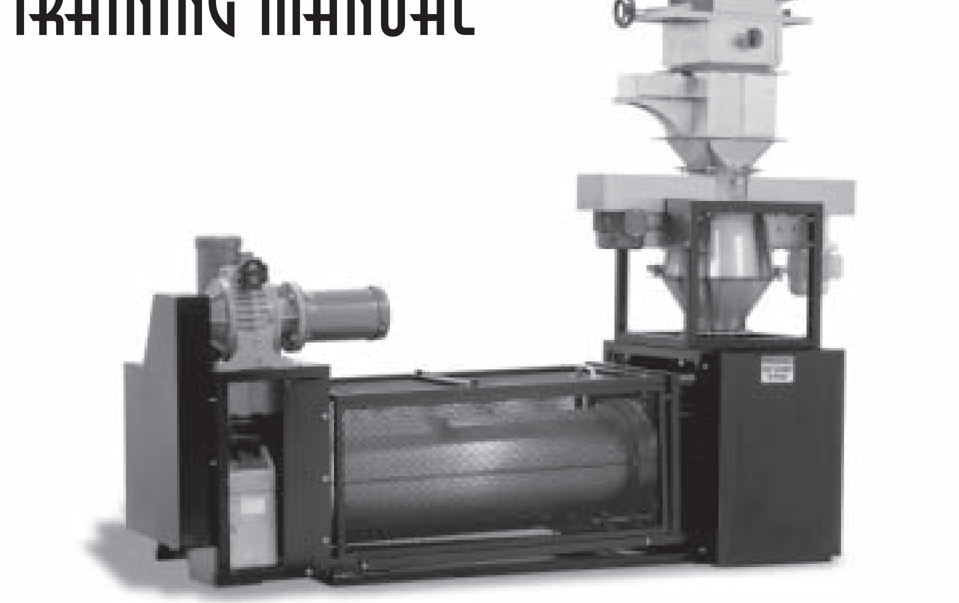
SEED TREATMENT

OREGON PESTICIDE APPLICATOR TRAINING MANUAL



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SEED TREATMENT

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Poison Center

The Poison Center has been established to provide information about the treatment of poisoning cases. Anyone with a poisoning emergency can call the toll-free telephone number for help 24 hours a day. Personnel at the Poison Center will give first-aid instructions and direct you to local treatment centers if necessary.

Telephone: 1-800-222-1222

Note: For immediate medical assistance and transport, please dial "911" directly.

Spill Assistance

For major spills, Oregon law requires that emergency notification be made to the Oregon Emergency Response System (OERS). They in turn notify the appropriate agencies for response. Their 24-hour emergency hotline number is (800) 452-0311 or (503) 378-4124

National Pesticide Information Center

National Pesticide Information Center (NPIC) is a toll-free telephone service that provides pesticide information to any caller in the United States, Puerto Rico, or the Virgin Islands. NPIC provides objective, science-based information about a wide variety of pesticide-related subjects, including pesticide products, recognition and management of pesticide poisoning, toxicology, and environmental chemistry.

Excluding holidays, you can call NPIC seven days a week from 8:30 a.m. to 6:30 p.m. (CST) at (800)858-7378. You can also contact NPIC by fax (541-737-0761) or by e-mail (npic+@ace.orst.edu).

Urbana, Illinois November 2001

Issued in furtherance of Cooperative Extension Work, Acts of May 8 and June 30, 1914, in cooperation with the U.S. Department of Agriculture. Dennis R. Campion, Director, University of Illinois Extension, University of Illinois at Urbana-Champaign. University of Illinois Extension provides equal opportunities in programs and employment.

CONTENTS

PREFACE

This manual was jointly prepared by the University of Illinois and Purdue University Extension Pesticide Applicator Training (PAT) programs and adapted for use in Oregon by the Oregon Department of Agriculture. It contains information that you must know to become certified as a Pesticide Applicator in the Seed Treatment Pest Control category. Although there are many pests that affect seeds and seedlings, this manual focuses on the major pests of interest to most seed treatment professionals.

Pesticides play an important role in managing pests. They protect plants and animals from insects, weeds, and diseases; prevent damage to houses and other buildings; improve the efficiency of food, feed, and fiber production; and provide for more comfortable living. But all pesticides must be treated as that may endanger people, pets, livestock, plants, and the environment.They should be used only when appropriate, applied correctly, stored safely, and disposed of properly.

The PAT program benefits the applicator and the general public. By learning how to handle and use pesticides correctly, applicators are able to protect themselves, others, and the environment from adverse effects of pesticides.In doing so, they will help to ensure the continued use of and benefits from pesticides as an option in pest management.

Acknowledgments

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The following sources were used in the preparation of this manual:

- Seed Treatment Pesticide Application Training. Kansas State Cooperative Extension.
- Seed Treatment: A Study Guide for Seed Treaters. MISC0199. Cooperative Extension. Washington State University.
- Iowa Commercial Pesticide Applicator Manual. Category 4. Seed Treatment. CS 16. Iowa State University Extension.
- Seed Treatment for the Commercial/Noncommercial Pesticide Applicator (Category 06). University of Nebraska–Lincoln. Cooperative Extension. Institute of Agriculture and Natural Resources.
- Report on Plant Disease fact sheet series, Department of Crop Sciences, Urbana, IL.
- Field Crop Scouting Manual. University of Illinois Extension.
- Plant Disease Compendium series (diseases of corn, soybeans, wheat, tomato, beans, etc.). The

CHAPTER ONE:
OVERVIEW OF SEED TREATMENTS

Since ancient times, farmers have fought disease and insect pests. Beginning more than 300 years ago, seed treatments were added to the arsenal of pest control weapons. The first seed treatments were simple inorganic chemicals, such as brine or lime solutions. Through a combination of accident and trial and error, they were found to reduce the incidence of wheat stinking smut (common bunt). In the early 1800s copper sulfate solution was found superior to lime in controlling bunt. In the 1920s, copper carbonate dust began to replace copper sulfate dips because it was more convenient and safer for the seed.

In the 1930s, organic mercurial seed treatments achieved great success against a number of seedborne 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 nonsystemic, organic chemical fungicides and insecticides were developed. Beginning in the 1960s and 1970s, several groups of systemic organic chemical seed treatments were produced. In the 1980s and 1990s, researchers developed the first biological seed treatments based on biocontrol with living microorganisms.

WHAT IS A SEED TREATMENT?

For the purposes of this manual, seed treatments are defined as chemical or biological substances that are applied to seeds or vegetative propagation materials to control disease organisms, insects, or other pests. Seed treatment pesticides include bactericides, fungicides, and insecticides. Most seed treatments are applied to true seeds, such as corn, wheat, or soybean, which have a seed coat surrounding an embryo. However, some seed treatments can be applied to vegetative propagation materials, such as bulbs, corms, or tubers (such as potato seed pieces).

WHAT IS NOT A SEED TREATMENT?

Seed-applied growth regulators, micronutrients, and nitrogen-fixing Rhizobium and Bradyrhizobium inoculants are not included because they are not intended for pest control. Treatments designed to protect stored food or feed grain are considered grain treatments rather than seed treatments. Pest control in stored grain and storage facilities requires additional licensing.

BENEFITS AND RISKS

Seed treatments are used on many crops to control a variety of pests. Seed treatments are commonly used to ensure uniform stand establishment by protecting against soilborne pathogens and insects. In fact, they are considered so essential for corn stand establishment that virtually all corn seed is treated. Seed treatments have had phenomenal success in eradicating seedborne pathogens, such as smut or bunt, from wheat, barley, and oats. Seed treatments can be used to suppress root rots in certain crops. Finally, some newer systemic seed treatments can supplement or may provide an alternative to traditional broadcast sprays of foliar fungicides or insecticides for certain early-season foliar diseases and insects.

Although seed treatments have important benefits, they also pose certain risks. One risk is accidental exposure of workers who produce or apply seed treatments. Another risk is contamination of the food supply by accidental mixing of treated seed with food

Factors that favor the use of seed treatments:
- Field is for seed production.
- Low test weight or older seed.
- Planting in unfavorable germination conditions, such as dry soil or cold soil.
- Planting into fields with a history of stand establishment problems.
- Planting to precise populations.
- Replanting will not be feasible if first planting fails.
- Seed is expensive.
- Seed thought to carry certain seedborne pathogens.
- Yield potential of field is high.

or feed grain. A third risk is accidental contamination of the environment through improper handling of treated seeds or seed treatment chemicals. All of these risks can be minimized by proper training and proper use of seed treatment pesticides.

INTEGRATED PEST MANAGEMENT

Seed treatments should be considered as tools in an integrated pest management (IPM) plan. IPM is the use of a combination of cultural practices, host resistance, biological control, and chemical control methods to simultaneously (1) minimize economic losses due to pests, (2) avoid development of new pest biotypes that overcome pesticides or host resistance, (3) minimize negative effects on the environment, and (4) 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.

To use seed treatments effectively, it is important to understand the purposes of seed treatment, alternatives or supplements to seed treatments, and the various advantages and disadvantages of seed treatments.

PURPOSES OF SEED TREATMENT

Control of Seedborne Pathogens

Seedborne, disease-causing pathogens may occur on the surface of seed, hidden in cracks or crevices of seed, or as infections deep inside the intact seed. These pathogens may be important for three reasons. First, some pathogens do not survive in soil or crop residue and are dependent on the seedborne phase for survival between crops. An example is the fungus that causes loose smut of wheat. Second, even if a pathogen can survive in soil or residue, being seedborne may allow it to get a head start and, thus, result in more severe disease. An example would be the fungus that causes Septoria leaf blotch of wheat. Third, seedborne pathogens may hitch a ride to new localities in seed shipments (such as the fungus that causes Karnal bunt of wheat or the bacterium that causes black rot of crucifers).

Seed treatments can often be used to control 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 nonsystemic (contact) fungicides can eliminate surface contamination of wheat seed by spores of the common bunt fungus. However, the fungus causing loose smut of wheat is borne within the seed embryo and cannot be controlled with a contact fungicide. In that case, a systemic fungicide is required to control the internal pathogen.

Protection of Seeds and Seedlings

Seeds and seedlings are vulnerable to many soilborne and foliar pests. Insects and pathogens can destroy germinating seeds and young plants, which are relatively tender and lack food reserves to recover from injuries or to survive extended periods of stress. Examples of stress include heavy rains, crusted soils, compaction, deep planting, cool soil, very dry soils, and some postemergence herbicides. Under stressful conditions, a number of aggressive or even fairly weak pathogens can become active and cause plant population and yield losses.

Seed treatments can protect the seed and seedling from attack by certain insects and pathogens. Nonsystemic fungicides or insecticides form a chemical barrier over the surface of the germinating seed. This barrier protects the germinating seed from chewing insects, such as wireworms, or soilborne pathogens, such as pythium. Certain systemic seed treatments can protect aboveground parts from sucking insects, such as aphids, or foliage diseases, such as rust. Systemic fungicides and biological seed treatments can also protect young plants from root rot. Although the duration of protection may be limited, a delay in infection can reduce the losses. For chronic diseases, such as root rots, the earlier that the infection takes place, the greater will be the damage.

Typically, seed treatments will last only about 10 to 14 days beyond planting, with pesticide breakdown being most rapid under warm, moist conditions. However, certain active ingredients can protect seedlings considerably longer when applied at the highest labeled rate.

