer tillers than healthy plants and the grain on infected plants may be shriveled. Seed treatment to control common root rot is similar to that for dryland root rot. The sterol-inhibiting (DMI) systemic fungicides are the best, but even their control is only partial.

Dry Seed Decay [5,8] Dry seed decay is caused by soil-borne penicillium, which is common to almost all soils and present throughout most of the High Plains region. Dry seed decay occurs when seed is planted into soil too dry to allow for germination of the seed. Often this is done with the hope that rains will come to stimulate seed germination. However, when the seed sits in dry soil for 6-8 weeks prior to germination, *Penicillium* will often infect the resting seed and destroy its ability to germinate. Such infected seed often appears blue due to the growth of the *Pencillium* fungus

Reduced germination potential and poor stands result. Unless prolonged dry soil conditions persist in the spring, dry seed decay seldom is a problem on spring wheat. Seed treatments with imazalil (FloPro IMZ®, Nu-Zone®, Double R®, Vitavax Extra® and Raxil MD Extra®) provide excellent control of this disease.

Fusarium Crown Rot[8] This is also a soil-borne fungal pathogenthat attacks the crown system of plants grown under moisture stress conditions. The loss of crown roots and the associated crown tissue can result in yield losses up to 20 percent. While some fungicides are effective in reducing root rot severity, a corresponding yield increase does not always result.

The conditions in which seed treatments for fusarium crown rot are likely to be beneficial include:

- Abundance of the fungus in the soil.
- Where there is continuous small grains or small grain-summer fallow cropping systems.
- Soils or locations with low growing season moisture.

The keys to management of fusarium crown rot in small grain cereals is to minimize plant moisture stress through conservation tillage, by introducing other crops into the wheat rotations to reduce the pathogen level, and planting tolerant varieties. This disease is commonly associated with common root rot.

Net Blotch of Barley [8] The fungus that causes net blotch, overwinters on barley residues. This foliar disease of barley is known to be seed-borne and up to 36 percent of seed in some lots may be infested with net blotch. The use of imazalil was effective in sup-pressing this seed-borne inoculum. However, in fields with heavy barley stubble, infection of new plants also commonly originates from inoculum residing on the residue.

Pythium Seedling Rot (Damping Off) [5,8] Often called water mold because it produces a swimming spore (oospore) when the soil is wet, pythium produces a soft rotting of the seed, or damping-off, before or after plant emergence.

This soil-borne fungus can cause pre- or post-emergence damping-off of wheat and barley seedlings. Symptoms include poor stands and/or patches of young plants that are pale green in color and stunted. Roots of young plants may have soft, wet, tan-brown areas at or near their tips. Older plants are not affected by pythium disease.

Pythium can be most damaging when small grains are planted in dry soil that is then soaked by rain or irrigation. When the soil first becomes wet after a dry period, the nutrient levels released from the seed and soil are high and competition from other soil organisms is low, thereby favoring pythium infection. Problems also are more likely in soils prone to crusting.

While wet soil seedling rot is not common in most areas of Montana, this disease does occur in scattered locations under favorable conditions. In problematic locations, systemic seed treatments containing metalaxyl (Apron® and Allegiance®) can protect against the damping-off stage. Since the activity of Apron® and Allegiance® is limited to pythium and related fungi, it should always be used in combination with materials active against other pathogens. Broad-spectrum products, such as maneb (DB Green®) and thiram, provide some Pythium suppression, but are less effective than metalaxyl (Apron® or Allegiance®) .

Rhizoctonia Root Rot [8] The pathogen *Rhizoctonia solani* can cause a root rot disease in small grains. Symptoms occur most prominently in the early season. Varying sized patches of plants become severely stunted, and the seminal and crown roots of infected plants have distinct sunken, brown lesions and "spear-tipped" roots. The disease sometimes occurs in minimum- and no-till systems that allow the pathogen to survive on intact residue and volunteer plants. In Montana, this disease has also been a problem in conventional tillage fields where large amounts of either volunteer wheat or cheatgrass were sprayed with herbicides containing glyphosate (Roundup®) and then seeded to small grains within one to seven days. Seed treatments can suppress rhizoctonia development; however, correct volunteer management and delayed seeding intervals remain the preferred control method for this disease.

Scab – Fusarium and Seed-borne [8] Although the same organisms cause both seed-borne scab and fusarium scab, these are two entirely different diseases. Fusarium scab infects plants at flowering and causes bleaching of the heads and powdery-white, shriveled kernels that often contain vomitoxin, which is toxic to livestock, especially swine. If seed infected with fusarium scab is planted, a seedling decay known as seed-borne scab can develop. This disease results in a poor stand. Seed from fields planted in corn the year before the seed crop of wheat was produced are more likely to have seed-borne scab problems.

If environmental conditions at flowering allow scab to develop in the heads, fusarium scab can be a problem in small grains regardless of the rotation. In years after fusarium scab is severe, it is important for producers to make seed purchases early for the next growing season since quality seed may be in demand. Cleaning and use of an effective seed treatment is important in seed lots containing even low levels of scab. The fungicide, Vitavax Extra®, which contains carboxin/imazalil/thiabendazole, and treatments containing fludioxyonil (Maxim®) provide excellent control of this disease.

Take-all[8] The take-all fungus *(Gaeumannomyces graminis)* is a major root-rot pathogen of cereals and grasses. It is most damaging to intensively grown wheat and barley crops, when the same crop is grown year after year on a site. It survives in the infected residues of one crop, and then invades the roots of the following crop, progressively destroying the root system.

Symptoms of take-all include patches of bleached plants with unfilled heads. Plants pull easily from the soil, and the root system is poor with shiny, coal-black roots and crowns. This fungal disease is indigenous to native prairie grassland soils at low levels. In Montana, take-all is most common in irrigated wheat fields. However, the disease also may occur in dryland fields in years of heavy rainfall in the spring and early summer. When combined with moisture, the following conditions also are favorable for take-all disease development:

- High soil alkalinity.
- Low fertility (especially nitrogen and phosphorous).
- Soil compaction
- Cool weather.
- Early-seeded winter wheat.
- Continuous wheat for two to five years.

In irrigated fields with a history of take-all, Baytan® (triadimenol) provides good to variable suppression of the disease for four to six weeks of plant growth. However, late-season control and yield responses have been variable in Montana. Dividend® (difenoconazole) applied at the maximum rate has shown variable results in Montana. No available product provides complete control of take-all.

BACTERIAL DISEASES

Bacteria (sing.=bacterium) are microscopic single-celled organisms that reproduce by cell division. Like fungi, most bacteria are beneficial, with only a few types causing plant disease. Because bacteria cannot move on their own, they depend on wind, animals, insects, farm equipment, seed, splashing rain, and other means to inoculate host plants.

Bacteria can only enter a plant through natural openings in the plant surface (stomates and hydathodes) or though wounds made by insect feeding, mechanical injuries, pruning, grafting, or other means.

Symptoms of bacterial infection include wilting, soft rots, leaf blights, and spots. Many different bacterial pathogens can be seed-borne. Some bacterial diseases can be controlled or suppressed, either directly or indirectly, with seed treatments. Bacterial diseases account for about 11% of the biotic diseases in Montana. Fire blight on apple, pear, cotoneaster, mountain ash and related plants is one of the most serious bacterial diseases in Montana.

While seed treatments control fungi residing on the seed surface or inside the seed, most seed treatments do not control bacterial pathogens and none control seed-borne viruses.

Seeds of field pea (*Pisum sativum* L.) occasionally show symptoms of the disease "pink seed." This disease causes pale, pinkish-brown to bright pink discoloration throughout the seed coat. Affected seed can bear a striking resemblance to seed that has been treated with fungicides. The causal agent of pink seed is the bacterium *Erwinia* (*Pectobacterium*) *rhapontici*.

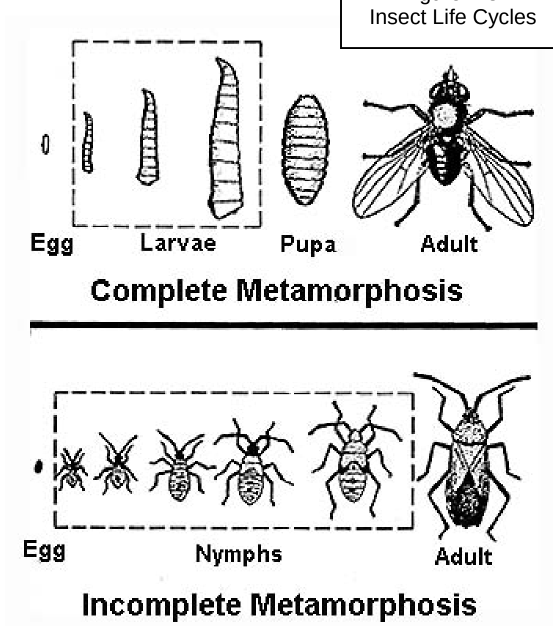
Seed Treatments With Beneficial Bacteria. Seed treatments containing the bacterium *Bacillus subtilis* (Kodiak®) have been shown to suppress disease organisms such as fusarium, rhizoctonia, alternaria and aspergillus that attack root systems. When used with a chemical seed treatment, the combination of chemicals and Kodiak® provides protection to the root for a much longer time than with chemicals alone. As the root system develops, the bacteria grow with the roots extending the protection throughout the growing season. As a result of this biological protection, a vigorous root system is established by the plant, which often results in more uniform stands and greater yields.

INSECTS

Insecticide seed treatments can be used to control or suppress various insects that attack seeds or below- or above-ground seedling tissues. Compared to other states, Montana has few insect pests that attack seeds; one of those being wireworms. However, a good pest manager must have a basic understanding of the different types of insect life cycles. This will help in selecting the appropriate pesticide treatments throughout the course of crop production.

There are several basic characteristics that are useful in identifying insects and the damage they cause. First, adult insects have three pairs of jointed legs and three distinct body regions: head, thorax, and an abdomen. Insects have either complete or incomplete metamorphosis (Figure 2-8).

Figure 2-8.
Insect Life Cycles



Insects with **complete** metamorphosis have four life stages: egg, larvae (pl.), pupa, and adult. Larvae are unable to reproduce, are wingless, and usually look very different from the adults. In some cases, insects with complete metamorphosis are known by different names depending on their stage of development. For example, many beetle larvae are called grubs, while most fly larvae are called maggots. The larva of the miller moth is known as a cutworm, a destructive pest of cereal grains. Larvae also tend to use a different food source than the adults; thus, for a given crop, usually either the larval or the adult stage is damaging but seldom both.

Insects with **incomplete** metamorphosis have three life stages: egg, nymph, and adult. Nymphs look much like adult insects, except they are smaller, do not have functional wings, and cannot reproduce. Nymphs and adults usually feed on the same plants. Aphids and grasshoppers have incomplete life cycles.

Mouthparts, wings, and legs vary considerably among insects and are useful features for their identification. Many fly maggot mouthparts are simple hooks; beetles and their larval grubs have chewing mouthparts; aphids have mouthparts that are strong enough to puncture plant tissues and then suck up the sap.

Beetles have hardened outer wings; true bugs have half-hardened outer wings; and flies and bees have membranous wings. Finally, close examination of an insects legs may reveal information about the nature of the insect. For example, many predatory insects, such as ground beetles, mantids, damsel bugs, and assassin bugs, have grasping front legs useful for capturing other insects.

Wireworms

These soil-inhabiting insects cause sporadic and sometimes severe stand reduction in wheat, barley and other crops, especially following seeding into sod or old pastures. Damage varies from feeding injury shortly after plant germination to stem clipping shortly after plant emergence.

In Montana, there are several species with life cycles that take from one to seven years to develop from the egg to an adult “click” beetle. Larvae move up and down in the soil profile in response to temperature and moisture. After soil temperatures warm to 50^0 F, larvae feed within 6 inches of the soil surface. Wireworms inflict most of their damage in the early spring when they are near the soil surface. When soil temperatures become too hot or dry in the summer (>80⁰ F), larvae will move deeper into the soil to seek better conditions. Later as soils cool, larvae may resume feeding nearer the surface, but the amount of injury varies with the crop.

Adult females emerge from the soil, attract males to mate, then burrow back into the soil to lay eggs. Females can re-emerge and move to other sites where they burrow in and lay more eggs. This behavior results in spotty infestations throughout a field. Some wireworms prefer loose, light and well drained soils; others prefer low spots in fields where higher moisture and heavier clay soils are present.

Since generations overlap, larvae of all ages may present be in the soil at the same time. Damage is more severe when spring weather is cool and wet. Most producers routinely treat their seed to minimize potential stand loss, especially in locations with a previous history of wireworm feeding injury.

Seed treatments containing lindane have been effective and relatively inexpensive seed treatment but are slowly being phased out. Gaucho® (imidacloprid) and Cruiser® (thiamethoxam) are also used to suppress wireworms.

SEED TREATMENT PRODUCTS AND SAFETY

According to the Administrative Rules of Montana (ARM), pesticide-treated seed means seed that is covered with material(s) whose objective is to reduce or control disease organisms, insects or other pests attacking seed or seedlings (Sub-chapter 31, Seed Labeling Rules, 4.12.3101).

FORMULATIONS

The manner in which a seed treatment pesticide is prepared for practical use is called a formulation. The formulation usually contains active ingredients (a.i.) and inert or other ingredients.

The **active ingredient** (a.i.) is that part of a pesticide formulation that actually controls the pest. The actual chemical is usually described by a simpler common name. For example, carboxin is the common name for the chemical 5,6-dihydro-2-methyl-1,4-oxathiin-3-carboxamide, the active ingredient (a.i.) found in Vitavax®. The **inert ingredients** have no pesticidal qualities but assist in storage, application, and generally make the pesticide more convenient and to apply.

Most seed treatment pesticides are formulated as a dry flowable (DF), flowable (F), flowable seed treatment (FS), liquid (L), liquid suspension (LS), or wettable powder (WP). Although the formulation you use may seem trivial, it can have a major impact on your equipment and treatment uniformity. For example, some formulations may not mix well in the tank, and some may readily settle out without constant agitation. Some products come in water-soluble packaging, which benefits the applicator by reducing exposure to the pesticide. Regardless of the formulation, be sure to read and follow the label instructions.

SEED TREATMENT USES

A major use of seed treatments is **control of seed-borne diseases** such as the smuts and bunts. Systemic seed treatments are best suited for this type of treatment as they are absorbed into the seed and control these seed-borne fungi that reside within the seed. Systemic fungicides for the control of smuts and bunts include the following active ingredients (a.i.) with their respective trade or brand name:

Carboxin – Vitavax®
Tebuconazole - Raxil®
Difenoconazole - Dividend®
Triadimenol - Baytan®

A second major use of seed treatments is to **improve stand establishment**. Most treatments do at least a fair job of controlling seed rots and seedling blights. Scab and black point are two seed-borne diseases that can reduce seed germination. If germination is low (less than 90%), a seed treatment could help raise the germination rate. There are a few treatments are available if wireworms are expected to be a problem.

A third use of seed treatments is **suppression of root rots**. Difenoconazole (Dividend®) and triadimenol (Baytan®) give some suppression of take-all root rot. Imazalil (Double R®, Flo-Pro®) and triadimenol (Baytan®) give some control of common root rot. Triadimenol (Baytan®), tebuconazole (Raxil®), and imazalil (Double R®, Flo-Pro®) can shorten the coleoptile, so avoid deep planting with these treatments.

The fourth use of seed treatments is the **control of fall-season foliar diseases**. Triadimenol (Baytan®) and difenoconazole (Dividend®) provide protection against fall infections of powdery mildew, leaf rust and some leaf blotches. However, these diseases may or may not be reduced in the following spring.

The last use for seed treatments is **insect control**. Lindane is the old standby for wireworms. But is gradually being phased out by the U.S. EPA. In its place, imidacloprid (Gaucho®) is labeled for the suppression of wireworms, grasshoppers, Hessian fly, and fall-season aphids. It also reduces incidence of barley yellow dwarf virus, which is carried by aphids. Cruiser® (thiamethoxam) is also used in Montana to suppress wireworms.

