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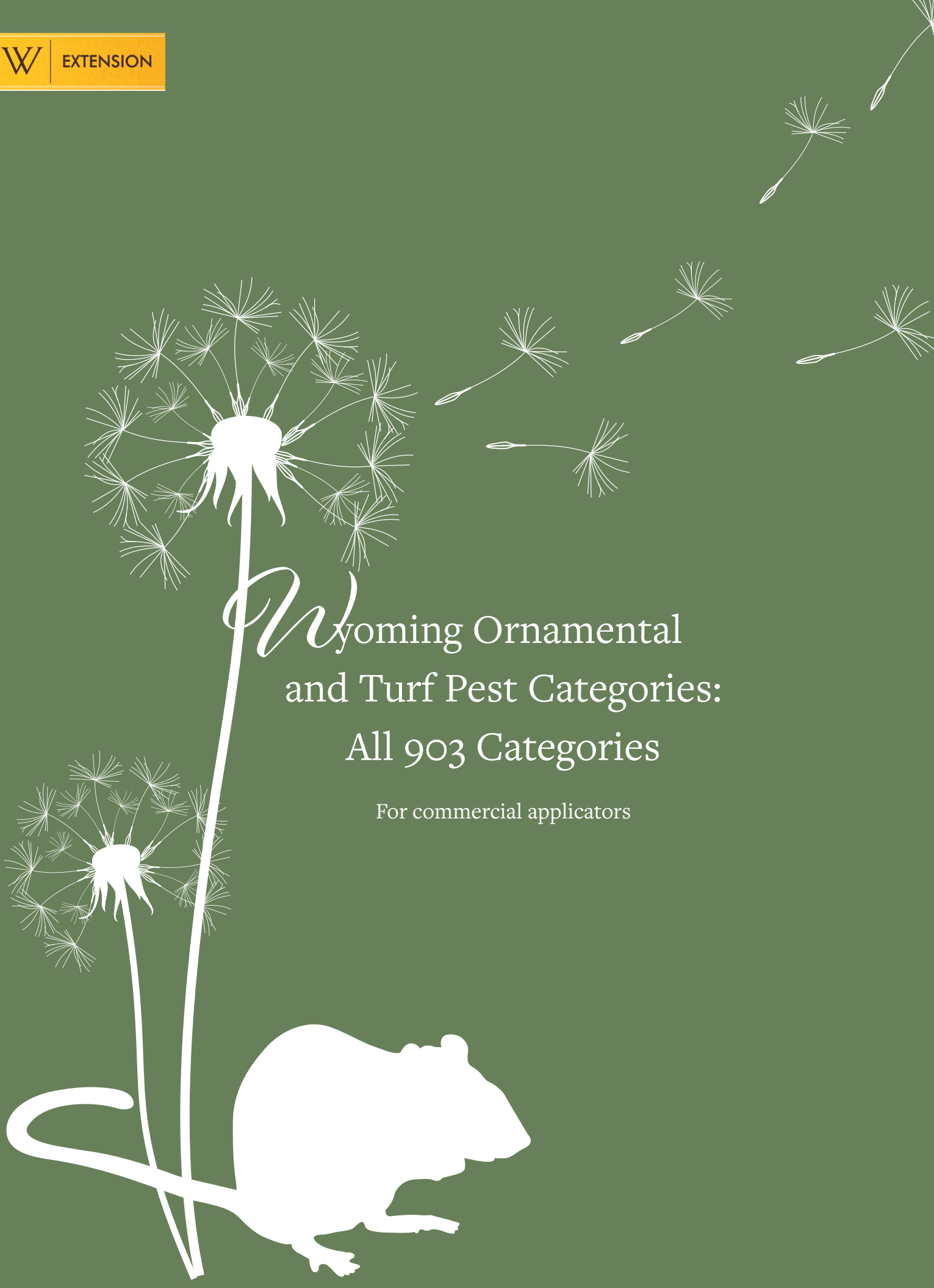

Wyoming Ornamental and Turf Pest Categories: All 903 Categories

For commercial applicators

Acknowledgments

Portions of this manual were adapted from Pesticide Applicator Training Manuals or information provided by University of Wyoming, The Wyoming Department of Agriculture, Purdue University, and Colorado State University.

The following individuals are gratefully acknowledged for reviewing this publication and for their valuable suggestions: Kent Drake, Chris Hilgert, Karen Panter, Scott Schell, and William Stump.

Wyoming Ornamental and Turf Pest Categories: All 903 Categories

MP-127.903, December 2017

by Jeff Edwards

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Issued in furtherance of extension work, acts of May 8 and June 30, 1914, in cooperation with the U.S. Department of Agriculture. Glen Whipple, director, University of Wyoming Extension, University of Wyoming, Laramie, Wyoming 82071.

Preparation for your Exam

The reader preparing to take any of the Wyoming Commercial Pesticide Applicator Exam(s) for categories 903 A-C & E, Ornamental and Turf Management, is encouraged to review this manual several times. Please read and respond to the learning objectives that correspond to each of the manual sections for which you plan on taking exams.

Exam questions may come from any section of this manual – this includes the definitions and appendices; however, when focusing on a specific subcategory of 903 – for instance 903A Ornamental and Turf Weed Management – the questions in the exam will be weighted to cover mainly this material in the manual.

Images of pest species have purposely been excluded from this manual for the following reasons:

- Images are readily available on the Internet.
- Images would increase the overall size and cost of this publication to something less manageable.

It is important that you take note of the following:

- You may bring a basic hand-held calculator with you to use during the exam (cell phones and other communication devices are prohibited – **you will be failed** if using your cell phone during the exam).
- Exams are closed book. You will not be allowed to refer to any notes, manuals, or other unauthorized training materials during the exam.
- You must pass each category with a 70% or better to be issued a license.
- Exams can be taken at any University of Wyoming County Extension office – please call your local Extension office to make an appointment.

Section 1- General Turf Maintenance Practices

LEARNING OBJECTIVES

After completing the following section, you should be able to:

Describe the benefits of a well-maintained turf in:

- Commercial and residential lawns
- Athletic fields
- Golf courses

A. Describe the temperature conditions (i.e., ranges) under which cool season turfgrass species perform best

B. Describe the temperature conditions (i.e., ranges) under which warm season turfgrass species perform best

C. List four common cool season turfgrass species
   - Distinguish which species are spreading- versus bunch-type

D. List two common warm season turfgrass species
   - State whether they are spreading- or bunch-type

E. List three criteria for judging the appearance of healthy turf

F. List common abiotic turfgrass problems

G. List common biotic turfgrass problems

H. Describe the benefits of a regular pest scouting program

I. Describe the relationship between turf cultural practices and pest pressure/environmental stress

J. State best practices (e.g., watering, mowing, fertilization, establishment, and traffic management) for each of the following grasses:
   - Kentucky bluegrass
   - Perennial ryegrass
   - Turf type tall fescue

INTRODUCTION

Careful turfgrass selection is an important first step in establishing, over seeding, or renovating a turfgrass. Many potential problems related to turf use, appearance, environment, insect or disease pests, and cultural practices can be avoided by properly choosing species and cultivars that best fit the situation in which the turfgrass will be grown.

A turfgrass often deteriorates and fails when planted in areas where it is not adapted. The result of planting a turfgrass where it is not adapted is a poor-quality turf that requires excessive pesticide applications, fertilization, and replanting to retain a green ground cover. A high-quality turf may not be obtainable in this situation.

Consider these desired quality criteria when selecting a turfgrass:

- Appearance – turf color, texture, density, growth habit, and uniformity.
- Use – turf purpose, (for example, athletic or play surface, lawn, erosion control).
- Pest resistance – turf resistance or tolerance to disease or insect pests.
- Culture – turf management requirements from a time and a financial viewpoint.
- Site – turf soil and sunlight requirements compared to those of the final planting site.

Turfgrasses differ with regard to these criteria. Careful selection at planting time is the best way to solve potential future problems.

Generally, the cost of planting turfgrasses, whether from seed, sod, plugs, sprigs, or stolons, should be of minimal concern. The cost difference between

poor-quality and high-quality seed or vegetative propagules is small in most normal plantings, and the time and money spent trying to produce high-quality turf from low-quality seed or vegetative material can often become great. The long-term benefit of planting high-quality turfgrasses in appropriate conditions is a healthy, cost-effective, quality turf.

TURFGRASS CATEGORIES BASED ON FUNCTION, MAINTENANCE, AND QUALITY

Frequently, turfgrasses are divided into three groups based on function, maintenance requirements, and quality. Turfgrasses that serve mainly as erosion controls, receive minimal maintenance, and have minimal quality are termed utility turfgrasses. Pasture-type tall fescues and common Kentucky bluegrasses fall into this category. Grasses from this group are commonly used on roadsides, industrial areas, low-use park areas, and other low-maintenance settings.

Turfgrasses grown for their aesthetic appeal, moderate maintenance, and moderate to high quality are placed in the lawn turfgrass category. Common and improved types of Kentucky bluegrass, perennial ryegrasses, and turf-type tall fescues are included in this group. These turfgrasses are commonly planted on home lawns, commercial areas, park settings, and other landscape areas requiring turf having a good appearance.

Sports turfgrasses function as athletic or recreation play surfaces, generally receive high maintenance, and are of high quality. Improved Kentucky bluegrasses, perennial ryegrasses, and turf-type tall fescues are used as sports turfgrasses in Wyoming. These grasses are often grown on golf course greens, tees, fairways, and roughs; and baseball, football, and other sports sites.

COOL SEASON AND WARM SEASON SPECIES

Most turfgrasses used in Wyoming are cool-season grasses; Kentucky bluegrasses, perennial ryegrasses, and tall fescues fall in this group. Cool-season grasses grow actively during the spring and autumn when air and soil temperatures are cool. Optimum growth of these grasses occurs when soil temperatures are between 50° and 65°F and air temperatures are between 60° and 75°F. Kentucky bluegrass possesses acceptable cold tolerance, while tall fescue and perennial ryegrass are generally considered to be somewhat less tolerant. Established tall fescue, on the other hand, has good heat and drought tolerance and performs well in Wyoming. Kentucky bluegrasses and perennial ryegrasses have less tolerance to heat and drought. All of these cool-season turfgrasses are easily established by seeding, while Kentucky bluegrasses and occasionally tall fescues are also established by sodding.

One other turfgrass species, buffalo grass, is occasionally grown in Wyoming in elevations below 6,000 feet. This is a warm-season grass, that is, warm-season grasses more tolerant of high temperatures and drought conditions than their cool-season counterparts. Optimum growth of these grasses occurs when soil temperatures are between 70° and 90°F and air temperatures are between 80° and 95°F. Buffalo grass does not maintain green color and active growth in cool temperatures from mid-autumn through mid-spring. When dormant during these periods, buffalo grass is brown and can be considered unattractive. Buffalo grass can be difficult to establish from seed, but it is a desirable selection in locations with heavy traffic, low water availability,

and where the need for low maintenance turf is required.

CULTIVARS AND VARIETIES, AND BLENDS AND MIXES

Cultivars and varieties can be considered subtypes of a given turfgrass species. Cultivars and varieties possess most of the characteristics common to a turfgrass species but are selected because they have a desirable trait(s) that sets them apart from the majority of the species population. For example, 'Merion' Kentucky bluegrass was selected and sold as a cultivar because it possessed a resistance to leaf spot that common Kentucky bluegrasses did not have. Another example, 'Shortstop' tall fescue, is different from most other tall fescues because it has a lower growing point and finer leaf texture.

Overall, turfgrass cultivars have been selected for traits such as improved appearance (color, density, growth habit, and leaf width), improved management (tolerance to close mowing and less frequent mowing, improved mowing quality, and establishment speed), improved disease and insect resistance, and improved environmental tolerance (shade, heat, drought, wear, cold). Generally, it is recommended that improved cultivars, rather than common-type turfgrasses, be used where possible.

In the majority of settings in which cool-season turfgrasses are grown, it is recommended mixes (combinations of two or more species of turfgrass) and/or blends (combinations of two or more cultivars of the same species) be planted. By combining compatible grasses, growers can create greater tolerance to varied growing conditions in their turf sites. In addition, different grasses can bring varied pest tolerances and resistances to a site, thus reducing the potential for extensive turf damage caused by a single disease.

TURFGRASS SPECIES ADAPTED TO WYOMING

Kentucky bluegrass, perennial ryegrass, tall fescue, and fine fescue are commonly used turfgrasses in the West. These species vary in growth habit, appearance, and maintenance requirements. The next sections will describe these turfgrasses and will detail their characteristics. Growth habits include rhizomatous (spread by underground stems), stoloniferous (spread by aboveground stems), and bunch (gradual increase in clump size). Appearance characteristics include overall turfgrass quality based on a combination of turfgrass color, leaf width, and density. Maintenance requirements include mowing, irrigating, fertilizing, cultivating, and controlling pests.

In addition, these grasses differ in environmental adaptation, wear tolerance, recuperative ability, and use. Environmental adaptation refers to the environment in which each turfgrass will normally perform best. For example, each turfgrass performs best in a particular type of soil and in a certain amount of light. Wear tolerance refers to a turfgrass' ability to withstand traffic, while recuperative ability indicates the turfgrass' ability to recover after damage that can result from insects, diseases, traffic, or environmental stresses. Finally, information concerning normal uses is presented for each of these turfgrasses.

Kentucky bluegrass (*Poa pratensis*)

Establishment method: seeding or sodding

Appearance: moderate to high quality depending on cultivar, management, and environment; medium texture; green to dark green with good density

Growth habit: rhizomatous

Wear tolerance: medium to good

Environmental adaptation: well-drained, moist, neutral to slightly acid, fertile soils; full sun to light shade; good low-temperature tolerance; poor to fair drought tolerance, depending on management and cultivar

Maintenance requirement: low to high depending on cultivar, use, and management level; mow frequently (depending on use), normal lawn heights are 2 to 3 inches; supply 2 to 4 pounds of nitrogen per 1,000 square feet per growing season – split application as to not apply more than 1 pound N per application; supply 1 to 1½ inches of water per week during the growing season to maintain green and active growth; vigorous cultivars grown under high maintenance are prone to producing thatch; diseases and insects can be a problem depending on cultivar, use, management, and growth environment

Recuperative ability: good

Uses: use low maintenance types in areas receiving minimal care; improved types are generally used for home lawns, commercial sites, and other areas requiring attractive turf; Kentucky bluegrass is also used on golf course fairways, tees, and rough areas, and in other athletic settings because of its recuperative potential and appearance

Other notes: most popular cool season turfgrass with many cultivars available; match cultivar to use and management level; slow to establish by seed; seedlings usually weak

Perennial ryegrass (*Lolium perenne*)

Establishment method: seeding

Appearance: moderate to high quality depending on cultivar, management, and environment; medium texture with good density and uniformity; similar to Kentucky bluegrass

Growth habit: bunch

Wear tolerance: good

Environmental adaptation: well-drained, moist, neutral to slightly acidic, fertile soils; full sun; avoid temperature extremes; lacks tolerance to excessive heat, cold, and drought

Maintenance requirements: moderate to high depending on cultivar, use, and environment; mow frequently (depending on use), normal lawn heights are 2 to 3 inches; supply 2 to4 pounds of nitrogen per 1,000 square feet per growing season – split application as to not apply more than 1 pound N per application; supply 1 to 1½ inches of water per week during the growing season to maintain green and active growth; thatch is not a major problem due to bunch-type growth habit; some cultivars are susceptible to diseases, especially red thread and Pythium blight

Recuperative ability: poor

Uses: use low maintenance types in areas receiving minimal culture; improved types are generally used with Kentucky bluegrass for home lawns, commercial sites, and other areas requiring attractive turf; perennial ryegrass is also used on golf course fairways, tees, and rough areas, and in other athletic settings because of its wear tolerance, appearance, and rapid germination

Other notes: rarely used alone; usually combined with Kentucky bluegrass in full sun or with Kentucky bluegrass (and fine fescue) in shady areas; good tolerance to soil compaction; very good for over seeding and renovation; germinates rapidly and strongly; insect pests and diseases can be a problem.

Tall fescue (*Festuca arundinacea*)

Establishment method: seeding and occasionally sodding

Appearance: medium-coarse to coarse texture with low density

Growth habit: bunch

Wear tolerance: good, after establishment

Environmental adaptation: adapts to wide range of soils and environments; full sun; tolerates some shade; does well in heat and drought; useful in the transition zone; tolerates short periods of submersion

Maintenance requirements: low to moderate; mow frequently (depending on use), normal lawn heights are 2½ to 3½ inches; supply 2 to 4 pounds of nitrogen per 1,000 square feet per growing season – split application as to not apply more than 1 pound N per application; supply water as necessary; established tall fescues have good drought tolerance and will require modest irrigation during most Midwestern summers; thatch is not a major problem due to bunch-type growth habit; brown patch can be a disease problem during some years

Recuperative ability: poor

Uses: lawns, parks, golf course roughs, and low maintenance areas; use turf-type tall fescues or fine fescue turf mixes where moderate to moderately high-quality turf is desired and pasture types for utility purposes

Other notes: can become an undesirable weed in other turf grasses

Fine fescue (*Festuca*)

Establishment method: seeding and occasionally sodding

Appearance: fine texture

Growth habit: creeping

Wear tolerance: poor

Environmental adaptation: adapts to wide range of soils and environments; full sun; tolerates some shade; does well in heat and drought; useful in the transition zone; not well adapted to excessive moisture

Maintenance requirements: low to moderate; mow frequently (depending on use), normal lawn heights are 2 to 3½ inches; supply 2 to 3½ pounds of nitrogen per 1,000 square feet per growing season – split application as to not apply more than 1 pound N per application; supply water as necessary; established fine fescues have good drought tolerance and will require modest irrigation during most Wyoming summers;

Recuperative ability: moderate

Uses: lawns, parks, golf course roughs, and low maintenance areas; use turf-type tall fescues or fine fescue turf mixes where moderate to moderately high-quality turf is desired and pasture types for utility purposes

Other notes: quickly goes dormant in high heat and drought conditions; excellent shade tolerance.

Recommended turfgrass planting combinations for specific applications	
Utility, lawn, and other non-sport areas	
Full sun	• Kentucky bluegrass blend (three or more Kentucky bluegrass cultivars) OR • 80/20 Kentucky bluegrass/perennial ryegrass OR • tall fescue blend (three or more tall fescue cultivars) OR • 100% fine fescue blend (three or more tall fescue cultivars) OR • 100% Buffalo grass below 6,000 feet of elevation
Dry shade	• 30-50% blend of shade-tolerant Kentucky bluegrasses + 50-70% fine-leaf fescues OR tall fescue blend
Wet shade	• 70% or more rough bluegrass + remainder in blend of shade-tolerant Kentucky bluegrasses
Sports areas	
Athletic fields (football, baseball, etc.)	• Kentucky bluegrass blend OR • 80%+ Kentucky bluegrass/perennial ryegrass OR • tall fescue blend
Putting greens	• creeping red fescue
Tees and fairways	• creeping red fescue OR • perennial ryegrass OR • Kentucky bluegrass OR • 80% Kentucky bluegrass + perennial ryegrass

Buffalo grass (*Buchloe dactyloides*)– warm season native

Establishment method: seeding and sodding or plugs

Appearance: medium-to fine texture with high density

Growth habit: Long living; sod forming; stolons

Wear tolerance: good, after establishment; tolerant to foot traffic

Environmental adaptation: Can be difficult to establish by seed; late green up and early fall dormancy (both can be mistaken for health issues) adapts to wide range of soils and environments; full sun; will go dormant during extended dry period; does well in heat and drought; not recommended above 6,000 feet elevation

Maintenance requirements: low to moderate; mow infrequently, normal lawn heights are 3 inches; supply 1 pound of nitrogen per 1,000 square feet twice per growing season; supply water as necessary; once established has good drought tolerance; require 1 to 2 inches of moisture every 2 to 4 weeks

Recuperative ability: Excellent once established

Uses: lawns, parks, and low maintenance areas

Other notes: Seeded cultivars (varieties) of buffalo grass that can produce a good quality lawn include Bison, Bowie, Cody, Plains, and Topgun; can be difficult to establish from seed; will not survive at elevations above 6,000 feet; does not perform well in shade; weeds can be difficult to manage as buffalo grass turf can be easily damaged by herbicides (including 2,4-D) when not dormant.

Summary

The effort and time expended selecting the right grass species, mixes, and/or blends will be well spent. Consider the site, use, desired appearance, and management the turf will receive when selecting the species combination. Then select cultivars that best fulfill the desired outcome. Often, there may be more than one “good fit” between turf species, mixes, and/or blends for the specific situation. In such cases, cost and availability may become important factors in the final decision. Plant only high-quality propagules (for example, seed, sod, plugs). When these steps are followed and the actual turf is planted, many potential problems will be reduced, or in the best of situations, eliminated.

Section 2 - Principles of Turf Fertility

LEARNING OBJECTIVES

After completing the following section, you should be able to:

A. List the three major nutrient requirements of turf grasses

B. Explain the purpose of turf soil testing

C. Given a fertilizer label guaranteed analysis, determine the percentage of each of its nutrient components

D. Given a fertilizer guaranteed analysis and a rate recommendation, calculate how much product is needed to treat a specified area

E. List advantages of liquid fertilizer applications

F. List advantages of granular fertilizer applications

G. List advantages of slow-release fertilizers

H. List advantages of quick-release fertilizers

I. Describe the influence of site use (for example, aesthetics, wear) on selection of a fertilizer program

J. Describe optimum fertilization timing for cool-season turf

K. Describe optimum fertilization timing for warm-season turf

INTRODUCTION

Healthy lawns provide aesthetic, recreational, and environmental benefits. Well-maintained lawns and landscapes not only significantly increase property values, they can build a strong source of community pride. Keeping a lawn healthy requires careful implementation of several key cultural management practices such as mowing and fertilization.

Periodic fertilization of an established lawn is important because it keeps the lawn looking good and reduces how much you have to water and control weed, insect, and disease pests – that saves money and is environmentally responsible. This publication answers questions about fertilizing cool-season lawns and provides tips for creating your own fertilization program.

WHAT KIND OF GRASS IS IN YOUR LAWN?

Most lawns in Wyoming contain cool-season grasses, which grow best in the cooler temperatures of spring and fall. During the hottest times of year, they may grow very slowly or even go dormant. Kentucky bluegrass, perennial ryegrass, tall fescue, and fine leaf fescue are common cool-season grasses.

By contrast, warm-season grasses perform best in warmer climates and are less common in Wyoming. These grasses thrive and grow when many cool-season varieties go dormant. Buffalo grass is the common warm-season species seen Wyoming.

If you're not sure what kind of grass you have, or what type of grass to plant, the turfgrass identification and lawn selector tools from Purdue University can help:

- **Purdue Lawn Turf Selection Tool** — www.agry.purdue.edu/turf/turfgrassSelectionTool/index.html
- **Purdue Turfgrass Identification Tool** — www.agry.purdue.edu/turf/tool/index.html

WHY SHOULD YOU FERTILIZE YOUR LAWN?

Fertilizing lawns maintains density and plant vigor, enhances green color, and encourages growth and recovery from turf damage and seasonal turf stresses (such as hot, dry periods). Unfertilized lawns will gradually lose density. When that happens, undesirable grasses (such as crabgrass) and broadleaf weeds (such as dandelion and clover) encroach, and the risk for soil erosion increases. Properly fertilized lawns better tolerate stresses such as heat, drought, and cold. Applying the right fertilizer at the correct time helps turf plants accumulate and store the essential plant foods (sugars/carbohydrates) used for growth and development.

As with all plants, malnourished turfgrasses are more prone to damage from diseases and insects — the damage is more noticeable and recovery takes longer. In short: dense, healthy, properly fertilized lawns require fewer pesticides to manage weeds, diseases, and insects. Lawns receiving periodic fertilization also help protect water quality by substantially reducing water runoff and potential soil losses.

WHAT NUTRIENTS DOES YOUR TURF NEED?

You should only apply the nutrients your lawn needs. The nutrients plants need in the greatest quantity are nitrogen (N), phosphorus (P), and potassium (K). Of these, N has the most impact on established lawns. N promotes green color and overall growth, especially leaf growth. Plants need P and K for strong root and stem growth, which is most crucial when establishing a new lawn.

Don't guess the nutrient needs of your soil: you should test your soil to determine what nutrients it needs. Turfgrass plants accumulate 13 essential nutrients from the soil.

Soil test results also indicate soil pH, which is the acidity or alkalinity of the soil. In Wyoming, the pH will be on the high side (more alkaline). High pH soils limit the availability of several nutrients, particularly iron. The result will be chlorosis of the turf, general decline, and the ability of weeds to thrive. High soil pH can be moderated by the addition of sulfur. In most instances in Wyoming, using sulfur and/or adding iron can alleviate turf chlorosis.

Some soils need to be tested more often than others. Test coarse-textured, sandy soils every year. Test fine-textured/heavy (that is, clayey) soils every two to three years.

Select an appropriate fertilizer source based on soil test results and your color and growth preferences. While soil tests recommend how much of nutrients like P and K your soil needs, there is no reliable soil test to determine the N needs for lawns. Nitrogen is applied to provide greening and growth, while iron is applied to provide greening without growth. Individual needs will vary depending on personal color preferences, the turf's need to recover, and its ability to maintain itself.

Local UW Extension Offices can provide information regarding soil sampling.

HOW DO YOU DEVELOP A FERTILIZER PROGRAM?

An annual fertilizer program generally consists of two (home lawns) to six (highly maintained sports turf) individual fertilizer applications. Base your annual fertilizer program on a specific goal for maximizing turf health, not a color response. If you want the greenest, most actively growing lawn, it is important to understand you will likely need to apply less fertilizer more frequently (four to six times over the growing season). Remember, where you apply more N, you will need to mow more often. If you apply iron, the lawn will green up without the need for more mowing.

If your primary goal is a very dark green lawn, consider selecting and planting grass cultivars that are genetically darker green. This may help reduce the amount you need to spend on fertilizer and decrease your mowing requirement.

WHEN SHOULD YOU FERTILIZE?

Lawns areas slow to green up in spring may benefit from a quick release (water soluble) N application. Quick release N rapidly increases leaf growth and improves green color. Slow release and organic fertilizers perform best in early summer after soils have warmed. Slow release N applications will improve turf appearance through the hottest, driest part of the year without a rapid increase in growth rate. Late summer and early fall applications of P and K (very low or no N) will prepare the turf for winter dormancy and promote root growth through the winter. P and K levels in Wyoming soils are usually adequate, and P and K applications may not be necessary. A soil test will help determine whether or not to apply P and K. Do not apply excessive N in fall. N application in fall promotes snow mold infection in lawns.

WHAT FERTILIZER SHOULD YOU USE?

There are many commercially available fertilizer products. By law, all fertilizers list three numbers on their labels (for example, 16-4-8). These numbers indicate the guaranteed minimum percentage nutrient analysis or amount of N, P (as phosphate), and K (as potash). For example, a bag of 16-4-8 fertilizer contains 16% N, 4% P_2O_5, and 8% K_2O.

Consult your soil test report to determine your specific P and K needs. Many consumer publications suggest applying P and K in the fall to “put the lawn to bed.” However, if a soil test indicates the soil has sufficient P and K, applying more is unnecessary.

Ideally, you should use “lawn” fertilizers. Avoid “general-purpose” garden fertilizers (such as 12-12-12). Lawn fertilizers are specifically designed to provide the nutrients that mature lawns need. They also are formulated to minimize turf injury and often contain some portion of slow-release nutrients to provide long-term, steady feeding.

CALCULATING GRANULAR FERTILIZER NEEDS

To determine how much fertilizer to apply, know three important things:

- The size of the area you plan to treat
- The target application rate you want to apply (normally between ½ and 1 pound of actual N per 1,000 square feet)

- The percentage of the nutrient in the fertilizer product you will use.

Let's say you have a lawn that is 5,500 square feet, your target application rate is ½ pound of actual N per 1,000 square feet, and you are using an 18-0-10 fertilizer product.

Here's how you determine how much actual fertilizer product to apply.

1. Convert the percentage of the nutrient to a decimal. The 18-0-10 fertilizer product contains 18% N, so the decimal value is 0.18.

2. Divide the target application rate (½ pound) by the decimal value from step 1.

   0.5 ÷ 0.18 = 2.78

   This is how many pounds of actual fertilizer product you will need per 1,000 square feet.

3. Divide the actual area of your lawn (5,500 square feet) by 1,000:

   5,500 ÷ 1,000 = 5.5

4. Multiply the results from Steps 2 and 3 to determine how much actual fertilizer you will need to apply to your lawn at the desired rate:

   2.78 x 5.5 = 15.29

You will need to apply 15.29 pounds of 18-0-10 fertilizer product to your 5,500-square-foot lawn to achieve the target application rate of ½ pound of N per 1,000 square feet.

If you want to skip the math, the Purdue Turf Fertilizer Calculator can perform these calculations for you. This online tool is available at www.agry.purdue.edu/turf/fertilizerCalculator/index.html.

Simply input the specific product analysis, target application rate, and size of the turf area you want to treat.

TWO KINDS OF N FERTILIZERS

N fertilizers are broadly classified into two categories:

1. **Quick-release products** are water-soluble and immediately available to plants. Quick release fertilizers benefit lawn's appearance for 4 to 6 weeks. Water in immediately after application. Quick-release fertilizers can burn turf if not watered in.

2. **Slow-release products** release N slowly over time. Slow-release products generally feed the lawn for 10 to 12 weeks. Water in immediately after application. Risk of fertilizer burn is less than quick-release fertilizers.

HOW MUCH SHOULD YOU APPLY?

All lawns will benefit *from* some fertilizer. Fertilization, especially with N, helps maintain density, color, and vigor. **But more N fertilizer is *not* necessarily better, and excess N fertilizer will contaminate surface and ground water**. Reports from the United State Geological Survey (USGS) for Wyoming indicate surface water and well water samples collected around municipalities confirm excess nitrogen and pesticides from use in towns are contributing to contaminated water systems.

Annual N requirements vary considerably depending on turfgrass species, growing environment, appearance expectations, and traffic. When considering how much N to apply, you must answer two questions:

- How much overall fertilizer is needed to meet expectations?
- How will this amount affect your ability to provide enough fertilizer to maintain the turf? For example, are you willing to provide the extra mowing that might be required?

In general, mature cool-season lawns in Wyoming should receive up to 4 pounds of actual N per 1,000 square feet per year, which depends on many factors. Selecting the specific fertilizer, rate, and timing for each application also depends on many factors. **Remember, the goal should be steady, sustained growth, not rapid growth flushes or greening**.

A product's maximum application rate depends primarily on the amount of water-soluble N it contains. **Do not apply more than 1 pound of actual water-soluble N per 1,000 square feet in any single application**. This helps minimize growth surges, potentially negative effects (such as leaf injury), and leaching and runoff loss.

If the fertilizer product contains more than 50 percent of its N from slow-release sources, you can apply the product at higher rates. For these products, do not apply more than 2 pounds of actual N per 1,000 square feet in any single application.

WHAT ELSE SHOULD YOU CONSIDER?

Growing environments and management practices affect overall N needs. In the 12 to 18 months after installing a new lawn (seeded or sodded), the turf may require up to 50 percent more overall N and more frequent applications than well-established lawns. By contrast, you may have to adjust the annual fertilization program if the lawn is extremely mature, it is shaded, it receives regular supplemental irrigation, or if clippings are removed during each mowing.

Mature lawns

Fully mature lawns that have been regularly fertilized for more than 10 years don't need as much N fertilizer. Over time, the soils in these lawns have accumulated organic N, which provides background nutrition. For mature lawns, consider omitting one or more applications or reducing application rates to meet your growth and color goals.

Lawns where clippings are regularly collected

Returning clippings during mowing benefits the lawn because grass clippings contain valuable nutrients that can be recycled into the soil. If you must regularly remove clippings when you mow, you may need to increase the amount of N you apply each year by 25 to 50 percent to maintain growth and color.

Shaded lawns

Shaded grasses grow more slowly, so they may require up to 50 percent less annual N than turf grown in full sun. The turfgrass species of choice for shaded areas are the fine-leaf fescues such as creeping red fescue. This grass will persist in moderate shade, but if you apply too much N, the stand's quality and density will decline.

In general, do not apply more than 2 pounds of actual N per year to turf in shaded environments. You can apply fertilizer at the same times you would apply it to sunny lawns, but you should simply reduce the overall N application rates by half.

MORE TIPS FOR RESPONSIBLE FERTILIZATION

Healthy lawns provide more than aesthetic beauty. A substantial amount of university research has demonstrated properly maintained and fertilized lawns considerably reduce water runoff, soil sediment, and nutrient losses. The movement of sediment and nutrients like N and P from urban areas, agricultural fields, and turf has been implicated in poor water quality.

Follow these suggestions to fertilize a lawn responsibly to maximize health and minimize nutrient loss.

- Mow general turf areas (home lawns, parks) at 3 to 4 inches high and return clippings when possible.
- Apply lower rates of fertilizer more frequently (such as ½ pound of actual N per 1,000 square feet every 21 days). This practice may provide more consistent color and growth responses than less frequent applications at higher rates.
- Only apply fertilizers to actively growing turf. Do not apply fertilizer to dormant or severely drought-stressed turf. *Do not* apply fertilizer during the winter or when the soil is frozen.
- Use a rotary spreader when possible. Rotary spreaders may be less time consuming, easier, and provide more uniform product coverage than drop-type spreaders.
- Clean up any fertilizer particles that end up on hard surfaces (sidewalks, driveways, roads, etc.). Return the particles to the turf using a broom or blower.

Section 3 - Calibrating Pesticide Application Equipment

LEARNING OBJECTIVES

After completing the following section, you should be able to:

A. Given a product label, determine:
   - appropriate application equipment
   - minimum spray volume (where appropriate)
   - agitation requirements (where appropriate)

B. Describe the function (for example, spot spray vs. broadcast) of the following application equipment:
   - boom sprayer (including ride-on sprayers)
   - hose reel sprayer
   - backpack/hand-held sprayer

C. Contrast the function of rotary vs. drop spreaders.

D. Define the word "skew" with respect to rotary spreaders.

E. Describe procedures for determining the desired application rate and uniform coverage for:
   - boom sprayers
   - hose reel sprayers
   - drop and rotary spreaders

F. Describe common means of adjusting output for the above sprayers.

G. Describe the relationship between application speed and application rate.

H. Describe the relationship between spray pressure and application rate.

I. Given length of calibration run, swath width, and gallons of mix or pounds of granules applied, calculate application rate.

J. Given a spray application rate and tank capacity, calculate how much area a full tank can treat.

K. Given a spray application rate, product rate, and tank capacity, calculate how much pesticide product is needed to mix a full tank.

L. Calculate how much pesticide product is needed to yield the correct concentration for a specific tank size.

M. Identify features of a suitable site for mixing turf products.

N. Describe the purpose of an air gap between the fill hose and spray tank.

O. Describe the general procedure (including order) when tank mixing two or more turf products.

P. Describe how people, pets, and man-made structures in and near the application site can influence staging decisions.

Q. Given a liquid application rate, area treated, and amount of liquid remaining in the spray tank, estimate application accuracy.

R. Given a dry application rate, area treated, and amount of dry product remaining in the hopper, estimate application accuracy.

INTRODUCTION

The performance of any pesticide used to manage pests of ornamental plantings and turf depends on its proper application to the target: insect, weed, host plant, or soil. This chapter covers the calibration of equipment used by commercial landscape managers for liquid and dry pesticide applications. Applicators typically use manual sprayers fitted with single-nozzle spray guns for small jobs; they use high-pressure, high-volume, hydraulic sprayers for large jobs such as spraying tall shade trees. Other situations may call for granular spreaders.

MANUAL SPRAYERS

Manual sprayers are ideal for making pesticide applications to shrubs, small trees, and areas such as flowerbeds too small to accommodate larger units; they also work well for spot treatments. Most manual sprayers are pressurized by hand pumping to generate enough pressure to force the spray liquid through the nozzle. They are relatively inexpensive, simple to operate, maneuverable, and easy to clean and store. Tank sizes range from one to three gallons for hand-held sprayers and four to six gallons for backpack sprayers.

Calibrating manual sprayers

There are multiple ways to calibrate manual single nozzle sprayers designed for use in small areas. Most do not have pressure gauges or controls, and pressure drops as the material is sprayed from the tank. You should fill the tank only two-thirds full, leaving enough air space for initial expansion, and repressurize (pump) the tank frequently.

Broadcast spraying (treating an area uniformly) requires the following technique. Hold the nozzle steady, at a constant height, so that treated swaths just touch. Maintaining a uniform walking speed during application is important.

Calibrate manual sprayers for broadcast applications as follows:

1. Measure and mark a small test area; 250 square feet (10 ft x 25 ft) is very convenient.
2. Fill the tank with water and clearly mark the fill level.
3. Spray the test area. Several initial practice runs may be helpful to establish consistency.
4. Refill the tank to the original fill mark. Note the exact amount of water needed to refill the tank. This is the amount applied per 250 square feet.
5. Multiply by 4 the amount applied per 250 square feet to determine the amount per 1,000 square feet (i.e., convert to standard label language).
6. Confirm the amount applied is within the label recommendation. If the volume applied is too low, repeat the test by walking slower to increase the application rate; if it's too high, walk faster to decrease the application rate.

HYDRAULIC SPRAYERS

Shade tree sprayers

Spraying tall ornamentals and shade trees for insect and disease control requires thorough coverage of leaf, stem, and trunk surfaces. This requires a considerable amount of spray pressure because of the long distance between the sprayer and the target and covering large surface areas.

Tree spraying normally is done with high-pressure, high-volume, hydraulic sprayers. Hydraulic liquid sprayer systems provide sufficient pressure to propel spray droplets to the point of application.