Alternatives or Supplements to Seed Treatment

Usually, seed treatments are not the only available method to control a particular pest. Seed treatments should be compared to alternative pest control measures for cost, efficacy, safety, and so on. Often, no single pest control method provides sufficient control. Seed treatments can often be supplemented with other control measures to achieve satisfactory results.

Certified seed. Certified seed is checked for the presence of certain seedborne diseases. Therefore, treatments for seedborne pathogens may be unnecessary with certified seed.

Crop rotation. Crop rotation reduces the populations of many insects and 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 an excess of major nutrients, such as nitrogen, can favor certain diseases. Maintaining appropriate soil fertility can reduce disease pressure.

Heat treatment. Hot water treatment can be used to rid seeds of certain seedborne pathogens while leaving the seed viable. For example, the fungi that cause black leg, downy mildew, and anthracnose of cabbage can be eradicated by soaking seed at 122°F for 25 minutes. This treatment will also eliminate the bacteria that cause black rot. Immediately after treatment, seed must be cooled in cold water for several minutes. Then seed must be dried. Procedures must be carefully followed. If the water is too cool, the seedborne pathogens will not be killed. If the water is too warm, the seed may be injured or killed. Because it is difficult and impractical for some seed types, 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, pythium root rot, and barley yellow dwarf are diseases that can be affected by planting date.

Soil-applied and postemergence sprays. Although seed treatments are convenient and have environmental and economic advantages over soil-applied and postemergence broadcast insecticides and fungicides, for a number of reasons they cannot effectively control every damaging pest.

Variety resistance. Variety resistance may be available for certain pests. Examples include Hessian fly on wheat, Phytophthora on alfalfa and soybean, and powdery mildew on wheat. Seed treatments may be unnecessary when high varietal resistance is available. For example, use of sweet corn hybrids with high resistance to Stewart's bacterial wilt makes seed treatment insecticides less necessary. However, seed treatments may be an important supplement when resistance is either weak, race specific, or inactive until sometime after seedling emergence.

Volunteer control. Several insects and diseases use volunteer (self-sown) crop plants as a reservoir. Eliminating volunteer wheat can reduce populations of Hessian fly, aphids, rust, and the like.

Advantages of Seed Treatment

- Seedborne pathogens are vulnerable. The seedborne phase is often the weak link in the life cycle for many plant pathogens. Using seed treatments to control seedborne pathogens is often very effective for disease control.
- Precision targeting. Seed treatments are not subject to spray drift. Because chemicals are applied directly to seeds, little is wasted on nontarget sites, such as bare soil.
- Optimum timing. Seeds and seedlings are generally more vulnerable to diseases and insects than mature 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 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. Treated seed looks like food to some animals. Hungry livestock that find carelessly handled treated seed will probably eat it. Birds, such as pheasants or quail, may consume spilled treated seed. Even young children may find and eat improperly stored treated seed.
- 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. Seed coating technologies are helping to overcome this limitation, but phytotoxicity may still be a problem.
- 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. This is a particularly serious limitation for seeds such as soybean, where seed germination and vigor decline relatively quickly.
- Phytotoxicity. Pesticide injury to plant tissues is called phytotoxicity. Since seed treatments must exist in high concentrations on the tender tissues of germinating seeds and seedlings, they generally have very low phytotoxicity. A few seed treatments

are partly phytotoxic when applied at high rates. Lower germination and/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. In the course of treating and handling large volumes of seed, workers may be exposed to seed treatment chemicals as aerosols. Inhalation of aerosols and skin contact with seed treatments must be prevented in the seed treatment process.

CHAPTER TWO:
SEED AND SEEDLING PESTS

Seed treatment labels often list the specific type of insects, pathogens, or general pest groups (for example, soilborne fungi) controlled. Understanding the different types of pests and where and when they attack will help in selecting the appropriate seed treatment(s). When evaluating a seed treatment, consider the fact that many pathogens and insects are not adequately controlled with current seed treatment products due to one or more of the following product limitations: (1) pesticides with appropriate activity are not available, (2) little or no systemic activity in the plant tissues, (3) limited or no product movement into the expanding root zone, (4) limited product duration—peak periods for pest protection and pest infection/damage do not significantly overlap, or (5) effective rates may simply be too expensive or may be phytotoxic to the seed or seedling. Where these limitations exist, pests may be better controlled using genetic resistance, a soil-applied pesticide, or other pest control strategy.

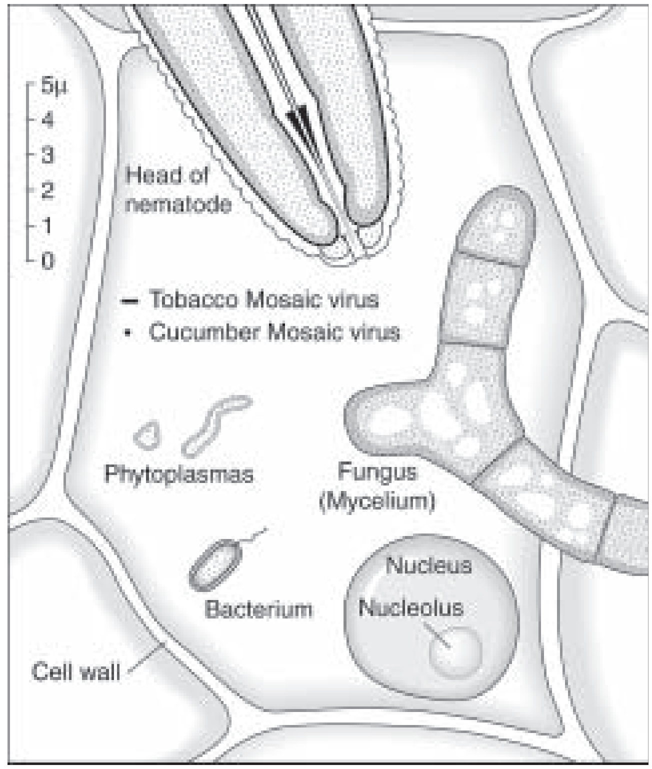


Figure 2.1 Shapes and sizes of certain plant pathogens compared to a plant cell.

SEED AND SEEDLING DISEASES

Fungal Diseases

Fungi (singular = fungus) are small (usually microscopic) organisms made of filaments called hyphae (Figure 2.1). 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 reproduce by microscopic spores; this allows them to be spread by wind, rain, insects, seeds, farm equipment, and runoff water or soil. Some plant-pathogenic fungi (for example, many causing leaf spots/blights) cannot survive in the soil for long periods and can be effectively managed through “clean plowing” and crop rotation. However, other fungi, such as most root and stem rot pathogens, are soil inhabitants and survive well despite our efforts to “starve them out” through crop rotation. Seed treatments can be used to control or suppress many seedborne, soilborne, and early-season foliar fungal diseases. The following paragraphs describe a few of the common fungal diseases.

Common bunt (also called stinking or covered smut) is caused by a fungus that infects the wheat coleoptile (sheathlike tissue that protects emerging leaves) before emergence. Once inside the plant, the fungus eventually moves into the developing head and replaces the developing kernels with fragile bunt balls containing masses of fishy smelling, dark powdery fungal spores. During harvest, the bunt balls get crushed, contaminating grain kernels and the soil. Infected plants are slightly stunted, often have increased tillering, and the heads usually remain bluish green longer than those on healthy plants. Common bunt may be controlled by the use of resistant varieties, clean seed, and seed treatment fungicides.

Foliar diseases of wheat, such as powdery mildew, rust, and septoria, may increase rapidly during favorable weather in the fall and again in the spring. Certain systemic fungicide seed treatments provide protection from these diseases in the fall and possibly through to spring. Powdery mildew causes cottony white fungal growth on leaves, stems, and reproductive parts. Rust pustules are typically orange and consist of thousands of spores erupting through the plant epidermis. Septoria (or Stagonospora) forms irregular, tan to reddish brown blotches with gray-brown to ash-colored centers, often surrounded by a yellow margin.

Fusarium and several closely related pathogens are able to infect and damage many broadleaf and grass seeds and seedlings. Symptoms on corn seedling roots range from a very slight brownish or dark black discoloration to completely rotted roots. Damage to soybean seedlings by Fusarium is usually uncommon unless the germinating seed and seedling are stressed (for example, due to cool or dry soils). Infections result in slow growth and stunting due to a generalized brown to black discoloration and deterioration of the root system. Cotyledons of seedlings may become yellow and later die and drop off. Seedlings infected with Fusarium die. Wheat seedling blight is usually due to seedborne inoculum (seeds from heads affected by scab). In such cases, seedlings may be killed before or soon after emergence, or they may be stunted and off color with brown lesions on the roots, crown, and coleoptile. Soilborne inoculum rarely causes seedling blight but can damage wheat seedlings in warm, dry soils. Advanced symptoms include constriction and blackening of the subcrown internode, yellowish basal leaves with brown lesions, reduced tillering, and premature ripening.

Loose smut is unique in that the fungus lies dormant and invisible within the embryo of infected wheat seeds. When infected seeds germinate, the fungus is activated and progresses, along with the developing plant. Infected plants produce masses of uncovered powdery black spores instead of seed. Smutted wheat heads emerge slightly before healthy heads; they are clearly visible in the field. The spores from infected heads are blown by the wind to infect newly opened wheat flowers. Infected kernels are symptomless but produce smutted plants the next year. Use of certified wheat seed is an effective way to avoid problems with loose smut. There are many different smuts and bunts that affect wheat and corn, but not all of them can be controlled using seed treatment fungicides. For example, common smut of corn bypasses the protective effect of a seed treatment because it survives in crop debris and soil and is blown to upper plant parts.

Pythium and Phytophthora (often called "water molds" because they produce a swimming spore when the soil is wet) produce a soft rotting of the seed, or damping-off, before or after emergence. With damping-off of broadleaf seedlings, a dark brownish or blackish soft rot of the roots and lower stem kills the plant. In grasses and broadleaf, infected roots lack root hairs and have soft and wet yellow-brown root tips. There are many different Pythium species able to infect a wide range of broadleaf and grass seeds and seedlings under both cool and warm soil temperatures. Phytophthora, on the other hand, is mostly restricted to a few broadleaf crops. Phytophthora is particularly damaging to soybean and alfalfa seedlings and can continue to infect and kill plants through much of the growing season. Even when using a resistant or tolerant variety, there are three reasons why it may be worthwhile to use an effective seed treatment where early-season Phytophthora has been a problem: (1) true resistance is not effective against all races of the pathogen; (2) tolerant varieties offer a broad but general type of resistance that may not be activated until 10 to 14 days after emergence; and (3) the seed treatment will also protect against pythium.

Rhizoctonia may damage many different crop seeds and seedlings but may be best known for its effects on soybean. The pathogen is not particularly aggressive and causes most damage in fields where stressing factors (such as hot and dry soils during emergence, soil compaction, or herbicide toxicity) affect early-season growth and development of a satisfactory root system. Rhizoctonia may damage or kill sprouted soybean seed outright. In addition, damping-off may occur a few days after emergence. Lesions appear at the base of the seedling stem and on roots just below the soil line. These may enlarge into a sunken lesion, usually brown, dark brown, or reddish in color. Decay may continue intermittently throughout the season, with continuing loss of plants. On wheat, the pathogen causes reddish brown lesions, which girdle and prune individual roots and rootlets. When severe, affected plants are stunted and exhibit symptoms of drought or nutrient deficiency. The disease is sometimes localized in fields, resulting in distinct bare or purple patches. Crop maturity can be delayed.