The ideal seed treatment should have the following characteristics:

- Harmless to seed (no phytotoxicity).
- Stable for long periods of time before planting.
- Provide an even coating to seed.
- Adheres well without giving a dull or unattractive appearance.

- Does not impair seed flow in equipment.
- Inexpensive.
- Registered for its intended use.

There are many seed treatment products available, each with different restrictions, labeled uses, active ingredients, dose rates, additives, or formulations. As with most pesticides, each active ingredient (a.i.) has strengths and weaknesses, which is why many seed treatments consist of one or more active ingredients. For example, DB-Green® contains both of the active ingredients (a.i.) maneb and lindane. Vitavax Extra ® is a combination of carboxin, imazalil and thiabendazole.

Active ingredients (a.i.) are often classified as either systemic or non-systemic (contact).

Systemic means that a compound is absorbed and translocated throughout a plant or animal. Systemic foliar fungicides are absorbed by the plant, then translocated throughout its tissues. Systemic seed treatments spread internally within the seed.

Contact or **non-systemic** seed treatments protect only the outside of the seed or seedling. These seed treatments are also known as protectants because they are intended to intercept a fungus and prevent it from attacking or infecting the seed. They do not penetrate plant tissues.

BACTERICIDES

Streptomycin (Ag-Streptomycin® and AgriMycin®) is an antibiotic that kills a broad-spectrum of bacteria. It can be used to control seed-borne populations of the halo blight pathogen on beans and as a potato seed piece treatment against soft rot and black leg.

FUNGICIDES

Biological agents consist of dormant micro-organisms that are applied to seeds. Under favorable conditions, these microorganisms grow and colonize the exterior of the developing seed or seedling. Biocontrol agents may reduce seed decay, seedling diseases, or root rot either by competing with pathogens or by producing antibiotics. The most common biological control organism is the bacteria *Bacillus subtilis* (Kodiak®) and the fungus *Trichoderma harzianum* (Bio-Trek®).

Chemical seed treatments kill or inhibit pathogens on surfaces, but a few kill pathogens within the seed. Many chemical seed treatments made prior to the 1960's were broad-spectrum protectants. More recently, seed treatment fungicides are lower in phytotoxicity with a more narrow range of activity.

A number of chemistries have been developed as seed treatments. These include captan (broad-spectrum), carboxin (smut), thiram (smuts), , maneb/mancozeb (broad-spectrum), imazalil (imperfect fungi), metalaxyl (pythium and phytophthora seedling rots), fludioxanil (broad-spectrum), and many others.

Captan is a broad-spectrum, non-systemic fungicide effective against various seed decay and damping-off fungi, such as aspergillus, fusarium, penicillium, and rhizoctonia.

Carboxin (Vitavax®) is a systemic fungicide with good activity against smuts and fair activity against general seed rot, damping-off, and seedling blights. It is commonly used to control wheat embryo infections caused by the loose smut fungus. Carboxin is commonly formulated with other fungicides or insecticides to increase the pest control spectrum.

Difenoconazole (Dividend®) is a broad-spectrum, systemic fungicide that controls common bunt and loose smut of wheat At high label rates, it has activity against some fall-season root rots and foliar diseases (powdery mildew and rust). Fall control of root rots and leaf diseases may or may not carry through to the following spring.

Fludioxonil (Maxim®) is a broad-spectrum, non-systemic fungicide effective against various seed decay and damping-off fungi, such as aspergillus, fusarium, penicillium, and rhizoctonia. In addition, it performs well against seed-borne wheat scab.

Imazalil (Flo-Pro IMZ®, Double R®) is a systemic fungicide used against common or dryland root rot of wheat caused by fusarium and cochliobolus (also called helminthosporium). In addition, it performs well against seedborne wheat scab.

Mancozeb and maneb are broad-spectrum non-systemic fungicides used for control of seed decay and wheat common bunt.

Mefenoxam (Apron XL®) and **metalaxyl** (Apron® and Allegiance®) are closely related, narrow-spectrum, systemic fungicides. They are effective only against pythium, phytophthora, and downy mildews. These fungicides are commonly used on a wide range of crops, often in conjunction with a broad-spectrum fungicide, such as captan, fludioxonil or tebuconazole

PCNB (pentachloronitrobenzene) is a non-systemic fungicide. It is especially useful against seedling fungi, such as rhizoctonia and fusarium, and has fair activity against common bunt of wheat. PCNB is commonly formulated with other fungicides to increase the disease control spectrum.

Tebuconazole (found in Raxil®) is a broad-spectrum, systemic fungicide. It controls common bunt and loose smut of wheat and has activity against some fall season root rots and some foliar diseases (powdery mildew). Fall control of root rots and leaf diseases may or may not carry through to the following spring. In addition, it performs well against seed-borne wheat scab. Tebuconazole is commonly formulated with other fungicides or insecticides to increase the pest control spectrum.

Thiabendazole (TBZ) is a broad-spectrum, systemic fungicide useful against common bunt and various seed decay and damping-off fungi, such as fusarium and rhizoctonia. In addition, it performs well against seed-borne wheat scab. Thiabendazole is commonly formulated with other fungicides to increase the disease control spectrum.

Thiram is a broad-spectrum, non-systemic fungicide labeled for a wide range of field crops and vegetable crops. It is also used for ornamental bulbs and tubers to control seed, bulb, and tuber decay, and damping-off, as well as common bunt of wheat.

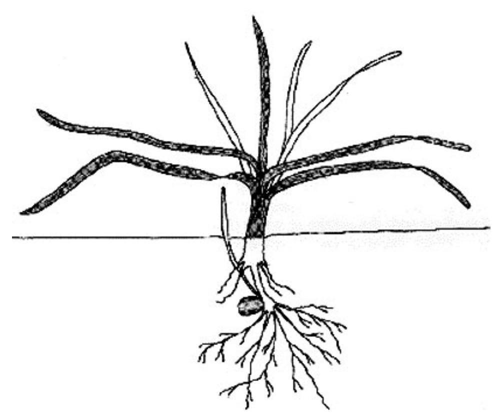
Triadimenol (Baytan®) is a broad-spectrum, systemic fungicide that controls common bunt and loose smut of wheat. At high label rates, it has activity against some fall-season root rots and foliar diseases (powdery mildew and rust). Fall control of root rots and leaf diseases may or may not carry through to the following spring. Triadimenol may be formulated with other fungicides to increase the disease control spectrum.

INSECTICIDES

Imidacloprid (Gaucho®) is a systemic insecticide effective against aphids, grasshoppers, Colorado potato beetle, flea beetles, Hessian fly, and wire-worms. It reduces incidence of some diseases by controlling the insect vectors. The length of control is influenced by the dosage used. For example, high label rates may be needed to reduce potential spread of barley yellow dwarf virus due to aphid vectors.

Lindane is a non-systemic insecticide useful against soil-borne insects such as wireworms. It belongs to an old class of insecticides called chlorinated hydrocarbons, which are currently being phased out by the US Environmental Protection Agency (EPA).

Thiamethoxam (Cruiser®) is a systemic, nicotine-based insecticide effective against various sucking and chewing pests, such as thrips, aphids, Colorado potato beetles, Hessian fly, flea beetles, leafhoppers, chinch bugs, and wireworms.



ADDITIVES

Seed treatment products usually contain a variety of additives in addition to the active ingredients (a.i.) If important additives are lacking in a product, they often can be added to a pretreatment mixing tank. Before using additives, consult the manufacturers instructions to avoid problems and duplication.

In most cases, **colorants** or **dyes** are required to be added to treated seed in order to prevent mixing with food grain. Colorants improve the appearance and also help ensure uniformity of treatment coverage. Color-enhancing agents may be added to further improve the appearance.

Carriers, binders, and stickers are listed on the label as inert ingredients. They are selected by the manufacturer, approved by the U.S. Environmental Protection Agency (EPA), and are usually neutral in pH, nontoxic to humans, and cause no apparent damage to the germination of the seed. They are added to increase the adherence of the pesticide to the seed, prevent dusting off, and/or cut down the dustiness in the seed treatment facility.

Antifoam agents suppress formation of troublesome foam.

Lubricants, such as graphite or talc, reduce the friction of seed flow through the seed treater or planter.

Micronutrients, such as molybdenum, may be added to legume seed treatments as a convenient way to introduce trace elements required for nodulation.

PESTICIDE COMPATIBILITY

When using unfamiliar mixtures or rates (or even when using familiar mixtures and rates with an unfamiliar crop), be sure to read and follow the label instructions of each product. For any clarification, contact the manufacturer or their representative directly.

To test the physical compatibility of mixed pesticides, make a small slurry. Be sure to add the proportionate amounts of the products to the mixture in the following order.

1. Add approximately 2/3 to 3/4 of the water volume.
2. Add any dyes and/or colorants.
3. Add any water-soluble products.
4. Add any wettable powders.
5. Add any water-dispersable granular (WDG) products.
6. Add any water-based products.
7. Add emulsifiable concentrates (EC).
8. Add any oil-based flowables (F).
9. Polymeric and/or coating additives are added last, but special rules may apply.

Be sure to include all products in the correct ratio and observe for signs of incompatibility, such as settling, separation, gelling, or curdling. Add water to bring the slurry to the desired volume. Note: for dry products, the rule of thumb is that 1 dry ounce will displace 1 fluid ounce (or 8 pounds will displace about 1 gallon).

Do not assume that biological seed treatments will be compatible with chemical seed treatments. Contact the manufacturer of the biological seed treatment product for questions about compatibility.

Finally, if a nitrogen-fixing inoculant will be used, contact the inoculant manufacturer regarding compatibility with seed treatments. In most cases, the inoculant should be applied just before planting, as the beneficial bacteria may not survive extended contact with certain pesticides. In-furrow application of inoculants may allow for use of seed treatments otherwise considered incompatible or marginally compatible.

LABELING TREATED SEED

Both the Federal Seed Act and Administrative Rules of Montana (Sub-chapter 31, Treated or Inoculated Seed, 4.12.3102), require special labeling for treated seed. This labeling provides the end user with instruction in proper handling and storage of treated seed and helps ensure that leftover seed is not used for any purpose other than as intended.

The Occupational Safety and Health Administration (OSHA) also require that additional information be provided with treated seed to help protect the health of persons working in and around seed treatment facilities or those using treated seed.

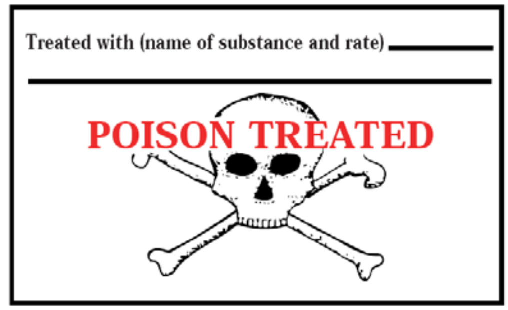
The Administrative Rules of Montana (ARM) for treated seed is based upon the Recommended Uniform State Seed Law (RUSSL) adopted by the Association of American Seed Control Officials (AASCO). RUSSL is a document that provides a format for states to draft and adopt a seed law that is similar between states and in compliance with the Federal Seed Act (FSA).

Montana's administrative rules (ARM) cover intrastate seed shipments (within Montana). If a Montana company ships seed interstate (between states), then Federal Seed Act is the final authority for labeling requirements. Under the Recommended Uniform State Seed Law (RUSSL), treated seed that is moved within the state must be labeled with the following information.

1. A word or statement indicating that the seed has been treated.
2. The commonly accepted coined, chemical or abbreviated chemical (generic) name of the applied substance or description of the process used.
3. If the substance in the amount present with the seed is harmful to human or other vertebrate animals, a caution statement such as "Do not use for food, feed, or oil purposes". The caution for mercurials and similarly toxic substances shall be a poison statement or symbol.
4. If the seed is treated with an inoculant, the date beyond which the inoculant is not to be considered effective (date of expiration).

For treated seed that is moved interstate, the Federal Seed Act requires the following information. All the information must be printed either on the same tag bearing the analysis information, on a separate tag attached to the seed container, or directly on a side or top of the container. The following information, in type no smaller than 8 points (1/9 inch), is required to be shown on the label:

1. A statement indicating that the seed has been treated with a pesticide.
2. The name of the seed treatment pesticide used (common name or chemical name, or both). Examples of common names are captan, carboxin, lindane, PCNB, and thiram.
3. Seed treated with highly toxic pesticides (LD50, less than 50) requires a label bearing a skull-and-crossbones and a precautionary statement such as, "This seed treated with poison, Do not use for food, feed, or oil purposes, or Poison-Treated." The skull-and-crossbones symbol must be at least twice the size of the type used on the label for the printed information. The statement must be in red letters on a contrasting background.



4. Seed treated with toxic pesticides (LD50, greater than 50) requires a label with an appropriate precautionary statement such as, "Do not use for food, feed, or oil purposes."
5. Labeling must include health hazards of the pesticide and indicate if the chemical is a skin irritant, a carcinogen, or capable of causing irreversible eye damage or other adverse effects.
6. Name, address, and phone number of the pesticide manufacturer or seed-treating facility, or both.

The above information is the minimum labeling required. Some seed treatment pesticide labels recommend additional information be added to the label of treated seed, such as special protection information, environmental hazards, or statements of practical treatment in case an accident should occur.

In most cases, the only legal use for treated seed is planting and most seed treatment pesticide labels prohibit the use of treated seed for food, feed, or oil purposes. Make sure to read the label of the seed treatment you are using. There may be exceptions to this rule!

SAFE HANDLING PRACTICES

Handle seed treatment pesticide products with care and always read the label and follow instructions precisely. Product labels provide information on safe handling and application. The label also provides the applicator with information about first aid, potential environmental hazards, directions-for-use, proper storage, and container disposal.

MANAGING A SAFE SEED TREATMENT FACILITY

Isolate the seed treatment area from other facility functions to keep pesticide dust and fumes from reaching unprotected employees and stored agricultural commodities. Install an approved exhaust and dust collecting system to remove toxic vapors and dust from the operating area.

For legal and safety reasons, it is important that non-treated seed does not become contaminated with pesticide residue and colorant. Sacks, containers, trucks, wagons, augers, and conveyors used for transport of treated seed should be used for that purpose only. Be sure to properly dispose of contaminated sacks so that they are not used for any other purpose. Thoroughly clean seed treatment equipment between different product batches to avoid cross-contamination. Consult the pesticide manufacturer for the names of appropriate cleaning techniques and directions.

Regular cleaning of seed treatment equipment also can help prevent equipment corrosion and settling or clogging problems. For minor spills or leaks, follow all instructions indicated on the label and material safety data sheet (MSDS). Clean up spills immediately and take special care to avoid contamination of equipment and facilities during cleanup procedures and disposal of wastes.

PERSONAL SAFETY

Use caution when handling seed treatment chemicals. Remember that exposure to seed treatment pesticides may cause a wide range of acute and chronic toxic reactions in people. When handling seed treatment pesticides, remember to:

1. Read and become familiar with the label and MSDS for each pesticide that you use. Make certain that these documents are readily available at all times, and refer to them in the event of an accident. Labels do change (often without notice), so be sure to review the label attached to the container each time you purchase a pesticide.
2. Avoid inhaling pesticide dusts or vapors, and always protect skin and eyes from exposure. Use proper protective equipment (PPE) as recommended by the pesticide label. Consider wearing goggles, rubber gloves, and a rubber apron, even when the product label does not specifically require it.
3. Wash thoroughly with soap and water before eating or smoking.
4. In case of exposure, immediately remove any contaminated clothing and wash the affected area thoroughly with soap and water. For safety purposes, install a safety shower in the immediate vicinity of the treatment equipment.
5. When treating large amounts of seed, change clothing frequently enough to avoid buildup of pesticides in the garments.
6. No matter how tired you may be, shower immediately after work and change all clothing. Wash clothing thoroughly (separate from the family wash) before reuse.