Obtaining uniform coverage of shade trees with hydraulic sprayers

Hydraulic sprayers used for spraying tall trees generally have tanks, pumps, and control systems that can handle high volumes of spray materials at high pressures. Sprayers are generally available with tank capacities up to 500 gallons and with pumps that can spray up to 60 gallons per minute (gpm) at pressures as high as 500 pounds of pressure per square inch (psi).

Applicators nearly always use hand-operated spray guns to direct the spray onto the tree, treating to the point of runoff to ensure thorough coverage. The most common type is the single-outlet gun with a pistol-grip valve.

Relatively good coverage is attainable with a spray gun using a high volume of water. However, coverage problems can occur at the tops of very tall trees. For optimum results, select the correct combination of pressure and nozzle flow rate.

Large spray droplets are necessary to reach the tops of trees and to keep wind from dissipating the spray. But droplet size decreases as pressure increases, thereby limiting the extent to which pressure can be increased to extend the range of the vertical spray stream. When vertical reach becomes a problem, select a nozzle of larger capacity rather than simply increasing the pressure. Guns and nozzle kits are available to spray trees up to 100 feet tall at pressures of 350 to 450 psi. Ladders, elevated truck-mounted platforms, or gun extensions also can help deliver the necessary reach.

Calibrating hydraulic hose-reel sprayers

A typical hose-reel sprayer setup consists of a stationary, truck-mounted pump and a 200- to 300-gallon spray tank. The applicator is tethered to the tank by 200 to 300 feet of high pressure sprayer hose. The application is made by swinging the spray gun in a side-to-side motion while walking in parallel passes across the target site.

Calibrate hose-reel sprayers as follows:

1. Identify the label-approved spray application rate. These usually range from ½ to 6 gallons per 1,000 square feet. (Note that 2 gallons per 1,000 square feet is a common spray application rate in the lawn care industry.)

2. Select a nozzle tip for the spray gun that delivers approximately the same number of gallons of spray per minute that will be applied per 1,000 square feet (i.e., select a 2-gallon per minute nozzle for a spray application rate of 2 gallons per 1,000 square feet).

3. Install the selected nozzle and, spraying water only, collect the output from the spray gun for one minute operating at the nozzle manufacturer's recommended pressure. This can be done into a bucket or any large container marked in 1-gallon increments. The objective is to collect the same number of gallons that the nozzle selected in step 2 is expected to deliver in one minute. This may take several trials, adjusting pump pressure up or down, to increase or decrease the spray delivery rate, until the desired delivery rate is achieved.

4. Measure a 1,000 square-foot calibration site (for example, 20 feet by 50 feet), preferably on asphalt or concrete

pavement. Calibrating on pavement allows the applicator to visually observe the results of their application technique for uniform coverage.

5. Spray the calibration site (with water) using proper application technique. The objective is to spray the 1,000 square-foot area in one minute while achieving uniform coverage. This may take numerous practice trials. Once trained to this action, the applicator has learned to apply the desired spray rate. For example, using a nozzle adjusted to deliver 2 gallons per minute to uniformly spray a 1,000 square feet in one minute ensures that the spray application rate is 2 gallons per 1,000 square feet.

Correct application technique for hose-reel sprayers

Spraying

Begin the first pass while walking at the same speed determined during the calibration run.

Hold the spray gun parallel to the ground and swing the spray gun in a back-and-forth arm motion, so as to cover approximately an 8-foot swath. Arm motion should be fast enough to, conceptually, allow for any point in the turf to be sprayed three times (once with the leading edge of the spray, once with the middle, and once with the trailing edge).

At the end of the pass, stop spraying and move over 4 feet. Return for the next pass, spraying back to the footsteps from the previous pass. Note that the edges of each 8-foot swath are tapered and this overlap ensures the entire area receives a full application rate (except the initial and final passes, see Trimming below).

Trimming

Trim turf borders along the initial and final application passes by increasing walking speed and using a more rapid arm swing.

Spray a 4-foot swath to the lawn edge.

Avoid spraying onto non-turf areas. Note that failure to trim the turf borders will result in only half of the proper application rate reaching the lawn edges.

BOOM SPRAYERS

Large boom sprayers are commonly used in golf course and athletic field management where they offer efficient, uniform coverage across large turf areas. Smaller ride-on boom sprayers (and single-nozzle boomless sprayers) are widely used in commercial and residential lawn care situations.

Calibrating boom sprayers

There are many different methods for calibrating boom sprayers. A generalized procedure for calibrating boom sprayers entails the following steps:

1. Determine the effective swath width. This can be done by measuring the distance between two adjacent nozzles (they should all be the same) and multiplying by the total number of nozzles. Note that for single-nozzle boomless sprayers the swath width is determined by spraying water onto pavement and measuring the distance, edge-to-edge, where water darkens the pavement the most. Exclude from the measurement the lighter, feathered edges where the spray tapers off.

2. Determine the length of a calibration run necessary to spray 1,000 square feet. For

example, if the swath width is 7 feet, the calibration run needs to be 1,000 ÷ 7 = 143 feet (7 feet x 143 feet = 1,000 square feet).

3. Measure the calibration run onto turf and flag the beginning and end.

4. Fill the tank half full with water.

5. Time how long it takes to travel the calibration run at the same speed (gear and RPM) that will be used to make the actual application. Repeating this step and calculating an average time improves timing accuracy.

6. With the sprayer stationary and the pump operating at the same pressure as it will be during the actual application, collect water from (each) nozzle into a container marked in ounces. Collect spray water for the same amount of time that it took to travel the calibration run and determine total boom output. Repeating this step and calculating an average boom output improves measurement accuracy.

7. The total boom output determined in step 6 equals the application rate per 1,000 square feet. Determine whether the application rate is appropriate.

8. If the application rate is too high or too low, then adjust nozzle pressure (if the equipment permits this option), select a different nozzle size, or change spray speed.

MIXING TURF PRODUCTS IN A SPRAY TANK

Always wear label-required personal protective equipment (PPE). Note that PPE requirements may be different for mixing than they are for application activities.

Mix turf products away from surface water. Also avoid mixing at sites from which spilled product could be carried into surface water by runoff.

Ideally, mixing should be done over an impervious mix pad (near the storage facility) that will collect any spilled material and keep it away from water and out of the soil. In the absence of a mix pad, mixing may be done at a label-approved application site where potential spills can be contained to protect water, desirable vegetation, etc. Note, however, that repeatedly mixing over the same unprotected area (gravel, soil, or turf), even though label-approved, may lead to site contamination due to the cumulative effects of numerous, minor product spills.

Remember to always protect the water source used for mixing by either equipping it with an anti-siphoning device or maintaining an air gap to prevent back-siphoning by keeping the fill hose above the tank opening.

Calculating how much product is needed to mix a full tank

To calculate how much product to add to the tank, the applicator must know:

- labeled recommended application rate
- spray tank capacity
- sprayer's calibrated output

First, calculate the total area (acres or square feet) a full tank can spray. Divide the number of gallons the tank can hold by the calibrated spray rate. Then, determine the amount of product to add to the tank by multiplying the area sprayed per tankful by the labeled product application rate.

For example, an applicator intends to apply 1.5 liquid ounces of product per 1,000 square feet. The sprayer is calibrated to deliver 2 gallons of spray per 1,000 square feet and is equipped with a 200-gallon tank. So, the 200-gallon tank can spray 100,000 square feet (200 gallons ÷ 2 gallons per 1,000 square feet = 100,000 square feet) and 150 liquid ounces of product are needed to mix a full tank (1.5 ounces per 1,000 square feet x 100,000 square feet = 150 ounces).

GRANULAR SPREADERS

Granular formulations are intended primarily for soil application of preemergence herbicides, insecticides, and fertilizers. They are typically applied either manually or by rotary spreaders.

Manual applications

Some granular products may be applied by hand –label permitting. The applicator, wearing gloves, sprinkles the product onto the site in as uniform a manner as possible.

The application of granular products by hand is sometimes facilitated by the design of the container. For example, some granules are sold in containers equipped with a cap that serves as the application device. The applicator twists (or, in some cases, removes) the lid and uses the container to shake an appropriate amount of material onto the application site. This allows for a reasonably uniform treatment.

The manual application of granular materials is best suited to small treatment areas such as flowerbeds or around shrubs where the granules are applied underneath the plants. To enhance uniformity of treatment, some herbicide labels will provide an illustration or photograph that depicts what the application pattern should look like.

Drop spreaders

Drop spreaders deliver a narrow, uniform pattern between the spreader wheels. While drop spreaders provide good product distribution, the edge of the pattern is sharp and steering errors will cause missed or doubled strips.

Rotary spreaders

Rotary spreaders consist of a hopper to hold the granules, an agitator at the bottom of the hopper to enhance product flow through an adjustable metering device, and a spinning disc underneath the hopper that delivers the granules in an arc to the front and sides of the spreader, creating a semicircular pattern. Granule distribution is fan shaped, with the heaviest concentration of product in the center of the pattern. Uniform distribution requires that the applicator overlap the pattern between passes within the treatment site.

Manufacturers produce a variety of rotary spreaders – some that are pushed, some that are hand-carried, and some that are shoulder- or neck-supported.

Rotary spreaders mounted on wheels can be used to efficiently treat large open areas: for example, where an applicator is applying product between rows of tree stock in a nursery or during the preparation of new, large, landscape beds where there is an unobstructed path to push the equipment through. However, their use in established plantings is limited. Foliage can intercept the granules and prevent them from reaching the ground (wet foliage may also be burned by the granules). And, if there are large shrubs in the bed, they can act as a screen, preventing granules from reaching the far side of the landscape bed.

Hand-operated rotary spreaders are more practical for small to mid-size areas. They are also more convenient to maneuver through planted sites.

The smallest hand-operated rotary spreaders are actually carried in one hand, while the other hand turns the handle that operates the device. The operator walks at a steady pace while turning the crank to achieve an even distribution of granules. Larger models (sometimes called belly grinders) operate the same way. However, they are held in front of the applicator, supported by a strap around the operator's neck. A covered hopper protects the applicator from inhaling any dust generated during the application.

The advantage of hand-operated rotary spreaders in the landscape is that they are more easily maneuvered around obstacles than push-type spreaders. However, they share a similar problem in that foliage can intercept the granules, increasing the possibility of plant damage and making a uniform application difficult.

Calibrating rotary spreaders

The principles for achieving application accuracy with granular products are the same regardless of what kind of rotary spreader is used. Spreaders are calibrated using the actual product that will be applied to the site; the person who will be making the application should also be the one who calibrates the equipment.

The general procedure first involves marking off a measured test area. Granules are then placed into the hopper. The operator, walking at a comfortable, uniform pace, treats the entire test area. The material in the hopper is weighed before and after the application, and the weight difference equals the amount applied. Mathematically comparing the amount applied to the test area with the label recommendation will indicate if a rate adjustment is necessary. The operator should – according to manufacturer's instructions – adjust the flow rate and repeat the test until the correct setting is obtained for the desired application rate. Re-calibration is necessary every time a new product is used because the distribution pattern varies with granule size.

Accurate applications also entail proper pattern overlap. The equipment instructions may provide guidance on how to achieve the appropriate degree of overlap, but applicator experience is also critical. Experienced applicators will learn to recognize the desired pattern of granules on the ground for those products they regularly use.

Distribution pattern

The pattern produced by a rotary spreader depends on impeller (rotor) characteristics (speed, height, angle, shape, and roughness) as well as the point onto which the granules drop. It also depends on the ground speed (for example, faster application speeds for push-type rotary spreaders cast a wider swath), the physical parameters of the product (density, shape, roughness of granule), and environmental factors (wind, temperature, and humidity). Rotary spreaders are sensitive to these variables, and operators must assess their effects during application to maintain a consistent pattern.

Checking the distribution pattern of a rotary spreader entails laying out a row of shallow boxes in a line on, preferably, a paved surface. Boxes 1 to 2 inches high, each with an area of 1 square foot, spaced on 1-foot centers will suffice. The row of boxes should cover 1½ to 2 times the anticipated swath width.

Fill the spreader approximately half full (with the same product that will be used during actual the application), making sure the equipment is adjusted according to label specifications (for example, gate setting). Operate the spreader in a pass perpendicular to the boxes (and over the center box). Repeat several times *in the same direction*. Weigh the material collected in each box and record the weights in the same order as the spreader approached the boxes, from left to right.

Alternatively, pour the material from each box into its own glass tube, vial, or small bottle. Place the glass containers side-by-side in the same order as the collection boxes. This permits a direct visual observation of the distribution pattern. The pattern should be highest in the middle and tapering toward the edges. Patterns where the heaviest distribution shifts to the left or right of center are termed "skewed." If the pattern is skewed, follow the spreader manufacturer's recommendations for making a pattern adjustment.

The pattern check will also reveal the effective swath width for the product applied under the given operating conditions. It is the distance between the two points on each side of the spreader where the amount of granules collected is half that collected from directly in front of the spreader.

Application rate

After confirming the distribution pattern is acceptable, the next step is to determine the application rate. Select a calibration area that is a labeled application site for the product, or plan to collect the granules.

The simplest way for an applicator to check the delivery rate of a spreader is to apply the product to a measured area. A calibration trial need only be a simple linear run since the effective swath width is already known (from the pattern check). For example, if the effective swath is 8 feet, the calibration run should be 125 feet (1,000 feet ÷ 8 feet = 125 feet) to yield a calibration treatment area of 1,000 square feet. Weighing product placed into the hopper before application and what is left over after treating the calibration run will indicate the actual application rate.

Remember to always calibrate the spreader with the product of choice. All applicators should be assigned spreaders for which they are responsible and which they, exclusively, should calibrate and use. And in addition to routine calibration, calibrate whenever the equipment is knocked out of adjustment or suffers mechanical damage.

Correct application technique for rotary spreaders that have an adjustable third port

Trimming (perimeter pass)

- Lower the deflector shield and close the third port.
- Hold the spreader handle so the impeller is level with the turf.
- Apply granules to the entire perimeter of the treatment site. Treat to the edge of the turf but take care to avoid applying granules to non-turf areas. Any granules that wind up on hardscapes should be swept or blown back onto the turf.

Spreading

- Raise the deflector shield and open the third port.
- Hold the spreader handle so that the impeller is level with the turf.
- Approach the turf, walking at the same speed as the calibration run, and open the spreader gate as the spreader passes onto the turf.
- Close the spreader gate when granules strike the area covered by the trim (perimeter) pass.
- Turn around and move over sufficient distance to achieve proper pattern overlap (approximately where the edge of the pattern reaches the wheel tracks of the previous pass).
- Make a series of equally spaced passes back-and-forth across the lawn until the entire area is treated.

Loading products in a spreader

Remember to read the product label and wear the required PPE. Make certain the hopper is closed. Load product over an asphalt or concrete surface

so as to easily sweep up any material that might be spilled. Always have a rain cover available in the event of a weather change.

Calculating how much product is needed to complete a job

Calculating the amount of granular product required for a job is a function of the size (area) of the treatment site(s) and the spreader's calibrated application rate.

For example, if a granular insecticide application will be made to 5 lawns, each approximately 6,000 square feet in area, at a rate of 1.8 pounds per 1,000 square feet, then 54 pounds of product are needed. The total area treated is 5 x 6,000 square feet = 30,000 square feet and 30,000 square feet x 1.8 pounds per 1,000 square feet = 30 x 1.8 = 54 pounds.) If the product is sold in 30-pound bags, then almost two bags will be needed to treat all five lawns (54 pounds required ÷ 30 pounds per bag = 1.8 bags).

SAMPLE PROBLEMS

1. An insecticide label instructs the applicator to thoroughly wet the foliage, using an application rate of ½ pound of product per 100 gallons of water. If the application requires only 3 gallons of spray liquid, how many ounces of insecticide are necessary? (1 pound = 16 ounces)

2. A fungicide label directs the user to apply the product as a spray, to runoff, at a rate of 2 pints of product per 100 gallons of water. How many tablespoons of fungicide are necessary if the treatment requires only 5 gallons of spray? (1 gallon = 8 pints = 128 ounces = 256 tablespoons)

3. An operator is using a high-pressure spray gun with a nozzle operating at 4.5 gallons per minute. It takes 3 minutes to treat a tree to the dripping point using a fungicide at an application rate of 1.5 pounds of product per 100 gallons of water. How many ounces of fungicide is the operator actually applying to the tree?

4. The label for a granular, preemergence herbicide indicates an application rate of 75 pounds of product per acre. Calculate the amount of product you will need to treat a site that measures 18 feet x 32 feet. (1 acre = 43,560 square feet)

5. An operator is using a rotary spreader with an effective swath width of 6 feet to apply a granular fungicide. He calculates an output of 2.0 pounds after a calibration run of 100 feet. What rate is the spreader applying in pounds per acre?

6. An applicator intends to apply an herbicide in 16-foot-diameter circles around the bases of 10 trees. The application rate is ½ ounce of product per 1,000 square feet. How much product is needed for all 10 trees? (Area = $\pi r2$, $\pi = 3.14$, r = radius)

7. A manual sprayer has a 4-gallon capacity. The operator calibrates the sprayer and finds that it delivers ½ gallon of water per 250 square feet. How much preemergence herbicide will he need to make a full spray tank if the label rate is 3 ounces per 1,000 square feet?

8. An applicator, walking at a speed of 2 miles per hour, sprays 2 gallons per 1,000 square feet. What would the application rate be if he increased his walking speed to 4 miles

per hour? (Speed and application rate are inversely proportional).

9. A hose-reel sprayer equipped with a 200-gallon tank is calibrated to apply 2 gallons per 1,000 square feet. How many square feet can a full tank treat?

10. A ride-on boom sprayer equipped with an 18-gallon tank is calibrated to spray .75 gallons per 1,000 square feet. How many square feet can a full tank treat?

11. A hose-reel sprayer is calibrated to apply 3 gallons per 1,000 square feet. The tank capacity is 200 gallons and the labeled rate of herbicide to be applied is 4 fluid ounces per 1,000 square feet. How many gallons of herbicide are needed to mix a full tank (1 gallon = 128 ounces).

12. A boom sprayer equipped with a 300-gallon tank is calibrated to spray 20 gallons per acre. The labeled rate of the herbicide to be applied is 16 fluid ounces per acre. How many gallons of herbicide are needed to mix a full tank (1 gallon = 128 ounces)?

13. A fungicide is packaged in 11-ounce, water-soluble packets. Each packet will treat 11,000 square feet. How many packets are needed to treat 1.5 acres (1 acre = 43,560 square feet)?

14. A spreader is calibrated to deliver 2 pounds of granules per 1,000 square feet with a product sold in 45-pound bags. How many bags of product are needed to treat 15 lawns, each measuring 6,000 square feet?

15. A spreader with an effective swath width of 6 feet is operated over a 167-foot calibration run and found to deliver 1.7 pounds of granules. What is the application rate in pounds per acre (1 acre = 43,560 square feet)?

16. A hose reel sprayer with a 100-gallon tank is calibrated to spray 2 gallons per 1,000 square feet. How much spray mix should remain in the tank after treating 4 lawns, each measuring 5,700 square feet?

17. The labeled mix rate to make a 1% herbicide solution for spot treatments is 1 1/3 fluid ounces of product in 1 gallon of water. How much product is needed to mix a full tank on a 4-gallon backpack sprayer?

18. A boom sprayer applies 20 gallons per acre while operating at a speed of 8 miles per hour. What does the application rate become if speed is decreased to 4 miles per hour (and no other equipment adjustments are made)?

Answers: 1. 0.24 ounces; 2. 3.2 tablespoons; 3. 3.24 ounces; 4. 1.0 pound; 5. 145.2 pounds per acre; 6. 1 ounce; 7. 6 ounces; 8. 1 gallon per 1,000 square feet; 9. 100,000 square feet; 10; 24,000 square feet; 11. 2.08 gallons; 12. 1.875 gallons; 13. 6 packets; 14. 4 bags; 15. 74 pounds; 16. 54.4 gallons (a little more than half full); 17. 5 1/3 ounces; 18. 40 gallons per acre

Section 4 - Ornamental and Turf Maintenance of Application Equipment

LEARNING OBJECTIVES

After completing the following section, you should be able to:

A. Given a turf product label, determine which PPE is suitable for a particular handling activity (for example, mixing, applying, or cleaning spills or equipment)

B. Describe how to properly inspect and maintain PPE

C. Describe what can happen to output and pattern when spray nozzles become:
   - clogged
   - worn

D. Explain when nozzles need to be replaced

E. Identify where leaks are likely to develop in application equipment

F. Discuss the options for properly dealing with turf products leftover after application

G. Identify features for a site suitable for washing application equipment

H. List general procedures for cleaning the interior and exterior of application equipment (including what to do with the rinse water)

INTRODUCTION

Application accuracy, reduced environmental impacts, and regulatory compliance all depend on application equipment being in good working order. Equipment maintenance, which includes regular cleaning, helps:

- prolong equipment life
- prevent unnecessary repairs and downtime
- reduce the potential for personal exposure and non-target damage

CLEANING SPRAYERS

Clean the sprayer as soon as practical between jobs. Dried herbicide residues are much more difficult to remove than herbicide still in solution. The following are general herbicide sprayer cleaning guidelines:

1. Mix only the amount of herbicide necessary for the job. Small amounts of leftover spray mix may be applied to appropriately labeled sites or collected, labeled, and stored securely for future use.

2. Select a cleaning location away from surface water, wells, or sites where runoff or excessive leaching may occur. This should be a site labeled for application of the product that was in the tank or on a cleaning pad where rinse water can be collected.

3. Rinse the outside of the sprayer thoroughly with clean water.

4. Fill the spray tank half full with clean water and add the label-recommended cleaning agent.

5. Circulate the cleaning solution through the spray system for several minutes and spray a small amount through the nozzles.

6. Allow the cleaning solution to remain in the sprayer for the manufacturer-recommended time before pumping it through the nozzles and draining the remainder from the tank.

7. Remove spray nozzles and strainers.

8. Rinse the tank interior with clean water and flush the system. This is a good time to check the spray system for leaks. Pay special attention to areas where leaks commonly occur (for example, hoses and hose connections).

9. Rinse and clean nozzles and screens with clean water.

NOZZLE WEAR

Spray nozzles wear over time. They become worn even with normal use, and this can occur especially quickly when abrasive formulations (those that form suspensions) are used regularly. A worn nozzle will have a greater flow rate than that of a new nozzle of the same type and size. Nozzles with flow rates in excess of 10 percent of that of a new nozzle should be replaced. The most accurate way to check flow rate, for example, during calibration, is by measuring each nozzle's output with either a flow meter or a graduated cylinder collection container and a timing device.

Nozzles can also get damaged during use. Damaged nozzles may have a distorted spray pattern and a higher than normal flow rate. The best way to protect nozzles is by matching them with appropriate strainers to prevent clogging. If a nozzle does get clogged, use a soft bristle brush to clean. Never use a metal object.

CLEANING AND MAINTAINING SPREADERS

A granular spreader is a precision tool and should be treated accordingly. A few simple steps can help extend its life and preserve its precision.

1. Wash spreaders after every use. Wear label-required PPE and clean the spreader on a label-approved application site. A cold-water wash is adequate for cleaning the residue left from most granular products. It is helpful to first close the spreader ports and fill the hopper with water. This should allow any material buildup to become loose enough to be rinsed out with a garden hose.

2. Next, wash the rest of the spreader. If there is a persistent buildup of material on the spreader that doesn't readily come off with cold water, try warm water and wipe with a cloth or sponge. Take care to wash off any buildup on the impeller. Operate the on/off linkage several times while spraying water onto the shut-off-plate to clean between the plate and the hopper.

3. Dry the spreader by placing it in a warm, sunny location. It may need to be turned upside down for part of the drying time to be sure all of the rinse water drains.

4. Remember to follow all of the manufacturer's cleaning instructions.

The gears on some rotary spreaders are designed to be greased, while others are not. The same advice applies to axle bearings; some are designed to be oiled or greased, and some are not. And be careful with lubricants around plastic components. Some popular spray lubricants may dissolve plastic spreader parts.

5. Store the spreader, long-term, with ports fully open, to relax the spring mechanism. Store indoors, away from moisture and direct sunlight, and, preferably, hang from a wall bracket.

MAINTAINING PERSONAL PROTECTIVE EQUIPMENT (PPE)

Remove PPE after completing pesticide-handling activities. Wash gloves first before handling other contaminated PPE, and again before removing them. Follow the PPE manufacturer's instructions for cleaning reusable PPE. If there are no instructions, use detergent and hot water. Air-dry when finished. And never reuse disposable (one-time) PPE.

When clean and dry, store reusable PPE in an area protected from dust, sunlight, extreme temperatures, excessive humidity and moisture. Never store PPE with pesticides, other chemicals, or personal clothes. Keep PPE in its original package or in a sturdy plastic bag with a zip closure. Point of storage is also a good time to check PPE for visual signs of wear. Look for holes, abrasions, or tears and any changes in the PPE material's appearance including staining, swelling, bubbling, or stiffening.

Note that disposable PPE and reusable PPE that has exceeded its expiration date, become damaged, or failed visual inspection may be bagged and discarded as regular trash only when properly cleaned first.

Section 5 - Rules and Regulations for Wyoming Applicators

LEARNING OBJECTIVES

After completing the following section, you should be able to:

A. Describe who is covered by the worker protection standard

B. Understand the responsibilities of employers, workers, handlers as described by the Worker Protection Standard.

C. Know how to find additional resources pertaining to the Worker Protection Standard.

D. Understand the Wyoming Statutes concerning the direct supervision of non-certified employees

WORKER PROTECTION STANDARD

The federal Worker Protection Standard (WPS) pertains to those who apply pesticides or who work in pesticide-treated areas of agricultural establishments – on farms and in forests, *nurseries*, and *greenhouses*. WPS requires employers to provide workers and pesticide handlers with protection against possible harm from pesticides applied to agricultural plants. Operations producing ornamental plant material (such as nurseries and greenhouses) are specifically covered under the WPS as agriculture-related establishments.

The WPS requires employers to take steps to protect workers and pesticide handlers from exposure to pesticides. A worker is anyone who is employed (including self-employed) for any type of compensation and doing tasks such as harvesting, weeding, or watering related to the production of agricultural plants in a nursery or greenhouse.

A pesticide handler is anyone who is employed (including self-employed) for any type of compensation by an establishment that uses pesticides in the production of agricultural plants in a nursery or greenhouse, and who does any of the following:

- Mixes, loads, transfers, or applies pesticides
- Handles open containers of pesticides
- Cleans, handles, adjusts, or repairs parts of equipment that may contain pesticide residues
- Assists with the application of pesticides, including incorporating the pesticide into the soil after the application has occurred

- Enters a greenhouse or other enclosed area to operate ventilation equipment or dispose of pesticides or pesticide containers

WORKER PROTECTION STANDARD REQUIREMENTS

If you are an agricultural pesticide user and/or an employer of agricultural workers or pesticide handlers, the WPS requires you to provide to your employees, and in some cases to yourself and others, the following:

- Information about exposure to pesticides
- Protection against exposure to pesticides
- Ways to mitigate – lessen the severity of – accidental pesticide exposures

Information

To ensure employees are informed about exposure to pesticides, the WPS requires:

- Pesticide safety training for workers and handlers
- Pesticide safety posters to be displayed for workers and handlers
- Access to labeling information for pesticide handlers and early-entry workers
- Access to specific information – a centrally located application list of pesticide treatments at the establishment

Protection

To ensure employees will be protected from exposure to pesticides, the WPS requires employers to:

- prohibit handlers from applying a pesticide in a way that will expose workers or others.
- exclude workers from areas being treated with pesticides.
- exclude workers from areas that remain under a restricted entry interval (REI), with narrow exceptions.
- protect early-entry workers who are doing permitted tasks in treated areas during an REI. Requirements include special instructions and duties related to correct use of personal protective equipment (PPE).
- notify workers about treated areas so that they can avoid inadvertent exposure.
- protect handlers during handling tasks. Requirements include monitoring while handling highly toxic pesticides, and duties related to the correct use of PPE.

Mitigation

To ensure employees accidentally exposed to pesticides receive immediate assistance, the WPS requires:

- Decontamination sites that provide handlers and workers an ample supply of water, soap, and towels for routine washing and emergency decontamination. A change of clothes must also be made available.
- Emergency assistance to make transportation available to a medical facility for workers and handlers in the event of a pesticide poisoning, and to provide information to medical personnel about the pesticide to which the victim was exposed.

For more information about employer responsibilities under WPS, see the Environmental Protection Agency's manual, "Worker Protection Standard for Agricultural Pesticides – How to Comply." The manual is available through the UW Extension Pesticide Safety Education Program, http://uwyoextension.org/psep/.

WYOMING REQUIREMENTS FOR THE DIRECT SUPERVISION OF NON-CERTIFIED EMPLOYEES

The Wyoming Department of Agriculture requirements for the direct supervision of non-certified pesticide users apply to all situations involving restricted-use pesticides and any pesticide application made for hire. Direct supervision of non-certified applicators may take two forms:

- The certified supervising applicator is physically present during the entire time that the non-certified individual is using the pesticide – if directed on the label or;
- The certified supervising applicator must be immediately available via phone or radio contact AND is no further than 60 minutes or 50 miles away from the site of application.

The certified supervising applicator must make available to the unlicensed applicator product labels, required personal protective equipment, and hand-written instructions how to apply the product.

Section 6 - Category 903A - Ornamental and Turf Weed Management

LEARNING OBJECTIVES

After completing the following section, you should be able to:

A. List the characteristics that distinguish grassy weeds from broadleaf weeds

B. Describe the life cycles of annual, biennial, and perennial weeds

C. State the general turf condition best able to minimize weed infestations

D. List five (cultural) mismanagement practices that can encourage weed infestations in ornamental plantings and turf

E. Contrast the following herbicide types:
- contact vs. translocated
- pre- vs. post-emergence
- selective vs. nonselective

F. List examples of growth regulator herbicides commonly used in turf

G. Describe how herbicides work for major herbicide mode of action types (for example, growth regulators)

H. Describe injury symptoms caused by herbicide types

I. Indicate the preferred herbicide type and time of application to control the following in ornamental and turf environments:
- winter annual broadleaf weeds
- summer annual broadleaf weeds
- biennial and perennial broadleaf weeds
- winter annual grasses
- summer annual grasses
- perennial grasses
- sedges

J. Explain how herbicide resistance develops in weed populations

K. List weed management practices that reduce the potential for resistance to develop in a weed population

INTRODUCTION

A weed is a plant out of place. Whether a plant qualifies as a weed depends primarily on where it is growing. For example, Kentucky bluegrass is a desirable turf species for residential lawns, but it becomes a weed when growing in flowerbeds.

Weeds can diminish the appearance and health of ornamental plants significantly. They compete directly with ornamentals for growing space, water, nutrients, and sunlight. Many species of weeds spread readily to newly disturbed environments such as freshly tilled soil. They are especially aggressive growers and prolific reproducers. Some species thrive in poor growing conditions and are indicators of problem sites in the landscape. For example:

- purslane in drier places
- knotweed in compacted areas
- ground ivy in shady spots
- yellow nutsedge in damp areas

It is not surprising weeds commonly overtake ornamental plants in the landscape. Weeds are often the symptom – not the cause – of poor landscape plant performance.

The prevention of competition between weeds and desirable plants is of major importance in ornamental plant management. Weeds such as field bindweed can crowd established trees and shrubs. Certain weeds can harm ornamentals indirectly by harboring pests. Weeds increase production costs by interfering with management practices, and some weeds even produce growth inhibitors that retard the development of desirable plants. Weeds also can affect people by triggering allergies.

The best way to reduce weeds in turf is to maintain healthy, dense turf by properly fertilizing and mowing the turf as well as planting the right turfgrass species for the right location. However, even when turf is maintained properly, weeds can encroach. To understand the best approach to controlling the weed, we must first understand more about the weeds as well as herbicides that can be used for control.

WEED TYPES

Properly identifying the weeds you want to control is an important first step to weed management because that will determine control options. Five common weed types in ornamental plantings and turf are:

- grasses
- broadleaves
- sedges
- rushes
- other weeds

Weed identification should begin with classifying weeds by type. The four most common weed types are grasses, broadleaves, sedges, and rushes.

Grasses

Grasses are monocotyledonous (monocots) plants, which means they have only one seed cotyledon (leaf) present when seedlings emerge from the soil. Grasses have joints (nodes) and hollow, rounded stems. The true leaves of grasses (as opposed to seed or cotyledon leaves) have parallel veins and are several times longer than wide. Crabgrass, goosegrass, quackgrass, and annual bluegrass are common grassy weeds found in turf.

Broadleaves

Broadleaf weeds are dicotyledonous (dicots) plants, which means they have two cotyledons when seedlings emerge and have net-like veins in their true leaves. Broadleaves often have colorful flowers compared to the inconspicuous flowers found on

grasses. Chickweed, henbit, broadleaf plantain, clover, and dandelion are common broadleaf weeds.

Sedges

Sedges have solid, triangular stems (in most species) that bear leaves extending in three directions (3-ranked). Sedges lack ligules and auricles, and they each have a leaf sheath that is continuous around the stem. Yellow and purple nutsedge are common sedge weeds.

Rushes

Rushes have round, solid stems and favor moist habitats. Path rush is a common rush weed, which can be found near golf cart paths, sports fields, and other compacted areas.

Other weeds

Not all weeds of turfgrass fall into the four categories. Some weeds are monocotyledonous plants but are not sedges, rushes, or grasses – for example, wild garlic, wild onion, and star-of-Bethlehem, are members of the lily family. Plants in the lily family are monocotyledons with linear leaves and parallel veins. Several have bulbs, while others have rhizomes.

WEED LIFE CYCLES

All weeds pass through four developmental stages: seedling, vegetative, reproductive, and maturity. Weeds emerge from the soil as seedlings and develop their first true leaves. **The seedling stage is the easiest stage to control**. Killing a weed at this stage in its life cycle also prevents it from depositing seed back into the soil to compound the problem in future years. During the **vegetative** stage, weeds undergo rapid growth of foliage, stems, and roots. Seed production or fruit set occurs during the **reproductive stage**. The movement of water and nutrients – primarily to the reproductive parts – limits growth.

At maturity, weeds exhibit little or no growth, and internal movement of water and nutrients is slow. Some species die at this stage, while others enter a dormant period.

Different species of weeds exhibit different life cycles. A weed's life span, its methods of reproduction, and its season of active growth are important factors in selecting an appropriate control method. There are three major types of weed life cycles, with several variations.

Annual weeds germinate from seed, grow, mature, and die in less than 12 months. Annuals may be further classified as winter or summer annuals.

- **Summer annuals** germinate in the spring, grow actively during the summer, flower, set seed in late summer, and die in the fall. Crabgrass and goosegrass are summer annual grasses. Prostrate spurge is an example of a summer annual broadleaf.
- **Winter annuals** germinate in the fall, overwinter as plants, mature in the spring, flower, set seed, and then die during the summer. Annual bluegrass is our most common winter annual grassy weed in turf. Henbit and common chickweed are examples of winter annual broadleaves.

Biennial weeds reproduce from seed and require two growing seasons to complete their life cycle; examples are musk thistle and bull thistle. Biennials generally germinate from seed in the spring. They pass through their vegetative state the first summer, growing a thick, fleshy root and a compact cluster of leaves (rosette). During the second season, biennials produce seed, mature, and die.

Perennial weeds live for more than two growing seasons; and once established, they are the most persistent and difficult weeds to manage. They may

reproduce from seed or from vegetative structures such as roots, rhizomes, stolons, tubers, corms, or bulbs. The time required for completion of their four developmental stages varies among perennial weed species. Most complete all four stages in the first season and repeat the vegetative, reproductive, and maturity stages over the next several years. Other species delay reproduction and maturity for several years after emergence. Some perennials die back to the ground every year, overwintering as dormant rootstock; others shed only their leaves each fall.

In addition to producing seed, many perennial weeds are capable of spreading vegetatively. They are subclassified on this basis as simple or creeping perennials.

- **Simple perennials** overwinter by means of a vegetative structure (such as a perennial root with a crown) and reproduce almost entirely by seed; but if the taproot is severed (during hand weeding, for example) the separate pieces generate new plants. Dandelion is a simple perennial.
- **Creeping perennials** can both overwinter and produce new, independent plants from vegetative reproductive structures by rhizomes (underground stems), stolons (creeping, above-ground stems), tubers, bulbs, and creeping roots. Canada thistle, yellow nutsedge, and ground ivy are creeping perennials.

MANAGING ORNAMENTAL AND TURF WEEDS

Control methods in successful weed management programs vary with specific site conditions and the weeds involved.

Accurately identify the weed species of concern. You should be able to identify grass and broadleaf weed species on-sight. Difficult samples may be referred to the University of Wyoming Extension.

Taking an inventory of weeds and monitoring weed activity on a regular basis aids plant managers in coordinating and implementing control tactics during susceptible stages of weed growth. Keep in mind weed management often requires a combination of techniques. There are six basic strategies used to manage landscape weeds:

Encourage vigorous ornamental and turf plant growth. Establishing healthy, dense ornamental plantings is the first step in weed management. Healthy landscape plants can compete successfully with weeds, so select species appropriate for the area; plant them correctly, in prime locations, and care for them diligently.

Prevent seed production. Weeds are capable of producing seeds that may be viable for years; for example, some annual weeds can release tens of thousands of seeds in one season. So management efforts should be concentrated to eliminate weeds before the seed production stage. Whenever possible, eliminate sources of weed seed in areas adjacent to the landscape. Take caution not to spread seeds via tools, soil, or plants. Use weed-free compost, mulch, top soil, or plant material.

Prevent seed germination. Completely eliminating weed seeds from the landscape is impossible, but there are several ways to prevent them from germinating. Many dormant seeds exist deep in the soil; take care not to disturb soil deeper than two inches to avoid bringing them to the surface where conditions are right for germination. The use of mulch also helps prevent sunlight from reaching weed seeds, thus discouraging germination.