Sclerotinia (also known as white mold) is not an important seedling pathogen, but research has shown that it can be moved from field to field via infected (even symptomless) soybean seed lots. Where a seed treatment is not used, a small percentage of the Sclerotinia-infected seeds will be transformed into a survival structure (sclerotium), which can survive in the soil for up to five years. Under cool, moist conditions, these structures will become active, releasing spores into the soybean canopy to initiate the foliar disease called Sclerotinia white mold. If a white fluffy growth and small black sclerotia should appear during a warm germination test, use an effective seed treatment.

Bacterial Diseases

Bacteria (singular = bacterium) are microscopic, single-celled organisms that reproduce by division (Figure 2.1). Like fungi, most bacteria are beneficial, with only a few types causing plant disease. Bacteria cannot move on their own and depend on wind, animals, insects, farm equipment, seed, splashing rain, and other means to get to host plants. Bacteria can only enter the plant through wounds or small natural openings, where they may cause either local or systemic infections. Symptoms of bacterial infection include wilting, soft rots, leaf blights, and spots. Many different bacterial pathogens can be seedborne. Some bacterial diseases can be controlled or suppressed, either directly or indirectly, with seed treatments.

Common bacterial blight, halo blight, and bacterial brown spot are the three major bacterial diseases of beans. Early-foliar symptoms are small, angular, light green, water-soaked or translucent spots. As the spots mature, the centers become dry and brown, and are surrounded by a distinct, narrow zone of yellow tissue. Halo blight lesions are surrounded by a relatively wide, diffuse, pale green to yellow coloration (halo). Pod lesions begin in much the same way as leaf lesions but mature to form sunken, irregular, frequently reddish brown blotches or lesions. The disease cycles of all three pathogens are similar. The bacteria, which may survive for 6 to 18 months in plant residue on the soil surface, are spread in infected seed and from plant to plant and field to field in many ways, including wind-driven and splashing rains, overhead irrigation, surface-drainage water, and farm machinery. One seed in 16,000 is thought to be sufficient to supply inoculum for a severe outbreak of halo blight where essentially every plant in a field becomes infected.

Stewart's bacterial wilt is a bacterial disease of corn (predominantly sweet corn hybrids but also susceptible dent corn inbreds) that is spread by overwintering, foliage-feeding corn flea beetles. Infected leaves develop long, yellowish streaks that run parallel to the leaf veins. Systemically infected seedlings usually wilt and may resemble drought, nutritional deficiency, or insect-feeding symptoms. In addition, the center of the seedling crown often develops a chocolate-brown, soft, rotted cavity. Seedlings may wither and die.

Viral Diseases

Viruses are submicroscopic infectious particles (Figure 2.1) (consisting of protein and DNA or RNA) that can be seen only with an electron microscope or identified using specialized testing methods. Like bacteria, viruses cannot move on their own and are most commonly spread ("vectored") by insects, such as aphids and leafhoppers, as well as by seed and plant propagation. A few viral pathogens (such as wheat soilborne mosaic virus and wheat yellow mosaic virus) are vectored by soilborne fungi. Viral diseases are usually systemic, and symptoms include discoloration (mosaics, mottles, ringspots), stunted or unusual growth, and poor development. These symptoms are frequently confused with nutrient deficiencies, pesticide or fertilizer injury, insect or mite activity, or other types of diseases. Table 2.1 describes several major virus diseases of winter wheat.

There are no pesticides for the control of plant viruses; however, certain systemic insecticides can control the insect vectors (usually aphids) that carry viruses from host to host. Vector control is effective in reducing virus spread only if the virus is transmitted in a persistent manner (BYDV is an example). Persistent transmission means that the virus accumulates within the vector and can be transmitted for several days or more after being acquired from a source plant. Vectors of persistently transmitted viruses tend to feed at one location for a considerable amount of time, making them more likely to succumb to the insecticide. Because of the short time needed to acquire and transmit nonpersistent (styletborne) viruses, insecticides are ineffective in preventing their transmission (examples include watermelon mosaic virus [WMV] in cucurbits and cucumber mosaic virus [CMV] in vine crops, peppers, and tomatoes).

Delayed planting also helps to reduce the impact of barley yellow dwarf virus and wheat streak mosaic virus by breaking something called the "green bridge," or the overlap in growing season, between two host crops, such as corn and winter wheat.

INSECT PESTS

Insecticide seed treatments can be used to control or suppress various insects that attack seeds or below- or aboveground seedling tissues. As with disease pests,

Table 2.1. Comparison and management of winter wheat viral diseases

	Barley yellow dwarf virus (BYDV)	Wheat streak mosaic virus (WSMV)	Wheat soilborne mosaic virus (WSBMV)	Wheat yellow mosaic virus (WYMV)*
Vector	A variety of aphids, some of which are blown in from the south.	Wheat curl mite (*Aceria toschella*).	A soilborne fungus (*Polymyxa graminis*)	A soilborne fungus (*Polymyxa graminis*)
Time of infection	Fall and spring; spring infections usually do not affect yield significantly.	Fall infections are frequent, but rarely develop before spring.	Important infections take place during cool, wet periods in the fall.	Important infections take place during cool, wet periods in the fall.
Typical field pattern	Field borders are often affected first, but large patches may develop anywhere in the field.	Field borders are affected first, and sometimes are the only areas affected.	May be uniform, but typically associated with low-lying areas.	Typically more uniform than WSBMV.
Plant symptoms	Seedling infection: winter kill, stunted growth, reduced tillers, older leaves brilliant yellow. Postseedling infection: fairly uniform yellow, red or purple leaf coloration.	Light green to faint yellow leaf blotches, dashes or streaks parallel to the leaf veins. Leaf edges often curl upward and inward. Stunted growth and sterile or partially sterile heads.	Moderate to severe stunting; leaves are typically twisted and colored from mild green to prominent yellow; leaf sheaths and new leaves appear mottled and develop parallel dashes and streaks.	Leaves have yellow-green mottling and develop parallel dashes and streaks like WSBMV. However, WYMV streaks have tapered ends, which resemble spindles. Later, the yellow-green areas become brown or reddish.
Recovery with warm weather	No	No	Yes, but symptoms remain in older leaves.	No
Other known hosts ("green bridge" plants)	Grasses and volunteer crops, such as corn and wheat.	Grasses and volunteer crops, such as corn and wheat.	Rye, barley and hairy bromegrass.	None known.
Management	Most varieties have intermediate resistance. Plant after the fly-free date in your area. Certain insecticide treatments may reduce BYDV by controlling aphid vectors.	Few varieties with decent resistance. Plant after the fly-free date in your area. No evidence to suggest insecticides will control the mite vector and WSMV.	Varieties tend to be either highly resistant or highly susceptible. Use crop rotation to reduce excessive vector and pathogen buildup.	Varieties tend to be either highly resistant or highly susceptible. Use crop rotation to reduce excessive vector and pathogen buildup.

*Wheat yellow mosaic virus was formerly known as wheat spindle streak mosaic virus (WSSMV).
Source: Bruce Paulsrud, University of Illinois Extension (2000)

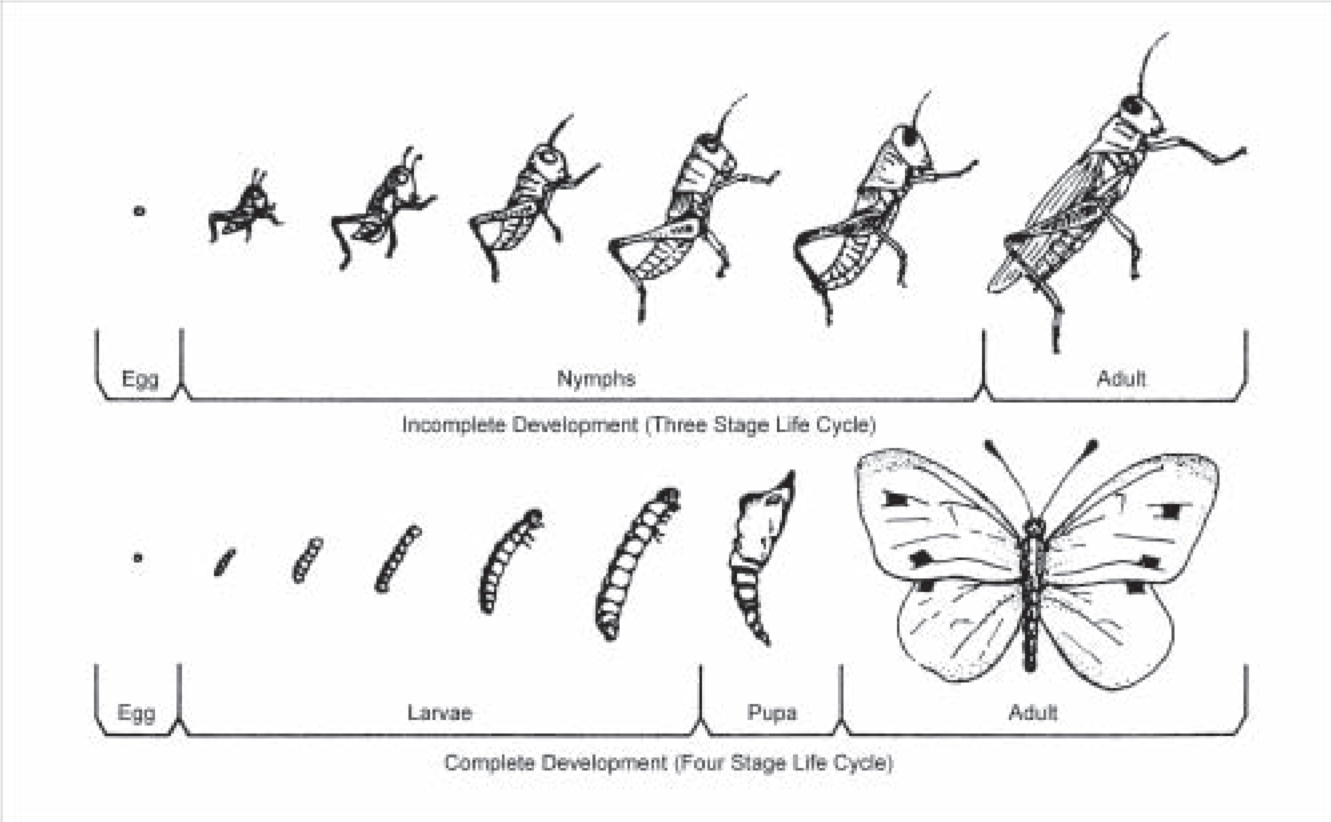


Figure 2.2. Life cycles of insects.

understanding the different types of insects and where and when they attack will help in selecting the appropriate seed treatment(s).

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 abdomen. Insects have either incomplete or complete metamorphosis (Figure 2.2). Insects with incomplete metamorphosis have three life stages: egg, nymph, and adult. Nymphs look very 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. Insects with complete metamorphosis have four life stages: egg, larva, pupa, and adult. Larvae are unable to reproduce, are wingless, and usually look very different from the adults. In fact, 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. 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.