Proper Pesticide Storage and Disposal

You are responsible for the safe storage, transport and disposal of pesticide in your possession. Do all you can to prevent problems and be prepared for emergencies. Many pesticide handlers use buildings or areas within existing buildings for pesticide storage. Some storage sites are temporary and on the job site. Regardless, if large amounts of pesticides will be stored, you may need to build a special pesticide storage facility. A well-maintained pesticide storage site needs to protect people, animals and the environment from accidental exposure and contamination. A well-designed storage area will also prevent damage to pesticides from temperature extremes, excess moisture, protect from theft, vandalism, unauthorized use, and reduces the likelihood of liability.

Secure the site -- Keep out unauthorized people. Whether it is a temporary or permanent facility, it is an important function of the storage site to keep pesticides under lock and properly secured. Post signs on doors and windows to alert people that pesticides are stored there. Post "No Smoking" warnings as well.

Prevent water damage -- Water from burst pipes, spills, overflows, excess rain or irrigation, or flooding streams can damage pesticide containers and pesticides. If the storage site is not protected from the weather or if it tends to be damp, place metal, cardboard, and paper containers in sturdy plastic bags or cans for protection. Large metal containers, which may rust when damp, often can be placed on pallets within the storage site.

Control the temperature – Since temperature extremes can destroy the potency of some pesticides, choose a cool, well-ventilated room or building that is insulated or temperature-controlled. It is always best to prevent freezing or overheating. Pesticide labeling may tell you at what temperature the product should be stored.

Provide adequate lighting -- Pesticide handlers using the facility must be able to see well enough to read pesticide container labeling, notice whether containers are leaking, corroding, or otherwise disintegrating, and clean up spills or leaks completely.

Use nonporous materials -- The floor of the storage site should be made of sealed cement, glazed ceramic tile, no-wax sheet flooring, or other easily cleaned, non-absorbent materials. Carpeting, wood, soil, and other absorbent floors are difficult or impossible to decontaminate in case of a leak or spill. For ease of cleanup, shelving and pallets should be made of non-absorbent materials such as plastic or metal. If wood or fiberboard materials are used, they should be coated or covered with plastic, polyurethane or epoxy paint.

Prevent runoff -- Inspect the storage site to determine the likely path of pesticides in case of spills, leaks, drainage of equipment wash water, and heavy pesticide runoff from firefighting or floods.

Provide clean water -- Each storage site must have an immediate supply of clean water. Potable running water is ideal. If running water is not practical, use a large, sealable container with clean water stored away from the chemicals but in close proximity. Change the water at least weekly to ensure that it remains safe for use on skin and in eyes.

Prevent contamination -- Only store pesticides, pesticide containers, and pesticide equipment (other than personal protective equipment) in the facility. Spill cleanup kits, personal protective equipment (PPE) necessary for emergencies and clean water can be stored AT the site but NOT IN IT! Store this equipment so that it can be accessed readily if needed.

While they can be on-site, do not keep food, drinks, tobacco, feed, medical supplies, veterinary supplies, medications, seeds, or clothing in the storage area. These items can be contaminated by vapors, dusts, or by spills and cause accidental exposure to people or animals.

Keep labels legible -- Store pesticide containers with the label in plain sight. Costly errors can result if the wrong pesticide is chosen by mistake. Labels should always be legible. They may be damaged or destroyed by exposure to moisture, dripping pesticide, diluents, or dirt. You can use transparent tape or a coating of lacquer or polyurethane to protect the label. If the label is destroyed or damaged, request a replacement from the pesticide dealer or the pesticide manufacturer immediately.

Keep containers closed -- Keep pesticide containers securely closed whenever they are being stored. Tightly closed containers help protect against spills, cross-contamination, evaporation of pesticides and dust, dirt, and other contaminants from getting into the pesticide, causing it to be unusable.

Use original containers -- Store pesticides in their original containers. Never put pesticides in containers that might cause children and other people to mistake them for food or drink. As an applicator, YOU are legally responsible for someone who is injured by pesticides that YOU have placed in unlabeled or unsuitable containers.

Watch for damage -- Inspect containers regularly for tears, splits, breaks, leaks, rust, or corrosion. When a container is damaged, put on appropriate personal protective equipment (PPE) and take immediate action. If the damaged container is an aerosol can or fumigant tank that contains pesticides under pressure, use special care to avoid accidentally releasing the pesticide into the air.

When a container is damaged – Either use the pesticide immediately at a site and rate allowed by the label, or transfer the pesticide into another pesticide container that originally held the same pesticide and one that has the same label still intact.

Chemical manufacturers may also be able to provide new unused containers. If possible, remove the label from the damaged container and use it on the new container. Otherwise, temporarily mark the new container with the name and EPA registration number of the pesticide, and get a copy of the label from the pesticide dealer or manufacturer as soon as possible. The pesticide label may list a telephone number.

Store volatile products separately -- Volatile pesticides should be stored separately from other types of pesticides and other chemicals. A separate room is ideal. Vapors from opened pesticide containers can move into other nearby pesticides and chemicals and make them useless. The labeling of volatile herbicides will usually direct you to store them separately from seeds, fertilizers, and other types of pesticides. You can also consult the pesticide's material safety data sheet (MSDS) for more information.

Isolate waste products -- If you have pesticides and pesticide containers that are being held for disposal, store them in a special section of the storage site. Accidental use of pesticides meant for disposal can be costly. Clearly mark containers that have been triple rinsed or cleaned by an equivalent method because they are more easily disposed of than un-rinsed containers.

Know your inventory -- Keep an up-to-date inventory of stored pesticides. Each time a pesticide is added to or removed from the storage site, update the inventory. The list will help you track your stock and will be essential in a fire or flood emergency. The inventory list also will aid in insurance settlements and in estimating future pesticide needs.

Do not store unnecessarily large quantities of pesticides for a long time. Buy only as much as you will need for a year. Pests, pesticides, or pesticide registrations may change by the following year making the pesticides useless. Some pesticides have a relatively short shelf life and cannot be carried over from year-to-year.

Consider shelf life -- Mark each pesticide container with the date of purchase before it is stored and use older materials first. If the product has a shelf life listed in the labeling, the purchase date will indicate whether it is still usable. Excessive clumping, poor suspension, layering, or abnormal coloration may indicate that the pesticide has broken down. Unfortunately, pesticide deterioration from age or poor storage conditions only becomes obvious after application and poor pest control or damage to the treated surface can occur. If you have doubts about the shelf life of a pesticide, call the dealer or manufacturer for advice.

PREVENT PESTICIDE FIRES

Some pesticides are highly flammable while others are not. The labeling of pesticides that require extra precautions will contain a warning statement in either the Physical/Chemical Hazards section or the Storage and Disposal section. Pesticides that contain oils or petroleum-based solvents are most likely to contain these warning statements. Some dry products also present fire and explosion hazards.

Store combustible pesticides away from open flames and other heat sources. Do not store glass containers in sunlight where they can focus the heat rays and possibly explode or ignite. Install fire detection systems in large storage sites, and equip each storage site with a working fire extinguisher approved for all types of fires, including chemical fires.

There are basically four different types or classes of fire extinguishers, each of which extinguishes specific types of fire.

- **Class A Extinguishers** will put out fires involving ordinary combustibles, such as wood and paper.
- **Class B Extinguishers** should be used on fires involving flammable liquids, such as grease, gasoline, oil, etc.
- **Class C Extinguishers** are suitable for use on electrically energized fires.
- **Class D Extinguishers** are designed for use on flammable metals and are often specific for the type of metal in question.

Many extinguishers available today can be used on different types of fires and will be labeled with more than one designator, e.g. A-B, B-C, or A-B-C. Make sure that if you have a multi-purpose extinguisher it is properly labeled.

If you store highly toxic pesticides or large amounts of any pesticide, develop a fire plan and inform your local fire department, hospital, public health officials, and police of the location of your pesticide storage building. Tell fire department officials what types of pesticides are regularly stored at the site, give them a floor plan, and work with them to develop an emergency response procedure.

TRANSPORT PESTICIDES SAFELY

When transporting pesticides, the following precautions should be taken:

- Carry pesticides in the cargo compartment and never in the passenger compartment. Steel beds can be more easily cleaned after a spill.
- Never carry pesticides near passengers, pets, fertilizers, seed, food, feed, or where contamination will result should a spill occur.
- All containers should be tightly closed and have legible labels.
- Secure containers so they will not roll or slide.
- Protect all containers from moisture and temperature extremes.
- Never leave a vehicle unattended when the pesticides are unsecured. The legal responsibility for the injury of curious children and careless or mischievous "adults" is yours.
- After transportation, all pesticide containers should be inspected for damage and leaks. The vehicle should also be inspected for contamination.
- Minimize travel adjacent to streams and sensitive areas with loaded pesticide sprayers. Careful route planning is a must.

SPILLS

The most hazardous activities involving pesticide use are during the mixing and loading of concentrated pesticides. It is important that you use no more pesticide than you need and do not combine spilled pesticides unless the combination is listed on the label or if you have consulted an authority. Remember to wear all personal protective equipment (PPE) as indicated on the pesticide label during the entire cleaning process.

In Montana, it is required that any pesticide spill be reported within 48 hours of the spill if:

- the spill is 5 liquid gallons or more,
- the spill is 100 dry pounds or more. This includes formulated product, diluent and other additives.

A report can be made to the main office of the Montana Department of Agriculture or one of the field offices.

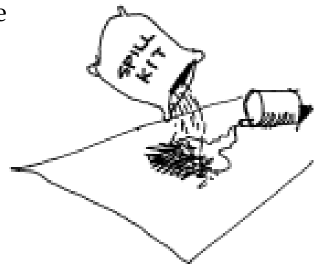
Helena Main Office 406-444-3730
Billings Field Office..............406-652-3615
Bozeman Field Office...........406-587-9067
Glasgow Field Office............406-228-9510
Great Falls Field Office 406-761-0926
Missoula Field Office 406-329-1346

When reporting a spill, the following information is required:

- Location of the spill (legal description, address or landmarks),
- Pesticides involved to include name, manufacturer and EPA registration number,
- Quantity spilled,
- Name of primary contact, address and phone number.

Should an accidental spill occur, follow these easy steps to clean up the spilled pesticide.

Control the spill by stopping the source of the spill. For example, if the spill is due to a broken hose, close the valve or temporarily patch or clamp the hose to stop the leak. Remember to use the appropriate personal protective equipment (PPE) when doing this. If the source of the spill is a container leak, place the leaking container in a larger, leak proof container or roll the container so that the source of the leak is above the liquid level.



Contain the spill so that it does not spread and get into water sources. Build a dam or barrier around the spill with dirt or other absorbent materials.

Clean up the spill immediately. Absorbent materials like kitty litter, sawdust or floor-sweeping compounds should be spread on the spill area to soak up the pesticide. Next, the contaminated material must be shoveled into a leak proof container for proper disposal. Do not flush the area with water or use a cleaning solution until talking with trained personnel. This will help avoid the risks of chemical reaction and possible groundwater contamination.

Clean up contaminated vehicles and equipment. Use diluted liquid bleach or detergent to clean metal surfaces. Porous materials and equipment such as brooms, leather gloves, and sponges cannot be decontaminated effectively and must be disposed of as you would a pesticide.

Decontaminate the area. For floors, work a decontamination agent (usually hydrated lime or a high pH detergent) into the spill area with a coarse broom. Add fresh absorbent material to soak up the now contaminated cleaning solution. Sweep or shovel the contaminated material into a heavy-duty plastic bag. Repeat this procedure several times to ensure thorough decontamination. For soils, remove the contaminated soil plus 3 inches of additional soil and shovel into a heavy-duty plastic bag. Next, cover the area with at least 2 inches of lime. Finally, cover the lime with clean topsoil. Minor spills can sometimes be cleaned up by immediately applying activated charcoal to the contaminated surface.

Dispose of contaminated materials. This also includes contaminated absorbent materials, soil, and porous equipment. Most materials can be disposed of in a licensed sanitary landfill, but some contaminated materials are considered hazardous waste and require special handling.

To help prevent exposure during cleanup, workers should **wear the appropriate personal protective equipment (PPE)**. To help prevent exposure in the future, cleanup work clothes and personal protective equipment should be cleaned before work resumes. Finally, take corrective measures to help ensure that another pesticide spills will not occur.

For major spills, or spills that may contaminate water, first **control** and **contain** the spill. Then call the CHEMTREC telephone number (800) 424-9300. A qualified person will answer and direct you regarding what procedures to follow and whom to notify. If necessary, the area coordinator will dispatch a pesticide safety team to the site. Spills may also require notification steps to other authorities. If a state or federal highway is the site of a spill, notify the highway patrol and the state highway department. If food is contaminated, notify state or federal food and drug authorities and city, county, or state health officials. If water is contaminated, notify public health authorities; regional, state, or federal water quality or water pollution authorities; and the state fish and game agency.

DISPOSAL

"Empty" pesticide containers are never truly empty. There will always be small amounts of pesticide even after they have been rinsed out properly. Never toss empty containers into streams, ponds, fields, or vacant buildings. Always be able to account for every pesticide container you used for the job. Never give them to children to play with or allow uninformed persons to have them for any use. Dispose of all your pesticide containers carefully and properly. And in Montana, it is illegal to burn pesticide containers.

As soon as they are emptied, containers with liquid pesticides should be triple-rinsed.

1. Allow the pesticide to drain from the container into the spray tank for at least 30 seconds.
2. Fill the container one-quarter full with the proper diluent (usually water).
3. Replace the closure or plug the opening of the container.
4. Rotate the container, making sure to rinse all surfaces.
5. Remove closure and drain container into spray tank.
6. Allow 30 seconds for rinsate to drain.
7. Repeat this procedure two more times.
8. Puncture the top and bottom of the container to prevent reuse. Crush flat.
9. Deposit the container in a licensed sanitary landfill.

In Montana, pesticide containers must be triple-rinsed within 48 hours of being emptied. Also, pesticide containers that are not triple-rinsed cannot be accepted at a sanitary landfill. Rinsed containers should not be used for any other purposes except where the label allows the container to be reused or recycled.

Contact the Montana Department of Agriculture for more information on disposing of pesticide containers.

Measuring containers should also be rinsed and the rinsewater used as future diluent. Rinse them at least three times with the same liquid that the tank is being filled with. Replace container caps and close bags. Return them to the pesticide storage area. All containers must be accounted for and properly stored or disposed. Otherwise, they too may end up in a water source or may poison other people or animals.

TREATED SEED

Pesticide-treated seed should be stored in a dry, well-ventilated location separate from untreated seed. It should never be stored in bulk storage bins that might also be used for edible grain storage. Store treated seed in special multi-wall (3- or 4-ply) or tightly woven bags. Some polyethylene or foil-lined bags are also good containers for treated seed. Make sure seed is thoroughly dry before bagging, as excessive moisture can cause rapid deterioration of the seed. Clearly label the seed (as described in previous sections) to indicate the type of seed treatment. If it is held in storage for a year or more, check the germination percentage prior to sale. Very few pesticide labels provide useful guidance regarding disposal of treated seed. As a result, proper and legal disposal of unwanted treated seed has been a contentious issue for many years. Seed treatment pesticide labels prohibit the use of treated seed for food, feed, or oil purposes. It is illegal to mix treated seed with food or feed products in an attempt to get rid of excess or otherwise unwanted treated seed. In most cases, treated seed may be disposed of by planting it at an agronomically acceptable seeding rate or disposing of it according to label instructions as you would most other pesticides. However, surface application without incorporation may present a hazard to humans and animals and may be illegal. If you have questions about proper disposal of treated seed, contact the Montana Department of Agriculture.