Common indicator weeds

Cultural Problem	Indicator Weeds
alkaline soils (high soil pH)	broadleaf plantain, buckhorn plantain
compacted soils	annual bluegrass, common chickweed, goosegrass, mouse-ear chickweed, prostrate knotweed, prostrate spurge
dry soils	black medic, carpetweed, red sorrel, sandbur
dry, infertile soils	lespedeza, yarrow
flooded soils	prostrate knotweed, yellow nutsedge
high-nitrogen fertility soils	annual bluegrass, crabgrass, creeping bentgrass, mallow, purslane
high-potassium fertility soils	dandelion
low fertility soils	plantains, red sorrel, smooth brome, timothy
moist or poorly drained soils	annual bluegrass, common chickweed, crabgrass, creeping bentgrass, ground ivy, mouse-ear chickweed, speedwells, violets, yellow nutsedge
moist, fertile soils	curly dock, henbit, yellow woodsorrel
moist, infertile soils	white clover
mowing too low	annual bluegrass, crabgrass, creeping bentgrass, white clover
new seedlings, summer	barnyardgrass, carpetweed, crabgrass, goosegrass, purslane, yellow foxtail
new seedlings, winter	annual bluegrass, henbit, shepherd's purse, wheat
shaded areas	annual bluegrass, common chickweed, ground ivy, moss, nimblewill, rough bluegrass, violets

Stop weed seedlings from emerging. Apply a preemergent herbicide to clean, prepared soil beds. Afterward, be careful not to break the preemergent chemical barrier.

Eliminate emerged weeds quickly. Weeds are most susceptible to management tactics when young. They should be eliminated before they become established. Small plants with immature root systems are easily removed or destroyed by mechanical means (hoeing or hand weeding).

Target established weeds at the proper time. Managing established weeds, especially perennials, is more difficult than controlling seedlings. It is important to target their most vulnerable stage, that is, when their food reserves are low and they are physically weakened: for woody perennials, in late spring after new leaves have fully expanded; for herbaceous perennials, during the bud-to-bloom stage. Perennials and second-year biennials can be forced into a stressed condition by repeated cutting, which forces them to produce new growth, so time herbicide treatments accordingly.

NON-CHEMICAL WEED CONTROL

All applicators should be aware of the potential for ornamental and turf plant damage when using herbicides. Drift, runoff, or otherwise misapplied herbicides can kill desirable plants outright. Even properly applied herbicides, when used over a number of seasons, can weaken ornamentals and turf and encourage development of herbicide-resistant weeds. Successful weed management programs usually incorporate chemical and non-chemical tactics. Following are descriptions of some non-chemical methods for managing landscape weeds.

Sanitation through the use of seed-free mulches, tools, and planting stock reduces the number of weed seeds in the soil.

Tillage disrupts root systems and buries weeds, killing annuals and most biennials; it does not eliminate established creeping perennial weeds. To prevent damage to desirable plants and minimize the number of weed seeds brought to the surface, do not turn the soil deeper than necessary.

Hand removal – pulling, digging, or hoeing – is a selective and effective means of controlling weeds.

Cutting is effective in limiting seed production and can weaken or kill plants. But only weeds such as annual broadleaves with growing points above ground level can be managed by cutting. Repeated cutting changes the species composition from tall growing to short-growing weeds.

Mulching effectively prevents weeds in the landscape but is not appropriate for all plantings. Geotextiles or landscape fabrics laid beneath the mulch are a good method of limiting weeds, but they can injure landscape plants by inhibiting the exchange of water and air between the soil and atmosphere.

Non-chemical control tactics, alone or in combination, are effective in managing many weed problems. Non-chemical methods also can enhance the efficacy of an herbicide program. The best defense against weeds is to culture healthy ornamental plantings and turf. Proper cultural practices can reduce weed populations by 70 percent or more, so herbicides should not be a substitute for a conscientious cultural program. Weeds will be less competitive when you choose the right species and cultivar for the site and follow proven fertilization, mowing, and irrigation practices.

Sometimes the weeds themselves can inform turf managers as to potential cultural problems. These specific weeds are called indicator weeds and if present can provide information on the condition of the soil. Indicator weeds help highlight potential cultural problems causing the desirable plants to be out-competed by weeds. For example, goosegrass commonly occurs in areas with compacted soils. Finding goosegrass may be a sign to cultivate the soil to reduce compaction.

When you see a weed, assess the growing conditions. Correct the underlying causes of unhealthy plantings before implementing a program using herbicides. And remember: although it can be helpful to view weeds as indicators of cultural problems, the presence of a weed does not always indicate a cultural problem.

The Common Indicator weeds table shows some common cultural problems and the weeds that can indicate those problems.

WEED CONTROL WITH HERBICIDES

There are several important things to consider when developing a weed control program:

1. Know what kind(s) of ornamental plants and turfgrass you have and the total area of each type.

2. Identify problem weeds and note what time of year they occur.

3. Determine why weeds invaded the area and correct the conditions or cultural practices that caused the problem (see Indicator Weeds).

4. When herbicides are needed:

    - Select a chemical that is effective on the weeds and labeled for use on the turfgrass species you are treating.
    - Follow all label directions — the label is the law.
    - Apply herbicide at the correct time (time of year and weed life cycle) and rate.
    - Apply herbicide uniformly over the turf area without skips or overlapping.
    - Repeat the herbicide application at the recommended interval when specified on the label.

5. Follow a sound turf management program in conjunction with the weed control program. An integrated approach — which includes enhancing desirable plant competition, using mechanical weed control, and using chemical weed control methods — will be the most successful weed control program.

There is a great variety of herbicides marketed for ornamental and turf weed management. Selecting the right product for a particular application requires consideration of how the following factors affect herbicide performance.

- Herbicide application methods
- Weed characteristics
- Environmental conditions

Herbicide application methods

Foliage-applied herbicide treatments target the leaves of growing weeds; this is a postemergence application. The herbicide, typically a liquid spray, may be effective on *contact*, killing only the green tissue the application reaches; or it may be *translocated* (circulated) within the plant to affect other parts of the weed.

Thorough coverage is necessary to ensure adequate control of plants by contact herbicides. Applicators generally use contact materials to control annual weeds, but contact herbicides will not provide permanent control of established perennials. In contrast, translocated herbicides enter and move in conducting tissues within the plant to some site of action. For example, a translocated herbicide might enter a weed through the leaves, then move to the roots (or possibly the growing points) where it disrupts some biological process and kills the plant. This type of activity allows translocated materials to be effective against established perennial weeds.

Applicators generally use soil-applied herbicides to control the emergence of weed seedlings. These are typically preemergence applications. An herbicide application made to the soil surface requires incorporation to move the chemical down into the root zone where the emerging weed can absorb it. Incorporation may be by irrigation, rainfall, or cultivation.

Preemergence and postemergence refer to the time when the weed is controlled.

Preemergence herbicides are applied to a site before weed seeds germinate and prevent weeds from properly emerging or developing. Irrigation or rainfall activates preemergence products.

As the name suggests, **postemergence herbicides** control weeds after they have emerged and visible.

Herbicide selectivity

Herbicides vary also in their degrees of selectivity.

Nonselective herbicides (also called broad spectrum herbicides) control or suppress most types of plants (broadleaf and grass plants) with which they come into contact. For example, glyphosate (Roundup and others), glufosinate

(Finale), and diquat (Reward) are nonselective herbicides.

Nonselective herbicides are often used to renovate areas or to trim along sidewalks and fences. Keep in mind a particular herbicide may be labeled nonselective, but that doesn't mean it controls every weed. For example, glyphosate is a nonselective herbicide, but it will often not control white clover and many woody weed species.

Selective herbicides are products that control **OR** suppress a narrow range of plant species (only grass plants OR only broadleaf plants) without harming the growth of desirable plants. Differential absorption, translocation, and morphological and physiological differences are all causes for selectivity between turfgrasses and weeds. The majority of turf herbicides are selective. Most broadleaf herbicides (2,4-D, MCPP, dicamba, triclopyr, and others) are examples of selective herbicides because they control broadleaf weeds but don't injure turfgrasses.

Be aware that even selective herbicides can sometimes injure turf, especially when the turf is stressed from heat, drought, low mowing, or other factors. Keep in mind that **selectivity is relative to many factors** including herbicide rate, environmental conditions, application timing, and the species and cultivar being treated. In other words, applying too much herbicide, or applying it at the wrong time or place, can injure turf.

Be sure to check the label not only for weeds species controlled, but also for susceptible ornamental or turf varieties.

Weed characteristics

The physical characteristics of a plant can affect the success of an herbicide application – especially foliage-applied herbicides. These include:

- **Growing points**. Contact herbicide sprays will not reach growing points that are sheathed or below the soil surface.
- **Leaf cuticle**. A waxy protective layer – the cuticle – covers the surface of plant leaves and may prevent foliage-applied herbicides from penetrating the plant.
- **Leaf hairs**. A hairy leaf surface can keep spray droplets perched up above the cuticle.
- **Leaf shape**. Herbicides tend to bounce off or runoff narrow, upright leaves; broad, flat leaves tend to hold herbicide longer.
- **Leaf orientation**. The leaves of some plants move throughout the day or droop at night, changing the spray target.

Remember, seedlings are most vulnerable to chemical control, and established perennial weeds in the vegetative and early bud stage are often best controlled with translocated herbicides.

Environmental Conditions

The immediate environment in the treatment area can have considerable impact on herbicide effectiveness. Consider the following:

Rainfall. Active plant growth is a requirement for successful weed control with herbicides. Weed growth and subsequent herbicide uptake require adequate soil moisture. Rainfall also provides the mechanism for movement of many soil-applied herbicides down into the layers of soil where weeds are germinating. However, excessive rainfall can leach herbicides too deeply into the soil, reducing weed control and increasing the possibility of ground water contamination. Rain immediately following a foliage-applied herbicide treatment may also wash the product off of leaf surfaces, thereby reducing control.

Temperature. Warm temperatures promote weed growth, improving the effectiveness of herbicide treatments. Higher temperatures can also mean

more rapid herbicide breakdown by microbial activity and herbicide loss through vaporization.

Sunlight. Adequate sunlight is another requirement for active weed growth, but some herbicides break down in the presence of sunlight. Incorporating soil-applied herbicides or applying a mulch over them avoids this problem. Some soil-applied herbicides require sunlight for activity and should not be incorporated or covered with mulch. Read the product label for post-application instructions.

Relative humidity. Water soluble, foliar-applied herbicides enter leaves more easily and rapidly during high humidity. Under such conditions, the weed leaf is more succulent and the cuticle more easily penetrated. High relative humidity also enhances weed growth.

Soil texture and structure. Soil-applied herbicides leach more readily through light sandy soils than through heavy clay soils. Herbicides applied to soils with a high organic matter content (and to a lesser degree, clay) are more likely to be adsorbed. And if an herbicide is strongly adsorbed to soil, it will not be available for weed uptake. For this reason, the labels of some soil-applied herbicides direct the user to apply higher rates to soils rich in organic matter.

HERBICIDE MOVEMENT IN PLANTS

Herbicides can be classified as systemic or contact.

Systemic herbicides move throughout the plant (they are translocated in plant vascular tissues). This movement of the herbicide within the plant is important for control because this allows the herbicide to move from a plant's leaves to its growing points and storage organs to help control them. Both selective and nonselective herbicides can be systemic. Most turf herbicides are systemic.

Contact herbicides do not move inside a plant. Instead, contact herbicides affect only the plant tissues they directly contact. Contact herbicides are typically fast acting and include bentazon (Basagran), and diquat (Reward).

Good spray coverage is essential when applying a contact herbicide and less critical (although still important) when using a systemic herbicide.

APPLICATION TIMING

The optimum time to control weeds depends on the type and life cycle of the weed and, in some cases, the specific weed and specific herbicide — so this is not a simple question to answer. Regardless of the timing and weed, selecting herbicides with a high efficacy for the weeds you are targeting is important.

In most locations, perennial broadleaf weeds are best controlled with postemergence herbicides in the fall. Herbicides on perennial broadleaf weeds are effective in fall because plants are more likely to translocate herbicides into root and stem tissues as days get shorter and temperatures cool. Typically, this will occur near or following the first frosts.

The formulation of the herbicide will also influence its effectiveness at certain application timings. Synthetic auxin herbicides (including 2,4-D, 2,4-DP, dicamba, triclopyr, and MCPA) are commonly formulated in two distinct forms: amine salts and esters. **Amine formulations are generally less volatile than esters** and safer to use when applying near sensitive plants (that is, ornamental landscapes and gardens) and during warm temperatures. Ester formulations have a higher vapor pressure and generally a higher

volatilization potential (with the exception of certain formulations labeled as "low volatile"). **Fall applications with amine or ester formulations of 2,4-D provide optimum broadleaf weed control**. However, spring applications are sometimes needed in weedy locations or if a fall opportunity is missed. **During cooler spring months, ester formulations are more effective than amine formulations for broadleaf weed control because they more readily penetrate the waxy leaf cuticle**. As temperatures in the spring warm, turf managers should switch to amine formulations because they work as well as esters during warmer temperatures in May and early summer. **What's more, amine formulations are less volatile than ester formulations, making them safer to use around landscape plantings**.

Winter annual broadleaves can be controlled at the same fall timing as perennial broadleaves. Fall timings are best for winter annuals because they are small after just germinating, and herbicides translocate well in the fall. Spring control of winter annual broadleaves is more difficult because the weeds are larger and are less likely to translocate herbicide. Additionally, controlling winter annuals in the spring is not typically necessary as these weeds will complete their life cycle and naturally die at the end of the spring.

Summer annual broadleaves and summer annual grasses are best controlled with preemergence herbicides applied in the spring before they germinate. They can also be controlled with postemergence herbicides in early summer before they become too large and before they produce seed.

Perennial grasses are difficult to control, and herbicide application timing and selection are very specific to the target grass.

Many herbicides are available for nutsedge control, but proper herbicide use and application timing are critical to optimize control. Herbicide applications made before nutsedge plants produce tubers (typically in late summer) will help reduce the severity of this weed. The most common mistake is to apply herbicides too late in the season after yellow nutsedge is large and is spreading by rhizomes and producing tubers. A good nutsedge control program will need to be implemented early in the season and continue for consecutive years to reduce tuber populations in the soil and prevent the spread of this problematic weed.

HERBICIDE MODE OF ACTION (MOA)

Herbicides with similar chemical properties and activities are grouped into **chemical families** (see table). For example, phenoxy-carboxylic acids (2,4-D, 2,4-DP (dichlorprop), mecoprop (MCPP), MCPA), pyridine-carboxylic acids (clopyralid, fluroxypyr, triclopyr), and benzoic acids (dicamba) are all distinct chemical families based on their chemical structures and activities, but all of these products have the same mode of action: synthetic auxins (growth regulators). **This mode of action is the important factor for you to understand**.

Mode of action describes the anatomical, physiological, and biochemical responses a plant has to the herbicide (injury symptoms). Mode of action also describes the herbicide's physical and molecular fate. In other words, the mode of action describes how a plant processes the herbicide that leads to injury in susceptible plants or tolerance in non-susceptible plants. For many modes of action, the symptomatology on plants is specific to the product, which can help applicators monitor the activity of the herbicide and detect off-target damage. A list of the modes of action of commonly used turf herbicides is provided below.

Common Names, Chemical Families, and Modes of Action of Commonly Used Turf Herbicides

Common Name	Chemical Family	Mode of Action[1]
2,4-D	phenoxy-carboxylic acid	O(4) Synthetic Auxins (Growth Regulator Herbicides)
atrazine	triazine	C1(5) Photosystem II Inhibitors
benefin	dinitroaniline	K1(3) Mitosis Inhibitors
bensulide	phosphorodithioate	N(8) Fatty Acid and Lipid Biosynthesis Inhibitors
bentazon	benzothiadiazole	C3(6) Photosystem II Inhibitors
bispyribac-sodium	pyrimidinyloxybenzoic acid	B(2) Acetolactate Synthase (ALS) Inhibitor
carfentrazone	triazolone	E(14) Protoporphyrinogen Oxidase (PPG or Protox) Inhibitors
clopyralid	pyridine-carboxylic acid	O(4) Synthetic Auxins (Growth Regulator Herbicides)
dicamba	benzoic acid	O(4) Synthetic Auxins (Growth Regulator Herbicides)
dichlorprop (2,4-DP)	phenoxy-carboxylic acid	O(4) Synthetic Auxins (Growth Regulator Herbicides)
diquat	bipyridilium	D(22) Photosystem I Inhibitors
dithiopyr	pyridine	K1(3) Mitosis Inhibitors
ethofumesate	benzofurane	N(16) Fatty Acid and Lipid Biosynthesis Inhibitors
fenoxaprop	aryloxyphenoxy propionate	A(1) Acetyl CoA Carboxylase (ACCase) Inhibitors
flazasulfuron	sulfonylurea	B(2) Acetolactate Synthase (ALS) Inhibitor
florasulam	triazolopyrimidine	B(2) Acetolactate Synthase (ALS) Inhibitor
fluazifop	aryloxyphenoxy propionate	A(1) Acetyl CoA Carboxylase (ACCase) Inhibitors
fluroxypyr	pyridine-carboxylic acid	O(4) Synthetic Auxins (Growth Regulator Herbicides)
foramsulfuron	sulfonylurea	B(2) Acetolactate Synthase (ALS) Inhibitor
glyphosate	glycine	G(9) Enolpyruvyl Shikimate-3-Phosphate (EPSP) Synthase Inhibitor
halosulfuron	sulfonylurea	B(2) Acetolactate Synthase (ALS) Inhibitor
imazosulfuron	sulfonylurea	B(2) Acetolactate Synthase (ALS) Inhibitor
isoxaben	benzamide	L(21) Cellulose Inhibitors

Common Name	Chemical Family	Mode of Action[1]
MCPA	phenoxy-carboxylic acid	O(4) Synthetic Auxins (Growth Regulator Herbicides)
mecoprop (MCPP)	phenoxy-carboxylic acid	O(4) Synthetic Auxins (Growth Regulator Herbicides)
mesotrione	triketone	F2(28) Carotenoid Biosynthesis Inhibitors (HPPD inhibitors)
metsulfuron	sulfonylurea	B(2) Acetolactate Synthase (ALS) Inhibitor
oxadiazon	oxadiazole	E(14) Protoporphyrinogen Oxidase (PPG or Protox) Inhibitors
pendimethalin	dinitroaniline	K1(3) Mitosis Inhibitors
penoxsulam	triazolopyrimidine	B(2) Acetolactate Synthase (ALS) Inhibitor
prodiamine	dinitroaniline	K1(3) Mitosis Inhibitors
pyraflufen ethyl	phenylpyrazole	E(14) Protoporphyrinogen Oxidase (PPG or Protox) Inhibitors
quinclorac	quinoline carboxylic acid	L(27) Cellulose Inhibitors, O(4) Synthetic Auxins
siduron	substituted urea	C2(7) Photosystem II Inhibitors
simazine	triazine	C2(5) Photosystem II Inhibitors
sulfentrazone	aryl triazinone	E(14) Protoporphyrinogen Oxidase (PPG or Protox) Inhibitors
topramezone	benzoylpyrazole	F2(28) Carotenoid Biosynthesis Inhibitors (HPPD inhibitors)
triclopyr	pyridine-carboxylic acid	O(4) Synthetic Auxins (Growth Regulator Herbicides)

[1] For each herbicide, the letter and number is a descriptive code for the mode of action that follows. This classification system (codes) was developed by the Herbicide Resistance Action Committee (capitalized letter) and the Weed Science Society of America (superscript number).

For each unique mode of action, below is a brief description of the anatomical, physiological, and biochemical responses of plants following an herbicide application. The mode of action for each herbicide can be found on the first page of the product label. A letter and a number are used as a descriptive code to describe the mode of action. For example, O(4) is the code for a synthetic auxins (also known as growth regulator herbicides). This classification system (codes) was developed by the Herbicide Resistance Action Committee (HRAC) using a capitalized letter and a superscript to denote the mode of action.

Acetyl CoA Carboxylase (ACCase) inhibitors - A(1)

This group of herbicides includes herbicides with active ingredients that end it -fop, -prop, or -dim. Examples include fenoxaprop (Acclaim Extra) and fluazifop (Fusilade). **This group of herbicides is specific to grasses** (**controls some grasses but not all**) **and has no activity on broadleaf weeds**. These herbicides inhibit a specific enzyme, Acetyl CoA Carboxylase, which is necessary for plants to produce fatty acids. Fatty acids are needed by plants to build new cell membranes required for growth. Symptoms of ACCase inhibitors are first observed by a general chlorosis (yellowing) of the weedy grass followed ultimately by complete necrosis (death). On crabgrass and goosegrass, injury to the meristematic regions (base of the stem) is often visible as the plants become chlorotic but prior to the death of the plant.

Acetolactate Synthase (ALS) Inhibitor - B(2)

Many herbicides are classified as ALS inhibitors including those in the chemical family sulfonylurea, which are active at low-use rates. Halosulfuron (SedgeHammer) is an example of an ALS inhibitor in this family. Acetolactate Synthase (ALS) is a key enzyme plants use to make amino acids. **Plant death will result by inhibiting amino acid production**. Typically, these herbicides work slower than other herbicides, and take 7-14 days to provide control. Symptoms typically include chlorosis followed by necrosis.

Photosystem II (PS II) inhibitors - C1(5), C2(7), C3(6) and Photosystem I (PS I) inhibitors - D(22)

These herbicides inhibit photosynthesis (energy making reactions inside the plant) by blocking electron transport and stopping the production of necessary high-energy molecules (ATP and NADPH) and CO2 fixation, which are needed for plant growth. Ultimately, plants die from the production of free radicals, which damage lipid membranes and proteins. Symptomatology is characterized by chlorosis, especially only older tissues. Atrazine (AAtrex 4L), simazine (Princep 4L), siduron (Tupersan), and bentazon (Basagran) are examples of PS II inhibitors, and diquat (Reward) is a PS I inhibitor.

Protoporphyrinogen Oxidase (PPG or Protox) inhibitors - E(14)

Protoporphyrinogen Oxidase (PPO) inhibitors **inhibit a key enzyme necessary for photosynthesis**. Blocking the production of this key enzyme leads to the formation of free radicals, which damage lipid membranes and proteins. **These herbicides are typically fast acting, and chlorotic symptoms can be evident within 24 hours**. Examples include carfentrazone (Quicksilver), oxadiazon (Ronstar), pyraflufen ethyl (Octane), and sulfentrazone (Dismiss). Carfentrazone, pyraflufen ethyl, and sulfentrazone are common ingredients in broadleaf products.

Carotenoid Biosynthesis inhibitors (HPPD inhibitors) - F2(28)

Carotenoids are important molecules that protect chlorophyll during photosynthesis. Carotenoids are pigments that are yellow, orange, or red in color. Hydroxyphenyl pyruvate dioxygenase (HPPD) is a key enzyme necessary in making a necessary

ingredient for carotenoid biosynthesis. When **these herbicides inhibit carotenoid biosynthesis, chlorophyll is no longer protected from sunlight and plants become pigmentless or bleached** (**or light purple before turning white**)**.** Mesotrione (Tenacity) and topramezone (Pylex) are examples of HPPD inhibitors. Bleaching symptoms typically start about 5-7 days after application and last 14-21 days.

Enolpyruvyl Shikimate-3-Phosphate (EPSP) Synthase inhibitor - G(9)

Glyphosate (**Roundup**) **is the only herbicide in this group. Glyphosate applications inhibit enolpyruvyl shikimate-3-phosphate synthase**, which leads to the depletion of certain amino acids needed to make necessary proteins involved in plant growth. Plant symptomatology includes the inhibition of growth followed by chlorosis and death.

Mitosis inhibitors - K1(3)

The preemergence herbicides benefin, dithiopyr (Dimension), pendimethalin (Pendulum), and prodiamine (Barricade) are examples of mitotic inhibitors. **These herbicides inhibit mitosis** (**cell division**)**, which prevents growth**. Symptoms include swelling of root tips and failure of seedlings to emerge (develop leaves) following the germination of the seed and radicle (first plant root).

Cellulose inhibitors - L(21), L(27)

These herbicides inhibit cell wall biosynthesis (**cellulose**) **in susceptible weeds**. These include Isoxaben (Gallery), which is a preemergence herbicide with activity primarily on broadleaf weeds, and quinclorac (Drive), which is a postemergence herbicide that controls grasses and broadleaves. Quinclorac is unique in that it has two modes of action: activity on grasses (as a cellulose inhibitor) and broadleaves (as a synthetic auxin).

Examples of Various Growth Regulator (Synthetic Auxin) Herbicides Used for Weed Control in Turf

Ingredient	Trade name(s)
2,4-D	2,4-D Amine 4, Barrage HF, Clean Amine, Hardball, Saber, WEEDestroy AM40, Weedone LV4 EC, Weedar 64
clopyralid	Lontrel
dicamba	Banvel, Diablo, Vanquish
MCPA	MCPA-4 Amine, MCPA ester 4
mecoprop (MCPP)	MCPP-p 4 Amine, Mecomec 2.5, Mecomec 4
quinclorac	Drive XLR8, Drive 75DF, Eject 75DF, Quinclorac 75DF, QuinPro Herbicide
triclopyr	Turflon Ester, Turflon Ester Ultra
Other products containing one or more of the above ingredients	2-D, 3-D, 4-Speed, 4-Speed XT, Battleship III, Brushmaster, Celsius WG, Chaser, Chaser 2 Amine, Chaser Ultra2, Confront, Cool Power, Eliminate, Eliminate LO, Eliminate-D, EndRun, Escalade 2, Horsepower, MEC Amine-D, Strike 3, Millennium Ultra 2, Momentum Q, Momemtum FX2, Onetime, Power Zone, Q4, Q4 Plus, Quincept, Speed Zone, SquareOne, Solitare, Strike Three Ultra 2, Surge, Tailspin, Threesome, Three-Way, Three-Way Ester II, Triamine, Triamine II, Trimec, Trimec 1000, Trimec 992, Trimec Bentgrass Formula, Trimec Classic, Trimec Encore, Trimec Plus, Triplet, Triplet Low Odor, Triplet Sensitive, Triplet SF, Tri-Power, TruPower2, Turflon II Amine, TZONE, Vessel

Fatty Acid and Lipid Biosynthesis inhibitors - N(8), N(16)

Ethofumesate (Prograss) and bensulide (Bensumec) are examples of fatty acid and lipid biosysnthesis inhibitors. **The activity of these herbicides is not well understood, but it is known that they inhibit growth through several plant processes**.

Synthetic Auxins (growth regulator herbicides) - O(4)

Several herbicides, including 2,4-D, clopyralid, dicamba, dichlorprop (2,4-DP) , fluroxypyr, MCPA, mecoprop (MCPP), quinclorac, and triclopyr, are herbicides that **act similar to naturally occurring auxins in plants**. When these herbicides are applied at labeled rates, they produce uncontrolled growth and abnormal development in susceptible species (dicots). Initial symptomatology is quickly apparent within a few days on new leaves and shoot regions. Symptomology includes bending and twisting of leaves and stems and cupping, crinkling, or strapping of leaves. **Death of susceptible plants typically occurs >3 weeks after application**.

Among these modes of action, the synthetic auxins or growth regulator herbicides are most commonly used in turf because of their activity on many broadleaf weeds and their safety on grasses. There are many products (trade names) with various combinations of these synthetic auxins, which are often sold together in some kind of two- or three-way mixture to enhance the spectrum of activity on multiple broadleaf weed species.

Herbicides affect susceptible landscape trees and shrubs in the same manner as turf weeds.

HERBICIDE RESISTANCE AND HERBICIDE TOLERANCE

Herbicide resistance is the inherited ability of a weed to survive and reproduce even though it was exposed to a normally lethal dose of herbicide.

Herbicide tolerance is the ability of a plant to remain uninjured by a dose of herbicide normally lethal to other plant species.

There are many examples of herbicide-resistant weeds in other crops (such as corn or soybean) than in turf since the turf itself acts as a natural weed deterrent and because there are fewer weed species in mown turf than in agricultural fields. However, that does not mean herbicide resistant weeds cannot show up in turf. Typically, a weed may become resistant to a particular family of herbicides that have a unique mode of action.

For example, dinitroaniline-resistant goosegrass (the dinitroaniline chemical family includes prodiamine, pendimethalin, benefin, trifluralin, and oryzalin) has been documented in turfgrass; however, these resistant goosegrass populations are still susceptible to oxadiazon (Ronstar), which is an oxadiazole herbicide (oxadiazole chemical family). In the Midwest, there are few reports of weed resistance in turf systems, although crabgrass is known to be resistant to quinclorac at some locations. **It is important to rotate the use of herbicides with different modes of action to avoid and/or delay the development of weed resistance. Rotating between products with different trade names, common names, or chemical families will not delay the development of resistance unless the herbicides have different modes of action**.

Section 7 - Category 903B - Ornamental and Turf Insect Pest Management

LEARNING OBJECTIVES

After completing the following section, you should be able to:

A. List three stages of development for insects that undergo gradual metamorphosis

B. List four stages of development for insects that undergo complete metamorphosis

C. Identify the damaging stage of insect pests

D. Identify by sight the (direct and indirect) turf damage symptoms caused by each insect pest

E. Describe the following insect pest scouting techniques:
- visual inspection
- turfgrass plug (cup cutter) examination
- flotation (disclosing solution) method

F. State the general turf condition best able to withstand insect pest pressure

G. Contrast the following insecticide types:
- contact versus stomach poison
- curative versus preventive

H. Explain how insecticide resistance develops in pest insect populations

I. List turf insect pest management practices that reduce the potential for resistance to develop in a pest insect population

J. Describe a "drench test"

INTRODUCTION

Many different kinds of insects and mites feed on ornamental plants and turf. Insects and insect-related problems associated with turfgrass have increased dramatically over the last 30 years. Prior to that, turf management literature seldom mentioned insects as a serious problem. Today, the control of these pests has become a major part of the turfgrass industry. Golf courses commonly allot up to one third of their annual chemical budget for insect control. In residential and other well-maintained turfgrass sites, the proportion of maintenance devoted to insect control is sometimes even greater.

But the mere presence of a pest does not mean there is a problem that must be corrected immediately. Natural enemies of insects and environmental factors, such as rain and wind, often play an important role in keeping pests under control. Sometimes, however, these natural protective forces fail. When that happens, you must adopt an integrated approach to insect and mite control on ornamental shrubs, trees, and turf in Wyoming.

ANATOMY AND BIOLOGY OF INSECTS AND MITES

Insects and mites belong to a group of animals called arthropods because their bodies share some common structures. Arthropods have jointed legs and a protective exterior support structure called an exoskeleton. Arthropods include the vast majority of species in the animal kingdom.

Knowledge of insect and mite anatomy and biology is essential to understand not only how they live and how to distinguish them from one another, but also how to control them.

ADULT INSECT STRUCTURE

The insect body generally conforms to the shape of an elongated tube with appendages such as legs, wings, or antennae on each side. The arrangement is called *bilateral symmetry*, i.e., each side is a mirror image of the other. The body has three distinct segments: **head, thorax, and abdomen**.

Head

The head bears the eyes, antennae, and mouth parts.

The heads of adult insects have specialized mouth parts including:

- chewing
- piercing and sucking
- lapping and sponging
- siphoning

Understanding the mouth parts and the damage they cause are key to identification of a pest species. Some adult insects, such as adult male scale insects, do not feed at all and have nonfunctional mouth parts. Like those of adults, the mouth parts of immature insects can be shaped to chew or to suck fluids.

Thorax

The thorax is directly behind the head. It has **three segments** that are usually joined firmly together. Insects have three pairs of true legs, one pair on each segment of the thorax. These legs are jointed and can be modified for particular functions. For example, the front legs of dung beetles are modified for digging into the soil. The **larval stages** of some insects (for example, caterpillars and sawflies) can walk with fleshy, unjointed legs called **prolegs**. These appendages are attached to segments of the abdomen. The **pronotum** is a distinctive piece of exoskeleton on the back between the head and the attachment of the first pair of wings on the thorax. The wings, if present, are on the second and third thoracic segments. Most species of insects have two pairs of wings as adults. These wings can be clear, or they can be covered with fine scales, as in the case of moths and butterflies. Some insect groups, such as beetles, have a thickened front pair of wings that protect the abdomen when the insect is not flying. Flies have only one pair of fully developed wings. The hind wings are greatly reduced.

Abdomen

The abdomen is usually as long as (or longer than) the head and thorax combined. It has a variable number of distinct segments that contain the gut and reproductive organs. Externally, it is usually softer than the head and thorax because it needs to be flexible enough to hold food, water, air, fat reserves, and eggs. The abdomen usually possesses additional appendages in the form of sex organs, or bristle-like extensions known as cerci.

INSECT BEHAVIOR

Insects interact with their environment instinctively; there is no particular reasoning or intelligent decision-making involved. Most insects lay their eggs in specific ways and places, feed on a particular food source, live in a given environment, and move from place to place in a typical way. Many insect reactions are simply toward or away from a stimulus such as light, color, temperature, moisture, scent, taste, or texture, the force of gravity, or currents of air or water. For example, vertical movement of annual white grubs in the soil profile can vary depending on irrigation, temperature, time of day, and light. This is an important concept

for turfgrass managers to understand when monitoring and controlling insect pests.

INSECT DEVELOPMENT

Most insects start life in an egg stage. The process of egg laying is called **oviposition**. Adult females of many species lay their eggs in the area where the young feed. For example, fall webworm moths lay eggs on the leaves where young caterpillars will feed. Insects use specialized organs called ovipositors to place their eggs in the correct location. Some ovipositors are internal except during oviposition; others are external and very obvious (sawflies). A few insects, such as aphids, may give birth to live young.

Weather conditions, especially temperature, directly influence the rate at which insects develop. Generally speaking, the warmer the conditions, the more quickly insects grow and develop.

INSECT GROWTH

Once an insect hatches from the egg, the immature insect grows in a series of distinct steps, each limited by the available space within its exoskeleton (the hard, external covering). To grow, immature insects form a soft, malleable new exoskeleton directly beneath the old one. Eventually, the old exoskeleton splits down the back, and the insect emerges and expands to a larger size before the new exoskeleton hardens. The process is called **molting**. The immature insect typically repeats the molting process four to eight times during its lifetime. The period between molts is known as an **instar**. Thus, we may refer to an immature insect as being first, second, or third instar, etc., depending on the number of molts it has completed. Growth and molting cease when the insect reaches adulthood.

METAMORPHOSIS

Either the immature or adult stages of insect pests – sometimes both – may damage ornamental plants and turf. This is important to understand when monitoring pest populations because the potential for damage can vary depending on the insect's stage of development.

Insects change not only in size but also in form during their development; an insect's appearance at one stage of development may be quite different than at other stages. The process of changing in form from egg to adult, including all steps in-between, is known as metamorphosis; but it is not the same for all insects. In some, there is very little change (except size) from molt to molt; the young look very much like the adults (**incomplete metamorphosis**). In others, there is dramatic change and very little resemblance between the immature and adult stages (**complete metamorphosis**). Ornamental plants and turfgrass insect pests may exhibit either type of development

Incomplete (or gradual) metamorphosis

Insects that undergo gradual metamorphosis exhibit three distinct stages of development: **egg, nymph** (**including several instars**), **and adult**. The nymph generally resembles the adult in form and function, preferred environment, and food requirements. The change in appearance between nymphal instars creates a slow but steady progression toward the adult. After the final instar nymph, the sexually mature adult stage emerges and functional wings may appear. Chinch bugs are an example of an insect that undergoes gradual metamorphosis.

Complete metamorphosis

Insects that experience complete metamorphosis develop through four stages: **egg, larva** (**with several instars**), **pupa, and adult**. The young larvae that emerge from the eggs do not resemble

the adult, and they **usually live in different environments and feed on different foods than the adults**.

The larvae of different insects exhibit various characteristics adapted to their particular mode of life. Some larvae lack legs entirely; others have legs attached at the thorax. Some have legs on the thorax and fleshy, leg-like appendages (prolegs) on the abdomen. Larvae typically have simple eyes on the sides of the head, and they never have wings.

After undergoing several molts, a larva moves into the next stage of development, known as a pupa. Although sometimes regarded as a resting stage, this is a very active stage in the biology of an insect as it develops adult body structures such as legs, wings, and antennae. Although many physical changes are taking place, **most pupae are immobile and do not feed**. Many pupae are completely covered by a silken or hardened cocoon. The adult insect eventually emerges from the pupal case. Adult insects are capable of reproducing and do not continue to grow. June beetle and black cutworm are examples of insects with complete metamorphosis.

Most adult insects have wings and are reproductively mature. (It seems there are exceptions to every rule with insects; many adult aphids are wingless). **An insect quits growing and never molts again upon reaching the adult stage**.

The rate of insect growth and development depends largely on temperature and the genetic traits of the species. Within limits, warmer temperatures speed development and shorten generation time. Time required to complete one generation varies considerably with the type of insect, the availability of food, and to some degree the geographical location, climate, and site conditions. Some aphids can complete a generation in about 10 days under ideal conditions, and they produce many generations a year; in comparison, the scale insects in Wyoming usually only have one generation per year. In summer, warm-season spider mite populations on honey locust or burning bush increase more rapidly in a warmer southern exposure than in a cooler northern exposure.

In climates with cold winters, insects either die or go into an overwintering, protective state of arrested development called **diapause**. The life stage an insect enters diapause will be unique for each species.

IMPORTANCE OF GROWTH AND DEVELOPMENT TO PEST MANAGEMENT

For the most part, immature and adult insects with simple metamorphosis feed on and injure the same parts of a plant as the adult of the same species. These pests should be monitored by examining susceptible parts of the plant for both the pest and its natural enemies. Likewise, applications of insecticides can be effective against adults and nymphs feeding on the same plant parts; for example, both adult and leafhopper nymphs feed on leaves, where they can be killed by insecticides.