Mouthparts, wings, and legs vary considerably among insects and are useful features for identification. Many fly maggots' mouthparts are simple hooks, beetles and their larval grubs have chewing mouthparts, and 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 insect's legs may reveal information about the nature of the insect: "Is it friend or foe?" For example, many predatory insects, such as ground beetles, mantids, damsel bugs, and assassin bugs, have grasping front legs useful for capturing other insects.

Soilborne Insects

Corn rootworm: Mature rootworm larvae are white and slender, about 1/2 inch long, have a brown head and a dark plate on the top side of the terminal segment. Larvae tunnel into corn roots from early June until late July. Lodging of corn plants due to root pruning is a typical symptom of damage. For many years, corn rootworm populations have been managed effectively using crop rotation; however, this management strategy is no longer be effective in certain areas. Under low corn rootworm pressure, seed treatment insecticides may provide some benefit, but where scouting indicates the potential for high corn rootworm pressure, a soil-applied insecticide should be considered.

Onion maggot: Onion maggots resemble seedcorn maggots, to which they are closely related. They are frequently destructive pests in the northern half of the United States. The larvae tunnel in the roots of onion and other related crops. Their feeding can result in the loss of seedlings and allow disease entry in older onions. Insecticide treatments are sometimes used to protect onion sets from attack by onion maggots.

Seedcorn beetle and slender seedcorn beetle: While many insects are damaging in their larval (or wormlike) stage, with these two species, the adults are injurious because they feed on germinating seed of many crops. Adult seedcorn beetles are approximately 1/4 inch in length and dark brown with a lighter, tannish colored border that extends around the margins of the wing covers. The slender seedcorn beetle is dark, shiny red, and appears flattened and elongated. The wing covers are wider than the thorax and do not have the black stripes evident on the seedcorn beetle. The adults often are seen crawling on the soil surface in fields of corn during the spring and early summer. Occasionally, large local populations develop. During such times the beetles may attack the seed sufficiently to result in significant stand loss. Damage is mostly to spring-planted crops. The probability of damage by these beetles may be increased during periods of cool, wet weather following planting. Related beetle species in this family are all predaceous and, therefore, beneficial. This is also true of seedcorn beetle larvae.

Seedcorn maggot: In its adult stage, the seedcorn maggot is a small, grayish to brownish fly that resembles a house fly but is somewhat smaller. Adults appear early in the spring and lay eggs on moist soil; fields that have a high organic-matter content or that have been heavily manured are most at risk. In its damaging stage, the seedcorn maggot is a pale, yellowish white, tapered (somewhat like a carrot), cylindrical maggot. It is legless, pointed at the front without a distinct head, but with small black mouth hooks. Mature larvae are slightly less than 1/4 of an inch in length. Maggots feed and burrow into the seed and destroy the germ. Some injured seeds that do germinate are stunted, weakened, and soon die. Several generations develop over the course of a year, although the first generation of the spring is the only one that is generally of economic importance. Seedcorn maggots are known to damage corn, cucurbits, green beans, and soybean crops.

White grubs: There are several species of white grubs but all look similar and feed below ground on the roots of corn and many other crops. White grub larvae are white to yellow in color, are larger than seedcorn maggots, have an obvious head capsule, and have three prominent pairs of legs. Root feeding may result in stunted, purple plants that exhibit nutrient deficiency symptoms. White grub damage can be significant but is usually limited to small areas of a field. Rescue or post-emergence treatments for white grubs are ineffective.

Wireworms: Wireworms are fairly common pests of corn, soybean, vegetables, and sometimes small grains. Many species of wireworms are pale yellow in color when small and become reddish brown as they approach an inch in length. Wireworms are shiny, wirelike, click beetle larvae and can live up to five years or more in the soil before completing their life cycle. The larvae cause damage by boring into the germinating seed or into the base of the seedling. Damage is often sporadic but tends to occur following small grain crops, sod, or pastures. Rescue treatments after damage is apparent are ineffective. Light infestations can be controlled by seed treatment, but where high populations are predicted or where damage justifies replanting, a soil-applied insecticide should be considered.

Foliage insects

Aphids: There are many different species of aphids that feed on and damage a wide range of plants. Aphids are small, pear-shaped, soft-bodied insects up to 1/8 inch long, usually with two tubes (cornicles) near the rear of the abdomen. Aphids are commonly green but can be any color; the nymphs are similar to the adults but smaller. During the summer under high temperatures, aphids may go through a life cycle in less than a week, resulting in a rapid population increase. Aphids feed by sucking juices from leaves with their needlelike mouthparts. Greenbugs (a specific type of aphid) are considered a more serious pest because their saliva contains a plant toxin that causes stunting and reduced yield. Several aphid species can cause indirect injury by transmitting plant viruses, such as (1) barley yellow dwarf virus (BYDV) in small grains, (2) watermelon mosaic virus (WMV) in cucurbits, and (3) cucumber mosaic virus (CMV) in many hosts. As previously mentioned (see “Viral Diseases”), certain systemic seed treatment insecticides have been shown to be effective against aphids and, thus, in reducing certain early-season viral infections.

Chinch bug: Historically, the chinch bug was a very damaging insect pest to corn, but in recent years has been a minor pest. Adult chinch bugs overwinter on clump grasses and migrate to small grains early in the spring to produce the first generation (there are two generations per year). As the small grains mature, the red-and-white or black-and-white, wingless nymphs crawl to adjacent fields of corn where they concentrate on the lower leaves at the base of the stalk. Under drought-stress conditions, they may be found on the stem and roots below ground. When infestations are intense, the whole plant may turn white and wilt. Generally, such infestations are concentrated along the field edges nearest maturing small grain crops.

Colorado potato beetle: The adult Colorado potato beetle is about 1/2 inch long and yellow with brown stripes. The larva is orange to red with black spots and can be 1/2 inch long when full grown. It overwinters as an adult. The larva and adult eat the leaf margins and entire leaves of potato, pepper, tomato, and eggplant. Certain systemic insecticides can be used as potato seed piece treatments to protect the foliage from Colorado potato beetle feeding.

Corn flea beetle: There are many species of flea beetles that may damage the foliage of sweet corn, eggplant, radish, bean, potato, tomato, and pepper. The corn flea beetle adult is a very small (1/16 to 1/8-inch-long) black beetle that jumps and flies when disturbed. Adults first appear in the spring as they emerge from their grassy overwintering sites; they are more numerous following a mild winter. Damage by the adults appears as scratches on the upper and lower leaf surfaces, usually parallel to the veins. The leaves of severely injured plants appear whitish or silvery. In the process of feeding, the corn flea beetle may also transmit Stewart's bacterial wilt to sweet corn (see previous discussion under "Bacterial Diseases"). Certain systemic seed treatment insecticides have been shown effective against corn flea beetles and, thus, in reducing early-season Stewart's bacterial wilt.

Hessian flies: Female Hessian flies emerge from wheat stubble in late summer and early fall and deposit eggs on the leaves of young winter wheat plants or volunteer wheat. Larvae mature to the pupal stage by midautumn, then overwinter as flaxseeds (puparia), from which next spring's adults will emerge. Larvae feed between leaf sheaths and stems and cause the plants to become dark green, stunted, and brittle. Hessian flies cause damage to wheat in the spring and fall. Certain systemic seed treatment insecticides have been shown effective against Hessian flies.

BIRDS AND RODENTS

Several species of birds and rodents may eat or uproot planted seeds and seedlings. Blackbirds and pheasants are the most common bird pests of planted seeds. Field mice and prairie voles may cause problems in fields planted near wooded areas and under no-till conditions where the rodent "runs" are not disturbed. For birds and rodents, the aboveground symptoms of damage are missing plants and reduced stands.

The State of Oregon protects all birds, except starlings, house sparrows, and feral (wild) pigeons, and most mammals, except commensal rodents (those that live with humans). Federal law protects all birds, except starlings, house sparrows, and feral pigeons, with the provision that blackbirds and crows be controlled only when they cause damage. Before you attempt to control any birds or mammals, protected or otherwise, contact the Oregon Department of Fish and Wildlife at (503) 947-6000 to request current information about legal, safe, and effective control methods (if any) and obtain any permit(s) that may be required.

CHAPTER THREE:
SEED TREATMENT PRODUCTS AND SAFE 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 has strengths and weaknesses, which is why many seed treatments consist of one or more active ingredients. The degree of pest control often depends on the dose rate of the active ingredient. Some pests may require higher rates than others to achieve control. Some seed treatment labels give a range of rates and indicate pest control responses that are expected for each rate. The applicator must choose the product(s) and rate appropriate for the crop, anticipated pest problem, and the application equipment.

When evaluating a seed treatment, consider the fact that many pathogens and insects are not adequately controlled with current seed treatment products due to one or more of the following product limitations: (1) pesticides with appropriate activity are not available, (2) little or no systemic activity in the plant tissues, (3) limited or no product movement into the expanding root zone, (4) limited product duration, which means peak periods for pest protection and pest infection/damage do not significantly overlap, or (5) effective rates may simply be too expensive or may be phytotoxic to the seed or seedling. Where these limitations exist, pests may be better controlled using genetic resistance, a soil-applied pesticide, or other pest control strategy.

ACTIVE INGREDIENTS

Active ingredients (commonly abbreviated as "a.i.") are often divided into those that are systemic and those that are nonsystemic (contact). Systemic seed treatments penetrate the roots and germinating seed, then move up into stems and leaves. Contact seed treatments protect only the outside of the seed or seedling. Following are some common seed treatment active ingredients, organized by the type of pest protection offered. ***The information provided here is not complete; be sure to read the product label for activity and current legal uses.***

Bactericides

Streptomycin (trade names Ag-Streptomycin and Agri-Mycin) is an antibiotic that kills a broad spectrum of bacteria. It can be used to control seedborne 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 microorganisms 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. Biocontrol organisms include the bacteria *Bacillus subtilis* (trade name Kodiak) and *Streptomyces griseoviridis* (trade names Mycostop, Subtilex, System 3), and the fungus *Trichoderma harzianum* (trade names T-22, Bio-Trek).

Captan is a broad-spectrum, nonsystemic fungicide effective against various seed decay and damping-off fungi, such as Aspergillus, Fusarium, Penicillium, and Rhizoctonia.

Carboxin (trade name 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 by the loose smut fungus. Carboxin is commonly formulated with other fungicides or insecticides to increase the pest control spectrum.

Difenoconazole (trade name 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 (trade name Maxim) is a broad-spectrum, nonsystemic fungicide effective against various seed decay and damping-off fungi, such as Aspergillus, Fusarium, Penicillium, and Rhizoctonia. In addition, it performs well against seedborne wheat scab.

Imazalil (trade name Flo-Pro IMZ) 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.

Mefenoxam (trade name Apron XL) and metalaxyl (trade names 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 or fludioxonil.

PCNB (also called pentachloronitrobenzene) is a nonsystemic 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 seedborne wheat scab. Tebuconazole is commonly formulated with other fungicides or insecticides to increase the pest control spectrum.

Thiabendazole (also called 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 seedborne wheat scab. Thiabendazole is commonly formulated with other fungicides to increase the disease control spectrum.