SEED TREATMENT EQUIPMENT AND CALIBRATION

The selection, operation, and maintenance of seed treating equipment (seed treaters) are important considerations for effective seed treatment. Problems such as non-uniform seed coverage, failure of a seed treatment pesticide, and lowered seed germination can be partially solved through proper selection and operation of equipment.

Weights and Measures Commonly Used in Seed Treatment

cc = Cubic Centimeters
cwt = Hundredweight (C is Roman for 100)
Generally 100 pounds of seed.
fl oz = fluid ounces
lbs = pounds
ml = milliliters

To convert fl oz to cc or ml: Multiply fl oz X 29.6

Seed treatment pesticides are mainly applied as slurries or liquids. The principal objective is to thoroughly coat the seed with an appropriate rate of pesticide. Therefore commercial seed treaters are designed to apply measured amounts of pesticides to a given weight of seed. Seed treatment rates are usually given as fluid ounces (fl oz) of product per bushel or per hundredweight of seed (100 pounds or cwt). In some case fluid ounces (fl oz) will need to be converted to either cubic centimeters (cc) or milliliters (ml) depending on the pesticide and equipment being used.

SEED TREATERS

Since commercial seed treaters are designed to apply measured quantities of pesticides to a given weight of seed, all treaters have two essential components: (1) a seed and pesticide flow control system, and (2) a seed and one or more pesticide mixing chambers. There are many different seed treaters that are in use and commercially available. For calibration purposes it is best to categorize treaters by how the seed and pesticide are measured or metered, either mechanical metering (weigh and dump) or electronic metering (by volume of seed).

MECHANICAL METERING

Many seed treaters control grain flow onto a double compartment weigh pan located just beneath the feed hopper on top of the treater (Figure 2-9). A counterweight adjustment determines the desired number of pounds per "dump" of seed. The dump weight of the seed trips the weigh pan which drops the seed into a mixing chamber.

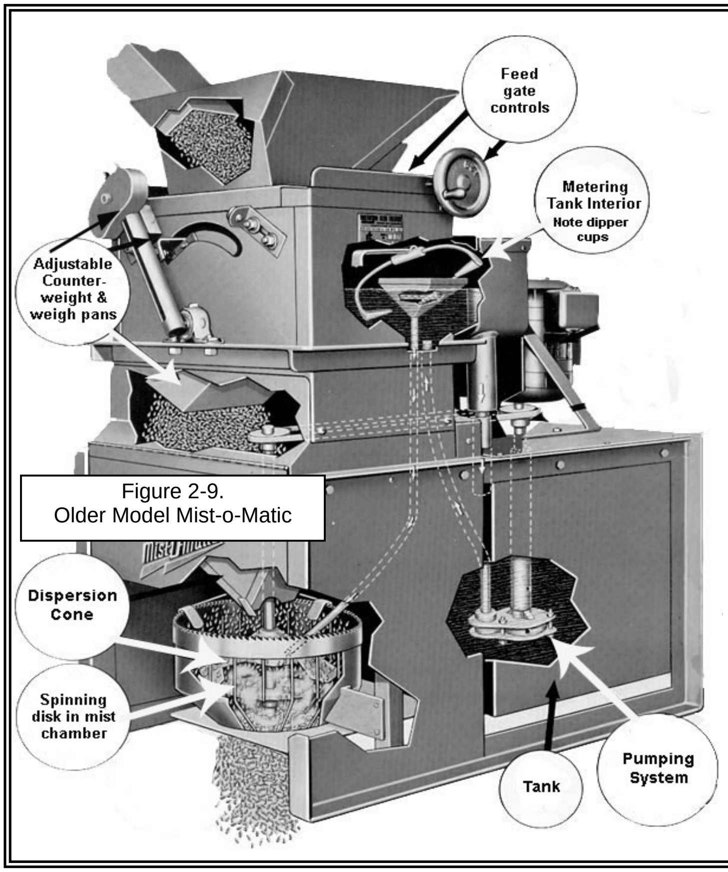


Figure 2-9.
Older Model Mist-o-Matic

The weight pan is attached to a rocker arm, which simultaneously dips pesticide from a reservoir in a metering tank and adds it to the mixing/mist chamber (Figure 2-10). One cup of pesticide is then mixed with each dump of the weigh pan. Pesticide is pumped to the pesticide reservoir from separate tanks.

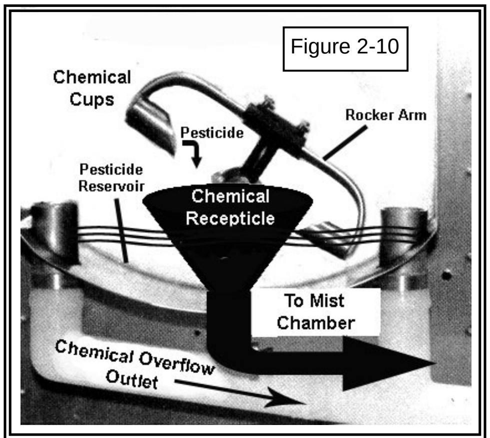


Figure 2-10

The adjustable counterweight is used to adjust the weight of the seed dump. The desired treating rate is then obtained through selection of treatment cup size and proper adjustment of the seed dump weight. Since treatment cup sizes and the way in which they are named or numbered vary depending on the manufac-turer, be sure to consult the manual for your specific treater.

ELECTRONIC METERING

The most recent seed treaters use computer technology to automate the seed treatment process. A programmable computer continuously monitors the weight of seed flow and metering of the chemical application to the seed. The treater automatically adjusts as the seed flow changes. The system can then use multiple metering pumps for water and other chemicals which are mixed prior to application to the seed. The computer can provide readouts on seed, chemical, and water usage, with minute, hourly, or daily totals available at any time. These auto-mated systems offer convenience and improved accuracy, and greatly reduce the calibration burden (Figure 2-11).

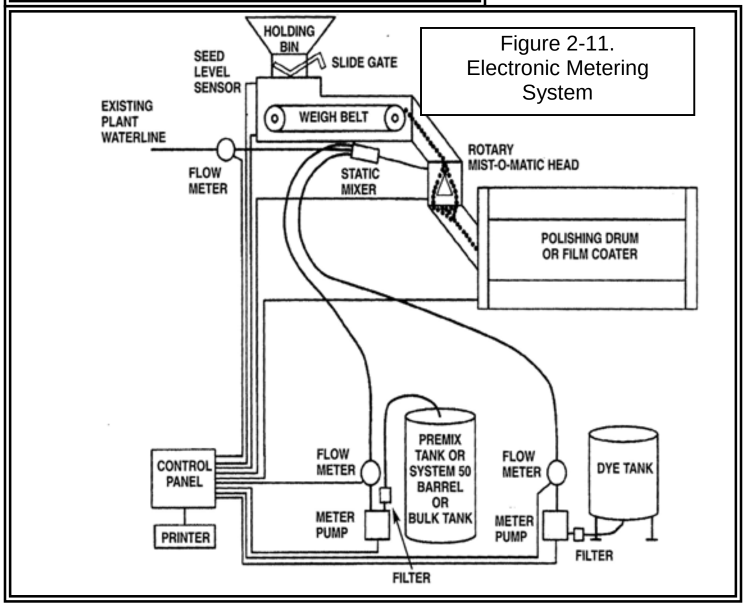


Figure 2-11.
Electronic Metering System

CALIBRATION

Strict adherence to pesticide label dosage rates is a requirement of the Federal Insecticide, Fungi-cide and Rodenticide Act (FIFRA). The purpose of calibration is to ensure that the seed treatment equipment is delivering the correct amount of pesticide and applying it uniformly over the correct amount of seed. Although different calibration procedures are used for different types of seed treaters, most have one thing in common; **accurate matching of the seed output and matching pesticide rates** (Figure 2-12).

DIRECTIONS FOR USE

WHEAT and BARLEY: For control of barley leaf stripe seedborne net blotch and *Septoria nodorum*, and protection against the seed and soilborne phases of the common root rot dis-ease complex *(Helminthosporium, Fusarium)*. Promotes stand establishment by protecting against seed and seedling blights caused by *Helminthosporium, Fusarium*, or *Penicillium*. Use 0.8 to 1.5 fl. oz. Nu-Zone 10 ME per 100 lbs. seed.

For ready mix treaters, Nu-Zone 10ME may be applied directly to the seed.

For slurry treaters, Nu-Zone 10ME may be diluted with water, not to exceed 7 fl. oz. addi-tional water per 100 lbs. of wheat and barley seed.

Figure 2-12.
NuZone® Label Rate

PLEASE NOTE! The information contained in this manual does not cover all types of seed treatment equipment or all methods of calibration. Reference to specific brand names of both seed treaters and seed treatment pesticides does not constitute endorsement. The information given here is to familiarize you with the basic principles of seed treater and seed treater calibration. REFER THE OPERATORS MANUAL FURNISHED BY THE MANUFACTURER FOR YOUR SPECIFIC TREATER.

To obtain proper calibration of a mechanical metered treater, you must know three things.

1. The label rate of the seed treatment chemical
2. How many pounds of seed are dumped each time the weigh pan arm trips.
3. The size of the chemical cups being used and consequently the amount of chemical discharge each time the weigh pan arm trips.

1. **Determine the labeled rate of pesticide to apply**. If the label rate is expressed in fluid ounces (fl oz) of pesticide per hundred-weight (cwt) of seed, you may need to convert fluid ounces (fl oz) to cubic centimeters (cc). This because most chemical metering cups are graduated in cc's. You can convert to cubic centimeters (cc) to ounces by multiplying ounces (oz) by 29.6 (29.6 cc = 1 oz).

   Luckily one cubic centimeter (cc) is also equal to one milliliter (ml). As a comparison, one cc (or ml) is equal to 1/5th of a teaspoon or roughly 20 drops.

BARLEY, WHEAT, OATS AND TRITICALE

In addition, loose smut *(Ustilago nuda)*, covered smut *(Ustilago hordei)*, and flag smut *(Urocystis agropyri)* are controlled on barley and loose smut *(Ustilago tritici)*, common bunt *(Tilletia caries)*, and flag smut *(Urocystis agropyri)* are controlled on wheat by RTU-VITAVAX-THIRAM Fungicide.

Use 5 to 6.8 fl. oz. of RTU-VITAVAX-THIRAM Fungicide per 100 lbs. of seed. The higher rate is recommended where smuts and bunt are severe.

Figure 2-13.
Vitavax-Thiram® Label Rate

If a seed treatment pesticide label recommends an application of 6.8 fluid ounces of product per 100 pounds (lbs) of seed (Figure 2-13), then the application rate in cc per hundredweight (cwt) is determined by:

6.8 fl oz per cwt x 29.6 cc per oz =201.28 or 201.3 cc per cwt;
or 2 cc per pound (201.3 cc ÷ 100 lbs*)

* Note: It is usually easier to work with 100 lbs of seed.

2. **Determine Seed Dump.** Since the weight of seed that is metered (dumped) is controlled by the placement of a counterweight, first run a minimum of 100 lbs of seed through the treater and count the times the weigh pan arm trips. For SS-series Mist-O-Matic ® type treaters, a single trip of the weigh pan arm releases one chemical cup of liquid treatment. For these types of treaters, the weigh pan arm is the seed treatment regulator. A complete swing in one direction up against a bumper pad is a trip, then a swing back in the opposite direction is another trip (Figure 2-14). It is desirable to have the weigh-pan trip 40 to 45 times per minute. Smaller increments of seed passing through the treater head will provide a more even flow of seed and result in better distribution of pesticide. This test must be done using the same type of seed you intend to treat.

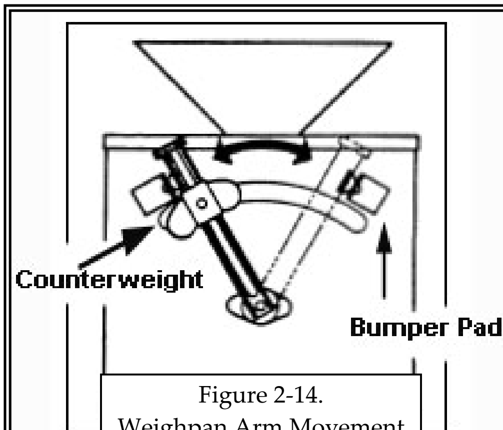


Figure 2-14.
Weighpan Arm Movement
Mist-O-Matic ®

To find how many pounds (lbs) there are per dump, divide the trips into the amount of seed going through the treater. Example: 12.5 trips or dumps with 100 lbs of seed is 8 lbs per dump (100 lbs ÷ 12.5 trips = 8 lbs per dump)

3. **Mathematically Determine The Proper Chemical Cup Size.** From Step 1, it was determined the number of cubic centimeters (cc) of product needed to treat 100 pounds of seed is 201.3 cc. Then determine the proper size of chemical cup in cubic centimeters:

$$\frac{\text{201.3 cc of product}}{\text{12.5 dumps}} = \text{16.1 cc cup size}$$

Choose a corresponding cup size for the weigh-pan. Most seed treaters are supplied with four chemical cups, 10 cc, 15 cc, 20 cc and 25 cc. If a 20-cc chemical cup is the nearest size available, the seed dump size needs to increase. Repeat the calibration. Increasing the seed dump size from 8 pounds to 10 pounds of seed will result in a 20.13 or 20 cc cup size. To do this you need to lower the number of trips to 10 (100 lbs ÷ 10 trips = 10 lbs per dump) by adjusting the counter-weight (Figure 2-14). However, adjusting the counter-weight after you have adjusted it for the desired amount of trips is generally not recommended.

The best option is to keep the same seed dump size, but adjust the cups in the metering tank. By moving the cups out, the amount of pesticide that is placed into the chemical receptacle is reduced.

In this example, you will choose a 20 cc cup size but move the chemical cups out on the rocker arm. To ensure that the equipment is actually applying the proper rate of pesticide to the seed, check the output of the treater. While running seed through the treater, detach the chemical hose from the treater and catch a minimum of 10 trips into a measuring cup. In this example you should have collected 161 cc of chemical (16.1 cc per dump x 10 trips). This is roughly 5 ½ ounces for 10 trips (161 cc ÷ 29.6 cc per ounce). If you collected less than this amount then you may need to move the chemical cups in or change to a larger cup size. If you collected more, then you need to move the chemical cups out along the rocker arm so that less chemical is poured into the chemical receptacle.

SLURRY MIXING

Assume you will be using a metered slurry treater to apply Raxil®-Thiram to wheat at a rate of 3.5 fluid ounces of product per hundred-weight (cwt). Further assume that you have a 50-gallon slurry tank and that you want to apply the slurry (pesticide/water) at a rate of 12 fluid ounces (fl oz) per hundred-weight (cwt). Determine how many gallons of each product will need to be added to the tank and how much seed can be treated with one tankful.

1. How many gallons of each product will need to be added to the tank:

50 gal premix tank x 128 fl oz = 6,400 fl oz per tank

$$\frac{\text{6,400 oz per tank}}{\text{12 fl oz per cwt}} = \text{533.3 cwt per tank}$$

533.3 cwt x 3.5 fl oz Raxil®-Thiram
= 1,865.55 fl oz (or 14.58 gal*) Raxil®-Thiram per 50-gallon tank

* 1865.55 fl oz ÷ 128 oz per gallon

PRODUCT NEEDS CALCULATION

Assume that you want to use Maxim XL® to treat 56,000 pounds of seed at a rate of 0.334 fluid ounces per hundredweight (cwt). How much Maxim XL® is needed to treat this much seed?

1. $56{,}000 \text{ lbs seed} \times \frac{1 \text{ cwt}}{100 \text{ lb}} = 560 \text{ cwt}$
2. Product needed is 0.334 fl oz per cwt.
3. 560 cwt x 0.334 = 187 fl oz or 1.46 gallons

PRECAUTIONS FOR TREATED SEED

Treated grain may not be stored with grain used for commercial food or animal feed. An auger used to treat or transport treated seed cannot be adequately cleaned for use in transporting grain intended for animal or human food consumption. Once an auger is used for seed treatment, it should be used only for treating or augering seed for planting.