Larvae and adults of species with complete metamorphosis often consume different foods. In many cases, only the larvae injure the plant when they feed. For example, adult moths feed on nectar and pollen, whereas their larvae feed on plants. Pesticide applications usually kill only larval stages, not adults, pupae, or eggs. In most all instances, immature insects are much easier to control or kill than the adults.

These pests should be monitored by examining their feeding sites for eggs and early signs of larval damage. In some cases, specialized traps have been

developed to monitor the flight of adults to help target damaging larval stages.

In other cases, adult insects feed on different parts of the plant. For example, adult June beetles skeletonize leaves and flowers, while the larvae (grubs) feed on turf roots. Similarly, black vine weevils notch leaves, and the grubs feed on roots. Monitoring and management activities need to be directed toward the susceptible part of the plant at the proper time of year.

MITES

Mites are not insects, but they are classified in the phylum Arthropoda with insects. Mites are in the class Arachnida, which also includes spiders and scorpions. Mites have two body regions and usually four pairs of legs as adults. They lack wings.

Mites are important pests of woody plants and measure about 1/50 of an inch (or smaller) when fully grown. Spider mites are important pests of spruce, honey locust, oak, and crabapple. They discolor leaves by extracting leaf fluids, and some species produce silk webbing, hence the common name. Some mite species are beneficial and prey on plant feeding mites, thrips, aphids, and the eggs of insects. Gall and rust forming mites, often generically referred to as "eriophyid mites," are very small but can cause aesthetic damage to plants.

DIAGNOSING PLANT PROBLEMS CAUSED BY INSECTS AND MITES

Routine and systematic inspections at several locations throughout ornamental plantings and turf may help detect insect infestations early. Look for plant symptoms and other signs of insect infestation. Observe the general appearance of the turf from a distance, and inspect individual plants close-up. Examine the aboveground parts of the plant, such as leaves and stems, for feeding scars and discoloration. Inspect the crown areas for damage by pulling several handfuls of grass. Pay special attention to the margins where damaged turf meets undamaged and prod into any obvious thatch layer with a knife. Examine the base of plants for feeding insects. If plants dislodge easily, the problem may be in the crown or root. To inspect plant parts below ground, use a cup cutter, or cut three sides of a 1-foot-square by 4-inch-thick section of sod. Then roll back the sod to expose the root zone and examine for root-feeding insects by working through the soil. Keep records of observations and note any repeat offenders.

Fertilizer burn, diseases, poor mowing practices, vandalism, urine spots from pets, and improper use of pesticides all cause symptoms that resemble insect damage. A thorough search should be made to determine if insect pests are truly causing problems. Always keep in mind that, although many insect species live in or on plants and turf, relatively few are cause for concern. Most are either beneficial or of no real consequence. Some insects are regarded as nuisance pests that may sting or otherwise interfere with normal activity, while others cause damage only in rare situations.

Most individuals recognize when a plant is unsightly, growing poorly, or having some other type of problem; however, determining the cause of poor plant performance can be difficult.

Insect pests of ornamental plants and turf cause visible and predictable changes in a plant's appearance. Assessment of damage is useful in determining what pest is causing the problem. Plant identification and the recognition of damage symptoms are important first steps in the diagnostic process. For convenience,

classify symptoms of insect damage into one of five categories:

- **Chewed or tattered foliage or blossoms**. In most cases, insects with chewing mouth parts cause the symptoms in this category. With this kind of damage, one can normally dismiss from consideration the large group of pests with sucking or rasping mouth parts.
- **Stippled** (**flecked**), **yellowed, bleached, or bronzed foliage**. When a plant has this type of damage and there are no holes in the foliage, insects or mites with piercing and sucking mouth parts are causing the injury. These symptoms begin when an insect inserts its mouth parts to remove plant sap and, at the same time, withdraws or destroys chlorophyll at the point of penetration. Tiny, stippled (flecked) areas appear on affected foliage. With large numbers of the pest present, these stippled areas blend to cover the entire leaf, resulting in leaves that appear yellowed, bleached, or bronzed.
- **Distorted plant parts**. Plant distortion may appear as curled or cupped leaves or as crooked shoot growth when pest feeding kills or weakens plant tissue and structures. Various types of galls on leaves, twigs, or stems are caused when plants produce abnormal growth in response to plant injury.
- **Dieback of plant parts**. Insects can cause leaf, twig, or branch dieback – or total plant death. Twigs and branches of deciduous plants that die during the growing season often retain dead leaves well into the subsequent dormant season because the plant will not have formed a leaf abscission layer before death. Dead sections of non-deciduous plants retain dead leaves for long periods. But retention of dead leaves does not always mean dieback. Some plants, like oaks, keep large numbers of dead leaves on the twigs until early spring.
- **Presence of honeydew, wax, or insect remains**. Some insects leave additional evidence of their presence, incidental to plant injury. These signs may remain intact for weeks (or months) after the pest has completed its activities. Insect pest evidence of this nature includes honeydew (a sticky, sugary liquid), fecal specks (droppings), tents and webs, and cast skins.

METHODS OF MANAGING PESTS

Successful insect management is based on proper identification and knowledge of the biology and life cycle of the insect. The best long-term, environmentally sound and sustainable approach to control combines cultural practices with judicious and responsible use of insecticides. The goal of this system, called **Integrated Pest Management** (**IPM**), is not the elimination of all insect pests but rather to **keep pest damage below an economically injurious or visually offensive level**. Although sound IPM will not always eliminate the use of insecticides, it can reduce reliance on these tools and improve environmental health and safety.

Sound cultural management practices that keep turf healthy and growing vigorously form the cornerstone of IPM. Healthy ornamental plants and turf can tolerate low-to-moderate numbers of insect pests and recuperate more quickly from damaging infestations. Proper turfgrass species or cultivar selection, mowing height and frequency, irrigation, fertilization, thatch management, etc., help ensure healthy plants. Unfortunately, even healthy plants may suffer serious insect damage from time to time. Routine inspection and good record keeping are critical elements

in any successful pest management program. When insecticides are necessary, keep in mind these products may also have negative effects on beneficial insects we rely on to help keep pest populations in check.

Integrated Pest Management methods fall into four basic categories: cultural, mechanical, biological, and chemical. Following is a review of each.

Cultural control

Keeping plants healthy can prevent a wide variety of pest problems. Researchers find plants under severe stress grow slower than normal, and that insects prefer them over healthy plants for feeding. For example, trees damaged by a lawn mower are more susceptible to borer problems than uninjured trees. Cultural controls are essentially horticultural practices that discourage pest problems. Some useful examples include:

- **Inspection of plant material**. Inspect plants and cuttings for pests before situating them in the production area or planting them in the landscape. New plant material can be a source of future problems.
- **Site selection and preparation**. Place plants in their appropriate environments; that is, consider light, drainage, and fertilization requirements.
- **Planting depth**. Plant to the proper depth to prevent injury that could make plants more attractive to pests.
- **Fertilization and irrigation**. Do not over or under fertilize or over or under water plants.
- **Mulching**. Mulch landscape plants to an appropriate depth (2 to 4 inches) but away from the root collar to conserve soil moisture and to protect roots from extreme temperatures. Mulching helps prevent bark injury from lawnmowers or motorized weeders by reducing the need to mow around trunks.
- **Pruning**. Prune plants appropriately to promote good plant structure. When possible, prune in the dormant season to prevent the attraction of borers to fresh wounds.
- **Host plant resistance**. Replace pest-prone plants with resistant plant varieties or species whenever possible. Many plant varieties are resistant to insect pests, so wherever they pose a recurrent problem, consider replacing susceptible plants with a species that is unattractive to that particular insect.
- **Designing for diversity**. Increase plant diversity to make it more difficult for pests to spread between plants, so choose a wide variety of plants in designing your landscape.

Mechanical control

Physically removing a pest and destroying it is an effective way to manage many pest problems. The bagworm is a good example. It wraps itself in a bag of silk and foliage for protection. Physically removing and destroying the bags in winter or early spring minimizes damage.

Pruning infested limbs also minimizes damage to vigorously growing plants; for example, it is an excellent means of controlling scale insects on fast-growing ornamentals. However, it is often *not* a good strategy for a young tree whose structure has not yet formed.

Biological control

Not all insects, mites, and disease organisms in a nursery or landscape are harmful to plants; many are predators, parasites, or pathogens of pests themselves. **Predators** attack, kill, and eat pests. **Parasites** lay eggs in or on pests. **Pathogens** are

microscopic organisms such as bacteria and fungi that cause disease in the pest.

Biological control is the use of living organisms to reduce or prevent plant damage. Some natural enemies are **generalists** that feed on many pest species; others are **specialists** that feed on one or only a few species. There are three approaches to using beneficial organisms to control pests: classical biological control, conservation, and augmentation.

Classical biological control

Classical biological control involves the importation of natural enemies from foreign sources to control pests. Approximately half of the plant pests in the United States have come from other countries; there are pests here because they arrived without the natural enemies that kept them from being problems in their homelands. But because importation of natural enemies is heavily regulated and costly, plant managers generally do not use classical biological control.

Conservation

Conservation is the adoption of practices that nurture the many natural enemies already present in managed landscapes and nurseries. Practically speaking, this means learning to distinguish between pests and natural enemies, avoiding the use of long-lasting, broad spectrum insecticides, and providing alternative foods and shelter for beneficial organisms by planting flowering and nectar-producing plants.

Augmentation

Augmentation is the release of natural enemies into a managed landscape to control pests. Currently, not enough is known about the behavior of most commercially available predators and parasites to recommend them as effective controls. So, for the present, conservation of beneficial insects and mites is a better approach.

Chemical control

The pesticide applicator should recognize the use of insecticides as one aspect of a comprehensive IPM program. When significant insect damage or high insect pest populations are detected during inspection, or when the need for control is otherwise immediate, insecticides may be the only solution. Property managers need to know how insecticides work. The following section describes how insecticides control pests and provides a useful scheme for classifying insecticides.

How insecticides enter the pest

Insecticides can enter insects by ingestion or by contact. Stomach poisons must be swallowed; examples are baits, on which the insects must feed, and certain dusts and liquids that insects ingest while feeding or grooming. Contact insecticides are designed to penetrate the insect's exoskeleton after the insect walks through or otherwise contacts an insecticide deposit (for example, droplets on a leaf surface). Most insecticides applied to trees, shrubs, and turf act as both contact and stomach poisons, but their persistence in the environment may vary greatly. The length of time an insecticide remains in the environment at levels that are effective against insect pests is referred to as **residual activity**. The residual activity of an insecticide can be an important determinant of how, where, or when it can best be used in a pest management program.

There are two kinds of chemical control: **conventional** and **alternative**. Conventional pesticides are typically synthetic materials. Alternative pesticides are often biological in nature.

The Insecticide Resistance Action Committee (IRAC) has classified all insecticides by their mode of action. According to IRAC, there are 25 defined mode of action groups. These groups can be simplified into the following categories based

on how the chemistry affects the insect or mite physiologically:

1) Nerve action
2) Nerve and muscle action
3) Growth regulation
4) Affecting the insect gut
5) Energy metabolism
6) Unspecified
7) Unknown

Conventional pesticides

The following groups have seen numerous applications in the landscape industry:

Organochlorines (nerve action) are very stable compounds and may persist in the environment for long periods. Organochlorines were notorious for their ability to bio-accumulate in the food chain. As a result, the EPA has sharply curtailed the availability of many organochlorines (examples: DDT, aldrin, dieldrin, and chlordane). Others are the active ingredients of various home and garden products and some agricultural, structural, and environmental pest control. Examples include dacofol, endosulfan, and lindane.

Organophosphates (nerve action) have replaced many of the uses of the organochlorines. Organophosphates tend to have short to moderate residual activity and deteriorate rather rapidly in the environment. They are one of the oldest groups of insecticides available for use in ornamental and turf. Although most of these insecticides were removed from use following the Food Quality Protection Act (FQPA) of 1996, a few still remain. Examples are trichlofon and chlorpyrifos.

Carbamates (nerve action) resemble organophosphates in many ways; however, they tend to have even lower toxicity to mammals. Most were removed from use following implementation of the FQPA. Like the organophosphates, the carbamates also tend to have relatively short residual activity. Carbaryl is an example.

Pyrethroids (nerve action) are synthetic materials that imitate the activity of a naturally occurring botanical compound. They are relatively nontoxic to mammals and find a tremendous variety of uses in insect pest control. They generally exhibit fast knockdown with short to moderate residual activity. Examples are beta-cyfluthrin, lambda-cyhalothrin, bifenthrin, deltamethrin.

Neonicatinoids (nerve action) form a relatively new class of compounds with very low mammalian toxicity and long-lasting, systemic activity in plants. Contributors or not, these insecticides have recently been associated with colony collapse disorder in honeybees and declines in populations of birds and other wildlife. New product labeling will indicate how these products can be used on flowering plants. Examples are imidacloprid, thiamethoxam, clothianidin, and dinotefuran.

Oxadiazines (nerve action) are another relatively new class of compounds with a novel mode of action that makes them particularly effective against caterpillars. They also have relatively little impact on beneficial predatory insects. Indoxacarb is an example.

Anthranilic diamides (nerve and muscle action) form the newest class of compounds with extremely low mammalian toxicity and extended residual activity. These insecticides incorporate a novel mode of action that makes them highly selective for insects. Chlorantraniliprole is an example.

Alternative pesticides

This group includes chemical compounds and liquid formulations of biological organisms that kill pests. These materials tend to be compatible with natural enemies in the landscape because they are active for shorter periods of time and because they are specific to the target pest. The following types of materials are available for the landscape and nursery industries – and more are likely to become available in the future.

Botanicals (nerve action) are plant extracts that have insecticidal properties. The synthetic analogs of the plant compound pyrethrin constitute the group of insecticides we refer to as pyrethrins. An example is azadirachtin.

Insect growth regulators (IGRs – growth regulation) usually are synthetic chemicals that act like insect hormones. They either kill insects during the molting process or prevent adults from reproducing. Generally, these materials are most active against immature insects that must still undergo several molts. They have little or no effect on the pupal stage of natural enemies growing inside host pests. Example: halofenozide.

Microbial extracts (nerve and or muscle action) are insecticides produced by microbial organisms. Examples include Bacillus thuringiensis, spinosad, avermectin-B, and Paenibacillus popilliae formerly Bacillus popilliae. With the exception of avermectin-B, these materials have a relatively minor impact on many natural enemies.

Biologicals (affecting the insect gut) are formulations of living organisms or their insecticidal byproducts that can be applied with conventional spray equipment. Biologicals sometimes require special handling, spray equipment, or application techniques. Examples include Paenibacillus popilliae, Steinernema carpocapsae, Bacillus thuringiensis subspecies kurstaki (Btk).

Horticultural oils are petroleum- or plant-based hydrocarbon chains with insecticidal activity. Toxicity to insects is due to suffocation or membrane disruption. Dormant oil applications are made to plants in winter dormancy, and summer oil applications are made on green plants.

Insecticidal soaps are potassium or sodium salts of fatty acid chains; they tend to be very good at controlling soft-bodied insects by smothering them or disrupting cell membranes.

The IRAC Mode of Action classification provides growers, advisers, extension staff, consultants, and crop protection professionals with a guide to the selection of insecticides or acaricides for use in an effective and sustainable insecticide or acaricide resistance management (IRM) strategy. For greater detail on insecticide mode of action, visit http://www.irac-online.org/documents/moa-classification/?ext=pdf

Following the guidelines below will increase the effectiveness of all chemical controls and decrease the possibility of insecticide resistance in the landscape.

- Treat only when pests are causing a problem.
- Restrict applications to infested plants.
- Time pesticide applications to coincide with susceptible stages of insect pests.
- When applying conventional pesticides, change mode of action classes (for example, organophosphate to pyrethroid) at the beginning of every new pest generation.

INSECTS AND MITES DAMAGING TO ORNAMENTALS

Damage type: chewed or tattered foliage or blossoms

Bagworms

From late June through August, bagworms may defoliate arborvitae, junipers, and other trees and shrubs. Bagworms are caterpillars that live inside spindle-shaped bags they construct to protect themselves against birds and other enemies. These bags, composed of silken threads and bits of foliage, look so much a part of the tree they may go unnoticed until extensive damage has occurred.

In Wyoming, bagworms are most commonly found on cedars. Early in June, the insects hatch from eggs that wintered in bags attached to tree branches. As soon as the young worms appear, they start to spin bags and continue to enlarge them as they feed and grow. The caterpillars crawl part way out of the bags to feed. If disturbed, they retreat safely inside.

Bagworms grow to about 2 inches by late August or early September. They attach bags firmly to branches or other objects and mature to the adult stage. Winged males fertilize wingless females, which never leave their bags. They complete only one generation each year, with up to 1,000 eggs overwintering in each female bag.

If only a small number of bagworms are infesting only a few small trees, picking off the bags and destroying them is an effective method of control. This works best from October through May, before the eggs hatch.

When bags are too numerous to remove easily by hand, applicators can control bagworms chemically by spraying infested trees in early June after the eggs hatch and young worms appear. Since it often takes three to four weeks for all eggs on a tree to hatch, a second application of insecticide may be needed in early July. Control becomes more difficult as the season progresses. Bacillus thuringiensis and spinosad are the preferred insecticides because they kill bagworms, selectively, without harming natural enemies of other pests. Satisfactory control requires the spray application completely wet the trees or shrubs being treated.

Fall webworm

The fall webworm can defoliate large sections of deciduous trees and cover them with fine webbing. They feed on a wide variety of deciduous trees including maple, elm, hickory, oak, poplars, willow, and fruit and nut trees. Unlike the tent caterpillars, these insects feed day and night within the fine webbed net they expand as feeding continues.

Fall webworms have one generation each year in the mountain states. They overwinter in cocoons in sheltered areas. The adult is a white moth. Female moths attach eggs to the undersides of leaves in June. These eggs are almost always laid on leaves near the tips of branches. Eggs hatch into caterpillars that feed in groups. They protect themselves from predators by keeping themselves covered with webs. One month after June egg hatch, these caterpillars make cocoons in the webs.

Watch for early signs of webbing and kill the caterpillars before they engulf the tree. Small webs can simply be pruned off and destroyed. When webbing covers too much of the tree, pruning the affected area may not be practical if it would alter plant structure or remove a substantial part of the tree.

Applications of the microbial insecticides Bacillus thuringiensis or spinosad are good alternatives to pruning trees. These materials kill caterpillars as they feed without harming their natural enemies. The spray can penetrate the webs and coat the leaves when webbing is not too extensive. As

webbing becomes more extensive, microbial insecticides are less effective since the caterpillars must ingest the material for it to work. When clients have trees that are heavily webbed in late summer, a high-pressure spray application of a pyrethroid insecticide can more effectively penetrate the webs and kill the caterpillars.

European pine sawfly

The European pine sawfly larva feeds on the needles of pines growing in landscapes, nurseries, and Christmas tree plantations. White pine, Scotch, Austrian, and Mugho pine are commonly injured.

The adult sawfly is a small, thick-waisted wasp. In early fall, the female slits the edges of pine needles with her ovipositor and lays eggs into these openings. Preferred egg laying sites are on new needles located near the ends of lateral branches. The eggs overwinter, and the larvae emerge in mid-spring. European pine sawfly larvae are caterpillar-like in appearance. The mature larva is grayish-green with a shiny black head capsule, a light stripe down the length of its back, and a dark green stripe along each side.

The larvae feed in groups. Immediately after hatching, they are too small to consume the entire needle, and they leave behind a slender brown straw. Identifying this "straw-stage" is critical for timing insecticide applications. As the larvae mature, they can defoliate branches and sometimes entire trees. In mid-summer, the larvae drop to the ground and pupate inside dark brown cocoons. Adults begin emerging in September.

Control small, localized European pine sawfly infestations by judicious pruning. Larger populations may require the use of insecticides applied in early to mid-May to manage the larvae when they are small and when injury is in the straw stage.

Tent caterpillars

Several species of tent caterpillars can occur in Wyoming. The western tent caterpillar is most often seen infesting aspen and mountain-mahogany during May and early June. Many other plants, particularly fruit trees, may also be infested. Western tent caterpillar is the most common and damaging tent caterpillar, sometimes producing widespread outbreaks that have killed large areas of aspen. The eastern tent caterpillar can occasionally be found on fruit trees.

These tent caterpillars spend the winter in egg masses glued to twigs of the host plant. The larvae emerge from the eggs shortly after bud break. The newly emerged caterpillars move to crotches of branches and begin to produce a mass of dense silk.

This silken tent is used by the developing insects for rest and shelter during the day. Most often the caterpillars leave the silk shelter to feed at night, returning by daylight, although they sometimes feed during daylight hours as well. The tent is gradually enlarged as the caterpillars grow.

The caterpillars become full-grown in late spring. Most wander from the area of the tent and spin a white cocoon of silk, within which they pupate. The adult moths, which are light brown with faint light wavy bands on the wings, emerge about two weeks later. The moths mate and the females then lay a single egg mass. Tent caterpillars produce only one generation per year.

The forest tent caterpillar is the most common and damaging tent caterpillar found in urban areas. Although its life history is similar to other tent caterpillars, the forest tent caterpillar does not produce a permanent tent as do the other species. Instead, they make light mats of silk on trunks and branches that are used as temporary resting areas during the day. Forest tent caterpillars feed on a wide variety of plants including aspen, ash,

and various fruit trees. Occasionally, they produce outbreaks that can damage plants

The microbial insecticide *Bacillus thuringiensis* (Dipel, Thuricide, etc.) can be an effective and selective control of all the tent-making caterpillars; however, to control fall webworm, Bt must be eaten by the insect. It must be applied before the colony covers all of the leaves.

Several contact insecticides also are effective for tent-making caterpillars. Sevin (carbaryl) has long been available. More recently various pyrethroids such as permethrin, cyfluthrin and esfenvalerate are available for homeowner application and are highly effective. Spinosad, a naturally derived product (sold as Conserve to commercial applicators) is very selective in its effects of species other than caterpillars.

If accessible, tents may also be pulled out and removed. More severe measures, such as pruning or burning, are not recommended because they can cause more injury than the insects.

Often, there is no need to control these insects. This is particularly true for fall webworm, which feeds late in the season. Such late season injuries can be well tolerated by plants. Control normally is warranted only where there is sustained, high levels of defoliation over several years.

Stippled (flecked), yellowed, bleached, or bronzed foliage

Pear slugs

Pear slugs feed on the leaves of certain commonly planted trees and shrubs during mid- to late summer. Among the more heavily damaged plants in Wyoming are cherry, cotoneaster, plum, apricot, pear, hawthorn, and mountain ash. Pear slugs are dark green to orange, swollen at the head end, and appear slimy. When full-grown, pear slug larvae may reach ½ inch. Pear slugs are usually confused with common garden slugs, but they are insects. They develop into small, dark, non-stinging wasps (sawflies) approximately ¼-inch long. The adults cause no real damage and are rarely noticed.

Pear slugs pass the winter underground in the pupal stage. During late spring, the adult insects emerge to mate and lay eggs. They lay eggs in slits made in the leaf.

Young pear slugs feed on leaves and become full-grown in approximately three weeks. Pear slug larvae feed on the upper leaf surface. They avoid the larger leaf veins and rarely penetrate the lower leaf surface. The resultant skeletonized leaves have a characteristic appearance. Chewed areas of the leaf turn brown. When heavily damaged, the entire leaf falls prematurely.

Pear slug injury occurs in two peaks during the growing season. This injury coincides with the presence of full-grown larvae, which do most of the feeding. In Wyoming, damage by the first generation often peaks in late July. Second generation larvae are usually most active in September. This later generation is often the most damaging and can completely defoliate susceptible plants.

Severe pear slug injury most often occurs late in the season and has little impact on plant health. However, the damage may be quite unattractive. Occasionally, heavy infestations can reduce plant vigor. In these situations, pear slugs may need control.

Most insecticides easily control pear slugs when used at labeled rates listed for control of caterpillars or leaf beetles on trees and shrubs. Among the effective insecticides are carbaryl (Sevin, Sevimol), malathion and Spinosad. Malathion and carbaryl can be used on fruit trees if waiting periods (1 to 14 days) are observed.

Pear slugs often can be controlled using a forceful jet of water to dislodge them. Soaps also have been effective for controlling pear slugs but can injure plants such as cotoneaster, plum, and cherry.

Spider mites

Spider mites are tiny, eight-legged arthropods closely related to spiders. They can be serious pests of ornamental trees, shrubs, and bedding plants. Under certain conditions, spider mite populations can increase rapidly and seriously threaten plant health.

Spider mites feed on plant leaves by piercing leaf tissues and sucking the liquid that oozes out. The leaves appear bronzed from the many tiny feeding spots, and heavily infested leaves and branches sometimes become covered with an almost invisible silken webbing.

There are a number of different species of spider mites that infest ornamental plants. Some are active primarily in the summer months, and others make their presence known during the cooler days of spring and fall.

The best way to confirm a spider mite infestation is to hold a sheet of white paper under a branch and tap the branch sharply. If present, they will fall off and be visible as tiny specks crawling over the paper.

Learn to recognize leaf stippling and bronzing as early feeding symptoms of spider mites. Inspect plants once every two weeks during the hot summer months for deciduous trees and bedding plants, and in spring and fall for conifers and broadleaf evergreens.

If biweekly monitoring reveals two dozen mites when a branch is tapped over a sheet of paper, a pesticide application should be considered. For bedding plants, use a 4 x 6 card and drop the threshold to 10 mites.

Spider mites thrive on plants under stress. Keep plants watered and give them adequate light; do not under- or over-fertilize.

Spider mites have many natural enemies in Wyoming landscapes. Conserve them by refraining from pesticide use until the mites threaten the health or appearance of landscape plants. When treatment is required, there are several mite specific active ingredients available including pyridaben (Sanmite) and hexythiazox (Hexygon). For more detailed miticide information, professor Raymond Cloyd has provided a summary online and is available at: https://gpnmag.com/article/mite-b-gone-understanding-miticides/

Dormant season treatments with horticultural oil can reduce problems caused by spider mites that overwinter on woody plants. Thorough coverage is essential to smother these mites. Avoid injury to plants by following label recommendations.

For best results during the growing season, apply insecticides where mites are feeding on the plant; this is especially important when using alternative pesticides. Observe whether the mites are feeding on the upper or lower leaf surface and direct your spray accordingly. If you elect to use conventional pesticides, avoid repeated applications of the same material for extended periods to delay the development of mite resistance.

Distortion of plant parts

Galls

Galls are abnormal growths on plants. These growths, stimulated by the feeding of certain insects and mites, represent the plant's attempt to wall off an invading organism. There are hundreds of kinds of galls, each characteristic of the insect or mite producing it.

Although galls may disfigure twigs and foliage, they usually do not affect the health or vigor of the host plant. If the plant is unhealthy or dying, chances are that something else is causing the problem.

Gall insects and mites spend most of their lives within a ball of plant tissue, sheltered from pesticide sprays. However, because their damage is so conspicuous, natural enemies can find them easily.

Generally, once you see galls on a tree, your best control is to remove and destroy them before the pest escapes from within and reproduces.

Many gall pests overwinter in bud scales or bark crevices; consequently, a dormant application of horticultural oil can minimize most gall problems. In many cases, gall pests become active in the weeks before bud break and are most susceptible to oil sprays at that time. Be aware that oils can temporarily remove the wax that gives some coniferous plants their blue color that protects leaves from scorching in full sun.

Dieback of plant parts

Zimmerman pine moth

The Zimmerman pine moth is the most important economic pest of pine trees in the Midwest. The larvae are capable of attacking and severely damaging most pine species in the north central part of the United States and poses a real threat to Christmas tree plantations. In eastern Wyoming, the insect causes greatest injury to Scotch and Austrian pines.

The first report of the Zimmerman pine moth in the United States dates to 1879. Since then, entomologists have observed it in 23 states, primarily in the northern part of the country.

The Zimmerman pine moth produces one generation each year. The adult moth is small, with a wingspan of about 1 to 1½ inches. The body is gray, and the forewings are mottled gray with zigzagged lines of red. The hind wings are light tan, becoming darker near the edges. Adults are active only at night and therefore rarely seen; they live from a few days to two weeks.

Each female moth lays 20 to 30 round eggs under bark flakes (near wounds) in mid- to late August. The eggs are initially cream-colored but turn light brown as they develop; the larvae hatch in eight to 10 days.

The larvae grow to approximately ¾-inch long. They have a brown head and a pink-to-greenish body (depending on the host pine species) covered with small black spots. The larvae overwinter as young caterpillars in shallow pits dug into the bark. When the weather warms in early April, the caterpillars crawl out of their resting places along the exposed bark surface to bore into the tree where the pine tree branches join the main trunk. Late in June and through July, when the caterpillars are deep in the trunk, wounds are gummy and covered with white crumbs of caterpillar excrement. The caterpillars pupate in mid to late July, and the adult moths emerge about 14 days later.

Wilting and browning of new tree growth are early symptoms of attack by Zimmerman pine moth larvae. Infested terminals wilt and curve downward to resemble a fishhook or shepherd's crook. The infested tops and branches of the tree die in late summer or fall, remaining on the tree as evidence of moth attack.

Once infested, trees are subject to repeated attack in the **whorl** region (where the branches attach to the trunk) and become a continuous source of infestation. Some then become partially girdled by

larval attack and develop large burl-like growths on the trunks, above the girdle.

Control requires both sanitation and insecticide application. Landscape managers should remove trees with extensive dieback, before late July. Christmas tree and nursery producers should remove all trees with visible signs of Zimmerman pine moth infestation.

Early April is the best time for chemical control of the moth because the caterpillars become active when the weather warms, crawling out onto the trunk surface. They can be killed by soaking the tree – especially the trunk – with a long-lasting insecticide. If the infestation persists, repeat the spray application in August to kill young caterpillars just hatching from eggs. Specific chemical control recommendations are usually never found in the literature concerning Zimmerman pine moth. Performing an online search of www.Greenbook.net identified multiple products with several of the following active ingredients permethrin, bifenthrin, endosulfan, chlorpyrifos, and diflubenzuron.

Clearwing borers

Like the Zimmerman pine moth, only the caterpillars of clearwing borers are destructive. The adults of most species of clearwing moths mimic the appearance of hornets for defense. The trees and shrubs that are attacked by clearwing larvae are: lilac, ash, privet, Virginia creeper, cottonwood, stone fruits, currants, Viburnum, elm, spruce, and Douglas-fir. The larvae bore, depending on the specific species into the roots, trunks, or branches of trees and shrubs. Injured trees exhibit loose or peeling bark, puncture wounds that ooze sap, and accumulations of sawdust-like excrement on the trunk and limbs. The caterpillars are usually ivory-colored with a light brown head. The adult (moth) has transparent wings and a slender body, and superficially resembles a wasp.

Depending on the species, clearwing borers may produce one or two generations per year. Females lay their eggs on the bark of susceptible trees, where caterpillars hatch and tunnel into the bark and wood and eventually pupate. Emerging adults leave the pupal skin hanging out of the exit hole.

Sex pheromone traps for some of the most common and destructive species, like the ash and peachtree borers, to monitor for and time insecticide applications can be useful. Apply a long-lasting, broad spectrum insecticide to the trunk and limbs of infested trees 14 days after finding the first moth in the trap. The two-week delay should coincide with the hatching of the caterpillars.

Recognize that, when used improperly, plastic trunk wraps can contribute to clearwing borer problems. A trunk wrapped too tightly is attractive to clearwing borers because it keeps the bark moist and serves to protect them from natural enemies. Loosely coil the wrap to allow at least 1/4 inch of air space. Recently pruned limbs attract adult moths, so avoid pruning when adults are flying.

Bronze birch borer

Sparse foliage, and dying upper branches of white, paper, and yellow birch trees are often the first visible symptoms of bronze birch borer damage. Closer examination will reveal ridges and bumps on the limbs and branches, as well as occasional D-shaped holes in the bark. Peeling back bark from infested trees will further reveal irregular, winding, sawdust-packed tunnels. It is these tunnels that girdle the branches and eventually kill the trees. Trees that receive no corrective measures usually die within a few years after the first branches begin to die.

The bronze birch borer is a serious, native insect pest. The adult is a black beetle about ½-inch long with a bronze iridescent back. It can be found

crawling on the sunny side of tree trunks during late May and early June.

The female deposits her eggs under cracks and crevices in the bark. Eggs hatch in two weeks or less, and the slender larvae tunnel immediately into the limbs to construct their galleries, pupating in late April or early May. Complete larval development may require one or two years.

Vigorously growing trees suffer less damage by borers than trees in poor condition; and lawn situations, in general, are not conducive to healthy, vigorous growth. Birch trees typically do not live long; thus, old age, as well as adverse weather and other insect-related stresses, contributes to their vulnerability.

One way to lessen the chance of borer attack is to plant native birch species like river birch that tend to be resistant. Resistant properties of native birches are enhanced when tree health is maintained by watering, fertilizing, and preventing defoliation by controlling other birch tree pests such as aphids and scales.

Spray living infested trees and adjacent susceptible birch tree trunks with an appropriately labeled, long-lasting insecticide between mid-May to mid-June as a preventative treatment (carbaryl).

Treating trees with insecticides to kill borers is only effective if the tree is in the initial stages of decline and dieback. When over 40% to 50% of the canopy has been killed by borers, the effectiveness of insecticides is greatly diminished and a treatment should not be made.

An annual soil drench with systemic insecticide in mid-May helps prevent invasion by the bronze birch borer and discourages infestations of other insect pests. If a borer infestation is already present in the vicinity, make it a practice to eliminate any dead or dying branches and trees before May to reduce the borer population. Systemic products labeled for bronze birch borer that contain the active ingredient imidacloprid are applied as a liquid drench to the soil around the trunk of the tree. Commercial applicators can also apply it as a soil injection or a trunk injection. Another active ingredient, dinotefuron, is usually applied as granules to the soil directly around the tree. Commercial applicators can also apply it as a bark spray, soil drench, or soil injection.

Mountain pine beetle

Mountain pine beetle is native to the forests of western North America. Outbreaks develop irrespective of property lines, being equally evident in wilderness areas, mountain subdivisions, and backyards. Even windbreak or landscape pines many miles from the mountains can succumb to beetles imported in infested firewood.

Mountain pine beetles develop in pines, particularly ponderosa, lodgepole, Scotch and limber pine. Bristlecone and pinyon pine are less likely to be attacked. During early stages of an outbreak, attacks are limited largely to trees under stress from injury, poor site conditions, fire damage, overcrowding, root disease, or old age. However, as beetle populations increase, attacks may involve most large trees in the outbreak area. As the population density increases, the diameter of trees attacked will decrease.

Mountain pine beetle has a one-year life cycle in Wyoming. In late summer, adults leave the dead, yellow- to red-needled trees in which they developed. In general, females seek out large diameter, living, green trees they attack by tunneling under the bark. Coordinated mass attacks by many beetles are common. If successful, each beetle pair mates, forms a vertical tunnel (egg gallery) under the bark, and produces about 75 eggs. Following egg hatch, larvae (grubs)

tunnel away from the egg gallery, producing a characteristic feeding pattern in the cambium layer. Trees will develop pitch tubes (which resemble gum or popcorn on the trunk of the tree) when under attack that may or may not force the adults out of the tree.

A key part of this cycle is the ability of mountain pine beetle (and other bark beetles) to transmit bluestain fungi. Spores of these fungi contaminate the bodies of adult beetles and are introduced into the tree during attack. Fungi grow within the tree and assist the beetle in killing the tree. The fungi give a blue-gray appearance to the sapwood.

One very effective way to kill larvae developing under the bark (though very labor intensive) is by peeling away the bark, either by hand or mechanically; this exposes the larvae to unfavorable conditions -- the larvae will dehydrate, starve and eventually die. Logs may also be burned or scorched in a pile -- preferably when there is snow on the ground (contact your local forester for assistance). They can also be buried under at least eight inches of soil, or chipped. Following beetle emergence, wood can be used without threat to other trees.

Many chemical control options for mountain pine beetle have been attempted with limited success. It is impossible to chemically control mountain pine beetle once they have infested the tree. There are several products labeled including carbaryl (Sevin), permethrin (Astro) and bifenthrin (Onyx) applied to the trunks prior to beetle infestation that have shown limited success as a protectant. “These sprays are applied to living green trees in early summer (before early July) to repel or kill attacking beetles. This preventative spray is quite effective through one flight (one year).” (2014) Cranshaw, Whitney, Colorado State University. Bul. 506A.

For mountain pine beetle, the best defense appears to be a healthy well-watered tree. Trees that have enough water have shown to have a greater ability to fend off attack by pitching out adults, preventing them from laying eggs.

Producers of honeydew or wax

Scale insects

Scale insects are common pests of shade trees and shrubs, yet landscape managers may overlook or ignore them until tree or shrub branches mysteriously start to die. If, upon close examination of branches, small bumps are found, the plant could be infested by scale insects, which damage plants by sucking out plant juices. Use your thumbnail to check plants for live scale infestations. Flip over suspicious-looking bumps on twigs and branches. The bark is intact beneath a scale as they have very slender piercing and sucking mouth parts. If flipping the bump rips open plant tissue, the bump could be a gall.

From a damage standpoint, there are two types of scales: those that excrete a sugary liquid (honeydew), and those that do not. Honeydew is both a nuisance and a threat to plant health. Parked cars, sidewalks, and benches beneath infested trees often become a sticky mess, and the sugary liquid attracts ants, flies, and wasps. Plants become unsightly when the liquid serves as a food for a black fungus called sooty mold, which can shade leaves and reduce plant growth.

Soft scales produce honeydew. The scales feed directly on plant parts that transport fluid and nutrients. Armored scales and pit scales do not produce honeydew. The armored scale’s strawlike mouth moves like a plumber’s snake to burst plant cells and feed on their contents, and pit scales do the same to the raised plant tissue that surrounds them.

Mature scales – unable to walk – spend most of their lives feeding in one place. Young scales (crawlers) are mobile for a period after they hatch from eggs beneath adult females. Crawlers are small (<1/32 inch) and flat and look like dust on the plant surface. Scale infestations spread when crawlers move to nearby plants or plant parts.