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

Triadimenol (trade name 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

Chlorpyriphos (trade name Lorsban) is a nonsystemic insecticide useful against soilborne insects, such as seedcorn maggot and seedcorn beetle. It belongs to an old class of insecticides called organophosphates, which are currently being phased out by the U.S. Environmental Protection Agency (USEPA).

Diazinon is a nonsystemic, organophosphate insecticide useful against soilborne insects, such as seedcorn maggot and seedcorn beetle. Diazinon has been commonly used as a planter-box treatment but is no longer labeled for soybean.

Imidacloprid (trade names Gaucho and Prescribe) is a systemic insecticide effective against aphids, chinch bug, flea beetle, Hessian fly, leafhopper, seedcorn maggot, thrips, whitefly, white grubs, and wireworms. It reduces incidence of some diseases by controlling the insect vectors. 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. Research has shown that imidacloprid seed treatment provides limited control of corn rootworms. Where the potential for high corn rootworm pressure exists, a soil-applied insecticide should be considered.

Lindane is a nonsystemic insecticide useful against soilborne insects, such as wireworm and seedcorn maggots. It belongs to an old class of insecticides called chlorinated hydrocarbons, which are currently being phased out by the USEPA. Lindane has been commonly used as a planter-box treatment but has largely been replaced by newer pyrethroid insecticides.

Permethrin (trade names Barracuda, Kernel Guard Supreme, and Profound) is a nonsystemic, pyrethroid insecticide useful against soilborne insects, such as wireworm and seedcorn maggots.

Tefluthrin is the active ingredient found in Force soil insecticide. As a seed treatment (marketed as Proshield), tefluthrin is currently only available on certain field corn hybrids. It is a nonsystemic, pyrethroid insecticide useful against soilborne insects such as wireworm and seedcorn maggots. Research has shown that Proshield seed treatment provides limited control of corn rootworms. Where the potential for high corn rootworm pressure exists, a soil-applied insecticide should be considered.

Thiamethoxam (trade name Cruiser) is a systemic, neonicotinoid insecticide effective against various sucking and chewing pests, such as thrips, aphids, Colorado potato beetles, seedcorn maggot, Hessian fly, flea beetles, leafhoppers, chinch bugs, and wireworms. Currently, the product is labeled for use only on wheat and barley seed.

FORMULATIONS

Seed treatment pesticides are commonly 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. However, as with all formulations, be sure to read and follow the label instructions to ensure proper mixing and compatibility.

Additives

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

Colorants or dyes are added to mark treated seed and 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. Legal requirements are addressed later in this chapter under "Coloring Treated Seed."

Carriers, binders, and stickers are listed on the label as inert ingredients. There is no requirement that the name of these materials be given. They are selected by the manufacturer; approved by the USEPA; 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 planter.

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

Compatibility Issues

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 labels of each product, and contact the manufacturer(s) if you need clarification. To test the mixture for physical compatibility, make a small slurry (include all products in the correct ratio) and observe for signs of incompatibility, such as settling, separation, gelling, or curdling. Furthermore, check the germination of a small amount of seed before committing the total seed lot to a selected treatment.

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 plant-ing, as the beneficial bacteria may not survive extended contact with certain pesticides. In-furrow application of inoculants may

General Procedures for Preparing Slurries

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 products.
6. Add any water-based products.
7. Add any emulsifiable concentrates.
8. Add any oil-based flowables.
9. Polymeric and/or coating additives are added last, but special rules may apply.
10. Add water to bring the slurry to the desired volume (whenever possible, use this water for rising containers).

Note: for dry products, the rule of thumb is that 1 dry oz will displace 1 fl oz (or 8 lbs will displace about 1 gal). Liquid equivalent estimates are made to determine how much water will need to be added to the slurry to achieve the correct final volume.

Source: Gustafson LLC, Shakopee MN

allow for use of seed treatments otherwise considered incompatible or marginally compatible.

LABELING AND VISUALLY IDENTIFYING TREATED SEED

The Federal Seed Act and the Oregon Seed Law require special labeling for treated seed. The labeling provides the end user with instructions on proper handling and storage of treated seed. It is a practical means of ensuring that treated seed is not used for any purpose other than for planting. In addition, the Occupational Safety and Health Administration (OSHA) may also require that seed treaters provide additional safety and training to help protect the health of persons working in and around seed treatment facilities or those handling treated seed.

Labeling Treated Seed

Federal and state seed laws mandate that seed treaters print the following specific information about the treatment on the same tag bearing the analysis information, on a separate tag attached to the seed container, or directly on a side or the top of the container.

- A word or statement indicating that the seed is treated, such as "TREATED"
- The accepted common or chemical name of all pesticides applied
- A statement, such as "Do Not Use for Food, Feed, or Oil Purposes" (Figure 3.1)
- In rare cases where a highly toxic pesticide (indicated by the "Danger/Poison" signal word on the pesticide product label) is applied to seed, the seed tag must also bear a skull and crossbones and a precautionary statement, such as "Treated with Poison." The word "poison" must be in type no

This Seed Treated With Captan

Do not use for food, feed or oil purposes

Figure 3.1. Basic labeling for treated seed.

smaller than 8 points and shall be in red letters on a distinctly contrasting background. In addition, the skull and crossbones must be at least twice the size of the type used for the precautionary statement (Figure 3.2).

OSHA has implemented additional label requirements under the hazard communication standards. This information is usually provided with the labeling for the treatment product and may include:

This Seed Treated With

POISON

Treatment used: Disulfoton

Do not use for food, feed or oil purposes

Figure 3.2. Basic labeling for seed treated with a highly toxic pesticide

- Appropriate hazard warnings (for example, statements such as "This chemical is a skin irritant" or "This chemical is capable of causing irreversible eye damage or other adverse effects")
- The name, address, and phone number of a responsible party to contact in case of problems

The information described is a minimum requirement. Some seed treatment pesticide labels recommend additional information that the treater should add to the label of treated seed. This may include special personal protection information, environmental hazards, statements of practical treatment in case of an accident, or grazing restrictions.

Remember, the only legal use for treated seed is planting. Seed treatment pesticide labels prohibit the use of treated seed for food, feed, or oil purposes.

Coloring Treated Seed

Federal Food and Drug Administration regulations require that all food grain seeds (for example, wheat, corn, oats, rye, barley) treated with seed treatment pesticide formulations be colored with an approved dye to contrast with the natural color of the seed to prevent its use as food or feed. This requirement provides a convenient means of detecting the presence of treated seed mixed with food or feed grains or products. Coloring is not required for planter-box formulations; however, dyes are commonly used to help the user confirm proper coverage.

Most seed treatment pesticides for in-plant use come from the manufacturer with the dye added. However, some seed processors may apply additional dye to modify the color. Approved colorants include dyes, color coat pigments, or color films. Dyes are designed to stain the seed with color, color coat pigments cover the seed with color, and color films are made from a polymer that creates a colored film around the seed. There is a wide variety of color and surface texture options available to seed processors. In addition to bright contrast, colorants must not affect seed germination or pose a health threat to personnel processing or using the seed.

Shipments of food grain seeds treated with a pesticide formulation lacking a colorant or grains that contain a mixture of treated and nontreated seed are subject to seizure and possible destruction. In addition to financial loss to the owner of the shipment, the person responsible for the violation may be prosecuted.

SAFE HANDLING PRACTICES

Handle seed treatment pesticide products with care. Product labels provide information on safe handling and application. Always read the label and follow instructions precisely. 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 nontreated 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. Regularly cleaning 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. Take special care to avoid contamination of equipment and facilities during cleanup procedures and disposal of wastes. For major spills, Oregon law requires that emergency notification be made to the Oregon Emergency Responce System (OERS). They in turn notify the appropriate agencies for response. Contact (800) 452-0311 or (503) 378-4124.

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:

- 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 with no notice), so be sure to review the label each time you purchase a pesticide.
- Avoid inhaling pesticide dust or vapor, and always protect skin and eyes from exposure. Use proper protective equipment recommended by the pesticide label. Consider wearing goggles, rubber gloves, and a rubber apron, even when the product label does not specifically require it.
- Wash thoroughly with soap and water before eating or smoking.
- 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.
- When treating large amounts of seed, change clothing frequently enough to avoid buildup of pesticides in the garments.
- 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 Storage and Disposal

Pesticides

Store unused seed treatment pesticides in their original, labeled, tightly closed containers in a dry, ventilated, locked location inaccessible to animals, children, and untrained persons. Do not store pesticide products near heat, fire, sparks, or open flame, or in direct sunlight. Protect liquid formulations from freezing temperatures. Check the pesticide label for appropriate product storage directions. Do not reuse pesticide containers.

Completely rinse and puncture empty pesticide containers, and offer for recycling or dispose of them in a sanitary landfill. Consider recycling excess pesticide solution and treatment wastewater by using them to dilute the next batch of the same product. Do not divert wastewater into ponds, lakes, streams, ditches, sewers, drains, and the like. Handle wastewater as you would excess pesticide. Always follow all local, state, and federal pesticide disposal requirements.

Treated Seed

Pesticide-treated seed must 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 multiwall (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 the previous chapter) 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. Certainly seed treatment pesticide labels prohibit the use of treated seed for food, feed, or oil purposes. Thus, 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. Obviously treated seed may be disposed of by planting it at an agronomically acceptable seeding rate. However, surface application without incorporation may present a hazard to humans and animals and may be illegal.

Rumors of disposal options abound, but which ones are legal and environmentally safe? The following excerpt should be helpful in this regard; it was taken from *Industry Guidelines for the Disposal of Seeds Treated with Crop Protection Products (2000)*, written by the Seed Treatment and Environment Committee of the International Seed Trade Federation (http://www.worldseed.org):

In all cases, the Seed Handler should validate the Disposal Agents' authorization and capabilities for handling the materials to be discarded. The following is a checklist of issues to consider:

- Ensure the Disposal Agent has all the necessary national and local environment permits to accept and handle the materials you are disposing.
- Regardless of the permits, consider the environmental impact (air, water, soil) of this disposal method and ensure you are satisfied with this option compared with alternatives.
- Ensure the Disposal Agent has adequate systems in place to provide a safe and healthy work environment.
- Determine the volumes/capacity of the facility and their schedule for accepting product versus your requirements.
- Determine what security measures and controls the operation has in place to ensure the material is disposed as agreed upon.
- Develop a contract with the Disposal Agent that identifies the responsibilities of each party in the event of misuse or mishandling of the treated seeds by the Disposal Agent.

CHAPTER FOUR:
EQUIPMENT AND CALIBRATION

METHODS OF SEED TREATMENT

Seed treatment pesticides are applied as dusts, slurries, or liquids. The principal objective is to thoroughly coat the seed with an appropriate rate of pesticide. The proper selection and operation of seed treatment equipment can help assure uniformity of coverage, adequate control of the target pest, and enhanced seed germination.

Dusts are dry powder formulations that are mechanically mixed with the seed. Dust applications add no moisture to the seed. However, they are difficult to distribute uniformly over the seed and tend to sift off seed readily. Slurries are prepared by mixing insoluble formulations (wettable powders, dry flowables, etc.) in water. Slurry treatments provide accurate and thorough seed coverage. Liquids (for example, solutions and emulsifiable concentrates) can be mixed with water in a manner similar to that for slurries. Liquid treatments also provide uniform coverage of seed. In addition, some liquid pesticide formulations are applied as neat (undiluted) treatments using a direct and closed-handling system, which reduces worker exposure to the pesticide.