FACILITY CONSIDERATIONS

All seed should be cleaned and graded before being treated. The seed treater should be the last machine through which the seed passes before bagging. In most seed processing plants, the treater is perma-nently installed above the bagging bin. Treaters located in other parts of the plant may need separate handling equipment to ensure that there is no cross contamination. Seed treaters are relatively light-weight when empty (300 to 600 pounds) and produce little vibration in operation. The weight of a treater increases by 8 pounds per gallon of liquid added to the storage tank. A small surge bin should be located above the treater to avoid premature tripping of the weighing pan. The treater should be level when in operation. When installed permanently, provision should be made for bypassing seed which need no treatment. During the treating process, the reserve tank may need frequent refilling. The treater should be located so that additional materials can be pumped or poured into the treater without difficulty. Floor level reserve tanks equipped with electric or manual pumps are available. If the seed treatment material is mixed with water, a source of clean, filtered water must be readily available. Locating a seed treater in the same line used to process non-treated seed requires a bypass around the treater, elimination of treatment spillage, and thoroughly cleaning the treating area before processing non-treated seed.

SUMMARY

Always follow label directions when handling seed treatment chemicals. These products are potentially poisonous if mishandled or misused. Extreme caution must be used when handling seed treatment chemicals: some are toxic, others may be irritating. An approved chemical respirator and goggles are recommended even if not specifically required by the fungicide label.

Always use the rate of application as prescribed by the label. To apply the correct rate, it is essential to calibrate application equipment carefully and to check calibration frequently.

Treated seed should not be used for food or feed, and treated grain should not contaminate grain delivered to elevators or be placed in bins or in trucks delivering to elevators.

Containers should be triple rinsed with the rinse water added to the treatment mixture. The rinsed containers should be punctured and crushed for disposal in an approved landfill.

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Brand and Common Names of Seed Treatment Pesticides Used in Montana - 2003		
Manufacturer	**Trade or Brand Name**	**Common name of fungicide/insecticide (% a.i.)**
Agsco	Apron XL	metalaxyl (32.3)
	Cruiser 5FS	thiamethoxam (47.6)
	DB-Green	maneb + lindane (50+18.75)
	DB-Green liquid	maneb + lindane (25.6+8.6)
	DB-Green + Double R	maneb + lindane + imazalil (25.6+8.6+10)
	DB-Green + Vitavax 34	maneb + lindane + carboxin (25.6+8.6+34)
	Double R	imazalil (10)
	Lindane ST40	lindane (40)
	Maxim 4FS	fludioxonil (40.3)
	Vitavax 34	carboxin (34)
	Vitavax Extra	carboxin + imazalil + thiabendazole (16.7+1.2+1.5)
	Vitavax+Thiram RTU	carboxin + thiram (10+10)
	Vitavax+Thiram+Lindane	carboxin + thiram + lindane (14+12+8)
Gustafson	Allegiance FL	metalaxyl (28.35)
	Allegiance LS	metalaxyl (17.7)
	Baytan 30	triadimenol (30)
	Baytan+Thiram	triadimenol + thiram (5.0+15.3)
	Captan 30 DD	captan (28.7)
	Captan 400	captan (37.4)
	Gaucho 480	imidacloprid (40.7)
	Gaucho XT	imidacloprid+tebuconazole+metalaxyl (12.7+0.62+0.82)
	Kodiak	Bacillus biological seed treatment
	Lindane 30C	lindane (30)
	Lorsban 30	chlorpyrifos (30)
	Lorsban 50-SL	chlorpyrifos (50)
	Poncho 600 – Canola & Corn	clothianidin (48)
	Raxil+Thiram	tebuconazole + thiram (0.6+20.0)
	Raxil XT	tebuconazole + metalaxyl (15+20)
	Raxil MD	tebuconazole + metalaxyl (0.48+0.64)
	Raxil MD Extra	tebuconazole + metalaxyl + imazalil (0.43+0.58+1.0)
	Raxil MD-W	Imidicloprid + tebuconazole + metalaxyl (1.5 + 0.5 + 0.6)
	Thiram 42S	thiram (42)
	Vitavax Extra RTU	carboxin + imazalil + thiabendazole (16.7+1.2+1.5)
	Vitavax Thiram - RTU	carboxin + thiram (10+10)
	Vitavax P PCNB	carboxin + PCNB (17+17)
	Vitavax - Thiram - Lindane	carboxin + thiram + lindane (14+12+8)
	Vitavax 200	carboxin + thiram (17+17)
Helena	Vitavax M	carboxin + molybdenum.
	Vitavax M DC	carboxin + Captan + molybdenum.
	Captan	captan + molybdenum.
	System 3	metalaxyl + PCNB + Bacillus subtilis
Syngenta	Apron XL	mefenoxam (32.3)
	Cruiser	thiamethoxam (47.6)
	Dividend Extreme	difenoconazole+metalaxyl (7.73+1.87)
	Dividend XL RTA	difenoconazole/metalaxyl (3.21+0.27)
	Maxim XL	fludioxonil (21.0)
	Mertect LSP	thiabendazole (30)
	Protege	azoxystrobin (9.6)
Trace Chemicals	Enhance Plus	carboxin +maneb + lindane (20+35+18.75)
	Grain Guard	mancozeb (50)
	Grain Guard Plus	mancozeb + lindane (50+18.75)
	Vitavax Thiram	carboxin + thiram (10+10)
Wilbur Ellis	Nu-Zone	imazalil (10)
	PCNB	PCNB (20)

SECTION 3
PEST CONTROL - GRAIN STORAGE & SEED TREATMENT FACILITIES

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While it is important to control grain insect pests during storage, other pests such as birds and rodents can contaminate stored grain. Also, weeds that surround a facility can also act as food and harborage for these vertebrate pests. In addition to insect fragments and parts, rodent and bird droppings and hairs are all undesirable components in foodstuffs. The standard for the acceptable amount of insect fragments and/or animal droppings in a milled product is regulated by the Food and Drug Administration (FDA). Flour mills will not accept grain with live insects or animal droppings.

RODENTS

In Montana, two rodents, the non-native house mouse (*Mus musculus*) and native deer mouse (*Peromyscus maniculatus*), probably cause the most problems around grain storage facilities. They damage both stored grain and the storage structure. They also contaminate grain with droppings, urine and hair. In addition, the deer mouse can also cause a potential disease problems because it is a vector for the hantavirus. The non-native Norway rat (*Rattus norvegicus*) may become a serious problem if not effectively controlled.

HOUSE MOUSE (*Mus musculus*)

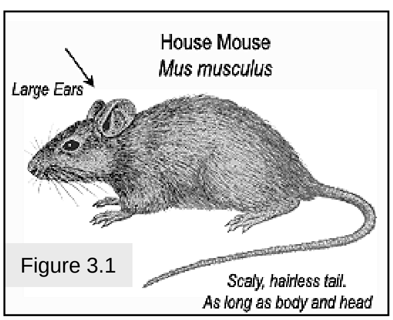

Figure 3.1

When fully grown at 1 month of age, the house mouse is usually 2 to 3 inches long and has a 3 to 4-inch tail. It has a pointed nose, large ears, and small eyes. During a 9- to 12-month average lifespan, a female can produce up to eight litters per year, with five to six offspring per litter.

Like most rodents, house mice rely on their senses of hearing, touch, taste, and smell. Their eyesight is poor, and they are color-blind. Mice also use runways or pathways along walls as they explore territories that usually extend only 10 to 20 feet from their nests. Mice are often active during the day, as well as at night. House mice readily investigate new objects and quickly enter bait stations. But because their active range is limited to such small areas, numerous bait stations or traps have to be used at any facility.

House mice feed mainly on grains and cereal products. The average mouse consumes about 2 pounds of food per year, but contaminates much more with droppings, urine, and hair. Mice drink much less water than rats and often obtain adequate moisture from their food.

DEER MOUSE (*Peromyscus maniculatus*)

The deer mouse in Montana measures approximately 6 ½ inches long, including its tail, and weighs under one ounce. Throughout the Intermountain West its color varies from pale gray to dark reddish brown on its back and upper tail. It has fine hairs on its tail. Its belly, legs and feet, and the underside of its tail are white. Although the upper fur blends to a lighter color along the sides, it is distinguished by the sharp definition between top and underside. The deer mouse's large, lightly haired ears and its big eyes which are well suited for its nocturnal habits and under-the-snow winter life, help to identify it.

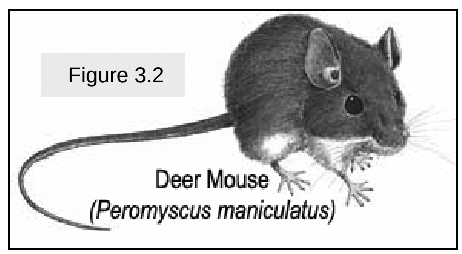

Figure 3.2

Unlike the house mouse, the deer mouse is not found in cities but is associated more with rural areas and buildings located in or near wooded areas. It does not commonly invade homes, but in rare instances one or more deer mice may invade a particular building.

The deer mouse is a medically important species because it carries the hantavirus. This virus can result in serious, often fatal, respiratory disease in humans. Cases of hantavirus are rare -- only about 300 to 400 cases have been documented in the past nine years, and most have been in the Western United States.

Hantavirus can be contracted in a number of ways:

- by handling dead, infected deer mouse carcasses,
- by breathing in mouse-urine-laden dust particles that contain the virus, or
- by inhaling dust from areas of accumulated deer mouse droppings.

You should avoid any area where infected deer mice have frequented unless wearing proper protective gear.

Hantavirus Prevention

Proper precautions should be taken to minimize any possible health risk. Remember, the risk of actually encountering hantavirus-infected deer mice is very remote, but taking the following steps can minimize any potential risk.

- Never sweep or vacuum mouse droppings, dust or debris in mouse activity areas.
- Soak mouse droppings and dusty areas with an EPA-registered disinfectant (or 1 ½ cups of household bleach in 1 gallon of water) then wipe up with paper towels. Place the soiled towels in a sealed plastic bag and dispose in an outdoor trash receptacle.
- Wear a respirator equipped with a High Efficiency Purifying Air (HEPA) filter as well as unvented protective goggles, and impermeable latex or rubber gloves.
- Clean protective equipment with the EPA-registered disinfectant, then again with soap and water, and allow to air dry before the next use.
- Spray dead deer mice with EPA-registered disinfectant before disposal.
- Handle traps wearing protective latex or rubber gloves and a HEPA-equipped respirator.
- Try to avoid touching or handling the carcass. Dispose of the carcass in a sealed plastic bag in an outdoor trash receptacle.

NORWAY RAT (*Rattus norvegicus*)

The Norway rat is a large rodent with a blunt nose, small eyes, and small ears. At 3 months of age it is sexually mature and fully grown, typically reaching a length of 8 to 10 inches. Its tail extends another 6 to 8 inches. The average life span for the Norway rat is 9 to 12 months. During that period a female can produce up to seven litters per year, with eight to twelve offspring per litter.

Rats have poor vision and are color-blind, but their senses of taste, smell, hearing, and touch are acute. Rats often use runways or pathways adjacent to walls or other vertical surfaces so they can keep their whiskers in contact with the wall. Although a rat's activity usually ranges 50 to 100 feet in any direction from its nest, they are shy and do not readily explore new areas or objects (including traps and bait stations). Rats rarely move about during daylight; daytime activity often indicates the presence of a large population.

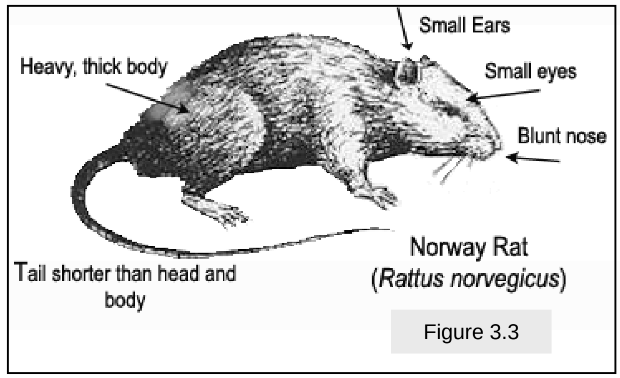

Figure 3.3

The Norway rat is omnivorous, and it eats almost any type of food. One rat consumes about 20 to 25 pounds of food per year. Rats prefer to nest near a source of water because, unlike mice, they need to drink water daily.

GROUND SQUIRRELS

In Montana, common small mammal pests of landscapes are the ground squirrels often called "gophers." These rodents may cause problems to grain storage facilities by digging under foundations and causing mounds and rough ground surface in areas near storage areas.

Figure 3.4

Any control measure used must be persistent since ground squirrels will readily re-infest an area from surrounding areas. Control should be initiated in the spring as soon as ground squirrels are apparent, before litters are born.

Snap traps and box traps may be effective for controlling small populations of ground squirrels. Locate the traps near burrows where ground squirrels have been sighted. Snap-type rat traps are better for trapping adult ground squirrels than the smaller mouse trap. Experiment to find the best bait or combination of baits for your area and time of year. Wiring the door of the trap open for several days while replenishing the bait daily helps overcome the squirrel's trap shyness and increases trapping success. It is important that traps be securely anchored to the ground.

Burrow fumigants release poison gas and consume oxygen when placed well down into a burrow. Labor and cost of materials usually restrict the use of fumigants to small acreages or sparse populations of ground squirrels. They are recommended as a cleanup method after the use of poison bait or in areas where it is considered unsafe to use poison baits.

Aluminum phosphide is another type of burrow fumigant that release toxic phosphene gas in the presence of moisture. Follow label instructions carefully. This is a restricted-use-pesticide that can only be applied by licensed applicators.

Rodenticides (pesticides used to control rodents) are inexpensive and effective but are a toxic means of controlling ground squirrels. Zinc phosphide is registered for rodent control but is very toxic to non-target species and is a restricted-use-pesticide (RUP) at concentrations greater than 2% active ingredient which require the applicator to be certified.

Anticoagulants are less harmful to non-target species particularly when the baits are placed inside the burrow or in properly placed bait stations.

CONSTRUCTION AND SANITATION PRACTICES THAT LIMIT RODENT POPULATIONS

Structural features that prevent rodent entry are extremely important to successful rodent control. The first step in making a structure rodent proof is understanding the capabilities of rats and mice.

These rodents can:

- climb or run along electrical wires, ropes, cables, vines, or trees to reach an entry point on a building,
- climb vertical surfaces such as brick, concrete, wood, or even weathered sheet metal,
- crawl horizontally along pipes, augers, conveyors, or conduit,
- gnaw through lead, aluminum sheeting, wood, rubber, vinyl, and cinder block.

In addition, rats can climb the outside of vertical pipes up to 3 inches in diameter. They also climb larger pipes attached to buildings, which they do by bracing themselves between the pipe and the wall. Rats can climb the inside of vertical pipes with diameters of 1 to 4 inches. They can also burrow into soil to depths of 3 feet.

To successfully exclude rodents from grain storage structures, rodent proofing efforts must overcome the capabilities mentioned above. Sites that require rodent-proofing include doors, holes and openings, vents and windows, and foundations and floors.

Holes that are greater than ¼-inch in diameter (whether around pipes or conduits, at the ends of metal siding, or as cracks in concrete or other material) allow mouse entry into structures.

Openings greater than ½-inch in diameter allow rats to enter. To seal such openings, use cement, masonry, or metal collars. Steel wool packed tightly into holes is a good temporary plug.