After an armored scale crawler begins to feed, it becomes very flat and covered with a clear wax shell. It continues to grow beneath its waxy armor, which is difficult to penetrate with insecticides. Winged males crawl out from beneath their cover and mate with covered females, who produce about 100 eggs each.

There is no waxy shell covering soft scales. Crawlers that hatch from eggs in midsummer usually crawl directly to leaves, where they spend most of the summer feeding. They return to the twigs and bark to overwinter as settled, second stage scales. They continue to grow on twigs in the spring until winged males mate with wingless females, which can swell with up to 1,000 eggs.

Scales thrive on trees under stress. Plant trees suited to the landscape to reduce the likelihood of vulnerability. Carefully inspect newly purchased plants for scales.

If a plant is normally a rapid grower, consider cutting out heavily infested branches with pruning shears to foster growth of non-infested shoots.

The stationary life of scales makes them an easy target for many natural enemies, including lady beetles and parasitic wasps. These beneficial insects can keep the numbers of scales quite low in a natural woodland setting. The managed landscape, however, is not a natural environment. Trees are often subject to extreme conditions that are also unsuitable for the natural enemies of scale insects, leading to heavy scale infestations.

Most conventional insecticides cannot penetrate the tough exterior of a scale. Although they can kill crawlers, it is difficult to coat the entire plant and get total control. Most natural enemies of scale insects are more susceptible to conventional insecticides than are the scales themselves; any scales left after treatment can multiply rapidly in the absence of natural enemies.

CHEMICAL CONTROL

Nonresidual, contact insecticides

Where plants can be sprayed, complete spray coverage of infested plant parts with horticultural oil at the proper time provides good control of most scales. Horticultural oils (for example, Bonide Horticultural Oil and Monterey Horticultural Oil) are specially refined petroleum products, often called narrow-range, superior, or supreme oils. Other non-persistent, contact sprays for garden and landscape plants include insecticidal soap (Safer Brand Insect Killing Soap Concentrate II), neem oil (Bayer Advanced Natria Neem Oil Concentrate, Green Light Neem, Garden Safe Brand Neem), canola oil (Bayer Advanced Natria Multi-Insect Control), and other botanical (plant-derived) oils.

These insecticides have low toxicity to people and pets and relatively little adverse impact on the populations of pollinators and natural enemies and the benefits they provide. To obtain adequate control, thoroughly wet the infested plant parts with spray, typically shoot terminals and the underside of leaves. More than one application per growing season may be needed. Thorough spray coverage is especially critical when treating armored scales and oak pit scales as these scales are generally less susceptible to pesticides than soft scales.

Dormant season

To control most scales overwintering on deciduous woody plants, thoroughly spray the bark of terminal shoots with oil during winter. For best results apply these products prior to bud break.

Foliage spray

Horticultural oil is effective in spring or summer on deciduous plants when sprayed soon after most crawlers have emerged and most scales are in the young nymph stage. When making an insecticide application, thoroughly cover the plant parts where scales occur, typically on twig terminals and the underside of leaves.

Precautions on using oils

Follow product labels, which may say to not spray certain plant species or mix oil with certain other products. For example, oil will remove the desirable bluish tinge from blue spruce foliage, although the plant's health is not impaired. Do not mix oil with chlorothalonil, sulfur, and certain other fungicides; and do not apply oil within three weeks of an application of sulfur-containing compounds, such as wettable sulfur. Do not apply oil or other insecticides when it is foggy, freezing (under 32°F), hot (over 90°F), when relative humidity is above 90%, or if rain is expected in the next 24 hours. Especially at locations with hot weather, be sure plants are well irrigated before spraying foliage.

Systemic insecticides

Systemic insecticides are absorbed by one plant part (trunks or roots) and moved (translocated) to leaves and other plant parts. In comparison with systemics that are sprayed onto foliage, products labeled for soil drench or injection, or for trunk injection or spray, minimize environmental contamination and may be more effective than contact insecticides. Trunk application of an effective systemic insecticide can provide relatively rapid control. There is a longer time delay between soil application and insecticide action.

Systemic insecticides for use on landscape plants include neonicotinoids (acetamiprid, dinotefuran, imidacloprid, and thiamethoxam) and the organophosphate acephate (Lilly Miller Ready-to-Use Systemic, Orthene). Properly applied, one application of an effective product may provide season-long control. However, neonicotinoids vary in effectiveness for scale control. For example, acetamiprid (Ortho Flower, Fruit & Vegetable Insect Killer) controls soft scales but is not very effective on armored scales and can only be applied by spraying foliage. Imidacloprid controls European elm scale and most soft scales but does not control cottony cushion scale and most armored scales. Dinotefuran (Green Light Tree and Shrub Insect Control with Safari 2G, Safari) controls most types of scales. Some of these products are for licensed professional applicators only.

Some systemic insecticides can cause spider mite outbreaks. Foliage sprays of systemics can be toxic to beneficial insects that contact spray or treated leaves. Systemics can translocate into flowers and have adverse effects on natural enemies and pollinators that feed on nectar and pollen. Do not apply systemic insecticides to plants during flowering or shortly before flowering; wait until after plants have completed their seasonal flowering unless the product's label directions say otherwise. With foliage spraying and soil application, when possible, wait until nearby plants also have completed flowering as spray can drift onto nearby plants or their roots may take up some of the soil-applied insecticide.

When applying systemic insecticide, use soil application or a trunk spray whenever possible. With trunk injection and implantation, it is difficult to repeatedly place insecticide at the proper depth. Trunk injection and implantation also injure woody plants and can spread plant pathogens on contaminated tools. When injecting or implanting into multiple plants, scrub any plant sap from tools

or equipment that penetrate bark and disinfect tools with a registered disinfectant (bleach) before moving to work on each new plant. At least one to two minutes of disinfectant contact time between contaminated uses is generally required. Consider rotating work among several tools and using a freshly disinfected tool while the most recently used tools are being soaked in disinfectant. Avoid methods that cause large wounds, such as implants placed in holes drilled in trunks. Do not implant or inject into roots or trunks more than once a year.

Residual, foliar sprays

Foliar sprays of broad-spectrum insecticides with residues that can persist for weeks are not recommended for scale control in landscapes and gardens. Pesticides to avoid include carbamates (carbaryl or Sevin), nonsystemic organophosphates (malathion), and pyrethroids (bifenthrin, fluvalinate, permethrin). These are highly toxic to natural enemies and pollinators and can cause outbreaks of spider mites or other pests. Because their use in landscapes and gardens can run or wash off into storm drains and contaminate municipal wastewater, these insecticides are being found in surface water and are adversely affecting non-target aquatic organisms.

Aphids

Aphids are small (usually <1/8 inch), pear-shaped insects with a pair of cornicles (tube-like structures) at the rear of the abdomen. They feed by sucking the sap from plant tissues, which stunts plant growth, deforms leaves and fruit, or causes galls to form. However, aphid damage is typically minor and poses little threat to the health of infested ornamentals. The principle problem aphids cause in the landscape environment is caused by the deposition of their liquid excrement called honeydew. This sweet liquid can become infested with a black sooty mold that discolors the plant and detracts from its appearance. In late summer honeydew can attract stinging insects and cause added nuisance.

There are many species of aphids that vary greatly in biology, which often restricts each species to certain host plants. Aphids can reproduce without mating, and they give birth to living young.

Insect predators and parasites frequently hold aphid numbers in check in outdoor landscapes. Conserve natural enemies by minimizing insecticide use whenever possible to allow the number of natural enemies to increase. If insecticide use becomes necessary, avoid using long-lasting, broad-spectrum materials. Insecticidal soaps and oils are better prospects, as they will control aphids and allow the reentry of natural enemies into the area after the insecticide has dried. Dormant oil applications can also kill aphids overwintering as eggs on ornamentals. Avoid planting trees and shrubs that are especially sensitive to aphid infestations in high-traffic areas where honeydew accumulations may be a problem.

Many insecticides are available to control aphids in the landscape, including foliar-applied formulations of malathion, permethrin, and acephate (nonfood crops only). While these materials may kill higher numbers of aphids than soaps and oils, their use should be limited, because they also kill the natural enemies that provide long-term control of aphids and other pests, and they are associated with bee kills and environmental problems. Repeated applications of these materials may also result in resistance to the material.

Formulations combining insecticidal soaps and pyrethrins may provide slightly more knockdown than soaps alone yet have fewer negative impacts on natural enemies than malathion, permethrin, and acephate, because pyrethrins break down very quickly.

Systemic insecticides are also available for aphid management, primarily for woody ornamentals. These materials, including imidacloprid, are very effective and are especially useful for serious infestations of aphids such as the woolly hackberry aphid, which is often not effectively controlled by biological control or less toxic insecticides. Imidacloprid can have negative impacts on predators, parasitoids, and pollinators, so its use should be avoided where soaps and oils will provide adequate control. To protect pollinators, don't apply imidacloprid or other systemic insecticides to plants in bloom or prior to bloom.

Professional applicators can use soil injectors, which provide better control with less runoff potential. Applications are usually made in spring when aphids first become apparent.

Adequate rain or irrigation is required to move the product through the soil to the roots and up into large trees, and it may take several weeks to see an effect on aphids feeding on leaves. One application on hackberry is enough to control hackberry woolly aphid for two to three years.

INSECTS DAMAGING TO TURF

Turfgrass insect pests may fall into one of three broad categories according to where they are found in turf: in the soil (root feeders), in thatch (crown- and stem-feeders), and on blades of grass (leaf-and stem feeders). Proper inspection technique, choice of insecticide and actions taken prior to and after an insecticide application can all depend on where the target insect lives and feeds.

SOIL INSECTS

White grubs

Among the most damaging turf insect pests in Wyoming are white grubs that feed on or otherwise destroy the root systems of grass plants. They are the larval stage of one of several species of beetles, masked chafers, May or June beetle (and Japanese beetles when they get here).

White grubs are robust, white, C-shaped larvae with many wrinkles or folds along the body, behind the head. The abdomen is slightly larger in diameter than the rest of the body and may appear darker in color as the grub ingests soil. White grubs have chestnut-colored hardened head capsules and six legs. Depending on species and age, they may range from ¼ to 1½ inches in length.

White grubs are most damaging in their later instars, when they can destroy large amounts of turfgrass root material. Larvae burrow below the freeze line to overwinter, then return to the root zone to resume feeding in the spring. Depending on the species involved, grubs may feed for a single year or several years. The most common pest species feed only for one year and are referred to as annual white grubs.

The first symptom of white grub damage is a wilting and discoloration of the turf. Eventually the turf collapses forming irregular dead patches. Damage is usually noticeable during late summer or fall, but may sometimes be detected in the spring. Other symptoms include sod that pulls up easily (like rolling back a carpet), revealing white grubs underneath. Sometimes raccoons, skunks, or flocks of blackbirds foraging in the lawn may indicate a severe grub infestation. The destructive foraging activity of these animals can sometimes cause more damage than the grubs themselves.

Drought often manifests grub damage to turf, and minor damage can sometimes be masked by increasing irrigation. Once grub damage becomes severe, insecticide treatments will not usually save the turf. Consider an insecticide treatment where there is evidence of a large grub population and damage is likely to occur or worsen. For most white grub species, traditional recommendations call for insecticide applications in late July or early August. However, modern chemistries with longer residual activity permit applications earlier in the summer where the turf has a history of serious grub infestation.

Insecticides used for grubs can be separated into two groups based on how they work - **preventive** chemicals and **curative** chemicals.

Preventive

Insecticide that will prevent grub damage next fall and the following spring. These products are used to prevent future grub problems, not to control the grubs present in the lawn in the spring. They will not work on grubs found in the lawn from the middle of October through the middle of May. However, when applied in June or July, they provide excellent protection against the next generation of grubs. So, if you need to apply the preventive insecticide BEFORE the grubs are there, how do you know if you need to use an insecticide or not? If you had confirmed (meaning that you found lots of grubs) grub damage the previous fall or spring, then you may want to use a preventive insecticide for one or two years to build a more dense turf that will be tolerant of grubs. If you have treated for several years and you do not see evidence of grubs in your lawn or in the neighbor's lawn, it may be time to stop treating. There is an erroneous philosophy that it is necessary to treat every year or your lawn will be damaged by grubs. This is not true.

Preventive products are the most effective.

Products containing imidacloprid, thiamethoxam, clothianidin, halfenozide or chlorantraniloprole **WILL NOT CONTROL GRUBS IN THE SPRING**. They are preventive products that work very well on newly hatched grubs present in July, but do not work well for large grubs found from September to May. There are different recommended timings for application depending on the active ingredient. Although the bag often says apply anytime from May to Aug 15, it is highly recommended that products containing imidacloprid, thiamethoxam, clothianidin or halfenozide be applied and irrigated into the soil in June or July. If applied in early spring they may move through the soil or partially degrade by the time the grubs hatch in late July. If applied too late they may not be effective as they work best on small grubs. Preventive products containing imidacloprid, thiamethoxam, halfenozide, or clothianidin will consistently give 75%-100% reduction of grubs if they are applied in June or July, and if they are watered-in with a ½- to 1.0-inch of irrigation immediately after application. Lawn sprinklers can be used if you do not have an irrigation system. Measure how much water you have applied by placing several coffee cups on the lawn and running the sprinklers until they fill ½- to 1.0-inch deep with water.

There is a new active ingredient in some insecticides called chlorantraniliprole that is also very effective in preventing grub problems, but it is less water soluble than the other preventive compounds mentioned above. Since it takes longer to move down to where the grubs will be, it is best to apply a product containing chlorantraniliprole as early in the spring as possible (no later than mid-May) for it to be most effective when the grubs hatch in July and August. Chlorantraniliprole, when applied in April or early May, and irrigated into the ground, will also give very good grub reductions for the following fall and spring of the next year.

Some of these products come in a granular formulation, and some come designed to be mixed with water and applied. If you are applying a product containing clothianidin, thiamethoxam or imidacloprid as a liquid application, the lawn should be mowed prior to the application. These active ingredients can be toxic to bees if foraging bees visit flowers that were recently sprayed. Mowing prior to making the application will ensure that there are no flowering weeds in the lawn that would be attracting bees. Bees won't visit lawns unless there are flowering weeds in the lawn.

Curative

There are two chemicals, carbaryl and trichlorfon, that are considered curative treatments. They are short-lived compounds that kill all life stages of the grubs. They are not as effective as the preventive compounds in reducing grub numbers. Consider carefully whether it would be best to wait and apply a preventive later. If the need should arise to use a curative compound, make sure to keep the infested lawn watered and fertilized and treat the area again with a preventive application the next summer or the problem will likely reoccur in the fall or the following spring.

Research shows that watering with ½ inch of irrigation immediately after the application is essential to get effective results from these insecticides. It will take 10-14 days for the grubs to begin to die after the insecticide is applied. *What is a ½ inch of irrigation?* A ½ inch of irrigation is when lawn sprinklers are run until several containers placed in the sprinkler pattern fill to a level ½ inch up from the bottom.

Insecticides that do not work on grubs

Do not use products containing ONLY lambda-cyhalothrin, gamma-cyhalothrin, bifenthrin, deltamethrin, cyfluthrin or permethrin for grub control. PRODUCTS CONTAINING ONLY THESE INGREDIENTS WILL NOT WORK FOR GRUB CONTROL because the active ingredient binds with organic material and will not move down to where the grubs are feeding. These products work well for aboveground feeding insects that live on the grass leaves or soil surface but not for insects that feed on the roots.

In summary

- Check the product to determine what active ingredient it contains.
- Do not use products containing ONLY lambda-cyhalothin, gamma-cyhalothrin, bifenthrin, deltamethrin, cyfluthrin or permethrin for any phase of grub control.
- Use preventive compounds such as clothianidin, thiamethoxam, imidacloprid or halfenozide in June or July to control grubs that would be damaging turf in the fall.
- The preventive compound chlorantraniliprole should be applied in late April or early May to control grubs that would be damaging turf in the fall, as it will take longer for the material to move to where the grubs will be feeding in July.
- To kill grubs in the spring (or fall) use carbaryl or trichlorfon.
- Always wear rubber gloves and rubber boots when applying insecticides to turfgrass.
- Make sure to irrigate the lawn with at least ½ inch of water and allow the grass to dry before allowing anyone (or pets) into the treated area. Irrigation is essential for the chemical to be most effective.*
- Store insecticide products in a locked cabinet not accessible to children.
- Proper fertilization is important to prevent and to allow the lawn to recover from grub damage.

THATCH INSECTS

Sod webworms

The adult moths are buff-colored insects with a wingspan of up to 1 inch. They have a tubular appearance when at rest because of the way their wings roll around the body. The moths have a distinctive snout and often rest head-down along the axis of a blade of grass. Sod webworms overwinter as larvae and sometimes damage turf during spring. Emerging moths commence egg laying by early June, and there are two to three generations per year.

Sod webworm larvae grow to approximately 1 inch in length. They are tan or dusky green, with distinct dark spots over their entire body. The larvae often hide in silk-lined tunnels within the thatch. They feed on the leaf blades and stems of a variety of turfgrass species, especially well-maintained turf in sunny locations. Although extensive feeding can cause thinning turf and brown patches, damaged areas usually recover. First instar sod webworm larvae are leaf skeletonizers. Later instars notch or cut off leaf blades and pull them into the burrow. Heavily infested turf (more than 100/sq. yd.) quickly appears moth eaten, with irregular patches of brown grass or bare areas. Significant damage can occur on drought-affected bluegrass and on bentgrass green and tee areas.

Sod webworms larvae can be flushed from the thatch using soapy water drench test (see below), and adult activity can be monitored using light traps. The best defense against sod webworms is well-maintained turf.

Management

When sod webworms are present, dethatching the turfgrass may help. Monitor to determine if treatment is needed.

Biological control

Natural enemies include earwig, rove beetle, robber fly, paper wasp, ant, and vertebrate predators. The extensive soil or thatch contact of sod webworms makes *Steinernema carpocapsae* nematodes a valuable control measure. *Bacillus thuringiensis* ssp. *kurstaki* (Bt), a microbial insecticide, can be used but it breaks down rapidly in sunlight, washes readily off leaves, and is ineffective against late instar larvae.

Cultural control

Thatch removal can assist in removing sod webworm habitat, although larvae do not require a thatch layer to be present in very high numbers. Control of clover and dichondra may help minimize damage. Damage is usually not noticeable in turf mowed at heights above 2.5 inches.

Monitoring and treatment decisions

Monitor for these pests from June to early October. Consider treating only when a drench test indicates there are more than 5 larvae per square yard on stressed greens or 15 larvae per square yard in other situations. If Bt is used, apply when there are predominantly early instar larvae. Other materials are also most effective on small larvae but will kill larger ones more effectively.

Mow and irrigate the site before applying insecticide and do not mow or irrigate the turfgrass for at least 24 hours after treatment unless nematodes were applied, in which case apply a post-treatment irrigation. When Bt is applied, do not irrigate for 2 days after treatment.

If an insecticide application becomes necessary, the following active ingredients are registered for use: spinosad (Conserve SC), carbaryl (Sevin), azadirachtin (Azatrol), permethrin (Astro) and deltamethrin (DeltaGard T&O). Apply the product to the turfgrass leaf blades and stems where the larvae feed. Avoid applications before rain,

and do not irrigate the turf for at least 24 hours after treatment.

Use a **drench test** to detect cutworms, sod webworms, and billbug adults. To carry out this test, mix one to two fluid ounces of liquid dishwashing soap in 1 gallon of water. Apply the solution to 1 square yard of turf as evenly as possible using a sprinkling can. This will irritate the insects so that they move to the surface within 10 minutes.

In large lawn areas such as parks, golf courses, and cemeteries, monitor several locations to determine the extent of an infestation. Certain pests, such as white grubs, often repeatedly infest limited areas where adults prefer to lay their eggs. If problems are localized, spot treatments may be suitable. Don't treat for insect pests unless treatment thresholds are exceeded.

Billbugs

Billbugs are a complex of stout, dark-colored weevils approximately 1/4-inch long. Their antennae are attached at the base of an elongated snout, which serves as a prominent feature for identification. The adults overwinter in protected areas in soil or leaf litter. In the spring, females lay their eggs inside the stems and aboveground shoots of various turf species. Legless, white larvae emerge from the eggs and begin feeding inside the plant stems. As the larvae mature, they move to the crown and roots, where they can kill the plant.

Characteristic symptoms include the appearance of individual dead plants that first give the turf a spotty appearance. These small spots then begin to coalesce into larger patches of dead and dying plants that easily break away from the soil. Damage is common in newly sodded lawns, on south facing slopes or swales, and around golf course structures such as bunkers, tees and greens.

To inspect for billbugs, routinely monitor sidewalks, cart paths, driveways, and curbs as adult billbugs often use these structures to move around and infest new areas. Pitfall traps can be placed in the turf to monitor adult activity, and soil cores can be examined for larvae. When billbug damage is suspected, a "tug test" can be performed by grasping several damaged/dead tillers and pulling. Plants damaged by billbugs will break-off at the soil line with very little force. The bottom ends of the broken tillers are sometimes packed with a fine, sawdust-like frass (excrement).

Insecticide applications may be targeted at either adult weevils during spring or at the larvae during summer months, but applications targeting the adults usually provide more reliable control.

False chinch bug

The adult false chinch bug is slightly less than ¼-inch long. It has a black body, brown to reddish-yellow legs, and white wings with triangular black areas midway back along the outer margins. Early instar nymphs are red with a white band across the body. Later instar nymphs bare the same characteristic white band across the body, but are darker in color.

False chinch bugs feed on a variety of weedy mustard species and are often mistaken for turf pests. As mustard weeds dry down in the early spring, the false chinch bug will migrate in large numbers to anything green (usually turf). They have piercing/sucking mouth parts and may withdraw sap from the turfgrass plant. Chinch bugs prefer hot, dry conditions and often feed in groups where the turf is under stress from drought. Their feeding results in the destruction of plant vascular tissue causing the plants to die in a top-down fashion.

The presence of large numbers of chinch bugs during hot, dry conditions may warrant an

insecticide treatment. Such treatments should be targeted to penetrate the turf canopy and may be lightly irrigated to facilitate movement into the thatch. However, false chinch bug infestations in Wyoming are a common occurrence and nuisance but not usually damaging to turf.

True chinch bug

Are not commonly found in Wyoming.

LEAF INSECTS

Black cutworm

The black cutworm is the most common cutworm species associated with turfgrass in Wyoming. The adults are dark-colored moths that migrate north in early spring and summer. Female moths lay their eggs on the leaves of turfgrass plants. The larvae are dark colored and tend to have a greasy sheen. They may grow to approximately 1 3/4 inches long. Early instars feed only on the foliage, but later instars develop a subterranean habit, cutting off plants at night and pulling them into a burrow in the ground to feed. Cutworms generally are not serious pests of lawn turf. However, black cutworms can become a problem in closely mowed golf turf. The presence of worm-feeding birds can sometimes indicate a cutworm infestation in turf.

Caterpillars such as armyworms and cutworms can be flushed from the thatch using a drench test. Adult activity can be monitored using light traps.

Apply insecticides for cutworm and armyworm control as soon as damage is confirmed. Be sure to mow and irrigate before making the application and do not mow or irrigate for at least 24 hours after.

OTHER INSECT PESTS THAT MAY BECOME IMPORTANT TO WYOMING ORNAMENTAL AND TURF MANAGERS

Japanese beetle

Japanese beetles cause problems throughout the Midwest and have been identified in Montana, Colorado, and Nebraska – they are most damaging to lawns, trees, and flowers. They can also be found in agricultural crops.

The Japanese beetle adult is about ½-inch long and is metallic green and bronze; it has a row of white tufts of hair that appear as spots on each side of its body. Adult beetles are most active from mid-June through July. They can feed on more than 300 species of plants but are especially fond of roses, flowering fruit trees, elms, linden, grapes, and flowers and fruit of all kinds.

Beetle larvae (grubs) develop in turf and cultivated land from eggs laid by the female in mid-summer. They feed on the roots of grasses and other plants and complete their growth the following spring, emerging as beetles in late June or early July.

Adults can fly considerable distances (more than 2 miles) to feed on leafy plants. In areas of heavy infestation, the adults attack and injure flowers and foliage, while the grubs may damage lawns and cultivated crops by feeding on the root systems.

Ornamentals can be protected against adult Japanese beetles by coating their leaves with insecticide during the peak of their flight period. Typically, two treatments are required, but landscape managers should inspect plants for additional beetle damage to verify the need for a second application.

Concentrate your efforts on trees that are susceptible to beetles. And, when possible,

replace susceptible plants with those resistant to adult feeding.

Emerald ash borer

The emerald ash borer is a wood-boring beetle of Asian origin that has become established in parts of the upper Midwest. It is extremely damaging to all North America species of ash (Fraxinus), including green ash and white ash that are very commonly grown in landscape settings. It does not attack Mountain Ash, which is not a true ash. The emerald ash borer in general is shaped like a bullet. The adult beetle is about ½ inch in length. The most conspicuous feature is that the emerald ash borer has uniformly green bright, metallic wing covers. The thorax may be more metallic brown and underneath the wing covers the abdomen is purple.

This pest species has been identified in Boulder, Colorado. It is believed that it was brought to the area in firewood from the Midwest.

Larvae feed by chewing the cambium layer under the bark producing meandering tunnels. When full grown, the larvae chew into the heartwood of the trunk and make a small chamber in which they pupate. After transformation to the adult beetle, they chew through the bark and emerge, making a characteristic "D"-shaped exit hole.

Be aware that these two species (Japanese beetle and emerald ash borer) are extremely damaging to desirable landscape plants used in Wyoming. If you have suspect insects you would like identified, collect and freeze the sample in a plastic bag. The sample should be placed into a non-crushable container and sent to:

Scott Schell
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University of Wyoming
College of Ag and Natural Resources
1000 E. University Ave.
Department 3354
Laramie, WY 82071

SUMMARY

Integrated Pest Management is the preferred approach for controlling insect problems in ornamentals and turf. Vigorous, healthy plants can tolerate higher insect infestation levels and will outgrow damage more quickly. However, if insecticide use does become necessary, remember that insecticides are designed to control insects, and do not bring dead plants back to life! Do not expect immediate improvement in the appearance of plants and turf after an insecticide application. Controlling turf insect pests only prevents further damage. The maintenance of high-quality grass requires implementation of a sound pest management program in concert with proper agronomic maintenance practices.

Section 8 - Category 903C - Ornamental and Turf Disease Management

LEARNING OBJECTIVES

After completing the following section, you should be able to:

A. List three components of the disease triangle

B. Explain the relationship among the components of the disease triangle and the development of plant disease

C. Describe how the following cultural practices can influence disease development in turf
- fertilization
- mowing
- irrigation

D. Describe the following fungicide types:
- contact
- local systemic also referred to as translaminar
- systemic

E. Explain how fungicide resistance develops in plant pathogens

F. List resistance management practices that reduce the potential for fungicide resistance to develop in plant pathogens

INTRODUCTION

Shade trees, ornamental shrubs, and turf add beauty to the environment, provide shelter for wildlife, save energy costs by shading, act as windbreaks, prevent soil erosion, and increase property values.

Unfortunately, trees, shrubs, and turf can develop a variety of problems that lessen their value in the landscape. Some problems are normal and unavoidable in an outdoor environment. Others may be unsightly but do not seriously affect the continued growth and well-being of shrubs and trees. Still others are harmful enough to require prompt action.

The purpose of this chapter is to describe common ornamental plant diseases and to provide an integrated strategy for maintaining plant health and vigor.

WHAT IS A PLANT DISEASE?

We may think of diseased plants as those whose development has been altered to such a degree that symptoms are obvious, either on the plants or by their yield. A broad, simplified definition of plant disease is “any continuous disturbance which interferes with the normal growth and/or reproduction of the plant.”

Plant pathologists divide the causes of plant disease into two basic groups: **abiotic** (noninfectious) and **biotic** (infectious). Unfavorable growing conditions such as too little or too much water or fertilizer,

improper light balance, and temperature extremes, cause abiotic diseases. Sudden plant injury or death by mechanical means or chemicals is not considered abiotic disease. Plant pathogens such as fungi, bacteria, viruses, and nematodes cause biotic diseases.

ABIOTIC DISEASES

Trees and shrubs, whether in a lawn or along a street, are subject to stresses that plants in their native environment seldom encounter. People often plant trees and shrubs into disturbed soils in the landscape setting, attempt to grow species poorly adapted to the local climate, or expose ornamental plants to poor cultural management practices.

Plants grow best within certain environmental ranges. Such environmental factors include temperature, soil moisture, soil nutrients, light, relative humidity, soil structure, and soil pH.

Stresses associated with growing ornamentals under less than ideal conditions can result in abiotic diseases. Abiotic diseases are not transmissible from one plant to another, but they are responsible for the majority of plant disorders found in the landscape. The symptoms of abiotic diseases vary in kind and severity, depending on the particular environmental or cultural factor involved, and the degree to which this factor varies from the norm.

The number of environmental conditions and cultural practices that can cause abiotic diseases is almost unlimited, but most affect plants by interfering with normal physiological processes. Such interference may be the result of:

- an excess of a toxic substance in soil or air (for example, road salt, automobile exhaust);
- the lack of an essential substance (for example, nutrient deficiencies, moisture deficits);
- an extreme in conditions supporting plant life (for example, temperature, light); and
- the activities of people (for example, heavy foot traffic, careless mowing and trimming practices).

The presence of certain characteristic symptoms associated with specific environmental or cultural factors sometimes makes abiotic disease diagnosis reasonably simple. Often, however, the symptoms of abiotic diseases are too vague for simple diagnosis. In such cases, accurate diagnosis requires careful examination and analysis of:

- the weather conditions prevailing before and during the appearance of the disease symptoms;
- recent changes in atmospheric and soil contaminants at or near the area where the plants are growing;
- the cultural practices preceding the appearance of disease symptoms.

Abiotic diseases can be controlled by:

- minimizing exposure of ornamental plants and turf to extreme environmental conditions;
- avoiding harmful cultural practices;
- supplying plants with protection from damaging substances in the environment;
- providing the necessary requirements for promoting plant growth.

Abiotic diseases include:

- Wilting, drought stress
- Winter dieback, desiccation
- Nutrient deficiencies
- Sun scald, scorch
- Herbicide, chemical damage, fertilizer burn

BIOTIC DISEASES

Biotic plant diseases differ from abiotic disorders because they are caused by living organisms and are infectious (can be transmitted from plant to plant). Many plant pathogens are microorganisms that exist near potential host plants at various times. Although plant pathogens may be common in many landscape situations, they cannot infect the plant and cause disease unless the environment is favorable for the interaction to take place.

Kinds of pathogens

Fungi

Fungi are a diverse group of single-celled and multicellular microorganisms that live by decomposing and absorbing the organic material in which they grow. Fungi that require living plant hosts to grow and reproduce are pathogenic. Not all pathogenic fungi are obligate pathogens, some can exist as **saprophytes**. Pathogenic fungi typically have a vegetative body called the **mycelium**, which consists of tiny filamentous strands of **hyphae** that grow through the tissues of the infected host. Reproduction in fungi is primarily by means of **spores**, and many species produce more than one type. Some act as resting structures to carry the fungus through adverse conditions, while others are responsible for the ongoing secondary spread of the organism. Wind, rain, irrigation water, insects, and cultural practices are among the many ways in which fungal spores may spread to new host plants.

Bacteria

Bacteria are microscopic, single-celled organisms that multiply by division. Plant pathogenic bacteria infect plants at wound sites or natural openings. They generally require warmth and moisture to multiply and usually are not a problem during dry summer weather, except where there is overhead irrigation. Splashing water, insects, or movement of infested plants, soil, or equipment may serve to spread disease-causing bacteria. In some instances, as with diseases of annual flowers, bacteria may be seed-borne.

Viruses

Viruses are submicroscopic particles that require a living host cell in which to replicate. They generally do not survive for very long outside of living tissue. Ornamental plant viruses rarely kill woody plants, and some infected plants exhibit no symptoms.

Aphids, leafhoppers, and other plant-feeding insects may spread plant viruses. Budding or grafting, or the movement of infected seeds, plants, plant parts, or infested equipment also can transmit viral infections. Once infected by a virus, a plant remains infected for its entire life.

Nematodes

Nematodes are microscopic, unsegmented roundworms. They feed on a tremendous variety of plant and animal materials and are probably the most numerous multicellular animals on earth. Those species that parasitize ornamental plants **frequently damage the roots**. They persist in soil and may damage newly transplanted stock; contaminated soil moved from one site to another serves as a vehicle for the spread of nematode problems.

Principles of biotic disease management

The occurrence of a biotic disease requires the presence of a susceptible host plant, a favorable environment, and a pathogen. These three elements make up what plant pathologists refer to as the disease triangle; a disease will not develop unless all three elements are present for a specific period of time. Understanding this basic principle about infectious plant disease is critical in developing successful disease management programs.

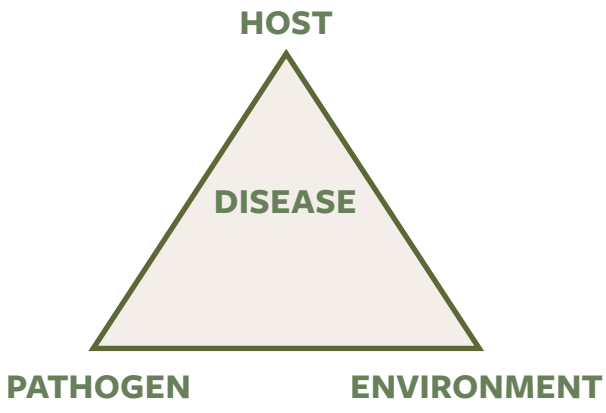
DISEASE TRIANGLE

The host component

Plants are resistant to most pathogens, but plant susceptibility varies according to species. Perennial ryegrass, for example, is very susceptible to Pythium blight and gray leaf spot, yet it is unaffected by the summer patch pathogen. Kentucky bluegrass, on the other hand, is susceptible to summer patch and is rarely affected by Pythium blight. Different cultivars (genetically different groups within a species) also can vary widely in disease susceptibility. It is fairly important to know which plant species are more prone to infection by local pathogens.

The pathogen component

Fungi are the most important pathogens of turf. Pathogenic fungi typically have a vegetative body called the mycelium, which consists of tiny threads that grow on and through the infected host. Some pathogens produce spores. Each piece of mycelium and each spore is infectious, i.e., they spread the pathogen and increase disease severity. Turf pathogens often survive in dead and decaying organic matter or within in the plant itself. In most important cases, turf pathogens are a natural part of the microbial community, and therefore the pathogen component of the disease triangle is almost always present.



The equilateral plant disease triangle. The three necessary causal factors of disease are positioned at the vertices.

The environmental component

If both a susceptible host plant (turfgrass) and a plant pathogen are present, environment becomes the determining factor for disease. It is a complex component, largely a function of interaction among temperature, moisture, plant nutrition, and mechanical maintenance practices – as outlined below.

Temperature

Temperature influences disease development by affecting both the pathogen and the host plant. Pathogens often are active within fairly well-defined temperature ranges. For example, gray snow mold fungi are most active at low temperatures (32° to 36° F), while the Pythium blight pathogen thrives during periods of high (70° to 75° F) temperature.

Temperature also influences disease by increasing the severity of symptom expression. Under high temperature stress, usually combined with drought stress, infected roots are unable to take up sufficient water to support the plant; the usual result is wilt and leaf collapse, followed by plant death. Take all patch is a root disease. The pathogen is active in moderate soil temperatures, but symptom expression may continue through summer in areas where turf is subjected to heat and drought stress. It is important for turf managers to understand that remedial treatments are effective only when pathogens are active, and that pathogen activity does not always coincide with symptom expression.

Moisture

Moisture has direct and indirect effects on disease development. Almost all fungal pathogens require water on plant surfaces for growth and infection, so it is a critical component of the

infection environment. Moisture sources include precipitation, irrigation, relative humidity, and dew. Soil moisture influences symptom expression in root diseases, as soil moisture deficits add stress to plants impaired by root infection.

Temperature and moisture combinations are critical to the development of foliar diseases. Most important are the duration (in hours) of the leaf wetness period AND the temperature during the leaf wetness period. Because Wyoming is considered a semi-arid environment there is generally less disease pressure in ornamental and turf plantings in our state when compared to many other states.

Nutrition and soil pH

Nitrogen nutrition is an important determinant for several diseases. In some cases (for example, brown patch and Pythium blight), plants exposed to excess nitrogen are especially susceptible to infection. In others (for example, dollar spot, red thread, and rust), plants suffering nitrogen deficiency are more prone to infection. Furthermore, they are slower to recover from disease, often prolonging the duration of symptom expression. Other nutritional elements, such as phosphorus and potassium, influence disease development, as well, but their individual effects are not as significant as those of nitrogen.

High soil pH favors infection by the take all patch pathogen. Other root diseases (summer patch and necrotic ring spot) are favored by alkaline soil conditions, but take all patch is the clearest example of pH effect on disease development.

Although these factors affect all plants growing in nature, their importance is considerably greater for cultivated trees and shrubs grown in areas where conditions for normal growth are marginal. Cultivated plants are frequently subjected to a number of cultural practices (for example, either excessive or inadequate fertilization, irrigation, and/or pruning), which may adversely affect their growth.

Mechanical maintenance operations for turf

Because turfgrass is managed intensively, maintenance operations can have significant effects on disease development and symptom expression. Among the most influential maintenance operations are mowing (height of cut), core aeration, topdressing, irrigation (scheduling), and other practices that improve air circulation and water drainage.

Closely mown turf is required for certain playing surfaces and generally is more aesthetically appealing than taller turf. However, taller turf is more tolerant of environmental (heat, drought, and compaction) stress, less disease prone, and generally less dependent on a carefully implemented disease control program. Close mowing also causes decreased root and rhizome growth. The reduced, shorter-than-normal root system requires more frequent irrigation and fertilization to compensate for the plants' reduced ability to secure moisture and nutrients from the soil.