Remember, it is essential that the treatment coat the entire seed with pesticide. Complete coverage is particularly important on weaker seed and on seed with cracked seed coats because they are more susceptible to seedborne and soilborne pests. Too much pesticide may injure germinating seed; too little pesticide is often ineffective. Adjust seed treatment equipment correctly and perform continual preventive maintenance. Make certain during application that the amount of pesticide used is in correct proportion to the amount of seed being treated.

APPLICATION EQUIPMENT FOR TREATING SEED

Commercial seed-treating systems (seed treaters) are designed to apply accurately measured quantities of pesticides to a given weight of seed. Thus, all treaters have two essential components: (1) a seed and pesticide flow control system, and (2) a seed and pesticide mixing chamber(s). There are many different treaters in use and on the market, but for calibration purposes it may be best to categorize them according to how the seed and pesticide are measured (metered), either mechanical metering or electronic proportional metering.

Regardless of the treatment equipment used, proper operation is critical to effective seed treatment. Poorly maintained or adjusted equipment can damage seed, apply incorrect amounts of chemical, or provide insufficient seed coating. All seed treatment equipment requires regular inspection to maintain the correct ratio of chemical used to the amount of seed treated. Ideally, this needs to be done daily and on a lot-by-lot basis.

Mechanical Metering

Dust treaters control grain flow onto a weigh pan (located just beneath the feed hopper on top of the treater) through a gate adjustment on the seed hopper (Figure 4.1). A handwheel on the side of the hopper opens or closes the gates, and a scale on the hopper indicates gate-size opening in inches. A proper gate opening meters seed onto the weigh pan at an appropriate rate, and a counterweight adjustment determines the desired number of pounds per dump of seed. Dust is metered onto the seed by a vibrating pan. Adjustment of the vibration speed determines the application rate per seed dump. Dust treaters are easy to clean and operate. However, they are limited to dust formulations, and their operation requires a dust-collection system for worker safety and

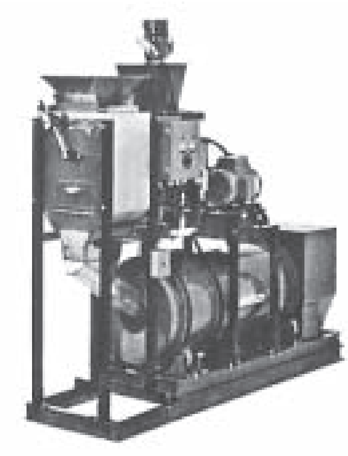


Figure 4.1. Dust treater

protection. Dust treaters are no longer common in commercial seed treating facilities.

Metered slurry treaters use the weight of the seed to meter the correct dosage of pesticide (Figure 4.2). When a sufficient amount of seed flows into the double compartment weigh pan, the weight of the seed trips the weigh pan, which drops the seed into the mixing chamber. The weigh pan is attached to a rocker arm, which simultaneously dips pesticide from a reservoir and adds it to the mixing chamber. Thus, one cup of pesticide is mixed with each dump of the weigh pan. Pesticide is pumped to the reservoir tank from a barrel or a premix (slurry) tank. An adjustable dump pan counterweight is used to adjust the weight of the seed dump. The desired treating rate is obtained through selection of treatment cup size and proper adjustment of the seed dump weight. Treatment cup sizes and the way in which they are named or numbered vary depending on the manufacturer, so be sure to consult the manual for your specific treater.

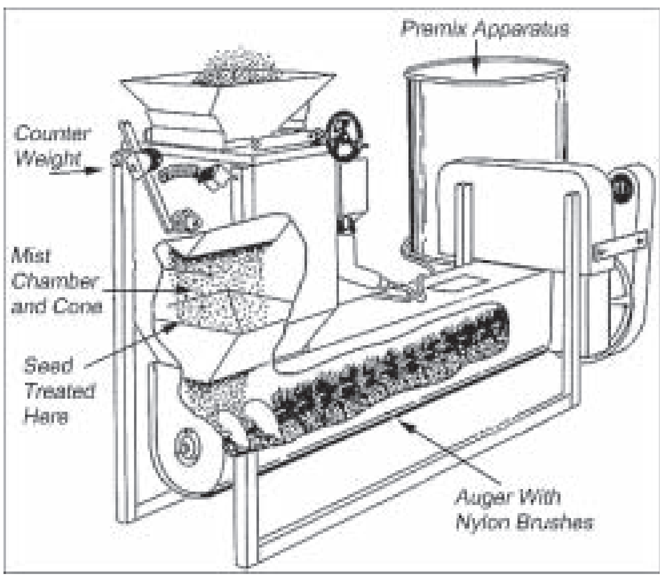


Figure 4.2. Metered slurry seed treater

Some models are designed to use neat (undiluted) pesticides pumped directly from the product container. In terms of worker exposure, such a direct system has a definite advantage over the slurry system because it is a closed system with no need for tank mixing. Equipment manufacturers use various techniques (nozzles, fluted discs, cones, paddles, augers, drum shape) to actually introduce and mix the seed and pesticide. One example of a common chemical-to-seed applicator is the Mist-O-Matic® (Figure 4.3).

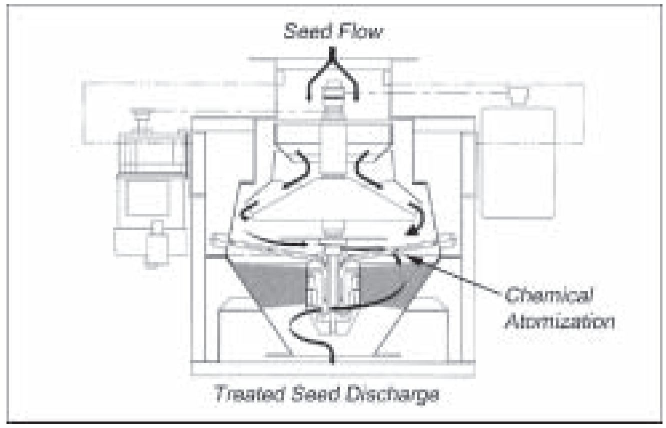


Figure 4.3. Mist-O-Matic applicator

Wheel-metered treaters use the revolution of a seed wheel and pesticide metering pod to accurately meter seed and pesticide (Figure 4.4). Seed flows from the seed hopper into the seed wheel. As a motor rotates the seed wheel, each wheel compartment fills with a specific amount of seed, which is then discharged into the mixing chamber. The pesticide is metered by another motor, which rotates a disc within a pesticide-metering pod. Each disc chamber is filled with pesticide by a pump from a premix tank and is then discharged into the mixing chamber. A programmable computer is used to adjust the revolutions per minute (RPMs) of the seed wheel and pesticide-metering pod(s).

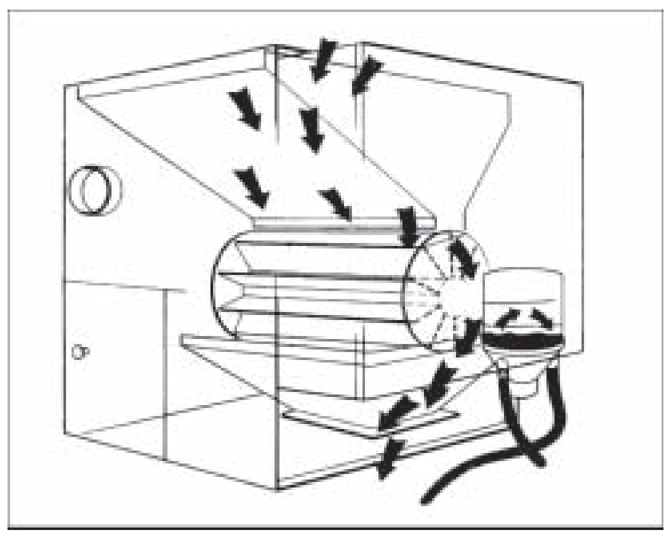


Figure 4.4. Accu-treat D.C. treater

Electronic Proportional Metering

The most recent treaters to enter the market use fairly sophisticated computer technology to augment other existing components and automate the seed treatment process. A programmable computer continuously monitors the weight of the seed flow and metering of the chemical application to the seed (Figure 4.5). The treater adjusts automatically as the seed flow changes. The system uses up to 12 metered pumps for water and various chemicals (in slurry or neat form), which are then mixed prior to application to the seed in an in-line mixer. The computer can provide readouts on seed, chemical, and water usage, with minute, hourly, or daily totals available at any time. These automated systems offer convenience and improved accuracy, and greatly reduce the calibration burden.

CALIBRATION AND CALCULATIONS

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. The procedures for calibrating a mechanical metered slurry treater are provided below. Although different procedures are used for different mechanical metering treaters, they all have one thing in common— accurate matching of the seed and pesticide flow rates. Consult the operator's manual furnished by the manufacturer for your specific treater.

Calibrating a Metered Slurry Treater

The following procedure is a practical and efficient procedure for calibrating mechanical metering slurry or liquid treaters. To properly calibrate these treaters, the operator must know:

- The label rate of the ready-to-use seed treatment pesticide or target slurry rate
- How many pounds of seed are dumped each time the weigh-pan arm trips
- The amount of pesticide discharged each time the weigh-pan arm trips—determined by the size of the chemical cups used