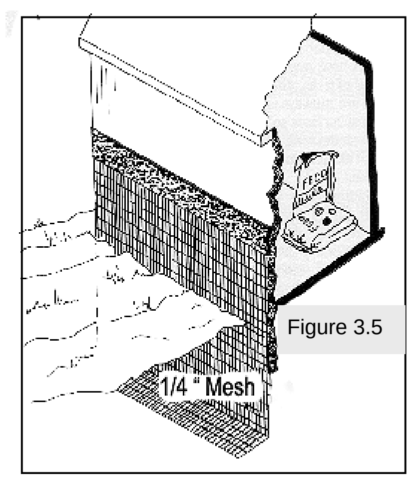

Figure 3.5

Vents and windows should be screened with galvanized hardware cloth. Doors should fit tightly, and the opening between the bottom of the door and the threshold should not exceed ¼ inch. To prevent rats from entering a structure by burrowing beneath the foundation, footings should extend at least 3 feet below the soil surface. Where deep footings are not used, curtain walls of concrete or ¼ inch wire mesh can be ex tended to a depth of 3 feet (Figure 3.5).

To prevent rodents from climbing or traveling beyond a certain point, sheet metal guards or barriers can be used. Rodents cannot cling to such material; and if the barrier is large enough, rats cannot reach beyond it to a surface suitable for climbing (Figure 3.6). Guards should be at least 12 inches wide (preferably 18-inches). Although stored grain always provides food for rodents, sanitation can limit rodent populations around grain facilities. Where rodents are unable to find shelter for hiding and nesting, even abundant food will not support high populations. Removing debris and controlling weeds around storage facilities is important in rodent control efforts. Replacing weed growth with a band of heavy gravel around the perimeter of storage also discourages rodent burrowing. Gravel should be at least 1 inch in diameter, and the band around the structure should be at least 2 feet wide and several inches deep. Lumber, firewood, and other materials should not be stacked adjacent to storage. Eliminating sources of standing (or even dripping) water near and within structures also reduces rat problems, because rats drink water daily.

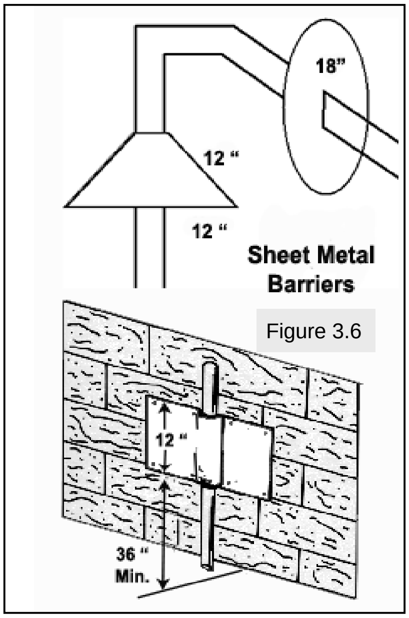

Figure 3.6

In feed rooms and warehouses, storage practices also influence rodent management. Stacking all bagged or boxed feeds and seeds on pallets, and not directly on the ground or floor, allows easier detection of rodent damage. Keeping all pallets at least one foot away from walls also encourages easier inspection and provides access to locations where traps or baits should be placed. Painting a one-foot-wide white border on the floor adjacent to all walls helps remind workers not to stack commodities against the wall; the white border also makes it easier to notice signs of rodent activity.

TRAPPING FOR RODENT CONTROL

Trapping often is an effective method of rodent control where infestations are not too severe. Traps are easy to handle and pose little threat of serious injury. Contrary to popular rumor, traps need not be handled in ways to remove human odors, as rats and mice commonly encounter and feed on many materials that humans have touched. Simple snap traps baited with peanut butter often are effective, but other foods or even nesting materials can also be offered on these traps.

Snap traps used for rats are considerably larger than mouse traps, but otherwise they are similar. Multiple-capture live traps such as the Tin Cat® and the Ketch-All® trap are effective for mice (not rats) and save time in disposing of the captured mice.

Rats are often trap-shy, and pre-baiting may be necessary for a trapping program to be effective. Pre-baiting is accomplished by placing a food bait in the target area, sometimes on a sprung trap. Rodents become accustomed to taking the bait, and a trapping program is then more successful when the traps are baited and set. Rats and mice prefer to continue feeding on a familiar food. Consequently, another appropriate practice is to clean up existing food supplies and use that same food as bait for traps.

Traps should always be placed adjacent to walls, against objects, or on rodent runways (evidenced by rub marks, etc.). Positioning snap traps across runways so that the trigger is adjacent to the wall (Figure 3.7) is most effective. Because mice only range over small areas, traps should be placed no more than 10 feet apart in locations where mice are active.

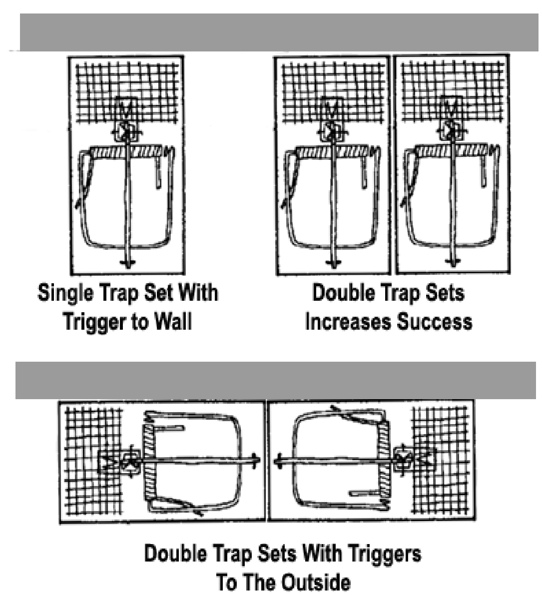

Figure 3.7

Glue boards are alternatives to conventional traps. In most situations they should be placed along walls where rodents travel. Glue boards are extremely sticky; do not use them where children or pets might encounter them. Placing glue boards inside cardboard boxes with appropriate access openings is sometimes necessary. Heavy coatings of dust can diminish the effectiveness of glue boards.

RODENTICIDES: RAT AND MOUSE POISONS

Rodent poisons are sold as ready-to-use (RTU) baits and as concentrates that can be mixed by the user. Ready-to-use baits are recommended in most instances because the user does not have to store and handle the concentrated poison. When applicators mix their own baits, they must follow label directions, which specify the proper amount of active ingredient (a.i.) to be included in the final bait. Baits that are too strong may not be accepted and eaten by rodents because they detect the toxic ingredient. More importantly, increased concentrations of active ingredients (a.i.) can make baits far more toxic to other accidental consumers such as pets, livestock, or children.

When applicators mix rodent poisons with grains or other food materials, they must add a distinct dye to signal that the commodity is contaminated and not to be used as food or feed. Because both rats and mice are color-blind, dyes that are added to bait do not diminish acceptance and feeding by these rodents. In addition to food baits, some rodenticides are formulated as tracking powders. Rodents walk through these poisons and then ingest them during grooming. Some compounds used to poison rats may be effective when prepared as water baits; even though stored grains provide a food source, rats must drink water daily.

Rodenticides are commonly grouped into two categories: anticoagulants and non-anticoagulants. Because rodents are mammals, the poisons used against them also pose special risks to other mammals, such as pets, livestock, and humans.

Anticoagulant Poisons

The anticoagulant rodenticides destroy the blood clotting abilities of poisoned animals, and these animals die from internal bleeding. The anticoagulant rodenticides are relatively slow-acting; they cause death 3 to 5 days after a lethal dose has been consumed. Most anticoagulants are lethal only if rodents consume them repeatedly for a period of 5 to 14 days. Brodifacoum and bromadiolone are exceptions; a single feeding on these compounds (sometimes called single-dose anticoagulants) may be lethal, even though rodents will survive and feed for a few days after consuming the fatal dose. The anticoagulants cause no immediate discomfort or illness, so no "bait-shyness" develops as they are used.

Remember! Anticoagulant baits must be made available continuously for up to 2 weeks to provide maximum control of a rodent infestation and can provide nearly 100 percent control if used in this manner. If baiting with anticoagulants does not provide adequate control, the remaining rodents may prefer a food different from the one offered in the bait. Switching to a new bait formulation may improve control.

Non-Anticoagulant Poisons

Non-anticoagulant baits are sometimes called single-dose poisons. They act rapidly and can quickly reduce rodent populations and will control anticoagulant-resistant populations.

With most non-anticoagulant poisons, pre-baiting with an unpoisoned bait for several days before adding the rodenticide will help increase bait acceptance and improve the likelihood that rodents will consume a sufficient dose to cause death.

Pre-baiting is necessary because rodents that consume too little bait (a sublethal dose) will be sickened by the poison and subsequently show bait-shyness, thus preventing success in subsequent baiting efforts. Because the non-anticoagulant rodenticides are fast-acting and because available antidotes are not always effective, it is especially important that they be used in ways that prevent access by pets, livestock, or children.

Zinc phosphide is a common non-anticoagulating rodenticide that produces phosphine gas in blood, causes heart paralysis, liver damage and kills in to 20 hours.

Bait Placement

Bait placement is extremely important for effective rodent control and the safety of non-target animals and humans. Whenever possible, place poisons directly into burrows. Whenever rodent poisons must be used in accessible areas, they must be enclosed in bait stations that prevent pets, livestock, and children from reaching the bait.

Bait stations, or bait boxes, increase the effectiveness and safety of rodent baiting programs. Bait stations protect baits from excess moisture and dust, and they provide rodents with a protected and secure place to feed on the toxic bait. They keep other animals and children away from the bait and allow use of baits in areas where hazards to non-target animals might otherwise prevent baiting.

Bait stations may contain solid or liquid baits. Although commercial bait stations can be purchased, applicators can improvise their own from wood, plastic or metal. Bait stations must effectively keep pets, livestock, and children from reaching the toxic bait. Locks or latches are needed in some situations, and sometimes it is necessary to tie or nail bait stations in place to prevent their movement. Bait stations should be labeled as such with the words **POISON** and **RODENT BAIT**.

Bait stations can be as simple as a board nailed against a wall or a pipe secured along a rodent runway. Where box-type bait stations are used, they should have at least one opening on each end (at least 2 inches in diameter, so that the rat or mouse can see its exit as it enters the station (Figure 3.8). Place the bait station against the wall or along a runway to increase the chances that rats or mice will use it.

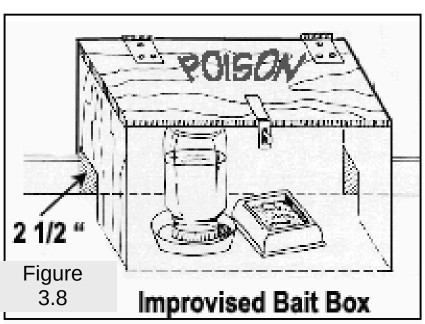

Figure 3.8

Remove old bait and rebait all bait stations frequently, and provide adequate amounts of baits. Dispose of spoiled or uneaten bait according to label directions. Be sure that disposal methods prevent access by pets and children.

Once rodent populations have been diminished by an effective trapping or baiting program, continued management is necessary. Rodent proofing and sanitation should be practiced, and a minimum level of trapping or baiting is recommended to monitor and limit any new infestations.

BIRDS AND BATS

Depending on the structure, birds and bats can become pests if they can gain access to the buildings. When they enter storage facilities, they consume stored grains and contaminate the commodities with their droppings. Large numbers of birds outside storage structures are problems for nuisance and health reasons.

Three species of birds are common pests around grain storage facilities:

1. The European starling (*Sturnus vulgaris)*,
2. The house sparrow (*Passer domesticus*), and
3. The pigeon or European Rock Dove (*Columba livia*).

EUROPEAN STARLING

Being non-native to Montana, starlings out-compete many native birds, especially hole nesting birds, taking over cavity nests and birdhouses from other species.

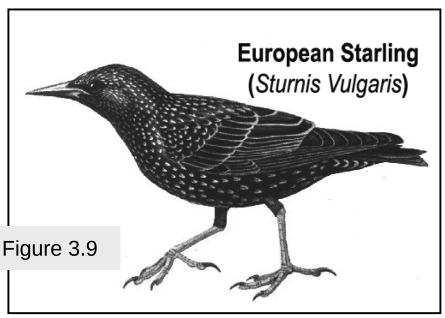

Figure 3.9

They also exploit any opening in buildings such as dryer, range and bathroom vents, and gaps around roofs and walls for nesting cavities.

Starlings can also transfer many diseases between livestock animals, particularly swine. Starlings have been associated with histoplasmosis, chlamydiosis and salmonellosis and most recently with West Nile virus. Starlings consume and contaminate livestock feed and water, and whitewash buildings with their droppings. Large winter flocks of 2,000 starlings in Alberta have been known to consume 1 to 2 tons of feed in a month and contaminate or spoil an additional 1,100 to 2,200 pounds of feed. Starlings may also selectively eat the high-protein portion of protein-supplemented livestock feed.

Starlings do differ in appearance from blackbirds. Although during most of the year adult starlings are nearly black, during the winter they are speckled with white. From January through June the bill is yellowish; it is nearly black the remainder of the year. Compared to blackbirds, the starling has a relatively short tail and short, triangular wings. It flies swiftly and directly, not undulating up and down in flight as do blackbirds.

Starlings breed and winter widely throughout the state. Starlings live in flocks that sometimes number several hundred during the summer. They nest in colonies and produce one or two broods of four or five young each year. Starlings leave their roosts at sunrise and travel 15 to 30 miles in smaller flocks to selected feeding or "loafing" areas. They return to their roosting sites each night.

HOUSE SPARROW

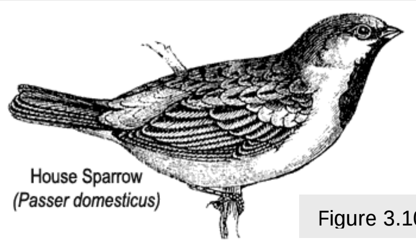

Figure 3.10

The house sparrow is a small, brownish bird that breed and winter widely throughout Montana. Males have a black "bib" or breast, black bill, and white cheeks, whereas females are less distinct, exhibiting a gray breast and a streaked back. They like to nest in and around buildings.

Since they gather in large numbers, most house sparrow damage is related to their nesting and feeding habits. In these situations they are a considerable nuisance, and often cause unsanitary or odorous conditions. Droppings can kill ornamental vegetation, contaminate grain and damage finishes on vehicles. House Sparrows are also a factor in the spread of several diseases such as chlamydiosis, New Castle disease, salmonellosis, toxoplasmosis and transmissible gastroenteritis. House Sparrows also carry parasites, insects, fleas, mites and ticks.

PIGEONS OR EUROPEAN ROCK DOVES

Pigeons or European Rock Doves are originally from Europe, Asia and Africa. They have spread throughout the world including the United States.

Originally domesticated in Europe and brought to the U.S., they eventually escaped to the wild. Consequently, pigeons are not a native wildlife species and are not protected in Montana. Pigeons may be taken at anytime, and their nests and eggs destroyed. The spread of pigeons has been most noticeable in urban areas where they have become a nuisance. Pigeons roost and nest almost exclusively in manmade structures such as buildings and bridges. They scavenge on grains and seeds and consequently can be very numerous around grain elevators. They produce two eggs per nesting; reproduction occurs throughout the year.

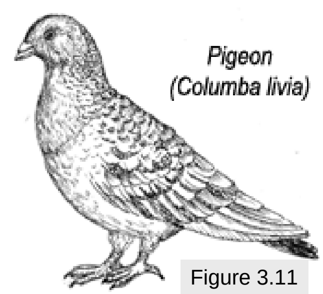

Figure 3.11

MANAGING PESTS SPECIES OF BIRDS

Non-chemical Methods of Prevention

In many situations, non-chemical methods of reducing bird populations are more successful than the use of avicides (pesticides for birds). Such steps include altering nesting sites, exclusion, sanitation, and the use of noise for frightening.

To prevent roosting or nesting, sites can be covered or closed off. For example, adding sheeting to seal around eaves prevents access to the nesting sites preferred by pigeons and house sparrows. A board or metal sheet attached at a 45^{o} angle prevents pigeons from roosting on ledges that cannot be covered in any other fashion (Figure 3.12). The use of porcupine wires (Figure 3.13) or glues also discourages roosting or nesting. “Porcupine” wire”, has several parallel rows of 3-inch stiff wire attached, is also useful in deterring birds from roosting or nesting areas.