Mowing sometimes has other effects as well: turfgrass pathogens may be spread with mowers; plant protectants (fungicides) may be removed from the turf; and damage from dull mower blades may contribute to plant stress.

Core aeration and topdressing are designed to improve root vigor; however, they also may contribute to environmental stress and injury and may spread root pathogens. Irrigation timing, use of fans, and even tree removal can be instrumental in improving air movement to facilitate the evaporation of dew from golf greens and tees.

HOST PLANT MANAGEMENT OPTIONS

Disruption of the disease triangle is essential to successful turf disease management. Various control options are effective against one or more of the three disease components:

- Genetic options (use of non-host species or resistant varieties) address the host component.
- Cultural options alter the environment to make it less conducive to disease development.
- Chemical options (mostly fungicides) protect against or suppress infection by the pathogen.

Plant selection is one of the most powerful disease management tools available. Choosing disease-resistant ornamental plants and turf varieties known to thrive under local climatic conditions normally prevents disease problems. New resistant plant materials are continually being developed.

Selecting plants to avoid disease problems is most useful when planning new landscapes, but it also can be useful when managing diseases in established plantings. In the latter case, resistance information can benefit the selection of replacement plants.

Cultural practices that promote the overall health and vigor of ornamentals and turf are important disease management tools. The importance of good cultural disease practices in total disease management is easy to overlook since the practices, themselves, may seem unrelated to disease. However, appropriate site selection, establishment procedures, fertilization, pruning, and irrigation all contribute to vigorous growth. Healthy plants are more resistant to infection by plant pathogens and more likely to survive the disease once infection has taken place. **Good cultural practices can help prevent diseases and limit their effects.**

Stress and damage management is another way of utilizing certain cultural practices to prevent or alleviate plant diseases. All plants experience unfavorable growing conditions at some time. However, when unfavorable conditions continue over a period of time, plants become stressed. Sometimes the landscape manager can do nothing to alleviate stress, but options are usually available. A proper nutrient management program prevents nutrient stress. Irrigation management programs prevent drought stress when water needs are high.

Damaged plants are susceptible to disease, so it is important to protect plants from injury. Sheltering or supporting them can minimize the possibility of damaged or broken branches. Protecting less-hardy plants during the winter can prevent winter injury. Guarding plants from damage by weed whips and lawn mowers also helps prevent disease.

ENVIRONMENTAL MANAGEMENT OPTIONS

There is only a limited number of ways in which we can manipulate environmental factors that influence infection and disease development. Most of these factors – moisture, temperature, and wind – are consequences of weather and climate, but some important environmental management options do exist. For example, many pathogens need water on plant surfaces to cause infection. When possible, do not water leaf surfaces. Watering carefully to avoid wetting foliage and watering early in the day so that plants dry off quickly are good control measures. Pruning and spacing of plants to allow better air movement and drying are also effective.

PATHOGEN MANAGEMENT OPTIONS

Exclusion

Exclusion of plant pathogens from an ornamental planting is an effective way of assuring that disease does not become a problem. One way of excluding pathogens is to use pathogen-free seeds, bulbs, cuttings, bedding plants, or nursery stock. It is important to seek reliable sources of high quality plant materials. Infested soil or mulch from diseased plants can spread diseases into the landscape. Do not use potentially contaminated tools in newly planted areas.

Early detection

Early detection is essential to effective disease management. Regularly inspect plants for the first signs of disease. It is important to know which diseases are most likely to occur on a plant and how to recognize their symptoms. The landscape manager who conducts regular inspections is able to take advantage of a wider range of management options when a disease problem does arise.

Eradication

Eradication or removal of the diseased plant or plant part can eliminate disease from a planting and prevent spread to other susceptible plants. Remove diseased plants or plant parts carefully so other plants do not become contaminated. Bury or otherwise discard diseased plants or plant parts in a way that prevents spreading the disease. Another option involves eradicating pathogens from infested soil, using chemicals or heat, before establishing new plants. Verify the pathogen is currently infesting the soil or that the plants previously grown in that soil were actually infected with a soil-borne plant pathogen.

Protection

Protection of healthy plants or plant parts by applying a protective pesticide is another pathogen management option. Protective treatments are effective only if the applicator applies the pesticide *before the pathogen has a chance to infect plants*. The use of pesticides requires special knowledge about which pesticides control specific pathogens and proper application techniques.

Using fungicides

Fungicides represent important disease management tools for all cultivated plants including turf. **In almost all cases, fungicides are fungistatic rather than fungicidal**. In being fungistatic, the active ingredient tends to suppress, inhibit, or limit disease development. Most cells of a fungal colony may be killed by a fungicide but not all. The few cases where the active ingredient is truly fungicidal usually involve circumstances where fragile spores are killed by fungicide deposits on leaf surfaces. Also, the concentration of the fungicide influences whether the activity is fungistatic or fungicidal. **The bottom line is that fungicides rarely cure a plant infection**; however, fungicides can be an important tool for maintaining high-quality turf.

Fungicides can be important components of the disease management program; however, it is important to remember to integrate their use with sound cultural practices, knowledge of pathogen and disease biology, and disease-resistant or less susceptible plants whenever possible.

Fungicides are effective only when the pathogen associated with the infectious plant disease is a fungus. In some cases, pests and disease follow other environmental disturbances and may not be the primary problem. In such cases, a fungicide application may help but not completely solve the problem. Also, it is important to remember fungicides are effective only if the applicator follows three rules:

- **Correctly diagnose** the plant problem and identify the pathogen. This is necessary to select the proper fungicide.
- **Use the correct application method** (foliar vs. drench applications.)
- Make certain the **timing and frequency** of the fungicide treatment is made according to label.

Correct diagnosis

You must be sure of what the problem is before proceeding. The most effective fungicides target specific situations and specific diseases, and their effectiveness hinges on correct diagnosis. Extension specialists and educators at the University of Wyoming can assist you in identifying the problem.

Correct diagnosis leads to selection of the proper pesticide to do the job. Typically, a number of materials are effective against a given disease. Before selecting a chemical, read the label. Can you carry out the instructions? Is the ornamental plant or turf variety requiring treatment listed on the label? If so, the chemical should be effective in providing disease control if used properly.

Due to rapidly changing regulations and fungicide registrations, this chapter does not provide specific fungicide recommendations. Product recommendations can be found online using https://www.cdms.net/ or http://greenbook.net/. Several of the specific agricultural chemical companies have created charts specific to fungicides for use in ornamental plants and turf and are also available online.

Using the correct method of application

Foliar applications

Fungicide sprays usually work in controlling infectious diseases because they act as a chemical barrier on leaf, stem, or flower surfaces. When the pathogen reaches the plant surface, it encounters this barrier and is unable to infect the plant. Effective fungicide use requires that this barrier be as complete as possible. A spray method must provide the best combination of practical usefulness and good coverage. For many diseases, the underneath surfaces of leaves (especially on the lower leaves of the plant), need to be sprayed as well.

The uniformity of the barrier depends on the plant surfaces. Hairy or waxy foliage can be especially difficult to cover properly. For this reason, spreader-stickers are included in most fungicide formulations. Always check the spray deposit after application to make certain coverage is adequate.

Drench applications

In cases of root disease, fungicide drenches of soil and root zone may be required. Use this method of application when the plants are small enough to allow complete saturation of the root area. Pay close attention to soil type, texture, and pH, which may influence the efficacy of the fungicide. Label recommendations differ for drench applications, compared to foliar applications, so always read and follow label directions.

Proper timing of fungicide applications

Timing refers to when and how often to make effective fungicide applications. Proper timing of the first application generally requires specific information about the disease cycle.

Fungicide labels usually direct the applicator to make the first application just before the estimated arrival of the pathogen on the plant surface. If the label does not provide this information, contact your local county extension office. In most situations, fungicides are not effective in controlling the disease if the pathogen has already entered (infected) plant tissues.

The first application establishes a pesticide barrier on the plant surface. Effective use involves keeping this barrier active and complete throughout the time when the pathogen might contact and infect the plant. Most fungicides do not persist in the environment for long periods of time. Rainwater, sunlight, and microbial action can decrease their effectiveness. In many cases, the applicator will have to re-apply the fungicide to keep the barrier active.

Plant growth also affects the uniformity of the barrier. Newly emerged leaves and shoots are unprotected and subject to infection; additional fungicide applications are necessary to protect the new growth.

The fungicide label gives reapplication guidelines, usually in ranges of 7- to 14-day intervals. If excessive rainfall or rapid growth of the plant occurs, use the shorter interval between sprays. If not, use the longer interval.

FUNGICIDE CLASSIFICATION

Fungicides are classified in a variety of ways, including how they are named (**nomenclature**), how they move in or on turf plants (**phytomobility**), and how they affect pathogenic fungi (**mode of action**).

Classification: chemical nomenclature

As with all pesticides, fungicides have three names – a trade name, a generic or common name (usually name of active ingredient), and a chemical name. Chemical names are almost never used in discussions of fungicides. Generic names are becoming more commonly recognized because, as patents on active ingredients expire, other manufacturers can produce the fungicide under whatever trade name they chose. It will become increasingly important to recognize the differences among fungicide names because regulations and restrictions will be applied toward active ingredients rather than specific products.

Classification: phytomobility

Fungicides are categorized according to their phytomobility, a characteristic that describes how fungicides move in or on turf plants. Most turf managers are familiar with fungicides in terms of their phytomobility. Traditional terms include "**contact**" and "**systemic**." Since the term systemic connotes translocation of the active ingredient in xylem AND phloem, a new nomenclature has been established for non-contact fungicides. The term "**penetrant**" refers to fungicides that diffuse into plant tissues and stop fungal growth inside the turf. Penetrants are subdivided into acropetal penetrants, local penetrants, and systemic penetrants – depending on how they move inside the plant.

Contact fungicides

These fungicides can be effective against germinating spores or active mycelium on plant surfaces by contact. They do not penetrate host tissues and so do not affect mycelium already established inside the host.

Contact fungicides are effective only at the site where applied and only as long as the deposit remains intact in a fungitoxic concentration.

Good spray coverage is essential for contact fungicides. They are subject to weathering and wash-off.

They have a low solubility and are not effectively drenched into soil, and they are generally not useful against root pathogens.

Their active ingredients have a broad spectrum of activity. Almost all are considered multi-site

inhibitors and are not at risk for development of resistant pathogen populations.

Local penetrant fungicides

Localized penetrants are absorbed by leaves and accumulate in the waxy cuticle. They are **not** translocated inside host tissues. Some of the active ingredient migrates into the leaf tissues in quantities that are toxic to the target organism. This capacity is referred to as **translaminar** activity. These compounds have some chemotherapeutic properties in the vicinity of the site of entry.

Localized penetrant fungicides are more soluble than contact fungicides but may be less effective against root pathogens than other penetrants.

Local penetrants have site-specific inhibitors, and are considered "at-risk" for development of resistance in certain pathogen populations.

Acropetal penetrants

Acropetal (moving from the base to the tip) penetrants are formulated to penetrate plant tissues rapidly, so they have limited activity on plant surfaces. They are **xylem mobile** and only move upward in the plant from the point of absorption.

Once inside the plant, acropetal penetrant fungicides restrict mycelial growth, limit colonization by the pathogen, or reduce the pathogen's ability to reproduce.

Acropetal penetrants are fairly soluble, and many are effective against root, crown, and rhizome diseases, as well as foliar diseases. It seems logical that for most effective control of root and crown diseases, they must be delivered to the site where absorption will permit their activity in the desired area of the plant.

They all have site-specific inhibitors and are "at risk" for the development of fungicide resistance in some pathogen populations.

Systemic penetrant fungicides

Systemic penetrants diffuse into plant tissues and move through cells with living protoplasts along the gradient that moves sugars (carbohydrate) from expanded leaves to roots and new growth.

They are the only fungicides that are **ambimobile**, i.e., able to move upward and downward through the plant.

Unfortunately, only phosphonates (of currently available fungicides) are ambimobile – and they are effective against only a few turf pathogens

Classification: mode of action

The mode of action describes how the active ingredient affects the fungal pathogen. Depending on the fungicide, mode of action may be described at several different physiological levels including morphological changes, affected cellular components or biochemical processes, and sites of molecular activity. The extent of our understanding of mode of action varies with different active ingredients. Where knowledge is limited, such as with the dicarboximide fungicides (iprodione and vinclozolin), mode of action is most often described in terms of the observed changes in fungal morphology and growth in laboratory cultures. In other cases, such as the benzimidazole fungicides (thiophanate-methyl), research has uncovered the exact molecular site (of activity. Because mode of action is related to other issues (especially fungicide resistance) research continues to explore the fundamentals of how fungicides affect target pathogens.

In very general terms, fungicide mode of action may be classified as "multi-site" or "site-specific." **Multi-site** compounds interfere with fungal

metabolism at many sites in cells of sensitive fungi and are not vulnerable to the evolution of resistant pathogen strains. **Site-specific** compounds target one or a few metabolic processes in sensitive fungi and are at risk for the development of resistant strains of some fungal pathogens.

FACTORS THAT AFFECT FUNGICIDE PERFORMANCE

Selecting the appropriate fungicide for the disease problem at hand does not ensure success. Numerous management and environmental factors may affect fungicide performance, either directly or indirectly, and must be considered an integral part of the management equation.

Application rate, timing of the initial application, and frequency of application are absolutely critical to fungicide performance. Every fungicide label has this information, usually in the Directions for Use section. Managers and pesticide applicators must select an application rate within that range – often relying upon their compiled experience.

Manufacturers also specify a volume of water to mix with the fungicide for treating a unit area of turf. The optimum volume provides the best coverage without diluting the fungicide to a less effective concentration. The recommended volume for most fungicides is 2.0 gallons per 1,000 square feet of turf. Rates of granular products are specified on product labels.

Suggested application rates and intervals differ for the various turf diseases and types of fungicides. Some labels recommend high rates at long intervals, while others specify low rates at short intervals. The recommended interval for contact fungicides may be 7-14 days, compared to 14-28 days penetrant fungicides. Again, experience enhances the applicator's ability to select the right product and application parameters for the situation.

Timing of the initial application has a critical influence on fungicide performance, and delaying the decision to apply a fungicide until the severity of disease reaches significant proportions can be costly. Successful property managers consider prevailing weather conditions and knowledge of disease history on a given site to schedule their initial fungicide application. Prevention is normally most effective and efficient.

Certain climatic factors influence fungicide performance by contributing to the loss of the chemical from plant surfaces. **Microbial degradation** limits the residual activity of fungicides to two weeks at best. **Precipitation** and **photodegradation** also contribute to the depletion of fungicide residues on turf surfaces over time.

Management factors can influence the effectiveness of fungicides for disease control, either directly or indirectly. For example, mowing and irrigation may remove fungicides from actively growing turf – a direct influence. Furthermore, low mowing stresses turf, making it more prone to damage by some diseases – and early-evening irrigation is likely to extend the dew period, thereby increase the opportunity of infection by some pathogens.

A final factor that influences fungicide efficacy is the relative sensitivity of the pathogen population to the active ingredient. **Some pathogen strains are resistant to certain fungicide active ingredients**. If resistant strains become predominant in the population, fungicides will be less effective – even totally ineffective – in controlling the target disease.

Fungicide-resistant pathogen populations arise through selection of naturally occurring strains that have resistance to the active ingredient. The

selection occurs through repeated use of fungicides with similar modes of action, allowing resistant strains to predominate.

Fungicide resistance is an important issue in disease control, but it is not the only issue. The following places it in proper perspective.

- Only site-specific fungicides are at risk to the development of resistant pathogen populations.
- Not all pathogens are prone to developing fungicide-resistant populations. To date, fungicide resistance has been documented in turf pathogen populations for only five diseases – anthracnose, dollar spot, gray leaf spot, pink snow mold, and Pythium blight.
- Turf maintenance practices that reduce environmental conditions favorable to infection (proper nitrogen fertility, improved air and water drainage, dew displacement, etc.) will also reduce the risk of resistance.
- Resistance management strategies often are included on fungicide labels. They usually instruct the user to
  - avoid repeated use of fungicides with a similar mode of action.
  - limit use of site-specific compounds when outbreaks are severe.
  - tank mix multi-site fungicides with site specific products.

GENERAL PROBLEMS AFFECTING MANY ORNAMENTAL PLANTS

The following information describes some of the more common ornamental plant disease problems found in the landscape. It suggests measures to prevent, minimize, or correct these problems.

Decline

Plant pathologists refer to the progressive deterioration of woody plants as *decline*. Any tree or shrub can develop this problem, although it more commonly affects certain tree species, such as maples.

Typically, no single factor is responsible for decline. In most cases, several agents act together over more than one growing season and collectively result in decline. The root system is the site of action for many of these factors. Anything that causes root death will eventually result in twig and branch death, as the impaired root system is unable to adequately supply water and nutrients to the entire tree canopy.

Conditions such as drought and defoliation by insects contribute to decline. They weaken the tree and allow other agents, such as fungi or boring insects, to cause more damage than would occur in a healthy tree. Some infectious diseases (Verticillium wilt) can be the primary cause of decline symptoms, but adverse environmental conditions may accelerate the progress of the disease. Root injury from construction is a common cause of decline of street trees and established trees in new home sites. Other "human activities" also contribute to root injury and decline: soil compaction by foot or vehicular traffic, deicers, and over-fertilization.

Symptoms of decline

Symptoms of decline vary with species and can include decreased growth rate, leaf scorch, abnormally small leaves, premature fall coloration, excessive fruit set, and dieback of twigs and branches.

Remedies for decline

Prevention is the best way to manage decline in trees. Proper selection of trees based on site characteristics and avoiding root injury after

planting are crucial for avoiding decline problems. Before treating trees that show symptoms of decline, examine the site to identify conditions that may be contributing to the problem. Develop a treatment program to alleviate stress factors. This may differ from tree to tree, depending on the particular problems present. Remove dead wood to improve appearance and to reduce possible safety hazards and the chance of secondary insect problems. Remove live branches, as necessary, to compensate for a severely injured or reduced root system. Proper watering and fertilization will help promote new growth. Insect or biotic disease problems may require special treatment. It may take several years of intervention to slow the progress of decline in large trees. Trees rarely return to full health and vigor after suffering from severe decline, so prevention of the problem is the best solution.

Chlorosis

This condition can occur in response to many types of environmental stresses and/or root injury. Chlorosis (yellowing) is often due to specific nutritional deficiencies induced by alkaline (pH above 7.0), compacted, or poorly drained soils. Iron deficiency is especially common in Wyoming.

Symptoms of chlorosis

Leaves will be smaller than normal. Only one section, rather than the entire plant, may show effects. Leaf scorch, wilt, and leaf drop may occur in later stages or during droughts. Iron deficiency causes yellowing of the newest foliage. The leaf veins remain green, while the areas between the veins become yellow-green to yellow, leaving a network of darker green veins on a light green or yellow background.

Remedies for chlorosis

Fertilization with "trace" minerals is effective against chlorosis caused by a nutritional imbalance. Addition of materials to increase soil acidity (lower the pH) also may help, especially when preparing the planting site; use sulfur. Methods commonly used to correct iron chlorosis are

- altering soil acidity with sulfur to lower the pH of an alkaline soil, or lime to raise the pH of acidic soils
- drenching the soil with a chelated iron compound
- spraying the foliage with a solution of iron (ferrous) sulfate or iron chelate, and
- introducing iron salts into the main stem or trunk of affected plants by implantation or injection.

The best and most permanent way to correct iron chlorosis is to lower the soil pH using sulfur. Sulfur should be incorporated into the soil to get desired results, and is best done prior to planting new turf and landscapes. At appropriate rates sulfur can neutralize an alkaline soil. Soil tests 3-6 months following sulfur application will indicate if soil pH levels are improved or if another application is needed. Spraying foliage with liquid forms of iron may be satisfactory for annual plants or when chlorosis is extremely severe and requires a quick response. Unfortunately, the effects are short-lived and the method is costly. Trunk implantation or injection, performed properly, has been shown very effective. As with soil treatments, trunk treatments can last several years.

If root stress or injury is the cause of chlorosis, follow the recommendations suggested for decline.

Leaf scorch

Leaf scorch is a problem common to many trees in Wyoming during summer months. Elm, cottonwood, oak, and various other trees and shrubs are affected. Scorch usually appears after periods of unfavorable weather conditions such as drought, high temperature and hot, dry winds. Leaf scorch symptoms also may appear following

damage to or disease in the roots, or after injury to the trunk. Salt damage, especially from deicing salt used on roads, sidewalks, or driveways near the tree, also will cause leaf scorch.

Symptoms of leaf scorch

The most common pattern of leaf scorch is a drying out and browning of the leaf margins. The symptom is often more severe on outer, more exposed leaves, especially on the sunward and windward sides of the tree. More severe symptoms may appear when hot, drying winds last for several days during a period of active tree growth. Browning of leaf tips and margins will progress inward between the leaf veins. Eventually, the entire leaf will turn brown and die. Under these conditions, new leaves often form if the moisture supply to the roots is adequate.

Remedies for leaf scorch

Deep watering is the obvious way to prevent leaf scorch. Frequent, brief periods of watering wet the soil to a depth of only a few inches and do not contribute to a strong, deep root system or to good tree health. A slow, deep soaking of the soil and root zone is required for established trees. Deep watering needs to be done only during drought periods. Use a slow trickle from the garden hose over several hours. Do not let the water puddle; it needs to soak in slowly. Mulching to prevent grass and weed competition for water is also advised. Proper watering of young trees is especially critical in the first few years after planting and may need to continue as trees mature in the arid climes of Wyoming.

In exposed areas, plant trees in groups rather than singly; plant sensitive trees in protected locations; fertilize trees that are not thriving; and do not plant shallow-rooted trees on extremely wet or dry sites.

Winter injury

A number of problems can affect plants during the dormant season. These are brought on by wide temperature fluctuations, extreme cold, desiccation (drying), and lack of suitable protection.

Symptoms of winter injury

Injury may appear as the absence of emerging leaves in the spring, or as branches that leaf out, then wilt and die. Lack of flowering, browning of leaves (including needles on evergreen plants), or elongated, sunken areas on bark on the sunward side of trees also may occur.

Remedies for winter injury

Plants in good health as they enter the winter are less likely than stressed plants to suffer injury. If soils are dry in the fall, water the root zone well (do not allow standing water) to ensure the plant will have sufficient water going into winter. Avoid fertilizing after mid-July, since this encourages new growth that will not have sufficient time to harden. Mulch to reduce water loss and to protect roots from cold temperatures; marginally hardy species need additional protection. Wrap trunks of trees (especially those with thin bark) with burlap or sissal kraft paper to protect from sunscald on cold, sunny days. Plant trees and shrubs in areas where they will not be exposed to north winds, or protect plantings from winds by using protective burlap or plastic screens. Remove dead wood after growth starts in the spring.

Powdery mildews

Powdery mildews are very common fungal diseases that can occur throughout the growing season. Disease cycles tend to intensify with warm, dry days followed by cool, damp nights. Many species of woody shrubs and trees are susceptible to infection.

Symptoms of powdery mildew

Powdery mildew fungi grow primarily on the surface of leaves. Grayish-white patches give

leaves the appearance of having been dusted with powder. Leaves can become distorted, dwarfed, and brittle. Tiny, black, pinhead-like fruiting bodies appear in the white patches in the fall and act as overwintering structures for the fungus.

Remedies for powdery mildew

Powdery mildew control begins with good sanitation practices. Rake and destroy fallen leaves to prevent overwintering of the fungus on debris. If using susceptible plants place them in a sunny location and space well to avoid overcrowding. Prune surrounding shade-producing vegetation to allow better air circulation and leaf drying, and avoid overhead irrigation late in the day or at night. In many instances, fungicide sprays are not necessary. However, a regular, preventive spray program may prove necessary on valuable, highly susceptible plants (for example, certain varieties of roses).

Scab of flowering crabapples

Flowering crabapple trees add color and beauty to many residential landscapes in Wyoming; however, each year many become diseased, resulting in heavy leaf drop by early summer. The cause of this problem is a fungal disease known as apple scab.

Symptoms of scab of flowering crabapples

Brown to olive-green, roughly circular fuzzy spots often originate along the veins of the leaves. In time, spots become black and velvety and develop fringed margins. Finally, leaves turn yellow and drop. Black, scabby spots of various sizes appear on infected fruits and often cause them to crack and/or become misshapen.

Remedies for scab of flowering crabapples

Host resistance is the best – means of managing scab on flowering crabapples. Many desirable varieties of resistant flowering crabapples are available.

This disease can be expected yearly on susceptible varieties grown in areas prone to wet spring weather. Some sanitation practices can help minimize disease impact in these instances. Because the fungus lives throughout the winter within infected leaves, rake and destroy fallen leaves before they become brittle and break into unmanageable fragments. Prune crabapples in late winter to maintain an open tree. The severity of infection increases the longer foliage remains wet. A well-pruned tree allows better air circulation and promotes faster drying.

Crabapples that are susceptible to apple scab should be sprayed annually, in the spring, to help control the disease. Regular, preventive fungicide applications from the time of bud break until two weeks after petal fall are recommended.

Cedar apple rust

Cedar apple rust is a common fungal disease of apples and crabapples. The fungus requires an evergreen host – juniper or red cedar – to complete its life cycle.

Symptoms of cedar apple rust

On apple and crabapple trees, the first symptoms of cedar-apple rust are bright yellow to orange spots on the upper leaf surface. As the disease progresses, the spots increase in size and hair-like projections appear beneath the spots on the lower leaf surface. These structures produce spores that the wind can carry to cause infections in junipers.

On junipers, cedar apple rust infections develop into galls on twigs. Fully developed galls are large, brown, solid structures. In early spring, bright orange, gelatinous spore horns emerge from the galls. The horns produce spores that, when wind-borne, can infect apples and crabapples. Pathologists consider junipers the primary hosts, although this disease generally does not cause them significant injury. The most damaging phase

of the disease is on the alternate hosts – apple and crabapple – where severe defoliation may occur, weakening the plant.

Remedies for cedar apple rust

Plant rust-resistant cultivars of apple and crabapple whenever possible. Avoid planting the two different host types near one another because rust fungi are dependent on the primary and alternate hosts for survival. The removal of one or the other breaks the life cycle of the fungus, thus preventing the disease. Where rust is a chronic problem on high value trees, causing leaf drop and poor tree vigor, use a fungicide on the broadleaf host. Apply the fungicide several times during the spring to maintain a protective coating on developing leaves, twigs, and fruit.

Aspen and poplar leaf spots

Foliage diseases can reduce the aesthetic value of aspen and cottonwood. Occasionally, a severe disease outbreak causes premature defoliation or dieback of parts of the tree.

If a tree loses its leaves early in the season, it may grow new ones and its health is not seriously affected. If it loses them in midsummer, however, growing new leaves may prevent the tree from fully hardening off before cold weather or reduce the amount of stored food. This leads to increased danger of frost damage, reduced growth, and predisposition to other diseases or insects. If the tree loses its leaves late in the season, it will not grow new ones or lose much vigor.

Marssonina leaf spot

The fungus *Marssonina* causes the most common foliage disease on aspen and cottonwoods in urban and forested areas of Wyoming.

Marssonina leaf spots are dark brown flecks, often with yellow halos. Immature spots characteristically have a white center. On severely infected leaves, several spots may fuse to form large black dead patches in late summer. Spots also may develop on leaf petioles and succulent new shoots.

Marssonina survives the winter on fallen leaves that were infected the previous year. With spring and warmer, wet weather, the fungus produces microscopic spores that are carried by the wind and infect emerging leaves. Early infections are rarely serious, but if the weather remains favorable, spores from these infections can cause a widespread secondary infection. Heavy secondary infections become visible later in the growing season and cause premature leaf loss on infected trees.

Septoria leaf spot

The fungus *Septoria* causes a common foliar disease mainly on cottonwoods and occasionally aspen in urban areas of Wyoming.

The appearance of *Septoria* leaf spots varies considerably between tree species and with time. Symptoms include, in early summer, a distinct tan circular spot with black margins and small black fruiting bodies in the center, and finally in late summer, irregular brown to black spots that coalesce into large areas.

The disease is rarely a problem on plains and eastern cottonwoods but can cause defoliation at least a month early and visual quality loss on lanceleaf cottonwoods. In wetter climates, another species of the fungus also causes cankers on twigs and main stems.

Septoria survives the winter on fallen leaves that were infected the previous year. With spring and warmer, wet weather (70 to 75 degrees F), the fungus produces microscopic spores that are carried by the wind and infect emerging leaves. Early infections are rarely serious. If the weather remains favorable, spores from these infections can cause a widespread secondary infection. Heavy

secondary infections become visible later in the growing season and cause premature leaf loss on infected trees.

Leaf rusts

A rust disease caused by the fungus *Melampsora* is often seen on aspen and cottonwood. Though common, this disease rarely causes serious damage to trees since the disease develops late in the summer/fall and rarely causes early defoliation. The disease damages leaves after most photosynthetic needs for the tree are completed.

The disease is easily recognized by small, yellow-orange pustules that are scattered on the lower leaf surfaces. These orange pustules are most visible in late summer and early fall.

The life cycle of this fungus requires two different tree hosts. During wet spring weather, spores are released from the fungus, which has overwintered on fallen cottonwood or aspen leaves. These spores infect evergreen needles, such as Douglas-fir, pine, fir or spruce, where they cause little damage. After two to three weeks, spores are produced on these evergreen hosts and are blown to aspen or cottonwood leaves. Once the rust is established on aspen or cottonwood hosts, it can multiply rapidly under favorable wet conditions throughout the summer. Several years of heavy infections can cause some growth losses, especially on younger trees. Fallen infected leaves shelter the fungus until the next year's disease cycle.

Remedies for cottonwood and aspen leaf diseases

Tree resistance is the best way to prevent foliar diseases. Several poplar hybrids or species are resistant to one or more of these diseases. Ask your local nursery for a resistant variety. Some aspens are resistant to leaf spots, but aspen production methods make it difficult to select trees for resistance.

Sanitation is an effective control for some foliar diseases. Fall removal of infected leaves, twigs, and branches can reduce the amount of disease the next spring. Raking and destroying infected leaves can reduce *Marssonina* and *Septoria* leaf spot and leaf rust. The shoot blight fungus overwinters in diseased stems and twigs, so it can be pruned out to reduce new infections.

Keep leaves as dry as possible to reduce the incidence of leaf spots:

- Irrigate in early morning so leaves can dry out.
- Keep sprinkler patterns adjusted so leaves don't stay wet.
- Space trees apart to reduce humidity to help prevent leaf diseases.

Fungicide sprays are not normally needed but if applied early enough, can prevent foliage diseases. Spraying will prevent only new infections; it will not cure leaves already infected. If an infection is developing on particularly valuable trees, or if there is good reason to believe an infection is imminent, the trees can be sprayed with fungicides. Trees that perennially have foliar diseases should be sprayed at bud break and then two or three times during the growing season at 12- to 14-day intervals. Check fungicide labels carefully since allowable uses and rates can change. Fungicides labeled for leaf spots should work well for all these diseases except for the rusts since they are in a different fungal group. Other fungicides may be required for rust diseases. Please follow label rates and directions when applying.

Dothistroma needle blight of pines

Dothistroma needle blight is a fungal disease that turns needles brown and results in early needle drop. Needle loss slows tree growth and severe infection several years in a row can result in tree death.

Pathogen and susceptible plants

Dothistroma needle blight is caused by the fungus *Dothistroma septosporum* (syn. *Mycosphaerella pini*). In Wyoming, plants most severely damaged by this disease include Austrian pine (*P. nigra*) and ponderosa pine (*P. ponderosa*) and to a lesser extent, mugo pine (*P. mugo*). Scotch pine (*P. sylvestris*) is generally resistant to this disease.

Identification

- Reddish brown spots scattered on green needles. Spots grow into a band encircling the needle.
- Tip of the needle is brown and the base of the needle is green. A reddish-brown band separates these two sections. The transition from green to dead areas is abrupt.
- Eventually needles turn completely brown and fall off.
- Older needles found close to the trunk are more severely affected compared to the younger needles that are found towards the ends of the branches.
- Tiny, black pimple-like fungal spore producing structures may be visible pushing through the surface of the needle within the spots and bands.
- Needles on lower 6 feet of a tree are most noticeably affected whereas needles about 20 feet high are rarely affected.
- New infections often appear in late summer to fall whereas dead needles and spots may be seen at any time during the year on a plant with reoccurring disease.
- Lab analysis is often necessary to distinguish Dothistroma needle blight from Brown spot.

Dothistroma needle blight is a slow-moving disease that takes over a full year to complete its life cycle and several years to develop into a serious problem within the tree canopy. Spore producing structures known as stromata are produced within infected needles on trees. Spores are produced throughout the growing season whenever cool, wet weather occurs. These spores are windblown or rain-splashed to mature needles. Second year or older needles are susceptible to infection anytime during the growing season but new needles are resistant until they reach maturity in early to mid-summer. At this point they become susceptible to infection. Several consecutive days of cool (41-77°F), wet weather are needed for successful establishment of new infections.

In Wyoming, symptoms do not typically appear until the fall when needles develop reddish brown spots. These spots expand into a reddish-brown band that entirely girdles the pine needle. The needle beyond the band then dies and turns brown leaving the bottom portion of the needle green. Infected needles may remain attached to the tree for one or two years depending on the age of the needle at the time of the infection. Eventually, infected needles turn completely brown and fall off prematurely. Tiny black fungal fruiting bodies appear in the bands or in dead areas of the needles. These fruiting bodies will release spores the following year to begin a new disease cycle.

Management

Do not overcrowd plants – use size at maturity as a spacing guide when planting.

Remove bottom branches from trunk to help increase circulation around the tree canopy.

Control weeds under the trees with wood mulch.

Maintain a 3 to 4 inch deep layer of mulch around your tree. Do not mound the mulch around the trunk of the tree but lay a flat layer with at least a 2-inch space between the mulch and stem to allow for air movement. Annually reapply mulch and inspect to ensure levels are maintained.

If the tree is in a landscape with a sprinkler irrigation system, make sure that water is not spraying the needles.

In low lying or other areas with cool, moist air, plant resistant Scotch pine instead of more susceptible pine species.

If the disease does occur, a copper-based fungicide can be applied once just before buds open in the spring (typically in mid-May) to protect needles from previous years and once after new needles have grown to their full length (in early to mid-summer).

Rhizosphaera needlecast on spruce

Spruce, in particular, Colorado blue spruce, can be infected with a needlecast disease caused by the fungus *Rhizosphaera kalkhoffii*. Trees planted in nurseries, Christmas tree plantations, and landscapes can be infected. Trees are not usually killed by this disease; however, premature needlecast results in trees that are not marketable, or which are not acceptable in the landscape.

Symptoms and disease cycle

A healthy spruce will retain its needles 5 to 7 years. A spruce severely infected with Rhizosphaera needlecast may hold only the current year's needles. Rhizosphaera needlecast infects needles on the lower branches first and gradually progresses up the tree. This pattern holds true for most needle diseases on conifers and is the result of more favorable conditions for disease development near the ground. Under epidemic conditions, this fungus may kill lower branches.

Although needles on new growth become infected in May and June, symptoms are not visible until late fall or the following spring, when infected needles turn purple to brown and begin to drop. Tiny fruiting bodies of the Rhizosphaera fungus protrude through the stomata of the infected needles. Under a hand lens, these stomata appear as fuzzy black spots instead of their usual healthy white color. During wet weather in late spring, spores are released from these fruiting bodies and are rain splashed onto newly developing needles where infection occurs and the disease cycle is repeated.

Management

Shearing when the foliage is wet may result in spread of the spores on shearing tools. To avoid this, do not shear infected trees when the foliage is wet (such as when dew is on the foliage in the morning). Shear healthy trees first to avoid carrying the spores from a diseased tree to a healthy one. If this is not possible, tools should be sterilized after shearing a diseased planting. Denatured alcohol, available at most paint stores, will kill the spores and also remove pitch from tools. A three- to five-minute dip will do the job.

Chemical applications should be made in the spring because Rhizosphaera infects newly emerging spruce needles. Begin treatment when needles are half elongated.

Fire blight of apple, pear, and crabapple

Fire blight is a bacterial disease particularly destructive to many varieties of apple and pear. It may also damage certain ornamental plants such as flowering crabapple, ornamental pear, hawthorn, mountain ash, cotoneaster, pyracantha, and spirea. If not controlled, fire blight can destroy the blossoms and fruit and may damage or kill the plant by stem infection.

Symptoms of fire blight

Fire blight usually first appears during bloom. Blossom clusters wilt, turn dark brown or black, and collapse. Twig blight follows shortly after blossom blight. The ends of twigs and branches assume a crooked appearance resembling a shepherd's crook. Leaves on infected stems turn

brown and wilt but do not drop. Bacteria will travel from the blighted twigs well into larger branches and even into the main trunk as the disease progresses. As bacteria kill the wood, branches become discolored, bark begins to crack and peel, and sunken cankers are visible on infected branches.

Remedies for fire blight

Fire blight bacteria overwinter in cankered limbs. These cankers may ooze a cloudy liquid during wet, spring weather. The liquid contains large numbers of bacteria, which insects and rain can carry to new infection sites. Fire blight is most damaging in years when spring temperatures are above normal and accompanied by frequent rains. The most effective management technique for fire blight is to plant resistant varieties. **Pesticides are not recommended for control of fire blight in landscape plantings**. Monitor trees and shrubs from mid- to late spring for fire blight symptoms. At the first sign of fire blight, prune infected stems at least 12 inches below the base of diseased tissue. When pruning, disinfect pruning tools after every cut. Dormant pruning to remove overwintering cankers is also very important. When dormant pruning, cuts need to be only about 4 inches below any evidence of dead bark. Also, because rapidly growing, succulent twigs are extremely susceptible to fire blight, use fertilization practices that do not promote excessive growth.