Step 1
For a ready-to-use pesticide, determine the rate of

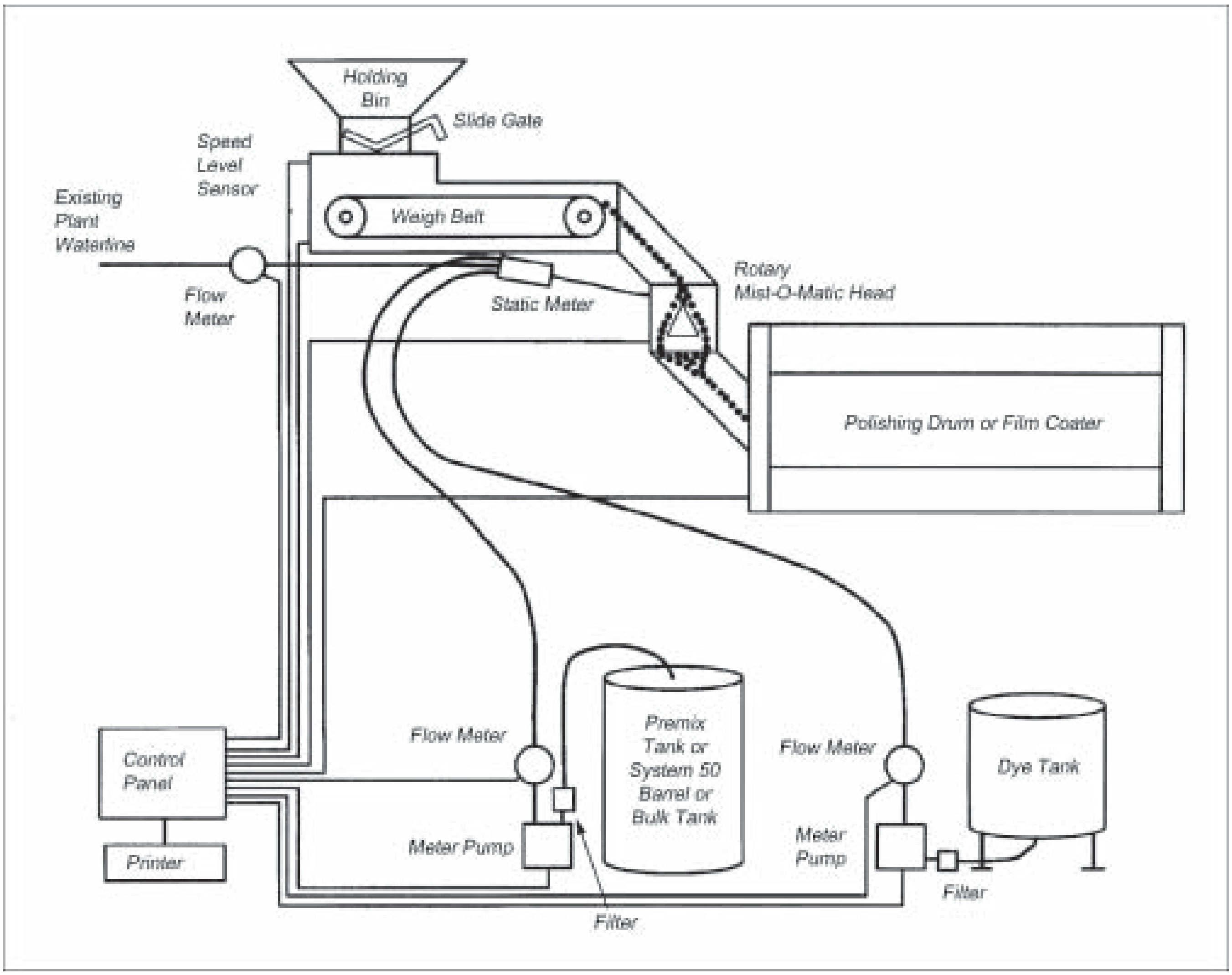


Figure 4.5. Seed and chemical electronic proportioner system diagram

pesticide needed to treat 100 pounds of seed. The pesticide label provides this information. Labels frequently express rates in fluid ounces of product per 100 pounds of seed, so convert fluid ounces to cubic centimeters by multiplying by 29.6 (29.6 cubic centimeters equals 1 fluid ounce). For example, a seed treatment pesticide label recommends an application of 10 fluid ounces of product per 100 pounds of seed:

10 fl oz of product per 100 lb of seed x 29.6 cc per fl oz
= 296 cc of product per 100 lb of seed

To determine the number of cubic centimeters per pound of seed (useful later):

$$\frac{\text{296 cc of product per 100 lb}}{\text{100 lb of seed}} = \text{2.96 cc per lb of seed}$$

Step 2

Prior to actual treatment, run a minimum of 200 pounds of seed through the treater and count the number of times the weigh-pan arm trips. Do this using the same seed you intend to treat. It is desirable also to have the weigh pan trip 40 to 45 times per minute (check your equipment manual for specific capacity information). Smaller increments of seed passing through the treater head provide a more even flow of seed and result in better distribution of pesticide.

Divide the total weight of seed run through the treater by the number of trips. This is the number of pounds of seed per trip. For example, if the weigh-pan arm tripped 40 times with 200 pounds of seed, then:

$$\frac{\text{200 lb of seed}}{\text{40 trips}} = \text{5 lb of seed per trip}$$

Step 3

To determine the proper chemical cup size to use, multiply the number of cubic centimeters per pound of seed by the pounds per trip:

2.96 cc of product per lb of seed x 5 lb of seed per trip
= 14.8 cc per trip

Mathematically, this treatment requires a 14.8 cubic-centimeter chemical cup size. Round to the next largest size and start with 15 cubic-centimeter cups. 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 head and catch a minimum of 10 trips into a measuring cup. If your treater was equipped with 15 cubic-centimeter chemical cups, you should catch 150 cubic centimeters of pesticide after 10 trips.

Making Adjustments

If your equipment is not delivering the desired rate, adjust one of the variables listed in Table 4.1. For additional information, see the calibration instruction manual furnished by the manufacturer with each machine. Equipment company representatives are an excellent source of help with equipment calibration concerns. Once the treater is calibrated, it is important that you determine and fine-tune the actual application rate by periodically comparing the amount of pesticide used with the amount of seed treated.

Slurry Mixing Calculation

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 hundredweight (cwt). Further assume that you have a 50-gallon slurry tank and that you want to apply the slurry at a rate of 12 fluid ounces per hundredweight. Determine how much seed can be treated with one tankful and how many gallons of each product will need to be added to the tank.

Determine Theoretical Capacities (Upper Limit)

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

Table 4.1. Metered slurry treater adjustments

Adjustment	What does it modify?	Need to recalibrate?
Distance between the chemical cup and its receptacle (moves cups farther from the receptacle to decrease chemical and vice versa)	Volume of pesticide delivered per trip (minor)	Yes, step 3
Chemical cup size	Volume of pesticide delivered per trip (major)	Yes, step 3
Water-to-pesticide dilution ratio in the premix tank	Pesticide concentration (minor)	No
Counterweight position on the seed weigh pan (raise counterweight to increase amount of seed dumped per trip and decrease the trip rate)	Weigh pan trip rate (major)	Yes, step 2

Table 4.2. Slurry preparation worksheet for liquid products

Product	Dry rate per cwt	Liquid rate per cwt	Calculation (liquid 128 fl oz./gal; dry 16 oz/lb)	Dry per tank	Liquid per tank
Raxil-Thiram		3.5 fl oz	x457 cwt= 1600 fl oz / 128		12.5 gal
Water*		8.5 fl oz*	x457 cwt= 3884 fl oz / 128		30.35 gal*
Total slurry		12 fl oz	x457 cwt= 5484 fl oz / 128		42.85 gal
*Determine the amount of water needed by subtracting all of the liquid (and liquid equivalent) volumes from the total slurry rate.					

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

533 cwt x 3.5 fl oz Raxil®-Thiram
= 1,865.5 fl oz (or 14.57 gal) Raxil®-Thiram per tank

Determine Convenient Capacities
For convenience and based on the pesticide packaging (in this case, 2.5-gallon jugs), round 14.57 gallons down to 12.5 gallons of Raxil-Thiram per tank. Then base all subsequent calculations (Table 4.2) on the following:

12.5 gal Raxil-Thiram x 128 fl oz =

$$\frac{\text{1,600 fl oz}}{\text{3.5 fl oz}} = \text{457 cwt per tank}$$

Determine Mix and Sequence in Tank
Add 25 gallons of water (use 75 to 90% of total water needed), 12.5 gallons of Raxil®-Thiram, and approximately 5.35 gallons of water to bring the total slurry volume up to 42.85 gallons.

Product Needs Calculation

Assume that you want to use Maxim XL® to treat 56,000 pounds (1,000 bushels) of seed corn at a rate of 0.334 fluid ounces per hundredweight. How much Maxim XL® is needed to treat this much seed?

1. $\text{Area} = \text{56,000 lb seed} \times \frac{\text{1 cwt}}{\text{100 lb}} = \text{560 cwt}$

2. $\text{Amount} = \frac{\text{0.334 fl oz}}{\text{cwt}}$

3. *Product needed (1 x 2)*
   = 560 x 0.334
   = 187 fl oz (or 1.46 gal)

Chapter Review Questions
Question 1: Assume that you want to treat soybeans with Rival® at a rate of 4 ounces per 100 pounds of seed. You run the treater, count 125 trips, and confirm that 1,250 pounds of seed passed through the treater. Based on these variables, go through the steps outlined earlier in the chapter to determine what size metering cups will be needed.

Solution: Mathematically, this treatment requires an 11.84 cubic centimeter chemical cup size. Round to the next largest size and start with a 12 cubic centimeter cup size. If a 12 cubic centimeter cup size is unavailable, you will have to select the next largest cup size, increase the number of pounds of seed per trip, and recalibrate.

Question 2: Assume you will be using a metered slurry treater to apply the following products to pinto beans: Captan 400 at 2 fluid ounces per hundredweight, Ag-Streptomycin at 0.625 ounce per hundredweight, Lorsban 50 at 2 ounces per hundredweight, and a colorant at 2 quarts per 5 gallons of Captan 400. Further assume that you have a 100-gallon slurry tank and that you want to apply the slurry at a rate of 10 fluid ounces per hundredweight. Determine how much seed can be treated with one tankful and how much of each product will need to be added to the tank.

Determine Theoretical Capacities (Upper Limit)
100 gal premix tank x 128 fl oz = 12,800 fl oz of slurry

$$\frac{\text{12,800 fl oz of slurry per tank}}{\text{10 fl oz of slurry per cwt}} = \text{1,280 cwt per tank}$$

Determine Mix and Sequence in Tank.
As calculated in Table 4.3, you would add 46 gal of water (use 75 to 90% of total water needed), 2 gal of colorant, 50 lb of Ag-Streptomycin, 160 lb of Lorsban 50, 20 gal of Captan 400, and approximately 5.75 gal of water to bring the total slurry volume up to 100 gal. Refer to the “Supplemental Materials” section on page 24 for a sample slurry preparation worksheet.

Table 4.3. Slurry preparation worksheet for liquid and dry products.

Product	Dry rate per cwt	Liquid rate per cwt	Calculation (liquid 128 fl oz./gal; dry 16 oz/lb)	Dry per tank	Liquid per tank
Captan 400		2.0 fl oz	x1280 cwt= 2560 fl oz /128		20 gal
Colorant***		0.2 fl oz	x1280 cwt= 256 fl oz /128		2 gal
Lorsban 50	2.0 oz		x1280 cwt= 2560 oz /16	160 lbs	
		2.0 fl oz*	From the above line: 160 lbs dry per tank/8 =		20 gal*
Ag-Streptomycin	0.625 fl oz		x1280 cwt= 800 oz /16	50 lbs	
		0.625 fl oz*	From the above line: 50 lbs dry per tank/8 =		6.25 gal*
Water**		5.175 fl oz**	x1280 cwt= 6624 fl oz /128		51.75 gal**
Total Slurry		10 fl oz	x1280 cwt= 12800 fl oz /128		100 gal

*For dry products, assume that 1 dry ounce will displace 1 fluid ounce (or that 8 lbs will displace about 1 gallon). These liquid estimates are made to determine how much makeup water will be needed to achieve the correct final amount of total slurry
** Determine the amount of water needed by subtracting all of the liquid (and liquid equivalent) volumes from the total slurry rate.
*** Rates for colorants or other additives may not be expressed in terms of fluid ounces per hundredweight. The slurry calls for 2 quarts (0.5 gal) of colorant per 5 gal of Captan 400. Since we will add 20 gal of Captan 400 to the tank, we will need 2 gal of colorant [(20 / 5) x 0.5 = 2 gal or 256 fl oz]. The rate per hundredweight in this case is 0.2 fl oz per hundredweight (256 / 1280).