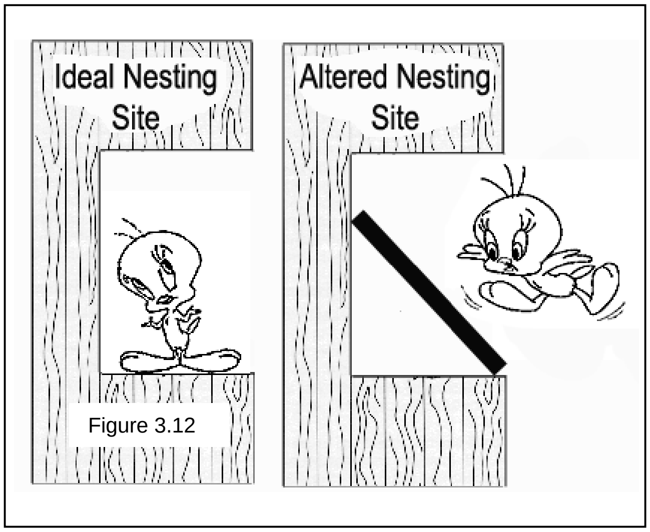

Figure 3.12

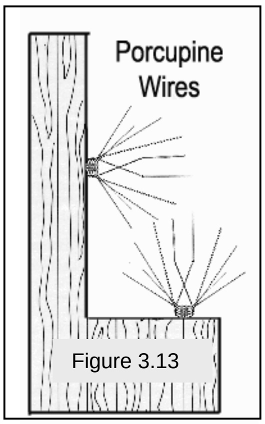

Figure 3.13

Exclusion is one of the best choices for bird control. Evict bird pests wherever they have gained entrance to buildings and seal the entrance with hardware cloth or metal flashing. All vents or windows should be screened, and holes around eaves, doors, etc. should be closed. Where traffic or ventilation needs require doors to be kept open for extended periods, suspending netting or screening across the upper portion of the doorway, or using plastic curtains (strips that part and allow passage of personnel and machinery) can reduce or prevent bird entry. Light materials such as nylon or plastic netting and window screen may not keep out determined birds such as starlings as they can easily tear these materials out.

Sanitation around grain facilities is very important, even though in some instances it can be very time-consuming. Where birds are feeding on grain spills at shipping or receiving sites, regular cleanup (perhaps even several times a day) will be necessary before other control tactics can be successful.

Noise can effectively frighten birds, especially where starlings migrate from some distance to a facility. If automatic devices or personnel create enough noise at the time birds normally arrive, and if the noise-making program is continued for several days, starlings often alter their foraging and flight routes and no longer come to that site.

CHEMICAL CONTROL

There are a few repellents registered for use on starlings, however some of these may be harmful to other birds that accumulate the material on their feet and feathers. Tacky Toes®, Roost-No-More®, 4-The-Birds® and Bird Tanglefoot® are a few of the non-toxic materials that have been useful in deterring starlings. These types of repellents are spread on roosting or perching ledges and rafters. These are non-toxic soft sticky materials that the birds do not like to get on their feet and feathers. Starlings need only 1" of space to roost or perch so make sure you cover the entire area.

Avitrol® (active ingredient: 4-aminopyridine) is a Restricted-Use-Pesticide (RUP) available in several bait formulations as a chemical frightening agent. Avitrol® baits contain a small number of treated grains or pellets mixed with many untreated grains or pellets. Birds that eat the treated portion of the bait behave erratically and/or give warning cries that frighten other birds from the area. Generally, birds that eat the treated particles will die. At the dilution rates registered for use, there is potential hazard to non-target hawks and owls that might eat birds killed by Avitrol®. So, it's important to pick up and bury or incinerate any dead birds found.

The Avitrol® pelletized feed formulation is generally recommended for starling control because starlings usually prefer pellets to cracked corn (corn chops). The Double Strength Corn Chops formulation is probably best for mixed flocks of starlings and black-birds. Because Avitrol® is designed as a frightening agent, birds can develop bait shyness (bait rejection) fairly quickly. Pre-baiting for several days with untreated pellets may be necessary for effective bait consumption and control. If the problem persists, changing bait locations and additional pre-baiting may be needed.

Bats

Bats roosting in a building often go unnoticed for years and may not appear to be causing problems. However, their droppings and urine not only stain walls and ceilings, they also cause objectionable, persistent odors that may attract insects and other bat colonies, even after the original colony is eliminated. Long-term accumulation of these droppings in attic spaces has been associated with the respiratory disease

Histoplasmosis. This disease is caused by a fungal spore called *Histoplasma capsulatum.* Bat and/or bird droppings that have decomposed from 2 to 5 years or longer provide an ideal habitat for spore growth and reproduction.

Bats can squeeze through cracks as small as inch wide. They may enter through openings found around a vent or siding. To locate exit/entry points watch from the corner of the building and look for bats flying in and out. Begin the watch 30 minutes before dusk and observe for 1 hour.

Its best to evict bats by allowing them to leave on their own and then denying entry. Seal all but the largest or most used entrance with building material (hardware cloth, netting or sheet metal).

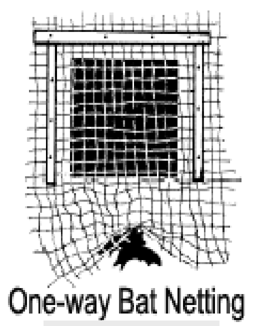

Figure 3.14

The last entrance should be covered with garden netting (one-way bat netting). Hang it over the entry point so it extends 2 feet below and to each side of the opening. Only the bottom edge should hang loosely. This allows bats leaving the building to crawl under and out, but returning bats cannot find their way back in. Secure the net in place so that it hangs free an inch or so away from the building. It will act as a one-way valve permitting exit, but closing when bats land on it to return. Leave the netting up for several days before sealing the opening, as some bats will not leave to feed at night.

Trapping is not recommended since excluding bats is less complicated to carry out, less time consuming, more effective and requires no handling of bats. Never attempt to poison bats! Poison is not effective because many bats are insectivorous and bats often roost deep in cracks where the poison won't reach. Poisoned bats will leave the house sick, and are then more likely to bite pets or people.

WEEDS

Because weeds growing around a grain storage facility can provide food and harborage for vertebrate pests, weed control is important for successful grain storage.

A weed is any plant growing out of control or growing in a place where it is not desired. Weeds around a grain storage/treatment facility and other farm buildings can harbor pests such as rats, mice, insects, and snakes. Weeds not only detract from the appearance of the operation, but vegetation growing close to buildings can be a fire hazard.

Grain storage managers can eliminate weed problems by removing all vegetation in a narrow band along the edges of buildings. To remove weeds, managers can use:

- Non-chemical methods - mowing or cutting,
- Chemical treatment,
- A combination of methods.

Before removing all vegetation from a particular area, managers should consider the potential for soil erosion. If buildings are surrounded by steep slopes, some ground cover will be necessary to prevent soil erosion and chemical runoff. Building structure is also a factor because of water coming off eaves. If this runoff is likely to cause soil erosion, some vegetation is needed.

NON-CHEMICAL CONTROL: CUTTING AND MOWING

Cutting or mowing weeds and grass around buildings helps limit threatening pests. Unmowed grass, tall weeds, and brush provide cover for rats, mice, snakes, insects, and litter. Grass that is 3 to 4 inches high provides resting places for flies during hot weather.

Cutting and mowing can also help control weed growth and prevent seed production of annual weeds which do not reproduce below cutting height. Perennial weeds are more difficult to control since they grow from underground vegetative parts. Repeated mowing for 2 or more years may deplete underground food reserves and control some perennial weeds. However, mechanical removal of all these underground structures to prevent resprouting is impossible; therefore, most perennials will require some chemical control.

CHEMICAL CONTROL

The term for a pesticide that is used to control weeds is herbicide Clumps of unwanted brush and tall weeds can be spot treated with herbicides and are generally applied when the weeds are actively growing. However, weed size and environmental conditions will determine the safety and effectiveness of herbicide applications.

The size of the weeds to be controlled will determine the rate and amount of herbicide needed. Optimum conditions for herbicide treatment are affected by the environment. Weather conditions too hot, cold, dry, or wet can limit effectiveness, delay applications, and prevent control. All successful weed control programs start with the identification of the target weed. Proper identification is important to select an effective herbicide.

Selectivity Of Herbicides

Herbicides can be either selective or non-selective. Selective herbicides affect only certain kinds of plants. For example, some herbicides control only grass weeds. Other herbicides control only broadleaf weeds and brush. The herbicide 2,4-D is selective because it controls broadleaf weeds, but not grasses.

Non-selective herbicides control both grass and broadleaf weeds. The active ingredient (a.i.) glyphosate is used in many nonselective foliar-applied herbicides and is rapidly tied up on contact with clay-containing soils and soils high in organic matter. The active ingredient, glyphosate, is available in many formulations under the trade names Roundup®, Touchdown®, Glyfos®, just to name a few.

Weeds and other plants in non-cropland areas generally should be controlled before emergence or when very small to minimize the risk of drift, improve herbicide performance, and prevent vegetation brownout. Soil sterilant herbicides are generally applied preemergent or postemergent, alone or in combination with other herbicides to achieve short-to long-term weed control. Addition of a non-selective contact or systemic herbicide at application can provide burn-down of existing vegetation and long-term vegetation control. Initial high rates of a residual or combination of residual herbicides followed by treatment in subsequent years at rates of 1/3 to 2/3 the initial rate will give satisfactory extended control. For short term bare ground control, non-residual herbicides can be applied several times per year.

The herbicides listed below can be applied alone or in combination for complete or bare ground weed control. The type of vegetation to be controlled will determine the herbicide to use. For example, perennial grasses can only be controlled with Finale®, Fusilade®, glyphosate, or Poast®. Woody perennials can be controlled with Clarity®, Crossbow®, glyphosate, Spike®, Tordon®, or Weedmaster®. Deep rooted species, like field bindweed can be controlled with Clarity®, Crossbow®, glyphosate, or Tordon®. Control of both grass and broadleaf plants, especially for bare ground weed control will require a combination of herbicides or a high rate of a residual herbicide.

General precautions when using soil sterilants for bareground control are:

1. First! Always read the label of the herbicide you are using.
2. Know the weed species to be controlled. This is the key in choosing effective herbicides.
3. Do not move treated soil.
4. Avoid spray drift and reduce drift potential by applying at lower temperatures, use non volatile formulations, reduce spray pressure, and select nozzles that produce larger droplets.
5. Avoid applying where wind or water will move the treated soil.
6. Do not apply where roots of desirable vegetation may extend into the treated area.
7. Be familiar with and know the risks of the product to be applied.
8. Use a combination of herbicides with different modes of action to avoid resistant weeds.

Timing Of Herbicide Application

Proper application is necessary for the success of any herbicide treatment. Soil-active herbicides should be applied uniformly over a given area. Foliar translocated herbicides should be applied uniformly to the foliage of vegetation at the proper time. Both soil and foliar active herbicides require proper timing and good coverage for effective performance.

Preemergence herbicides are applied to the soil and are absorbed by the seed or by the roots or stems of tiny seedlings before the plants emerge from the soil.

Postemergence herbicides are applied after weeds have emerged from the soil and generally act through the foliage of the plant.

HERBICIDES USED FOR NON-CROPLAND AND BAREGROUND WEED CONTROL THE INFORMATION IN THIS TABLE IS FOR REFERENCE ONLY AND MAY CHANGE. ALWAYS REFER TO RATES AS NOTED ON THE HERBICIDE LABEL		
Herbicide	**Product/Acre** (lb ai/Acre)	**Remarks**
2,4-D	**2 to 8 pt** (1 to 4)	Systemic, short residual herbicide. For control of annual and perennial broadleaf plants. Avoid drift to desirable plants and sensitive crops. **Short residual.**
Banvel/Clarity ® **Vanquish** ® (dicamba)	**0.5 to 6 pt of a 4 lb/gal conc.** (0.25 to 6)	Use 0.5 to 1.5 pt/A to control annual broadleaf plants, 0.5 to 3 pt/A to control biennials, 1 to 12 pt/A to control perennials. Apply when weeds are actively growing. Refer to label for registered tank-mixes. **Long residual.**
Weedmaster ® (dicamba + 2,4-D)	**0.5 to 4 pt** (0.25 to 2)	Controls broadleaf weeds and woody plants. Apply when weeds are actively growing. Adjuvants may used for wetting, penetration, or drift control. **Moderate residual.**
Crossbow ® (triclopyr + 2,4-D)	**1 to 1.5 gal/100 gal, 2 qt to 4 gal/A**	Use 1 to 1.5 gal product/100 gal water for spot treatment, 2 to 4 qt/A for broadleaf weeds, 1.5 to 4 gal in sufficient water to deliver 10 to 30 gpa for woody species. **Moderate residual.**
Diuron/Direx ® **Karmex** ® (diuron)	**1 to 8 gal** **5 to 15 lb** (4 to 32)	Refer to label for use in irrigation ditches. Higher rates needed for perennial grasses and broadleaf weeds. Deep rooted perennials will require retreatment. **Long residual.**
Escort ® (metsulfuron)	**0.3 to 2 oz DG** (0.2 to 1.2 oz)	For annual broadleaf weed control. Can be applied anytime except when ground is frozen. No grazing restrictions up to 0.75 oz/A. Kochia biotypes have developed resistance. Apply with another herbicide of a different mode of action. **Long residual.**
Gramoxone Extra ® (paraquat) **RUP**	**2 to 3 pt** (0.625 to 0.94)	Nonselective/**nonresidual**/contact. Controls top-growth only of perennial species. Add NIS and repeat application as necessary. Avoid drift and contact with desirable species.
Hyvar X ®**, Hyvar DF** ® (bromacil)	**3 to 15 lb DF** (2.4 to 9.6)	Use 3 to 6 lb for annual grass and broadleaf weeds or 7 to 15 lb for perennial weeds. Noncorrosive, nonvolatile, nonflammable. Refer to label for tank-mixes. **Long residual.**
Finale ® (glufosinate)	**3 to 6 qt** (0.75 to 1.5)	Nonselective, **nonresidual** herbicide. Use 1.5 to 4 fl oz/gal for spot application, 3 to 4 qt/A for weeds less than 6 to 8 inches, 5 to 6 qt/A for weeds greater than 6 to 8 inches.
Krovar I ®, **WeedBlast** ® (bromacil + diuron)	**4 to 30 lb DF** (3.2 to 24)	Provides effective control of annual grass and broadleaf weeds. Apply preemergence or early postemergence. Refer to label for registered tank-mixes. **Long residual.**
Oust ® (sulfometuron)	**2 to 4 oz DF** (1.5 to 3 oz)	Use high rate in high moisture areas such as railroad shoulders, under asphalt and concrete. Will control leafy spurge at 3 oz/A. Do not spray near water. **Long residual.**
Pramitol ® (prometon)	**5 to 30 gal** (10 to 15)	Use 5 to 7.5 gal/A for annual and susceptible perennial weeds, 20 to 30 gal/A for hard-to-kill perennial weeds. Apply before weeds emerge or EPOST. **Long residual.**
Roundup Brands **Glyphos** ® **Private labels** (glyphosate)	**2 to 10 qt of a 3 lb ae/gal conc. or 1.5 to 7.5 qt of a 4 lb ae/gal conc.** (1.5 to 7.5)	Nonselective/**nonresidual**/systemic herbicide. Effective on annual and perennial grass and broadleaf plants. Avoid drift and contact with desirable species.
Sahara ® (imazapyr + diuron)	**3 to 4 A/copack or 6.5 to 13 lb** (0.5 to 1 + 4 to 8)	Provides residual PRE and POST control of annual weeds and POST control of perennial weeds. Apply POST with NIS at 0.25% v/v or MSO type adjuvants at 1.5 to 2 pt/A alone or with UAN at 2 to 3 pt/A. Can be tank-mixed with Roundup, Finale, Krovar, Hyvar X, Oust, Garlon, and Clarity. Do not apply with 2,4-D due to reduced weed control. **Long residual.**
Spike ® (tebuthiuron)	**5 to 30 lb 20P** **2.5 to 15 lb 40P** (1 to 6)	Controls over 125 grass and broadleaf species and 110 woody species. Rate varies by weed species and duration of control desired. Avoid drift and contact with desirable species. **Long residual.**
Telar ® (chlorsulfuron)	**0.25 to 3 oz DF** (0.19 to 2.24)	Use higher rate for perennial weed control. Avoid treatment to dry soil that may move off target. Apply with another herbicide for broad spectrum weed control. **Long residual.**
Touchdown ® (glyphosate-tms)	**0.75 to 6.33 pt** (0.32 to 2.71)	Nonselective/**nonresidual**/systemic herbicide. Effective on annual and perennial weeds. Avoid drift and contact with desirable species.
Tordon 22K ® (picloram) **RUP**	**0.25 pt to 2 gal** (0.06 to 4)	For control of most annual and perennial broadleaf weeds and woody plants. Avoid drift and contact with desirable species. **Long residual.**

Preventing Injury To Non-target Vegetation

The major sources of herbicide injury to off-site vegetation are from spray drift and volatility. When injuries occur, the damage is near the area treated and might have been avoided by a more careful application. One important factor herbicide applicators should be aware of at all times is spray drift: the movement of airborne spray particles from the target area.