COMMON TURF DISEASES

Gray snow mold

Gray snow mold is a true snow mold, which means it is found only on turf after extended periods of snow cover. All northern turfgrasses are susceptible to gray snow mold. Gray snow mold can be very damaging on grass left long and matted down in the fall. Excessive N fertilization in fall promotes snow mold infection. Gray snow mold rarely occurs in situations where snow cover occurs for fewer than 40 days. Severe damage can occur where snow cover exceeds 90 days. This is because the fungus grows rapidly at temperatures just above freezing. The snow insulates the soil, keeping temperatures optimum for gray snow mold development.

Symptoms

As snow melts, symptoms of gray snow mold appear in roughly circular patches that may grow together, forming irregularly shaped infected areas. Large areas of turf may die under extreme conditions; but more typically, the fungus kills only the leaf blades, and the turfgrass recovers from its crowns. Infected grass blades are crusty, white, and matted together. A diagnostic feature of gray snow mold is the presence of hard, brown-to-black, pin-sized fungal structures called sclerotia on the grass blades. The fungus over-summers as sclerotia in the thatch layer and can reappear in the same place each year.

Control

Cool-season turfgrass species appear to be uniformly susceptible to gray snow mold, so using resistant varieties is not an option at this time. Cultural management practices are aimed at limiting conditions for infection and patch development in winter and hastening turf recovery in spring. **Continued mowing of lawns, landscapes, sports fields, and golf course roughs to a height of 2½ inches into the dormant period will decrease the risk that matted turf will provide favorable conditions for disease development**. Avoid N fertilization in the fall. Snow management (such as strategically removing snow and using snow fences), will limit the opportunities for extended periods of snow cover in locations where quality turf is a high priority. Turf areas damaged and thinned by gray snow mold can be repaired by raking and over-seeding as soon as possible in the spring.

Since snow cover is essential for infection and disease development, having fungicide protection in place prior to initial snowfall is important. Golf course superintendents have been known to apply a contact fungicide between the Thanksgiving and Christmas holidays for protection against gray and pink snow molds. Contact fungicides can be applied as late as possible in the fall. Penetrant fungicides must be applied before turf goes dormant.

Home lawns can be raked if snow mold appears. Raking brakes up the matted turf, creating a more aerobic environment and allowing new growth to emerge. Turf that remains matted will recover slowly and will have more severe damage.

Pink snow mold

Pink snow mold is similar to gray snow mold, except infection occurs over a broader temperature range. Extended periods of snow cover favors infection but are not required. Disease develops during cool, wet weather from October through May. All cool-season turf species are affected by pink snow mold, but juvenile creeping bentgrass is the most susceptible.

Symptoms

Symptoms closely resemble those of gray snow mold in that well-defined circular patches develop during cold wet weather. Sometimes, but not always, spores produced by the pathogen give the margins of patches a pink color. The two snow mold diseases are often distinguished from one other by the observation that pink snow mold does NOT produce the sclerotia (survival structures) on blighted leaf blades.

Control

Non-chemical control options are the same for pink and gray snow molds. Chemical options also are largely the same, but because of the wider temperature range for infection, there are more penetrant fungicide options for controlling pink snow mold.

Leaf spot/melting out

Until the latter part of the 1900s, leaf spot and melting out were classified as a single disease and referred to as Helminthosporium leaf spot. Modern classification divides the Helminthosporium diseases into numerous groups that can be loosely described as “melting out” and “leaf spot.” These diseases occur on various cool-season turf species.

Symptoms

From a distance, the leaf spot disease symptoms resemble a diffuse pattern of thin, off-color turf. Close inspection of leaves from affected plants reveals decaying leaf blades usually with purple/brown lesions. These diseases can damage large areas of turf if favorable conditions persist. Melting out typically appears in April and May during cold, rainy weather. High nitrogen fertilization during the middle weeks of spring also favors disease development. Leaf spot diseases generally occur during summer and require long wet periods, elevated evening temperatures, and ample precipitation for establishment and spread. Disease development is favored by excess nitrogen fertility during periods of pathogen activity. Close mowing can aggravate disease outbreaks by increasing stress on plants and allowing spores greater access to crowns and roots.

Control

There appears to be good, reliable genetic resistance to leaf spot and melting out infection in Kentucky bluegrass cultivars. Perennial ryegrass cultivars appear to be uniformly susceptible. Over-seeding damaged areas with resistant cultivars for Kentucky bluegrass stands offers the least expensive option for long-term disease control. Avoiding excess nitrogen fertility in early spring and midsummer will limit the severity of disease outbreaks. Raising the mowing height and relieving

other stresses, like redirecting traffic away from affected turf, will reduce disease severity and hasten turf recovery. Also, avoiding irrigation during the late afternoon and early evening during the heat of the summer helps restrict the development and spread of leaf spot.

In situations where severe outbreaks of either of these diseases occur in the same location in successive years, fungicide application may be necessary to suppress disease development to tolerable levels. Application timing is critical for satisfactory fungicide performance. Sprays should be applied at the first sign of the leaf spot stage of the diseases, or apply them preventively when disease-favorable weather arrives. Once large areas are blighted to the point of crown infection and plant death, the disease pressure will be too great to be confident a single application will provide adequate control. Even repeated fungicide applications may be only marginally effective in such cases. Also, an application for melting out control in April will have no effect on leaf spot development in July and August.

Dollar spot

Dollar spot traditionally has been a problem on golf courses but also may become a problem on residential turf. It is most serious on creeping bentgrass and annual bluegrass but can affect Kentucky bluegrass, perennial ryegrass, and fescues. Dollar spot tends to be most damaging to nitrogen-deficient turf during warm (60˚-80˚ F), humid weather but can affect turf during spring and fall.

Symptoms

On golf course greens, dollar spot appears as dead turfgrass areas about the size of a silver dollar; hence, the name. On higher-mown turf, patches may be 3 to 6 inches in diameter and can coalesce into even larger dead spots. Dollar spot lesions on leaf blades are hourglass shaped, with reddish-brown margins. Affected leaf blades also have a bleached, white appearance. When the fungal pathogen is active, white cottony mycelium appears on turf in early morning.

Control

Severity of dollar spot outbreaks often can be reduced with attention to nitrogen nutrition, and avoiding nitrogen deficiency. Light, supplemental applications in late May will help alleviate the disease in problem-prone areas. Avoiding irrigation in early evening hours will reduce the chances for infection. Golf courses regularly apply fungicides for dollar spot control on their most vulnerable sites. In some cases, fungicides are warranted on residential turf.

Take all patch

Take all patch is a disease of creeping bentgrass that can occur on golf course greens, tees, and fairways. Most take all patch development occurs on less mature creeping bentgrass stands, whether on newly constructed golf courses or in areas that have been fumigated prior to renovation. The disease also is influenced by soil pH. Pathogen development is significantly suppressed in acidic soils (pH ≤ 6.0) while roots in alkaline soils (pH ≥ 7.5) are much more prone to infection.

Symptoms

Take all patch symptoms may be evident throughout the growing season. Initial symptoms are the result of extensive infection in creeping bentgrass roots when soils are cool (less than 65°F) and wet. Circular patches (8-24 inches in diameter) normally expand in early spring as infected plants wilt, collapse, die, and turn orange-tan. In stands with deep and extensive root systems, plants will recover, and initial patch symptoms may disappear as soil temperatures increase and pathogen activity becomes limited. However, symptoms may remain throughout the summer where there are shallow or

sparse root systems partially impaired by infection that are unable to recover.

Control

Because take all patch infection is favored by alkaline (pH ≥ 7.5) root zone soils, acidifying treatments may be effective in limiting the severity of patch development. Research results on the effects of acidifying treatments (whether they involve ammonium sulfate or direct manganese sulfate application) are mixed. Under the best circumstances, acidifying fertilizers alone will not control the disease, but they can help limit patch development. Other non-chemical options involve relieving stress on infection-impaired root systems to prevent the permanent wilting and death of affected plants. In the spring and fall, such practices include aeration and topdressing to promote healthy root growth and limit thatch accumulation. During the summer, careful attention should be given to timely irrigation to relieve drought stress, syringing to relieve heat stress, and redirecting traffic to reduce compaction.

Certain penetrant fungicides may be used to suppress take all patch outbreaks. Enhanced effort to deliver fungicides to turfgrass roots may improve performance against root diseases such as take all patch. Fungicide labels usually specify application with 2-4 gallons of water per 1,000 square feet. For putting greens, best results may be achieved by following a four-step procedure that includes irrigation, aeration (small solid tines), fungicide application, and, to carry more fungicide into the root zone, irrigation again. Timing of the fungicide application also influences fungicide performance. Applications should be made when root zones are cool in spring and fall.

Pythium blight

Pythium blight is a foliar disease especially damaging to perennial ryegrass, rough bluegrass, creeping bentgrass, and annual bluegrass. Kentucky bluegrass and tall fescue can be infected, but disease development is limited and turf is rarely damaged. Among turfgrass diseases, Pythium blight receives considerable attention because it spreads very quickly, affects leaves and crowns, and kills plants, resulting in extensive loss of the turf stand. Pythium blight occurs during the most uncomfortable days of summer, when dew periods are long (greater than 14 hours) and evening temperatures average 68°F or higher. Turf with lush growth and excessive nitrogen fertility is especially vulnerable to infection.

Symptoms

Initial symptoms include small, circular patches of collapsed, water-soaked leaves and stems on close-mown turf. If observed early in the morning, infected plants may have cottony white mycelium. Infected turf dies and becomes matted. If disease-favorable conditions persist and no efforts are made to interfere with disease progress, large areas of turf may be killed within a matter of days.

Control

Modifying the turf environment may help reduce the severity of Pythium blight. Water management and proper drainage to avoid waterlogged root zones during summer are especially important. Selective pruning of trees and shrubs will generally improve air circulation and can limit the duration of the dew period. Avoiding conditions that approach excessive nitrogen fertility during midsummer will reduce vulnerability to Pythium outbreaks.

Because of the pathogen's survival and spread characteristics, Pythium outbreaks normally occur in the same "problem" areas each year when extreme weather conditions prevail. In high-risk areas or on golf course putting greens where mycelium is evident, morning mowing should be delayed until surfaces are dry. Precautionary spot treatment with fungicides on problem putting

greens and tee boxes is advisable. Because of the speed of disease establishment and spread, and the serious consequences of Pythium infection (turf death), fungicides represent essential tools for Pythium blight control on high value turf.

Brown patch

Brown patch is caused by a fungal pathogen that affects all cool-season turfgrass species. It is a foliar disease that does not damage crowns or roots. The pathogen becomes active during hot, humid periods when dew periods exceed 10 hours and nighttime temperatures remain above 65° F. Also, outbreaks will be more severe when nitrogen fertility is excessive during disease-favorable weather.

Symptoms

On creeping bentgrass and annual bluegrass putting greens and tees, brown patch development results in well-defined circular brown stains, ranging from 4 to 12 inches in diameter. Leaf blades within the patch turn brown after infection, while a gray-white colored band (called a smoke ring) is normally evident at the perimeter of active patches. Smoke rings may occur on taller mown turf but are much less evident. Individual lesions on leaf blades with brown margins occur on all affected grass species but are most evident on tall fescue.

Control

Brown patch severity can be reduced by avoiding excess nitrogen during the summer, improving air circulation, and scheduling irrigation during the day or early morning to avoid extended periods of leaf wetness in the evening. Numerous, very effective fungicides are registered for brown patch control.

Summer patch and necrotic ring spot

Summer patch and necrotic ring spot pathogens are soil-inhabiting fungi that infect turfgrass roots, rhizomes, and crowns during cool, damp, spring weather. They infest the roots and water-conducting tissues of turfgrasses, limiting the plants' ability to absorb and transport water. Symptoms typically do not appear until the arrival of hot, dry weather. The two fungi are similar in most respects, and identification and control of summer patch and necrotic ring spot are virtually the same. These also are arguably the most damaging diseases in well-maintained Kentucky bluegrass turf.

Symptoms

Summer patch and necrotic ring spot symptoms first appear in mid-summer as small patches of turf 1 to 3 inches in diameter. Summer patch eventually can form patches up to 12 inches in diameter or develop streaks or crescents in the turf. Necrotic ring spot patches can reach 36 inches in diameter, with live grass in the center forming a "frog eye."

Control

A variety of non-chemical options may show promise for managing summer patch and necrotic ring spot. Newer Kentucky bluegrass cultivars tend to have reduced susceptibility. Perennial ryegrass and turf type tall fescues are not susceptible and may help repair damaged turf in cases where uniform appearance is not the top priority. Furthermore, proper attention to sound agronomic practices, including aeration and topdressing, to promote deep and extensive root systems will increase turf's tolerance to summer stress despite mild or even moderate levels of infection. Because summer patch outbreaks are associated with heat and drought stress during the summer, cultural practices that relieve summer stresses will minimize disease damage.

Fungicides may be effective in reducing the severity of summer patch and necrotic ring spot outbreaks although currently there are no effective fungicides that will move down through the plant into roots. The likelihood of satisfactory fungicide performance will be increased with practices

designed to deliver fungicide to roots in thatch and soil. Fungicide labels often recommend increased (2-4 gal/1,000 sq ft) application volumes for root disease control. Acropetal penetrant fungicides should perform best since they seem to possess sufficient solubility to reach roots in thatch and soil, and once absorbed into roots, they have a greater chance of suppressing existing infections because they are transported through xylem cells. Relying solely on fungicides for root disease control is always expensive, and results often are inconsistent. Research results with effective fungicides can vary among years and locations. Fungicide performance will be greatly improved with attention to cultural practices that reduce disease pressure and relieve summer stress to turf.

Rust diseases

Rust is a disease of taller mown turf. Outbreaks are most common on residential lawns, low-budget athletic fields, and on golf course roughs. Rust is largely cosmetic, but the orange spores that dislodge easily from leaf surfaces can be a greater nuisance, covering shoes, pets, and lawnmowers with a rusty residue. Rust can severely damage new spring-seeded lawns that lose vigor during heat and drought conditions. Rust outbreaks are most common in late summer and early fall, although sometimes the disease is active in the early spring, especially on poorly nourished turf.

Symptoms

From a distance, rust-infected turf appears chlorotic. Symptoms occur in a diffuse pattern around the initial site of infection as disease increases. Outbreaks often first occur in shaded or protected areas, such as around the bases of evergreens or next to a structure's foundation. Close inspection of rusted leaves reveals numerous yellow-orange pustules on leaf blades. Walking through grass with significant amounts of infection will disturb and release the spores within these pustules and leave a distinct orange color on shoes and pets.

Control

Maintaining a healthy and vigorous turf stand is the most effective and efficient method of rust control. Since slow-growing turf in late summer is most vulnerable to outbreaks, small amounts of nitrogen fertilizer (0.25-0.5 pound of N per 1,000 square feet) in chronic trouble spots – shaded and possibly compacted areas – will help control the disease. The nitrogen will promote leaf growth and allow for regular mowing, which helps the turf outgrow rust's relatively slow infection cycle. Avoiding irrigation during the early evening also will help limit disease spread by lessening the chance of extended wet periods.

A variety of modern fungicides are very effective against rust, but on well-established turf, should be considered only as a remedial treatment when cultural practices fail to prevent an outbreak. On newly seeded stands, fungicides should be applied at the first sign of disease. In most cases, a single application of an effective fungicide, combined with efforts to encourage turf growth, will quell outbreaks.

Gray leaf spot

Gray leaf spot is a foliar disease that affects perennial ryegrass and tall fescue. It is caused by a fungal pathogen (very different from the leaf spot melting out fungi) that readily infects and kills leaf blades. Leaf infections can progress into the crown area, resulting in the death of individual plants. Juvenile (less than 1-year old) stands of susceptible species are extremely vulnerable to infection. Under moderately favorable conditions, large areas may collapse in a matter of weeks.

Symptoms

From a distance, initial gray leaf spot outbreaks resemble drought stress. Affected turf often

assumes a blue-gray cast and is noticeably thinned by dead and decaying leaf blades. Close inspection reveals blighted leaves, some with distinct lesions. The leaf spot symptom may be short-lived because the gray leaf spot epidemics progress so rapidly on perennial ryegrass. When leaf spots are apparent, they may be confused with symptoms caused by other leaf spot diseases. Accurate identification is critical. Under particularly humid conditions, a distinct gray mold will be apparent on leaves blighted by gray leaf spot. This mold is quite distinct from the cottony mycelium produced on leaf surfaces by other diseases, including dollar spot, brown patch, and Pythium blight.

Control

Perennial ryegrass cultivars vary in their susceptibility to gray leaf spot, although none can be considered resistant, and all will succumb under high disease pressure. Efforts should be made to avoid practices that extend dew periods because moisture on leaf surfaces is important throughout the disease cycle.

Fungicides are important for gray leaf spot control on golf courses and sports turf. Timing of applications is critical because the extent of disease pressure will greatly influence fungicide performance. A preventative approach is essential for turf with a history of the disease. If gray leaf spot outbreaks are in an advanced state by the time fungicide sprays are initiated, it is likely that levels of control will be unacceptable. Fungicide-resistant strains of the pathogen have been identified. Fungicide selection should be guided by a sound resistance-management strategy.

Powdery mildew

Powdery mildew is a foliar disease of Kentucky bluegrass and some fescues. Outbreaks can occur in golf course roughs, athletic fields, professional landscapes, and residential lawns. The disease rarely is responsible for any lasting damage to turf. Powdery mildew occurs most often on slow-growing turf, usually in shaded areas. Pathogen activity is favored by cool, cloudy conditions that prevail in spring and fall. Excess nitrogen fertilizer may increase risk of infection.

Symptoms

Powdery mildew is simple to diagnose. From a distance, affected turf has a white or light gray appearance. Close inspection of affected leaf blades reveals the presence of small (around 1/16 inch in diameter) colonies with masses of white spores that may eventually cover the entire leaf. The spores provide the only significant means of dispersal of the pathogen. Only leaves are infected, and no web-like mycelium is produced on the plant surfaces. Leaves look like they were coated with flour.

Control

Shade-tolerant Kentucky bluegrass cultivars tend to be less susceptible to powdery mildew. Over-seeding shaded areas with these cultivars will reduce powdery mildew establishment and spread. Improving air circulation by careful pruning of trees and shrubs also will help limit mildew development and will serve to suppress some mid-summer diseases as well. Avoiding excess levels of nitrogen in disease-prone areas also may contribute to a reduction in mildew outbreaks. Fungicides may be applied for effective control if the appearance of mildew-infected turf is absolutely intolerable.

Fairy ring

Numerous types of soil-inhabiting fungi cause fairy rings in stands of all turfgrass species. The appearance of fairy rings on high maintenance golf turf, athletic fields, and manicured landscapes is often unacceptable, although symptoms are frequently cosmetic and result in no lasting turf damage. Sometimes, however, fairy ring activity kills turf, and in areas where it does, new growth is very difficult to re-establish.

Symptoms

Typically, fairy rings are dark green circular bands in turf. They range from less than 1 foot to more than 100 feet in diameter. Sometimes, they appear as arcs or incomplete circles and may result in bands of dead turf. The rings are more prevalent in dry soils during dry months in summer and fall. After extended periods of precipitation, mushrooms of all sorts may be associated with some fairy rings.

Control

The simplest means of managing fairy rings is to use additional N fertilizer – spoon feed 0.1-0.25 lb. per 1,000 square feet– in the areas where rings occur to mask the dark green bands. Another non-chemical method involves excavating soil in affected areas, replacing it, and re-establishing the turf. The excavation option is obviously very expensive and only practiced on very high maintenance golf and sports turf.

Fungicides may be effective in suppressing fairy ring development under certain conditions where the fungicide is effectively applied to the soil.

Research conducted in several states showed significant improvement in fairy ring control by applying effective fungicides tank mixed with a soil surfactant. Foliar sprays with 2-4 gallons of water per 1,000 square feet have yielded inconsistent results. Chemical fumigation of affected areas is another option; however, the expense is nearly prohibitive.

SUMMARY

There is no way to eliminate disease-causing pathogens from the environment. Disease management should focus on preventing outbreaks and mitigating the effects of infection and disease development. Understanding the conditions that promote disease and recognizing characteristic symptoms will lead to a more informed approach to disease management. Consider cultural control options and resistant species or cultivars before deciding on using fungicides for disease control.

Section 9 - Category 903E - Ornamental and Turf Small Animal Damage Management

LEARNING OBJECTIVES

After completing the following section, you should be able to:

A. Be able to explain why it is important in some situations to manage rodents and other vertebrates.

B. Explain the four points of assessing vertebrate damage.

C. Understand and describe the diseases that are vectored by vertebrates.

D. Identify and understand the control tactics for a variety of vertebrate pests.

E. Describe what causes bait shyness.

F. Understand the Federal requirements for baiting rodents and how it impacts the record keeping and program documentation.

PREFACE

Small mammalian pests in normal situations are considered a minor nuisance; however, populations of these pests are often cyclical, and many hungry mouths can have significant impact on well-managed turf and kill ornamental trees and shrubs. Small mammalian activities can also negatively affect irrigation, interrupt electrical supply, and crop production. They also have the potential to transmit diseases to livestock and humans.

Small animal control tactics have experienced few recent improvements. The majority of the information presented below has been taken from university publications available through a variety of means. Most of the material was published originally in the mid 1990s with revisions made in the 2010s. One of the compilations for small animal control is available electronically through University of Nebraska-Lincoln (UNL) NebGuides (http://digitalcommons.unl.edu/icwdmhandbook/?utm_source=digitalcommons.unl.edu%2Ficwdmhandbook%2F22&utm_medium=PDF&utm_campaign=PDFCoverPages)

The information presented below has been designed for two purposes:

1. To provide necessary information to persons interested in becoming a certified private or commercial applicator of pesticides used in wildlife damage control.

2. To serve as a resource manual in providing information in the control of wildlife commonly found in Wyoming.

The material in this section can be used as a comprehensive reference of North American vertebrate species that can cause economic damage to resources or become a nuisance at various times and places. The information is intended for use by extension agents and specialists, wildlife biologists, animal control officers, public health personnel, pest control operators, teachers and students of wildlife biology, and others who deal with wildlife damage problems.

Wildlife damage management is an essential part of contemporary wildlife management. This publication is a condensation of current, research-based information on wildlife that cause problems and the control of damage that they cause. While the material emphasizes prevention of damage as being desirable when possible, it does not neglect the necessity of population reduction in cases where animals must be removed to solve problems. This publication stresses an integrated approach to damage management and includes treatment of materials and techniques such as exclusion, habitat modification, repellents, frightening stimuli, toxicants, fumigants, trapping, shooting, and others. All of the major vertebrate pesticides currently federally registered are included.

The Wyoming Department of Agriculture recognizes many products other than those listed may be commonly used, legally registered, and distributed by firms not mentioned. In addition, the applicator must keep in mind that many products may be canceled, their uses restricted, or new products developed at any time. Users of these products are encouraged to check with the appropriate federal, state, or county authorities for updated information.

The mention of specific pesticide product manufacturers and distributors listed herein is supplied with the understanding that no discrimination is intended and no endorsement of any product is implied by the Wyoming Department of Agriculture or the University of Wyoming.

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INTRODUCTION

Wildlife management is often thought of in terms of protecting, enhancing, and nurturing wildlife populations and the habitat needed for their well-being. However, many species at one time or another require management actions to reduce conflicts with people or with other wildlife species. Examples include an airport manager modifying habitats to reduce gull activity near runways, a forester poisoning pocket gophers to increase tree seedling survival in a reforestation project, or a biologist trapping an abundant predator or competing species to enhance survival of an endangered species.

Wildlife damage control is an increasingly important part of the wildlife management profession because of expanding human populations and intensified land-use practices. Concurrent with this is the growing need to reduce wildlife-people conflicts, public attitudes, and environmental regulations restricting use of some of the traditional tools of control such as toxicants and traps. Agencies and individuals carrying out control programs are being more carefully scrutinized to ensure their actions are justified, environmentally safe, and in the public interest. Wildlife damage control activities must be based on sound economic, ecological,

and sociological principles and carried out as a positive, necessary component of overall wildlife management programs.

Wildlife damage control programs can be thought of as having four parts:

1. Problem identification; refers to determining the species and numbers of animals causing the problem, the amount of loss or nature of the conflict, and other biological and social factors related to the problem.

2. Ecology of the problem species; refers to understanding the life history of the species, especially in relation to the conflict.

3. Control methods application; refers to taking the information gained from parts 1 and 2 to develop an appropriate management program to alleviate or reduce the conflict.

4. Evaluation of control. Allows an assessment of the reduction in damage in relation to cost and impact of the control on target and non-target populations and the environment.

Increasingly, emphasis is being placed on integrated pest management whereby several control methods are combined and coordinated with other management practices in use at that time.

ASSESSING DAMAGE

Introduction

The objective of any responsible rodent or predator control program is not to eliminate the target species, but to reduce or eliminate. Reducing the population may be necessary in some situations to alleviate wildlife damage, while at other times, removal of the problem animal may be the correct solution.

Control personnel should be aware of values placed on wild animals by persons not affected with wildlife damage. Non-affected persons often object to any type of control activities. A concept promoted by some organizations and individuals is to preserve all wildlife in the interest of conservation. However, at times this concept may actually work against the desired results. Control personnel must remember this concept when considering control activities, as the wildlife values of the non-affected party are generally different than those of the affected party.

The animal species covered in this manual are **vertebrates**. Vertebrates, simply stated, have a jointed spinal column (vertebrate) and include fish, amphibians, reptiles, birds, and mammals. A vertebrate pest is any native or introduced, wild or feral, non-human vertebrate animal that is currently troublesome to one or more persons in a particular situation or over a large area, either by being a health hazard, a general nuisance, by destroying food, fiber, natural resources, or damaging monetary or aesthetic items of value to man.

Any animal that may currently be a pest to one or more persons may at the same time be desirable or of neutral interest to someone else. Examples can include birds, tree squirrels and deer.

Judgment as to the propriety of controlling vertebrate pests is a relative matter. A homeowner usually will not tolerate the presence of a single rodent, snake or other animal that he may consider a pest; whereas a farmer or rancher usually does not object to most of these same species unless they become so numerous as to cause him

economic loss. Damage to habitat and economic loss will occur if necessary pest control measures are not carried out. A good management system will employ integrated control, which is a system that uses all suitable techniques and methods in a compatible manner to maintain pest animals at levels below those causing economic or habitat.

Assessing damage

Before implementing a control program an assessment or evaluation should be made for each situation. This assessment is necessary to be successful in reducing damage without endangering non-target animals, for which several factors should be considered.

1. **Problem identification and verification of the pest causing damage**. The first thing to do in any pest control program is to accurately define the problem including the amount of loss or nature of the conflict, the species doing the actual damage and the number of animals causing the damage. Proper identification of the pest is imperative in conducting successful control. Wrong identification will lead to wasted money and time as many species have similar damage-causing characteristics. When physical evidence is present, the experienced person usually does not have any difficulty in identifying the animal or animals responsible for the damage. Situations will arise where evidence may be difficult to find, and when found may be inconclusive to the observer. When this occurs, it may be advisable to consult other people who are more knowledgeable in properly identifying the pest.

2. **Ecology of the pest species**. To properly control any pest, the control personnel must have knowledge and understanding of the life cycle of the target animal(s), especially in relation to the damage being caused. By knowing the life cycle, the control personnel may be able to select the proper control measure and time its application to be the most successful in controlling the pest.

3. **Selection of control methods and application**. After the control personnel have made the proper identification of the pest and understand its ecology, the correct control method and its application may be made to reduce or alleviate the damage. Proper timing of control is often necessary in controlling the target pest. Preventive and protective control is often overlooked by those being affected, causing added expense and the need for extended control measures. In some situations, the habitat can be altered making it undesirable for the pest species; in others, the food supply may be removed or reduced. There are many situations when these non-lethal control measures will not be applicable, but they should be considered.

4. **Evaluation of control**. The evaluation of control is an assessment of the reduction in damage in relation to the cost and impact of control. By taking this final step and evaluating the results, the control personnel may take the appropriate measures in the future to alleviate or reduce the damage prior to implementing control methods that may be more costly and time consuming. In addition, the control personnel in assessing their methods, can make the necessary changes to be more successful in the future.

WILDLIFE DISEASES AND HUMANS

Introduction

Diseases of wildlife can cause significant illness and death to individual animals and can significantly affect wildlife populations. Wildlife species can also serve as natural hosts for certain diseases that affect humans (zoonosis). The disease agents or parasites that cause these zoonotic diseases can be contracted from wildlife directly by bites or contamination, or indirectly through the bite or arthropod vectors such as mosquitoes, ticks, fleas, and mites that have previously fed on an infected animal. These zoonotic diseases are primarily diseases acquired within a specific locality, and secondarily, diseases of occupation and a vocation. Biologists, field assistants, hunters, and other individuals who work directly with wildlife have an increased risk of acquiring these diseases directly from animal hosts or their ectoparasites. Plague, tularemia, and leptospirosis have been acquired in the handling and skinning of rodents, rabbits, and carnivores. Humans have usually acquired diseases like Colorado tick fever, Rocky Mountain spotted fever, and Lyme disease because they have spent time in optimal habitats of disease vectors and hosts. Some general precautions should be taken to reduce risks of exposure and prevent infection.

General precautions

Use extreme caution when approaching or handling a wild animal that looks sick or abnormal to guard against those diseases contracted directly from wildlife. Procedures for basic personal hygiene and cleanliness of equipment are important for any activity but become a matter of major health concern when handling animals or their products that could be infected with disease agents. Some of the important precautions are:

1. Wear protective clothing, particularly disposable rubber or plastic gloves, when dissecting or skinning wild animals.
2. Scrub the work area, knives, other tools, and reusable gloves with soap or detergent followed by disinfection with diluted household bleach.
3. Avoid eating and drinking while handling or skinning animals and wash hands thoroughly when finished.
4. Safely dispose of carcasses and tissues as well as any contaminated disposable items like plastic gloves.
5. Cook meat from wild game thoroughly before eating.
6. Contact a physician if you become sick following exposure to a wild animal or its ectoparasites. Inform the physician of your possible exposure to a zoonotic disease.

Precautions against acquiring fungal diseases, especially histoplasmosis, should be taken when working in high-risk sites that contain contaminated soil or accumulations of animal feces; for example, under large bird roosts or in buildings or caves containing bat colonies. Wear protective masks to reduce or prevent the inhalation of fungal spores.

Protection from vector-borne diseases in high-risk areas involves personal measures such as using mosquito or tick repellents, wearing special clothing, or simply tucking pant cuffs into socks to increase the chance of finding crawling ticks before they attach. Additional preventive methods include checking your clothing and body and your pets for ticks and removing the ticks promptly after returning from infested sites. If possible, avoid tick-infested areas or locations with intense mosquito activity during the transmission season. Reduce outdoor exposure to mosquitoes especially in early

evening hours to diminish the risk of infection with mosquito-borne diseases.

Equally important preventive measures are knowledge of the diseases present in the general area and the specific habitats and times of year that present the greatest risk of exposure. Knowledge of and recognition of the early symptoms of the diseases and the conditions of exposure are essential in preventing severe illness. Also important are medical evaluation and treatment with proper antibiotics; for example, if you become ill following some field activity in a known plague-endemic area and you recognize the early symptoms of the disease, seeking medical care and informing the attending physician of your possible exposure to plague will aid in the correct treatment of your illness and reduce the risk of complications or even death.

In addition to taking personal precautions, risk of acquiring vector-borne diseases can be reduced in specific locations through area-wide applications of insecticides to control mosquito or flea vectors or acaricides to control tick vectors. Reduction in host populations (for example, rodents) and their ectoparasites (fleas or ticks) may be needed to control transmission of such diseases as plague or Lyme disease. Vaccination of wildlife hosts as a means of reducing zoonotic diseases is being investigated and may soon be available for diseases like rabies.

Conclusion

Wildlife workers tend to ignore the risks associated with handling wildlife species and working in natural environments. Diseases of wildlife or diseases present in their habitats can infect humans and some can cause serious illness or even death. Becoming aware of the potential diseases present and taking precautions to decrease exposure will greatly reduce chances of becoming infected with one of these diseases.

You can prevent infection with zoonotic diseases and reduce the seriousness of an illness by observing the following recommendations:

1. Become aware of which zoonotic diseases are present in your area and their clinical symptoms.

2. Obtain any pre-exposure vaccinations that are available, particularly for rabies.

3. Take personal precautions to reduce exposure to disease agents and vectors such as ticks, mosquitoes, and fleas.

4. Practice good sanitation procedures when handling or processing animals or their products.

5. If you become ill, promptly seek proper medical treatment and inform the physician about possible exposures.

Some important wildlife diseases that affect humans

Disease	Agent	Method of transmission	Wildlife host	Type of human illness/ symptoms
Direct				
Rabies	Virus	Animal Bite, Aerosol	striped skunk, raccoon, fox, bats, other mammals	paralysis, convulsions, coma, death
Hantavirus	Virus	Animal Bite, Aerosol	deer mice, other wild and commensal rodents	fever, headache, muscle aches, nausea, vomiting, back pain, respiratory syndrome
Leptospirosis	Bacteria	Urine, contamination ingestion	urbanized wild rodents: rabbit, fox, skunk, raccoon, opossum, deer	fever; jaundice; neurological pain; pain in abdomen, joints or muscles; nausea; may be fatal
Brucellosis	Bacteria	Contamination ingestion	hoofed animals, predators (coyotes, wolves)	intermittent fever, chills, headache, weakness, weight loss
Rat-bite Fever	Bacteria	Rodent Bite	commensal rodents	abrupt onset with chills and fever, headache, muscle ache, rash on legs and arms, arthritis
Salmonellosis	Bacteria	Ingestion of food contaminated by feces from infected animals	rodents, swine, cattle, birds, poultry, pet turtles	sudden onset of headache, fever, abdominal pain, nausea, diarrhea, vomiting
Ornithosis	Chlamydia	Inhalation of contaminated air	fowl	fever, chills, headache, muscle pain, loss of appetite, sweating, pneumonia
Histoplasmosis	Fungus	Inhalation of spores	none-grows in soil under bird and bat roosts	mild fever, flu-like illness, pneumonia, hepatitis, endocarditis, death
Cryptococcosis	Fungus	inhalation is suspected	none-grows in droppings in pigeon nests	meningitis, lung, liver and bone infection, skin lesions or ulcers.
Trichonosis	Nematode	Ingestion of under or uncooked meat containing larval cysts	swine, bear, wild and domestic carnivores, wild and domestic rodents	nonspecific gastroenteritis, loss of appetite, nausea, swollen eyelids, fever, chills, muscle aches
Ascarid roundworm	Nematode	Ingestion of nematode eggs (from fecal contamination)	raccoon	larval stage invades and damages organs, including the brain
Direct and Indirect				
Plague	Bacteria	Contamination from skinning animals, flea bites	wild rodents (prairie dogs, ground and tree squirrels, chipmunks) rabbits, carnivores.	Fever, headache, severe discomfort, shaking, chills, pain in groin and armpits (swollen lymph nodes), death

Disease	Agent	Method of transmission	Wildlife host	Type of human illness/ symptoms
Tularemia	Bacteria	Contamination from skinning animals, ticks, insect bites	Wild rodents, hares, rabbits, carnivore, birds, hoofed animals	Mild illness to severe meningitis, pneumonia, ulcer at inoculation site, swollen lymph nodes, death
Indirect: Tick-borne				
Colorado tick fever	Virus	Tick	Wild rodents, hares, rabbits, marmots, carnivores	High fever, headache, muscle ache, lethargy, biphasic symptoms
Rocky Mountain spotted fever	Rickettsia	Tick	Wild rodents, hares, rabbits, carnivores, birds	Rapid onset, fever, headache, muscle ache, nausea, vomiting, abdominal pain, rash, loss of muscle control, death
Ehrlichiosis	Rickettsia	Tick	Unknown, possibly dogs and other carnivores	Fever, headache, nausea, vomiting, muscle ache, fleeting rash
Lyme disease	Bacteria	Tick	Wild rodents, raccoon, deer, rabbits, birds	Skin lesions, fever, headache, fatigue, muscle ache, stiff neck, cardiac and neurological manifestations, arthritis
Relapsing fever	Bacteria	Tick	Wild rodents, who make their homes in old cabins or caves	Rapid onset, severe headache, muscle weakness, rigor, joint pain, recurring fever
Babesiosis	Protozoa	Tick	Wild rodents	Gradual onset. Loss of appetite, fever, sweating, fatigue, muscle aches, prolonged anemia, can be fatal
Indirect: Mosquito-borne				
St. Louis encephalitis	Virus	Mosquito	Mostly birds, some rodents	Fever, headache, musculoskeletal aches, malaise, low fatality
Eastern equine encephalitis	Virus	Mosquito	Birds, bats	Fever, intense headache, nausea, vomiting, muscle aches, confusion, coma, high fatality
Western equine encephalitis	Virus	Mosquito	Birds, jack rabbits, rodents	Fever, headache, nausea, vomiting, malaise, loss of appetite, convulsion, low fatality
California encephalitis	Virus	Mosquito	Eastern chipmunk, tree squirrel, red fox, deer mouse	Fever, irritability, headache, nausea, vomiting, loss of muscle control, confusion, come low fatality.
Indirect: Flea-borne				
Typhus (murine)	Rickettsia	Rat flea	Domestic rats, wild rodents, opossum	Fever, severe headache, chills, general pains, possible skin rash

USE OF TOXICANTS

Introduction

When persons consider controlling pest animals through the use of toxicants, it is important to acquaint all affected parties with the intent of the control program including effectiveness, safety, and approximate cost.

Additionally, local officials in the proposed control area should be contacted and control plans discussed in detail prior to implementation. Local officials can include weed and pest supervisors and University of Wyoming Extension Agents who are familiar with current control technology and can assist, advise, and coordinate the control program.