SUPPLEMENTAL MATERIALS

SLURRY PREPARATION WORKSHEET FOR LIQUID AND DRY PRODUCTS

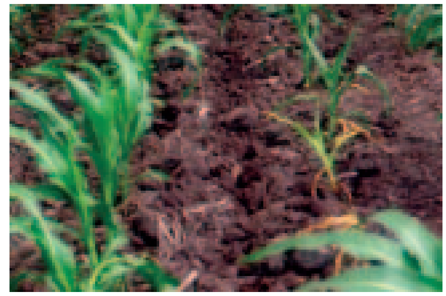
Product	Dry rate per cwt	Liquid rate per cwt	Calculation (liquid 128 fl oz./gal; dry 16 oz/lb)	Dry per tank	Liquid per tank
		_________fl oz	x _____cwt= ______ fl oz /128		________gal
		_________fl oz	x _____cwt= ______ fl oz /128		________gal
		_________fl oz	x _____cwt= ______ fl oz /128		________gal
		_________fl oz	x _____cwt= ______ fl oz /128		________gal
	_________ oz		x _____cwt= ______ oz /16	________ lbs	
		_________ fl oz*	From the above line: ________ lbs dry per tank/8 =		_______gal*
	_________ oz		x _____cwt= ______ oz /16	________ lbs	
		_________ fl oz*	From the above line: ________ lbs dry per tank/8 =		_______gal*
	_________ oz		x _____cwt= ______ oz /16	________ lbs	
		_________ fl oz*	From the above line: ________ lbs dry per tank/8 =		_______gal*
	_________ oz		x _____cwt= ______ oz /16	________ lbs	
		_________ fl oz*	From the above line: ________ lbs dry per tank/8 =		_______gal*
Water**		________fl oz**	x _____cwt= ______ fl oz /128		_______gal**
Total Slurry		__________fl oz	x _____cwt= ______ fl oz /128		________gal

*For dry products, assume that 1 dry ounce will displace 1 fluid ounce (or that 8 lbs will displace about 1 gallon). These liquid estimates are made to determine how much makeup water will be needed to achieve the correct final amount of total slurry
** Determine the amount of water needed by subtracting all of the liquid (and liquid equivalent) volumes from the total slurry rate.

CORN DISEASES

Corn seedling blight

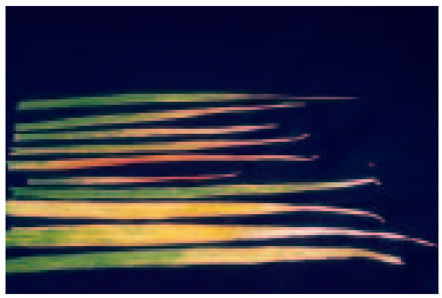
Stewart's bacterial wilt



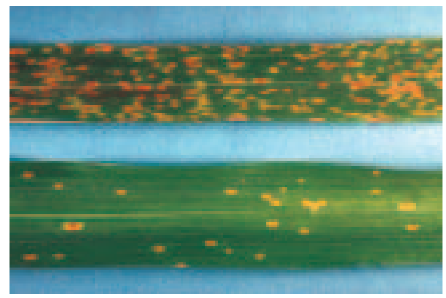
Corn seedling blight

WHEAT DISEASES

Common bunt of wheat

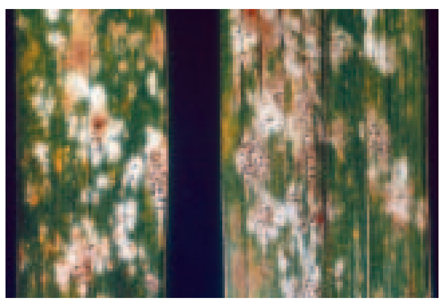


Barley yellow dwarf virus (BYDV)

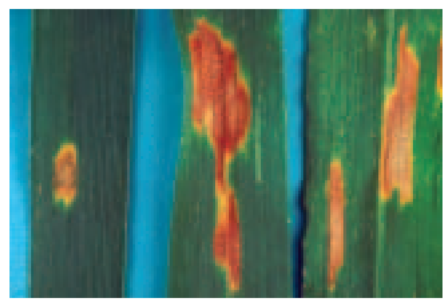


Leaf rust of wheat

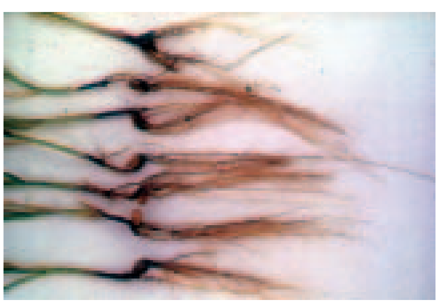
Loose smut of wheat



Powdery mildew of wheat



Septoria leaf blotch of wheat



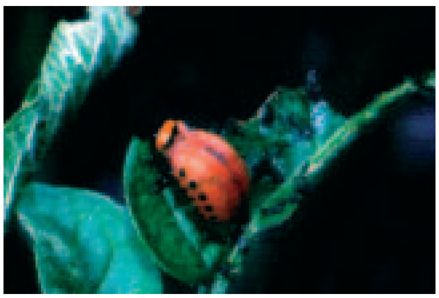
Wheat seedling blight

INSECTS

Aphids

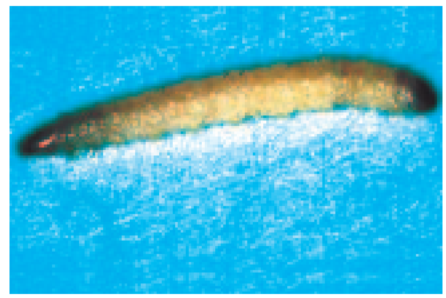
Chinch bug

Colorado potato beetle adult



Colorado potato beetle larvae

Corn flea beetle

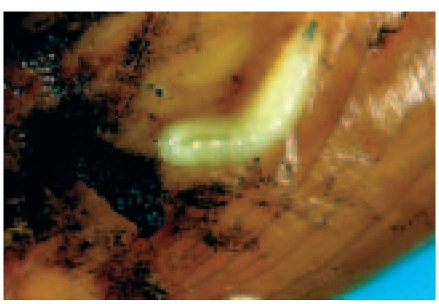


Western corn rootworm larvae

Western corn rootworm adult

Hessian fly larvae

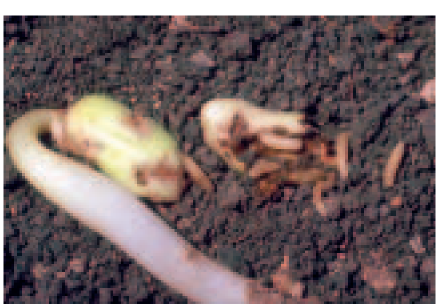
Hessian fly pupae



Onion maggot larvae

Slender seedcorn beetle

Seedcorn beetle



Seedcorn maggot larvae

White grub larvae

Wireworm larvae

COLOR ILLUSTRATION CREDITS

Corn Diseases

Corn seedling blight. Source unknown.
Corn seedling blight. Wayne Peterson, University of Illinois.
Stewart's bacterial wilt. Field Crop Scouting Manual, University of Illinois Extension, 1999.

Wheat Diseases

Common bunt of wheat. Field Crop Scouting Manual, University of Illinois Extension, 1999.
Barley yellow dwarf virus (BYDV). Field Crop Scouting Manual, University of Illinois Extension, 1999.
Septoria leaf blotch of wheat. Field Crop Scouting Manual, University of Illinois Extension, 1999.
Loose smut of wheat. Field Crop Scouting Manual, University of Illinois Extension, 1999.
Wheat seedling blight. APS Press.
Leaf rust of wheat. Field Crop Scouting Manual, University of Illinois Extension, 1999.
Powdery mildew of wheat. Field Crop Scouting Manual, University of Illinois Extension, 1999.

Insects

Colorado potato beetle larvae. Phil Nixon, University of Illinois.
Colorado potato beetle adult. Clemson University.
Onion maggot larvae. Joe Ogrodnick, New York State Agricultural Experiment Station, Cornell University.
White grub. Field Crop Scouting Manual, University of Illinois Extension, 1999.
Slender seedcorn beetle adult. University of Illinois.
Seedcorn beetle adult. Field Crop Scouting Manual, University of Illinois Extension, 1999.
Hessian fly maggots. Field Crop Scouting Manual, University of Illinois Extension, 1999.
Hessian fly pupae. Field Crop Scouting Manual, University of Illinois Extension, 1999.
Western corn rootworm larvae. Field Crop Scouting Manual, University of Illinois Extension, 1999.
Western corn rootworm adult. Field Crop Scouting Manual, University of Illinois Extension, 1999.
Chinch bug adult. Field Crop Scouting Manual, University of Illinois Extension, 1999.
Corn flea beetle damage. Field Crop Scouting Manual, University of Illinois Extension, 1999.
Corn flea beetle adult. Field Crop Scouting Manual, University of Illinois Extension, 1999.
Wireworm larvae. Field Crop Scouting Manual, University of Illinois Extension, 1999.
Seedcorn maggot larvae. Field Crop Scouting Manual, University of Illinois Extension, 1999.
Aphids. Texas A&M University.

COMPARATIVE MEASURES, WEIGHTS, ABBREVIATIONS, AND FORMULAS

Fluid Measures

1⁄6 fluid ounce = 1 teaspoon
½ fluid ounce = 1 tablespoon = 3 teaspoons
1 fluid ounce = 2 tablespoons = 0.5 cup = 29.57 milliliters
8 fluid ounces = 1 cup = 0.5 pint
16 fluid ounces = 2 cups = 1 pint
32 fluid ounces = 4 cups = 1 quart = 946 milliliters
128 fluid ounces = 16 cups = 1 gallon

Area Measures

144 square inches = l square foot
9 square feet = 1 square yard
30 ¼ square yards = 1 square rod
272 ¼ square feet = 1 square rod
43,560 square feet = 1 acre
4,840 square yards = 1 acre
160 square rods = 1 acre
640 acres = 1 square mile

Linear Measures

1 inch = 2.54 centimeters = 25.4 millimeters
1 foot = 12 inches
1 yard = 3 feet
1 rod = 5 ½ yards = 16 ½ feet
1 mile = 320 rods = 1,760 yards = 5,280 feet

Weights

1 ounce = 28 grams
1 pound = 16 ounces = 454 grams
2.2 pounds = 1 kilogram = 1,000 grams
1 ton = 2,000 pounds = 907 kilograms

Formulas

1 pound/acre = 1.12 kg/ha
OPM = GPM X 128
quarts/acre x 0.73 = ounces/1,000 square feet
pounds/acre x 0.37 = ounces/1,000 square feet
GPM = GPA X MPH X W (inches sprayed per nozzle)/5,940
GPA = GPM D 5,940 /MPH X W (inches sprayed per nozzle)
MPH = Distance (feet) X 60/Time (seconds) X 88
area of a circle = 3.14 X radius squared
volume of a cylinder = 3.14 X radius squared X height
area of a triangle = 1⁄2 base X height

Aquatic Liquid Measures

1 cubic foot = 62.4 pounds
1 cubic foot = 7.5 gallons
1 part per million = 2.7 pounds
(per acre foot of water)

Abbreviations

ft2= square feet
PSI = pounds per square inch
GPM = gallons per minute
GPA = gallons per acre
RPM = revolutions per minute
OPM = ounces per minute
MPH = miles per hour
in = inches
ft = feet
lb/A = pounds per acre
kg/ha = kilograms per hectare
a.i. = active ingredient