Foliar active herbicides can be injurious if the spray moves to non-target plants near the treatment area. The amount of drift depends primarily on droplet size (the smaller the droplet the longer it takes to reach the ground), the wind velocity, and the height above the ground that the spray is released.

Herbicides should be sprayed only when there is no danger of spray drift due to excessive wind speeds and when wind is blowing away from sensitive areas. The danger to non-target plants, both on and off site, should always be considered.

Volatility refers to the tendency of a chemical to vaporize or give off fumes. Vapor drift may damage susceptible plants or reduce the effectiveness of the herbicide treatment through loss. Chemicals differ in volatility. The herbicides listed in the table are not classified as volatile formulations. Herbicides should be applied when there is little wing and when daily temperatures are less than 90°F.

Protecting Groundwater

Groundwater protection is a major concern with herbicide use. Pesticides may move (leach) through the soil to groundwater. When herbicides are applied to the soil, soil texture and organic matter play a key role in herbicidal activity. Herbicides tend to leach more readily in coarse textured sandy soils with low organic matter content. Herbicides that are highly soluble in water have increased leaching potential.

Leaching can be minimized by proper herbicide selection, use rate, timing, and method of application. Herbicides that break down slowly (more residual) have a greater potential for soil leaching. In general, herbicides that are highly water soluble, relatively persistent, and not readily absorbed by soil have the greatest potential for soil leaching. High water tables are especially vulnerable to contamination by herbicides due to the relatively short distance between the soil surface and groundwater. The potential for groundwater contamination is great in areas with coarse-textured soils and high water tables. In these sensitive sites, herbicide use should be limited.

Applying Herbicides Safely

<u>The most important step in safe application of herbicides is reading and following label directions.</u>

Each herbicide has specific application information on the label. These application instructions—as well as disposal directions—should be followed carefully. In addition, equipment should be properly calibrated. Following directions and calibrating equipment provides best weed control results and also minimizes the possibility of groundwater contamination.

GLOSSARY

Active ingredient (a.i.) – Chemical(s) in a pesticide formulation that controls the pest(s).

Ambient – Surrounding air and its properties, temperature and humidity.

Anticoagulant - Substances that kill by preventing normal blood clotting and causing internal hemorrhaging.

Asci (Ascus sing.) – Sac-like cell of hyphae in which meiosis occurs and which contains ascospores.

Ascospore - specialized haploid cell produced during meiosis.

Asexual – Not involving union of sex cells. Usually vegetative reproduction in plants and asexual spore production in fungi.

Atomized – To reduce to tiny particles or a fine spray.

Avicides – Pesticide used to control or repel birds.

Basidiospores – A sexual fungal spore of fungi in the division Basidiomycetes which includes mushrooms, puffballs, smuts and rusts. Basidiospores are usually borne on a microscopic **basidium** or stalk.

Bunt – Fungal disease of small grains. Bunt affects plants by destroying the contents of the infected seed kernels and replaces them with spores of the fungus

Bushel – A unit of volume that is 2152.42 cubic inches. Also denotes 60 pounds of wheat

Bushel (bu) – 1.2444 cubic feet or 149 eight-ounce cups.

Cadaver – Dead Body

Cereal Crops – A grass plant such as wheat, oats, or corn, the starchy grains of which are used as food.

cfm/bu – cubic feet per minute per bushel

CHEMTREC - The Chemical Transportation Emergency Center (CHEMTREC®) is a 24-hour emergency communications center operated as a public service by the American Chemistry Council. 1-800-424-9300

Chlamydiosis - A rare infectious disease that causes pneumonia in humans. The illness is caused by a chlamydia, which is a type of intracellular parasite closely related to bacteria. Also known as Parrot fever.

Chlorotic – Lacking chlorophyll. Yellowing of plant leaves.

Codex Maximum Residue Limits - Following the application of a pesticide product, trace residues may be present at harvest on agricultural commodities, such as fruits, vegetables, or cereal grains or in processed commodities, such as fruit juices, vegetable oils, and flours. Thus, government regulatory authorities have established maximum residue limits (MRLs) or tolerances as a check for compliance with national good agricultural practices (GAP) and to facilitate international trade. MRLs are referred to as "tolerances", and in general the two terms are synonymous. On the international level, the Codex Alimentarius Commission has sought to establish a globally applicable listing of harmonized MRLs to support international trade. Thus, many countries refer to Codex MRLs when considering regulatory and trade aspects of pesticide residues.

Coleoptera – An order of insects that includes the beetles. Beetles constitute the largest and most diverse order of insects on earth, making up about 30% of all animals.

Coleoptile – Sheath covering the growing shoot of a young plant seedling. As growth continues, the coleoptile ruptures to expose the first leaf.

Commodity - A product that can be used for commerce and includes agricultural products such as grain, livestock, etc.

Conidiophore – A specialized hypha on which one or more conidia are produced.

Conidium (Conidia pl.) **–** An asexual spore.

CWT - The abbreviation for hundred-weight, which is the equivalent of 100 pounds.

Damping Off – Destruction of seedlings near the soil line, resulting in the seedling falling over on the ground.

Detritus - Parts of dead organisms and cast-off fragments and wastes of living organisms.

Diatomaceous Earth (D.E.) - Fossilized skeletons of one-celled organisms called diatoms. When soft-bodied insects come in contact, D.E. causes massive loss of body fluids and death. When the dust is eaten by insects, the D.E. inhibits breathing, digestion and reproduction. Because it kills by mechanical action rather than poison, insects do not usually develop resistance.

Diluent – Substance that is added to a pesticide formulation to dilute its concentration. Usually water.

Encephalitis - An inflammation (irritation and swelling with presence of extra immune cells) of the brain, usually caused by infections.

Exuviae – (Pronounced ig'-zoo-vee-ay. Cast-off skins or coverings of various organisms such as insects

Filamentous – Thread-like

Formulation – The manner in which a pesticide is prepared for practical use and usually contains the active ingredients (a.i.) and inert or other ingredients.

Frass - Debris and fecal matter produced by insects

Gastroenteritis - Inflammation or irritation of the stomach and /or intestine.

Genus (Genera – pl.) - A grouping of organisms that usually contains a group of closely related species.

Glume – Small leaf-like structure found at the base of grass spikelets

Grain Protectant – Usually a liquid insecticide applied directly to grain.

Hantavirus - A type of virus carried by rodents causing severe respiratory infections in humans and, in some cases, hemorrhaging, kidney disease, and death.

Haploid – Having one set of chromosomes.

Harborage – A place of refuge or shelter.

Hardware Cloth – A metal fabric also known as wire cloth; the mesh openings are larger than window screening, but smaller than fencing.

HEPA - **H**igh **E**fficiency **P**articulate **A**ir filters that have been tested to assure removal of 99.9% of particles that are 0.3 microns (μm) in size

Histoplasmosis – A disease caused by the fungus Histoplasma capsulatum; may infect lungs, skin, mucous membranes, bones, skin, and eyes.

Host – A plant that is invaded by a pathogen and from which the pathogen obtains its nutrients

Hundredweight (cwt) – One hundred pounds, usually of seed. C is Roman for 100. Wt means weight.

Hydathode – Gland occurring on the leaf edges of many plants and secretes water.

Hypha (pl. Hyphae) **–** Thread-like filaments forming the mycelium of a fungus.

Imperfect fungi - Imperfect fungi, comprise about 25,000 species, many of which do not have a defined sexual cycle. They typically reproduce asexually by spores called conidia on specialized hyphae called conidiophores. The imperfect fungi include many molds, some of which are important to humans. Penicillium, the mold used to develop the first antibiotic, is sometimes classified as an imperfect fungi.

Inert Ingredients – That part of a pesticide formulation that has non-pesticidal qualities. Inert ingredients usually aid in storage and application.

Infection peg - A very fine hypha that is thrust through the cuticle or epidermis of a plant host cell.

Inoculant, Inoculum (Sing.), Inocula (pl.) – The pathogen or its parts that causes infection. Also refers to beneficial nitrogen-fixing bacterium that is applied to legume seeds to produce nodulation.

Inoculation - Arrival or transfer of a pathogen onto a host.

Insectivorous – Eats insects.

LD50 – A single dose of a material expected to kill 50 percent of a group of test animals. The LD50 dose is usually expressed as milligrams or grams of material per kilogram of animal body weight (mg/kg or g/kg). The material may be administered by mouth or applied to the skin. The lower the LD50, the more toxic a compound.

Lepidoptera - An order of insects that includes moths and butterflies.

Lesions – A localized area of discolored, diseased tissue

Meisosis - A special process of cell division during which spores are produced. Meiosis involves the reduction by half in the amount of genetic material.

Meningitis - An infection which causes inflammation of the membranes covering the brain and spinal cord.

mm – Millimeter. One millimeter is 1,000th of a meter or 1/25th of an inch.

Mode-of-action – The way in which a pesticide affects a pest at the cellular level.

Montreal Protocol - The Montreal Protocol on Substances That Deplete the Ozone Layer is an international agreement designed to protect the stratospheric ozone layer. The treaty was originally signed in 1987 and substantially amended in 1990 and 1992. The Montreal Protocol stipulates that the production and consumption of compounds that deplete ozone in the stratosphere are to be phased out by 2005.

Mosaics – Symptoms of certain viral diseases characterized by intermingled patches of normal and light green or yellowish color.

Mycelium – The combined mass of microscopic thread-like strands (hyphae) that makes up the body of fungi and produces vegetative spores.

Mycotoxins - Toxic substances produced by fungi or molds on agricultural crops that may cause sickness in animals or humans that eat feed or food made from contaminated crops.

Necrosis describes the condition of being dead or discolored.

Necrotic – Dead and discolored.

New Castle Disease -A highly contagious virus disease of domestic poultry and wild birds characterized by gastro-intestinal, respiratory and nervous signs.

NIOSH – National Institute of Safety and Health

Nodulation – Creation of nodes (swelling or bumps) on legume roots by nitrogen-fixing bacteria.

Non-systemic – Does not move within a plant or animal. Usually affects on the part that it touches.

Ovule – A structure found in plants that contains an egg cell and develops into a seed after fertilization.

Pericarp – Seed wall which develops from the mature ovary wall.

Pesticide - A chemical substance (e.g. an insecticide or fungicide) that kills, controls or repels harmful organisms and is used to control pests, such as insects, weeds, microorganisms, rodents, birds, etc.

Pheromone - A chemical released by an insect or other animal through which it communicates with another individual of the same species through a sense of smell.

Phytoplasmas – Smallest bacteria-like microorganisms. Formerly called mycoplasma-like organisms. They differ from bacteria by lack of a solid wall

Pistil – The flask-shaped female reproductive unit of a flower that is composed of the ovary, style and stigma.

Postemergent, Postemergence – Usually refers to herbicides applied after weeds have emerged from the soil and generally act through the foliage of the plant.

Preemergent, Preemergence - Usually refers to herbicides applied to the soil and are absorbed by the seed or by the roots or stems of tiny seedlings before the plants emerge from the soil.

ppm – Parts Per Million

Pycnidia – Asexual, flask-shaped fruiting bodies lined inside with conidiophores that produce conidia.

Race – A genetically and often geographically distinct mating group with a species. Also a group of pathogens that infect a given set of plant varieties.

Rachis - The central axis of a grain spike, flower cluster, or compound leaf

Restricted-Use-Pesticide (RUP) - A pesticide that can be sold to or used by only certified (licensed) applicators.

Rodenticides - Pesticides used to control rodents

Root Rots – Softening, discoloration and often disintegration of succulent root tissue as the result of fungal or bacterial infection

Rusts – A disease giving a "rusty" appearance to a plant and caused by one of the rust fungi.

Salmonellosis – An infection caused by Salmonella bacteria and commonly manifested by diarrhea, abdominal pain, nausea, and sometimes vomiting.

Saprophyte - An organism that uses dead organic matter for food

Sclerotium (pl. Sclerotia) **–** A compact mass of hyphae with or without host tissue, usually with a darkened outer shell, and capable of surviving under unfavorable environmental conditions.

Seed Rots - Softening, discoloration and often disintegration of seed tissue as the result of fungal or bacterial infection.

Slurry – A suspension formed when a quantity of powder is mixed into a liquid in which the solid is only slightly soluble (or not soluble). Fungicides and some insecticides are applied to seeds as slurries to produce thick coating and reduce dusts.

Smuts – A disease caused by the smut fungi (Ustilaginales). Smuts are characterized by masses of dark, powdery spores

Snap Trap – Usually a common mousetrap. A piece of equipment used to quickly trap or catch mice and is usually composed of three parts: base, trigger, and the spring-loaded snap.

Spores – The reproductive unit of fungi consisting of one or more cells.
Sporulating, Sporulation – Producing spores
Stigma – The upper part of the pistil of a flower on which pollen is deposited.
Stomata (pl.) or Stoma (sing.) – A microscopic pore in a leaf or stem through which gases and water vapor can pass. The exchange of air and transpiration of water are regulated by the two cells (called guard cells) on either side of a stomate.
Systemic – Absorbed and translocated throughout a plant or animal. Systemic fungicides are absorbed by the plant, then translocated throughout its tissues. They can be applied after an infection occurs and still have a benefical impact.
Tampico - A tough vegetable fiber used as a substitute for bristles in making brushes.
Teliospore – A thick-walled spore characteristic of the rust and smut fungi.
Thermal Inertia - The tendency of an object with large quantities of heavy materials to remain at the same temperature or to fluctuate only very slowly.
Thermocouple - A thermoelectric device used to measure temperatures accurately, especially one consisting of two dissimilar metals joined so that a potential difference generated between the points of contact is a measure of the temperature difference between the points.
Tillering – Producing a shoot, especially one that sprouts from the base of a grass.
Toxoplasmosis - An infection with the protozoan intracellular parasite *Toxoplasma gondii.*
Translocated – Movement of a substance within a plant or animal
Vector – Animal capable of transmitting a pathogen
Volatile - The term given to a substance that is easily converted to the gas state.
Volunteer Plants - Plants outside of a defined row and are usually produced from "leftover" seed from the previous growing season. Plant arising from seed dispersed from a previous crop.
Webbing – A network of threads spun by certain insect larvae.

West Nile virus (WNV) - West Nile virus is transmitted by mosquitos and causes an illness that ranges from mild to severe. Mild, flu-like illness is often called West Nile fever. More severe forms of disease, which can be life-threatening, may be called West Nile encephalitis or West Nile meningitis, depending on where it spreads.