Label requirements may also mandate that additional agencies that are involved with controlling pest animals be contacted. These agencies can include the Wyoming Department of Agriculture, Wyoming Game & Fish Department, U.S. Forest Service, Bureau of Land Management, and the U.S. Fish and Wildlife Service.

Toxicology

Toxicology is a science that deals with poisons and their effects upon the target animals. Applicators of toxic materials such as those used in rodent control should have a basic understanding of how individual toxins effect target animals and be able to understand the terms used in describing the established lethal quantities or dosage rates of specific toxins for individual animal species.

Toxic substances are often incorporated in or on a food commonly attractive to the target animal species, (see Grains Commonly Used in Rodent Baits). This food is referred to as a "bait," and is also the prepared formulation which contains the toxicant. When toxic materials are developed, laboratory tests are conducted to determine the effective quantity of concentration of toxic material necessary in a prepared formulation to control a specific pest.

The term used to describe the toxicity of a particular pesticide to specific animals is the Lethal Dose (LD). A LD50 is the amount of concentration of the toxicant necessary to kill 50 percent of a test population. From this established quantity of toxicant, a LD100 is determined, which is the amount of toxicant necessary to kill 100 percent of a population. A concentration of toxicant for field application would be that amount that would provide control at LD100.

An LD50 or an LD100 is expressed as the quantity of the toxin in milligrams lethal to an animal of a specific body weight, expressed in kilograms (mg/kg). Immature or smaller animals are usually more susceptible to toxins than larger or adult animals; a larger quantity of the toxin is normally necessary to control adult animals. When the LD50 or LD100 of toxic materials are provided for an animal species, the range usually given covers the minimum and maximum limits of bodyweight of each species. An example of a specific LD100, for a species, would be 1.0-2.0 mg/kg. The LD100 provides assurance the concentration of the toxicant is sufficient to control the largest and/or most resistant animals that may be found in any given population.

Grains commonly used in rodent baits

Three grains, barley, wheat and oats, have been found most useful and successful as carriers of rodent toxicants.

Wheat is commonly used for bait in gopher and house mouse control. Barley and oats are used in various forms for the control of other rodents and jackrabbits. These grains may be used whole or may be mechanically altered to improve their effectiveness and lessen their attractiveness to birds. There are specific terms used to describe

mechanical alteration, and these terms are often incorporated in the description of bait formulas.

Whole grains

"Whole" grains are those that have not been mechanically altered. The hull remains in the case of barley and oats.

Rolled grains

The term "lightly rolled" whole barley, wheat, and oats indicates these grains have been processed by steam rolling to provide a somewhat flattened grain. Barley and oats processed for stock feed are normally rolled so the grain is flat or crushed. These are generally not satisfactory for use in rodent control formulas. "Crimped" whole oats, barley, and wheat are very lightly rolled. For example, crimped barley is not over 2½ times normal width.

Hulled grains

Barley with the hulls removed is known as "hulled" or "potted" barley. The term "potted" is taken from the name of the machines (potting machines) used in removing the hulls. "Oat groats" refers to oats from which the hulls have been removed. A "squirrel oat groat" is a "light rolled" oat groat. "Oat grits," a product commonly used in chicken feeds, is prepared by hammer milling so small particles result. The product is also called "steel cut oat groats."

Color Additives Used in Rodent Baits

Adding colored dyes and pigments to toxic rodent baits is based upon the following reasons:

1. To protect seed-eating birds through the application of a physiological principle, which indicates some species of diurnal birds distinguish and show an aversion to certain colors when these are applied to food, while lower animals, including rodents, do not.
2. To prevent possible accidental human consumption and to reduce the hazard of baits being diverted to livestock feed.
3. To aid in bait identification purposes, including the times when the bait is in storage and while being used in the field.
4. To aid in bait preparation by the manufacturer to assure thorough mixing, as indicated by the uniformity of color additives in the finished product.
5. The dyes and pigments that are used in baits have been selected to reduce as much as possible nonacceptance of the bait by the target pest due to an imparted taste, texture, odor, and color of the finished product.

Safety precautions

Toxicants used in vertebrate pest control can be handled and used safely if the proper precautions are taken. All toxic baits, such as rodenticides, and the application equipment should be clearly marked and labeled "Poison" and stamped with skull and crossbones. It is extremely important for the applicator to avoid inhaling dust from the baits and skin contamination while handling and using these products.

Respirators or dust masks, rubber gloves, and aprons should be worn to avoid such exposures. In addition, the applicator should not allow the hands or application equipment to contact the face. Eating, drinking, chewing tobacco or gum and smoking should be prohibited during the use of these products. The hands and any clothing worn during the handling and application should always be washed with soap and water after using the products.

All pesticide products should be stored in a locked room or building separate of human habitations and livestock feed, when not in use, and clearly marked with signs warning others that pesticides are stored there. Do not leave poison baits where they will be accessible to children, irresponsible persons, or animals.

Endangered species labeling

Most pesticide products registered for use have specific label prohibitions against exposure where endangered species may be adversely affected. The taking of an endangered species by the use of a pesticide constitutes several state and federal offenses, including violation of the Endangered Species Act and using pesticide product inconsistent with its labeling.

Species that may be adversely affected in Wyoming include grizzly bears, gray wolves, black-footed ferrets, whooping cranes, Prebles meadow jumping mouse, and Wyoming toads. Applicators need to read, understand, and comply with all product labeling prior to use.

Specific information on endangered species requirements is available from the Wyoming Game & Fish Department, or from the U.S. Fish and Wildlife Service, Endangered Species Specialist, in Cheyenne at 307-772-2374.

You may be required to visit the EPA BULLETINS LIVE! Two website and find details concerning product use in your specific area. Bulletin information can be access using this link; http://www.epa.gov/oppfead1/endanger/bulletins.htm

RODENTS

Pocket gophers

Classification and legal status in Wyoming

Classified under the *Wyoming Game & Fish Commission Chapter 52: Non-game Wildlife Regulation* as non-game wildlife and may be taken (without permit) during the calendar year in the entire state.

See the *Wyoming Game & Fish Commission Chapter 52: Non-game Wildlife Regulation, Section 9. Mammals* at https://wgfd.wyo.gov/Regulations/Regulation-PDFs/Regulations_Ch52.pdf for additional information.

Damage prevention and control methods

Exclusion – Generally not practical. Small mesh wire fence may provide protection for ornamental trees and shrubs or flowerbeds. Plastic netting protects seedlings.

Cultural methods – Damage resistant varieties of alfalfa. Crop rotation; grain buffer crops; control of tap-rooted forbs; flood irrigation; plant naturally resistant varieties of seedlings.

Repellents – Synthetic predator odors are all of questionable benefit. There is no data available to suggest that the use of castor bean oil acts as a repellent.

Toxicants: Baits – Chlorophacinone; Diphacinone; Zinc Phosphide; Strychnine alkaloid (below ground use only). The following forms are available: 0.35% Strychnine Milo & 0.5% Strychnine Steam Rolled Oats - for use in hand probes and the burrow builder; 0.5% Strychnine Oat Groats

Note: For information on using hand probes or the mechanical burrow builder, contact the Wyoming Department of Agriculture.

Fumigants: Carbon monoxide from engine exhaust. Others are not considered very effective, but some are used: aluminum phosphide and gas cartridges.

Trapping – Various specialized gopher kill traps. Common spring or pan trap (sizes No. 0 and No. 1).

Shooting – Not practical.

Other – Buried irrigation pipe or electrical cables can be protected with cylindrical pipe having an outside diameter of at least 2.9 inches (7.4 cm). Surrounding a buried cable with 6 to 8 inches (15 to 20 cm) of coarse gravel, 1 inch [2.5 cm] in diameter may provide some protection.

Damage and damage identification

Several mammals, most common are the Richardson ground squirrel, thirteen-lined ground squirrel, vole and the mole, are sometimes confused with pocket gophers because of variations in common local terminology, or in the similarity of behavioral characteristics. In addition, in the southeastern United States, pocket gophers are called "salamanders," (derived from the term sandy mounder), while the term gopher refers to a tortoise. Pocket gophers can be distinguished from the other mammals by their telltale signs as well as by their appearance. Pocket gophers leave soil mounds on the surface of the ground. The mounds are usually fan-shaped and tunnel entrances are plugged, keeping various intruders out of burrows.

Damage caused by gophers includes: destruction of underground utility cables and irrigation pipe; direct consumption and smothering of forage by earthen mounds; and change in species composition on rangelands by providing seedbeds (mounds) for invading annual plants. Gophers damage trees by stem girdling and clipping, root pruning, and possibly root exposure caused by burrowing. Gopher mounds dull and plug sickle bar mowers when harvesting hay or alfalfa, and silt brought to the surface as mounds is more likely to erode. In irrigated areas, gopher tunnels can channel water runoff, causing loss of surface irrigation water. Gopher tunnels in ditch banks and earthen dams can weaken these structures, causing water loss by seepage and piping through a bank or the complete loss of or washout of a canal bank. The presence of gophers also increases the likelihood of badger activity, which can also cause considerable damage.

Deer mice

Classification and legal status in Wyoming

Deer mice are classified under the *Wyoming Game & Fish Commission Chapter 52: Non-game Wildlife Regulation* as non-game wildlife and may be taken (without permit) during the calendar year in the entire state.

See the *Wyoming Game & Fish Commission Chapter 52: Non-game Wildlife Regulation, Section 9. Mammals* at https://wgfd.wyo.gov/Regulations/Regulation-PDFs/Regulations_Ch52.pdf for additional information.

Damage prevention and control methods

Exclusion – Rodent-proof construction will exclude mice from buildings and other structures. Use hardware cloth (114-inch [0.6 cm] mesh) or similar materials to exclude mice from garden seedbeds.

Habitat modification – Store food items left in cabins or other infrequently used buildings in rodent-proof containers. Store furniture cushions, drawers, and other items in infrequently used buildings in ways that reduce nesting sites.

Frightening – Not effective.

Toxicants – Anticoagulants; zinc phosphide

Fumigants – None are registered.

Trapping – Snap traps. Box- (Sherman) type traps. Automatic multiple-catch traps.

Other methods: Alternative feeding – Experiments suggest application of sunflower seed may significantly reduce consumption of conifer seed in forest reseeding operations, although the tests have not been followed to regeneration.

Damage and damage identification

The principal problem caused by deer mice is their tendency to enter homes, cabins, and other structures that are not rodent-proof. Here they build nests, store food, and can cause considerable damage to upholstered furniture, mattresses, clothing, paper, or other materials they find suitable for their nest-building activities. Nests, droppings, and other signs left by these mice are similar to those of house mice. Deer mice have a greater tendency to cache food supplies, such as acorns, seeds, or nuts, than do house mice. Deer mice are uncommon in urban or suburban residential areas unless there is considerable open space (fields, parks) nearby.

Deer mice occasionally dig up and consume newly planted seeds in gardens, flowerbeds, and field borders. Their excellent sense of smell makes them highly efficient at locating and digging up buried seed. Formerly, much reforestation was attempted by direct seeding of clear-cut areas, but seed predation by deer mice and other rodents and birds, caused frequent failure in the regeneration. For this reason, to reestablish Douglas fir and other commercial timber species today, it is often necessary to hand-plant seedlings, despite the increased expense of this method.

In the early 1990s, the deer mouse (*P. maniculatus*) was first implicated as a potential reservoir of a type of hantavirus responsible for an adult respiratory distress syndrome, leading to several deaths in the Four Corners area of the United States. Subsequent isolations of the virus thought responsible for this illness have been made from several Western states, including Wyoming. The source of the disease is thought to be through human contact with urine, feces, or saliva from infected rodents.

Porcupines

Classification and legal status in Wyoming

Classified as a "predatory animal" under Wyoming Game & Fish Statutes and are not protected.

Damage prevention and control methods

Exclusion – Fences (small areas). Tree trunk guards.

Cultural methods – Encourage closed-canopy forest stands.

Repellents – None are registered. Some wood preservatives may incidentally repel porcupines.

Toxicants – None are registered.

Fumigants – None are registered.

Trapping – Steel leg hold trap (No. 2 or 3). Body-gripping (Conibear®) trap (No. 220 or 330). Box trap.

Shooting – Day shooting and spotlighting are effective where legal.

Other methods – Encourage natural predators.

Damage and damage identification

Clipped twigs on fresh snow, tracks, and gnawing on trees are useful means of damage identification. Trees are often deformed from partial girdling. Porcupines clip twigs and branches that fall to the ground or onto snow and often provide food for deer and other mammals. The considerable secondary effects of their feeding come from

exposing the tree sapwood to attack by disease, insects, and birds. This exposure is important to many species of wildlife because diseased or hollow trees provide shelter and nest sites.

Porcupines occasionally will cause considerable losses by damaging fruits, sweet com, alfalfa, and small grains. They chew on hand tools and other wood objects while seeking salt. They destroy siding on cabins when seeking plywood resins.

Porcupines offer a considerable threat to dogs, which never seem to learn to avoid them. Domestic stock occasionally will nuzzle a porcupine and may be fatally injured if quills are not removed promptly.

Prairie dogs

Classification and legal status in Wyoming

Classified under the *Wyoming Game & Fish Commission Chapter 52: Non-game Wildlife Regulation* as non-game wildlife and may be taken (without permit) during the calendar year in the entire state. The prairie dog is also a "designated pest" under the Wyoming Department of Agriculture, Weed & Pest Control Act statutes, http://www.wyoweed.org/images/Designated_List.pdf.

Damage prevention and control methods

Exclusion – Wire mesh fences can be installed but they are usually not practical or cost-effective. Visual barriers of suspended burlap, windrowed pine trees, or snow fence may be effective.

Cultural methods – Modify grazing practices on mixed and mid-grass rangelands to exclude or inhibit prairie dogs. Cultivate, irrigate, and establish tall crops to discourage prairie dog use.

Frightening – No methods are effective.

Repellents – None are registered.

Toxicants – Zinc phosphide. Note: Zinc phosphide baits require pre-baiting and used when green forage is not available to be effective. When baiting for prairie dogs, you must visit and follow instructions on the EPA Bulletins Live! Website http://www.epa.gov/oppfead1/endanger/bulletins.htm. Further instructions for use will be included on the product label.

Anticoagulants – Chlorophacinone; diphacinone

Fumigants – Aluminum phosphide. Gas Cartridges.

Trapping – Box traps. Snares. Conibear® No. 110 (body gripping) traps or equivalent.

Shooting – Shooting with .22 rimfire or larger rifles.

Other methods – Several home remedies have been used, but most are unsafe and are not cost-effective.

Damage and damage identification

Several independent studies have produced inconsistent results regarding the impacts of prairie dogs on livestock production. The impacts are difficult to determine and depend on several factors, such as the site conditions, weather, current and historic plant communities, number of prairie dogs, size and age of prairie dog towns, and the intensity of site use by livestock and other grazers. Prairie dogs feed on many of the same grasses and forbs that livestock feed on. Annual dietary overlap ranges from 64% to 90%. Prairie dogs often begin feeding on pastures and rangeland earlier in spring than cattle and clip plants closer to the ground. Up to 10% of the aboveground vegetation may be destroyed due to their burrowing and mound-building activities. Overall, prairie dogs may remove 18% to 90% of the available forage through their activities.

The species composition of pastures occupied by prairie dogs may change dramatically. Prairie dog activities encourage shortgrass species, perennials, forbs, and species that are resistant to grazing. Annual plants are selected against because they are usually clipped before they can produce seed. Several of the succeeding plant species are less palatable to livestock than the grasses they replace.

Other studies, however, indicate prairie dogs may have little or no significant effect on livestock production. One research project in Oklahoma revealed there were no differences in annual weight gains between steers using pastures inhabited by prairie dogs and steers in pastures without prairie dogs. Reduced forage availability in prairie dog towns may be partially compensated for by the increased palatability and crude protein of plants that are stimulated by grazing. In addition, prairie dogs sometimes clip and/or eat plants that are toxic to livestock. Bison, elk, and pronghorns appear to prefer feeding in prairie dog colonies over non-colonized grassland.

Prairie dog burrows increase soil erosion and are a potential threat to livestock, machinery, and horses with riders. Damage may also occur to ditch banks, impoundments, field trails, and roads.

Prairie dogs are susceptible to several diseases, including plague, a severe infectious disease caused by the bacterium *Yersinia pestis*. Plague, which is often fatal to humans and prairie dogs, is most often transmitted by the bite of an infected flea. Although plague has been reported throughout the western United States, it is uncommon. Symptoms in humans include swollen and tender lymph nodes, chills, and fever. The disease is curable if diagnosed and treated in its early stages. It is important the public be aware of the disease and avoid close contact with prairie dogs and other rodents. Public health is a primary concern regarding prairie dog colonies that are in close proximity to residential areas and schoolyards.

Ground Squirrels

Species: Franklin, Richardson, Columbian, Washington, and Townsend

Classification and legal status in Wyoming

Classified under the *Wyoming Game & Fish Commission Chapter 52: Non-game Wildlife Regulation* as non-game wildlife and may be taken (without permit) during the calendar year in the entire state. The ground squirrel is also a "designated pest" under the Wyoming Department of Agriculture, Weed & Pest Control Act statutes, http://www.wyoweed.org/images/Designated_List.pdf

Damage prevention and control methods

Exclusion – Limited usefulness.

Cultural methods – Flood irrigation, forage removal, crop rotation, and summer fallow may reduce populations and limit spread.

Repellents – None are registered.

Toxicants – Zinc phosphide. Chlorophacinone. Diphacinone. Note: Not all toxicants are registered for use in every state. Check registration labels for limitations within each state.

Fumigants – Aluminum phosphide. Gas cartridges.

Trapping – Box traps. Burrow-entrance traps. Leghold traps.

Shooting – Limited usefulness.

Damage and damage identification

High populations of ground squirrels may pose a serious pest problem. The squirrels compete with livestock for forage; destroy food crops, golf courses, and lawns; and can be reservoirs for

diseases such as plague. Their burrow systems have been known to weaken and collapse ditch banks and canals, undermine foundations, and alter irrigation systems. The mounds of soil excavated from their burrows not only cover and kill vegetation, but damage haying machinery. In addition, some ground squirrels prey on the eggs and young of ground-nesting birds or climb trees in the spring to feed on new shoots and buds in orchards.

Ground squirrels are more destructive than prairie dogs because they occur in larger numbers and over more diverse terrain. To be truly effective in controlling ground squirrels, cooperative efforts between landowners must be implemented, as the ground squirrel will quickly re-invade from areas that have not been treated.

Tree Squirrels

Classification and legal status in Wyoming

Classified under the *Wyoming Game & Fish Commission Chapter 11: Upland Game Bird and Small Game Hunting Seasons* as a "Small Game Animal," requiring a license to take tree squirrels. For more information https://wgfd.wyo.gov/Regulations/Regulation-PDFs/REGULATIONS_CH11.

Damage prevention and control methods

Exclusion – Install sheet metal bands on isolated trees to prevent damage to developing nuts, fruit, and bark. Close external openings to buildings to stop damage to building interiors. Place an 18-inch (46 cm) section of 4-inch (10 cm) diameter plastic pipe or a one-way door over openings to allow squirrels to leave and prevent them from returning. Plastic tubes on wires may prevent access to buildings.

Cultural methods – Remove selected trees or their branches to prevent access to structures.

Repellents – Naphthalene (moth balls), Ro-pel, capsaicin, and polybutenes are registered for controlling tree squirrels.

Toxicants – None are registered.

Fumigants – None are registered.

Trapping – Leghold traps. Box and cage traps. Rat snap traps. Box choker traps.

Shooting – Effective where firearms are permitted. Use a shotgun with No. 6 shot or a .22-caliber rifle.

Damage and damage identification

Squirrels may occasionally damage forest trees by chewing bark from branches and trunks. Pine squirrels damage Ponderosa pine, jack pine, and paper birch. Tree squirrels may eat cones and nip twigs to the extent they interfere with natural reseeding of important forest trees. This is a particular problem in Ponderosa pine forests where pine squirrels may remove 60% to 80% of the cones in poor to fair seed years. In forest seed orchards, such squirrel damage interferes with commercial seed production.

In nut orchards, squirrels can severely curtail production by eating nuts prematurely and by carrying off mature nuts. Pine, gray, and fox squirrels may chew bark of various orchard trees.

In residential areas, squirrels sometimes travel power lines and short out transformers. They gnaw on wires, enter buildings, and build nests in attics. They frequently chew holes through pipelines used in maple syrup production.

Squirrels occasionally damage lawns by burying or searching for and digging up nuts. They will chew bark and clip twigs on ornamental trees or shrubbery planted in yards. Often, squirrels take food at feeders intended for birds. Sometimes they

chew to enlarge openings of bird houses and then enter to eat nestling songbirds. Flying squirrels are small enough to enter most bird houses and are especially likely to eat nesting birds.

In gardens, squirrels may eat planted seeds, mature fruits, or grains such as corn.

Voles

Classification and legal status in Wyoming

Most vole species in Wyoming are Classified under the *Wyoming Game & Fish Commission Chapter 52: Non-game Wildlife Regulation* as non-game wildlife and may be taken (without permit) during the calendar year in the entire state.

See the *Wyoming Game & Fish Commission Chapter 52: Non-game Wildlife Regulation, Section 9. Mammals* at https://wgfd.wyo.gov/Regulations/Regulation-PDFs/Regulations_Ch52.pdf for additional information.

Damage prevention and control methods

Exclusion – Recommended to protect trees, ornamental plants, and small areas.

Habitat modification – Eliminating ground cover reduces populations. Soil cultivation destroys burrows and reduces cover.

Frightening – Not effective.

Repellents – Effectiveness uncertain.

Toxicants – Zinc phosphide. Anticoagulants (registered in most states).

Fumigants – Not usually effective.

Trapping – Mouse snap traps. Live traps (Sherman or box-type traps).

Shooting – Not practical or effective.

Damage and damage identification

Voles may cause extensive damage to orchards, ornamentals, and tree plantings due to their girdling of seedlings and mature trees. Girdling damage usually occurs in fall and winter. Field crops (for example, alfalfa, clover, grain, potatoes, and sugar beets) may be damaged or completely destroyed by voles. Voles eat crops and also damage them when they build extensive runway and tunnel systems. These systems interfere with crop irrigation by displacing water and causing levees and checks to wash out. Voles also can ruin lawns, golf courses, and ground covers.

Girdling and gnaw marks alone are not necessarily indicative of the presence of voles, since other animals, such as rabbits, may cause similar damage. Vole girdling can be differentiated from girdling by other animals by the non-uniform gnaw marks. They occur at various angles and in irregular patches. Marks are about 1/8-inch (0.3 cm) wide, 3/8-inch (1.0 cm) long, and 1/16-inch (0.2 cm) or more deep. Rabbit gnaw marks are larger and not distinct. Rabbits neatly clip branches with oblique clean cuts. Examine girdling damage and accompanying signs (feces, tracks, and burrow systems) to identify the animal causing the damage.

The most easily identifiable sign of voles is an extensive surface runway system with numerous burrow openings. Runways are 1 to 2 inches (2.5 to 5 cm) in width. Vegetation near well-traveled runways may be clipped close to the ground. Feces and small pieces of vegetation are found in the runways.

The pine vole does not use surface runways. It builds an extensive system of underground tunnels. The surface runways of long-tailed voles are not as extensive as those of most other voles.

Voles pose no major public health hazard because of their infrequent contact with humans; however,

they are capable of carrying disease organisms, such as plague (*Yersinia pestis*) and tularemia (*Francisilla tularensis*). Be careful and use protective clothing when handling voles.

Woodrats (Packrats)

Classification and legal status in Wyoming

Woodrats are classified as non-game animals. In most states, they can be taken (controlled) when they threaten or damage property. Check with your local wildlife or agriculture department for laws and regulations specific to your area.

Damage prevention and control methods

Exclusion – Is the most effective method of eliminating damage. Woodrats may be excluded from buildings. No hole larger than ½ inch (1.3 cm) should be left unsealed. Make sure doors, windows, and screens fit tightly. If gnawing is a problem, edges can be covered with sheet metal. Coarse steel wool, wire screen, and lightweight sheet metal are excellent materials for plugging gaps and holes.

Repellents – No woodrat repellents, registered by the EPA.

Toxicants – Available for woodrat control include anticoagulants and zinc phosphide, registered under Special Local Needs 24(c) provisions. Registered products vary among states. When using toxic baits, follow label instructions carefully. Chorphacinone or diphacinone have also proven effective.

Trapping – Woodrats show little fear of new objects in their environment and are easily trapped. Baited snap traps, cage traps, burrow entrance traps, and glue boards are effective.

Damage and damage identification

Populations generally are fairly dispersed, but economic damage to agricultural crops can occur in limited areas. Agricultural damage results when woodrats clip small twigs and branches and when they debark citrus and other fruit trees and seedling and sapling conifers, especially redwoods. Loss of trees can occur.

Woodrats are sometimes a nuisance around cabins, outbuildings, and other infrequently used structures or vehicles. As the name packrat implies, they have a tendency to pack away small objects such as jewelry, cooking and eating utensils, can tabs, and other items. At times, this behavior can become a nuisance to backpackers and others. More seriously, woodrats may also shred upholstered furniture and mattresses for lining nests, and may take up residence in parked vehicles, gnawing on wires and other mechanical components.

Woodrats can be an important factor in the transmission of certain diseases, most notably plague, where this disease occurs. Dead or dying woodrats should not be handled.

Kangaroo rats

Classification and legal status in Wyoming

Legal Status: Most kangaroo rats are considered non-game animals and are not protected by state game laws. Certain local subspecies may be protected by regulations regarding threatened and endangered species. Consult local authorities to determine their legal status before applying controls

Damage prevention and control methods

Exclusion – Is most often accomplished by the construction of rat-proof fences and gates around the area to be protected. Most kangaroo rats can be excluded by ½-inch (1.3-cm) mesh hardware cloth, 30 to 36 inches (75 to 90 cm) high. The bottom 6 inches (15 cm) should be turned outward and buried at least 12 inches (30 cm) in the ground. Exclusion may be practical for small areas of high-value crops, such as gardens, but is impractical and too expensive for larger acreages.

Cultural methods – Alfalfa, corn, sorghum, and other grains are the most likely crops to be damaged by kangaroo rats. When possible, planting should be done in early spring before kangaroo rats become active to prevent loss of seeds. Less palatable crops should be planted along field edges that are near areas infested with kangaroo rats. High kangaroo rat numbers most often occur on rangelands that have been subjected to overuse by livestock.

Repellents – There are no registered repellents for kangaroo rats.

Toxicants – Zinc phosphide. At present, 2% zinc phosphide bait is federally registered. Carefully read and follow all label instructions.

Fumigants – There are no fumigants registered specifically for kangaroo rats. Aluminum phosphide and gas cartridges are registered for "burrowing rodents such as woodchucks, prairie dogs, gophers, and ground squirrels."

Trapping – **Live traps**. Trapping with box-type (wire cage) traps can be successful in a small area when a small number of kangaroo rats are causing problems. These traps can be baited successfully with various grains, oatmeal, oatmeal and peanut butter, and other baits. Do not release kangaroo rats in areas where landowners do not want them. **Snap traps**: Trapping with snap traps is probably the most efficient and humane method for kangaroo rats.

Other methods – Flooding

Damage and damage identification

Kangaroo rats are nocturnal and harvest seeds and seed heads of mainly grass species. They are larder hoarders, meaning they collect food, store it, and feed on it during the winter. They can significantly reduce a pasture's ability to reseed itself and can impact the grazing quality of grass pasture. They can also dig up and consume newly planted vegetable seeds. Burrows are quite extensive and can be mistaken for gopher damage. They are extremely sensitive to temperature changes and will seal burrow opening with soil during the heat of the day.

CARNIVORES

Foxes

Classification and legal status in Wyoming

Red Fox are classified as predators and may be taken at any time within the entire state, whether or not they are causing damage.

Gray Fox are classified under the Wyoming Game & Fish Regulations as non-game wildlife, but may not be taken unless the following conditions exist: 1) It is determined to be unavoidable and does not result from conduct with lack of reasonable care, or 2) It results from control measures approved by the Game & Fish Department as necessary to address public health concerns. See the *Wyoming Game & Fish Commission Chapter 52: Non-game Wildlife Regulation, Section 4. Taking of Non-game Wildlife* at https://wgfd.wyo.gov/Regulations/Regulation-PDFs/Regulations_Ch52.pdf for additional information.

Damage prevention and control methods

Exclusion – Net wire fence. Electric fence.

Cultural methods – Protect livestock and poultry during most vulnerable periods (for example, shed lambing, farrowing pigs in protective enclosures).

Frightening – Flashing lights and exploders may provide temporary protection. Well-trained livestock guarding dogs may be effective in some situations.

Repellents – None are registered for livestock protection.

Toxicants – M-44 sodium cyanide mechanical ejection device. The M- 44 is registered for use in Wyoming and is labeled for both red and gray fox. Contact the Wyoming Department of Agriculture for more information.

Fumigants – Gas cartridges for den fumigation, where registered.

Trapping – Steel leghold traps. Cage or box traps. Snares.

Shooting – Predator calling techniques. Aerial hunting, (available by permit through the Wyoming Department of Agriculture).

Other methods – Den hunting. Remove young foxes from dens to reduce predation by adults.

Damage and damage identification

Foxes may cause serious problems for poultry producers. Turkeys raised in large range pens are subject to damage by foxes. Losses may be heavy in small farm flocks of chickens, ducks, and geese. Young pigs, lambs, and small pets are also killed by foxes. Damage can be difficult to detect because the prey is usually carried from the kill site to a den site or uneaten parts are buried. Foxes usually attack the throat of young livestock, but some kill by inflicting multiple bites to the neck and back. Foxes do not have the size or strength to hold adult livestock or to crush the skull and large bones of their prey. They generally prefer the viscera and often begin feeding through an entry behind the ribs. Foxes will also scavenge carcasses, making the actual cause of death difficult to determine.

Pheasants, waterfowl, other game birds, and small game mammals are also preyed upon by foxes. At times, fox predation may be a significant mortality factor for upland and wetland birds, including some endangered species.

Rabies outbreaks are most prevalent among red foxes in southeastern Canada and occasionally in the eastern United States. The incidence of rabies in foxes has declined substantially since the mid-1960s for unexplained reasons. In 1990, there were only 197 reported cases of fox rabies in the United States as compared to 1,821 for raccoons and 1,579 for skunks. Rabid foxes are a threat to humans, domestic animals, and wildlife.

Skunks

Classification and legal status in Wyoming

Classified as predators and may be taken at any time within the entire state, no license required.

Damage prevention and control methods

Exclusion – **Buildings**: close cellar and outside basement and crawl space doors; seal and cover all openings including window wells and pits. **Poultry yards**: install wire mesh fences. **Beehives**: elevate and install aluminum guards.

Habitat modification – Removal of garbage, debris, and lumber piles.

Frightening – Lights and sounds are of limited value.

Repellents – Some home remedies such as moth balls or flakes or ammonia solution may be useful, but no repellents are registered.

Toxicants – None are registered.

Fumigants – Denning gas cartridges, (available from the Wyoming Department of Agriculture).

Trapping – Box trap. Leghold trap.

Shooting – Practical only when animals are far from residential areas.

Other methods – Skunk removal. Odor removal.

Damage and damage identification

Skunks become a nuisance when their burrowing and feeding habits conflict with humans. They may burrow under porches or buildings by entering foundation openings. Garbage or refuse left outdoors may be disturbed by skunks. Skunks may damage beehives by attempting to feed on bees. Occasionally, they feed on corn, eating only the lower ears. If the cornstalk is knocked over, however, raccoons are more likely the cause of the damage. Damage to the upper ears of corn is indicative of birds, deer, or squirrels. Skunks dig holes in lawns, golf courses, and gardens while searching for insect grubs found in the soil. Digging normally appears as small, 3- to 4-inch (7- to 10-cm) cone-shaped holes or patches of up-turned earth. Several other animals, including domestic dogs, also dig in lawns.

Skunks occasionally kill poultry and eat eggs. They normally do not climb fences to get poultry. By contrast, rats, weasels, mink, and raccoons regularly climb fences. If skunks gain access, they will normally feed on the eggs and occasionally kill one or two fowl. Eggs usually are opened on one end with the edges crushed inward. Weasels, mink, dogs, and raccoons usually kill several chickens or ducks at a time. Dogs will often severely mutilate poultry. Tracks may be used to identify the animal causing damage. Both the hind and forefeet of skunks have five toes. In some cases, the fifth toe may not be obvious. Claw marks are usually visible, but the heels of the forefeet normally are not. The hind feet tracks are approximately 2½ inches long (6.3 cm). Skunk droppings can often be identified by the undigested insect parts they contain. Droppings are ¼ to ½ inch (6 to 13 mm) in diameter and 1 to 2 inches (2/5 to 5 cm) long.

Odor is not always a reliable indicator of the presence or absence of skunks. Sometimes dogs, cats, or other animals that have been sprayed by skunks move under houses and make owners mistakenly think skunks are present.

Rabies may be carried by skunks on occasion. Skunks are the primary carriers of rabies in Wyoming. When rabies outbreaks occur, the ease with which rabid animals can be contacted increases. Rabid skunks are prime vectors for the spread of the virus. Avoid overly aggressive skunks that approach without hesitation. Any skunk showing abnormal behavior, such as daytime activity, may be rabid and should be treated with caution. Report suspicious behavior to local animal control authorities.

To prepare and secure a skunk for rabies testing, the animal should be shot in the body, taking care not to hit the head. The head should then be removed and submitted to the State Veterinary laboratory for analysis. Proper protective precautions should be exercised, (i.e., wearing of protective gloves) when preparing the animal for testing as the rabies virus is contagious.

OTHER MAMMALS

Bats

Classification and legal status in Wyoming

See Wyoming Game & Fish for additional information.

Damage prevention and control methods

Exclusion – Polypropylene netting check-valves simplify getting bats out. Quality bat-proofing permanently excludes bats. Initiate control before young are born or after they are able to fly.

Repellents – Naphthalene: limited efficacy. Illumination. Air drafts/ventilation. Ultrasonic

devices: not effective, some even attract bats. Sticky deterrents: limited efficacy.

Toxicants – None are registered.

Trapping – Available, but unnecessarily complicated compared to exclusion and bat-proofing.

Other methods – Sanitation and cleanup. Artificial roosts.

Removal of occasional bat intruders – When no bite or contact has occurred, help the bat escape (otherwise submit it for rabies testing).

Conservation and public education – Information itself functions as a management technique.

Damage and damage identification

Bat Presence. Bats often fly about swimming pools, from which they drink or catch insects. White light (with an ultraviolet component), commonly used for porch lights, building illumination, street and parking lot lights, may attract flying insects, which in turn attract bats. Unfortunately, the mere presence of a bat outdoors is sometimes beyond the tolerance of some uninformed people. Information is a good remedy for such situations.

Bats commonly enter buildings through openings associated with the roof edge and valleys, eaves, apex of the gable, chimney, attic or roof vent, dormers, and siding. Other openings may be found under loose-fitting doors, around windows, gaps around various conduits (wiring, plumbing, air conditioning) that pass through walls, and through utility vents.

Bats are able to squeeze through narrow slits and cracks. For purposes of bat management, one should pay attention to any gap of approximately 1/4 x 1½ inches (0.6 x 3.8 cm) or a 5/8 x 7/8 inch (1/6 x 2.2 cm) hole. Such openings must be considered potential entries for at least the smaller species, such as the little brown bat. The smaller species require an opening no wider than 3/8 inch (0.95 cm), that is, a hole the diameter of a US 10-cent coin (Greenhall 1982). Openings of these dimensions are not uncommon in older wood frame structures where boards have shrunk, warped, or otherwise become loosened.

The discovery of one or two bats in a house is a frequent problem. If unused chimneys are selected for summer roosts, bats may fall or crawl through the open damper into the house. Sometimes bats may appear in a room, then disappear by crawling under a door to another room, hallway, or closet. They may also disappear behind curtains, wall hangings, bookcases, under beds, into waste baskets, and so forth. Locating and removing individual bats from living quarters can be laborious but is important. If all else fails, wait until dusk then the bat may appear once again as it attempts to find an exit.

Roosting sites. Bats use roosting niches that are indoors (human dwellings, out-buildings, livestock quarters, warehouses), semi-enclosed (loading docks, entrance foyers), partially sheltered (porches, carports, pavilions, highway underpasses, bridges), and open structural areas (window shutters, signs). Active bats in and on buildings can have several economic and aesthetic effects, often intertwined with public health issues (Frantz, 1988). Unusual roosting areas include wells, sewers, and graveyard crypts. Before considering control measures, verify that bats are actually the cause of the problem.

Rub marks. Surface areas on walls, under loose woodwork, between bricks, and around other bat entryways often have a smooth, polished appearance. The stained area is slightly sticky, may

contain a few bat hairs, and is yellow-brown to blackish brown in color. The smooth gloss of these rub marks is due to oils from fur and other bodily secretions mixed with dust, deposited there as many animals pass repeatedly for a long period over the same surface. Openings marked in this way have been used heavily by bats.

Noise. Disturbing sounds may be heard from vocalizations and grooming, scratching, crawling, or climbing in attics, under eaves, behind walls, and between floors. Bats become particularly noisy on hot days in attics, before leaving the roost at dusk, and upon returning at dawn. Note that rustling sounds in chimneys may be caused by birds or raccoons and scratching and thumping sounds in attics and behind walls may indicate rats, mice, or squirrels.

Guano and urine. Fecal pellets indicate the presence of animals and are found on attic floors, in wall recesses, and outside the house at its base. Fecal pellets along and inside walls may indicate the presence of mice, rats, or even roaches. Since most house bats north of Mexico are insectivorous, their droppings are easily distinguished from those of small rodents. Bat droppings tend to be segmented, elongated, and friable. When crushed, they become powdery and reveal shiny bits of undigested insect remains. In contrast, mice and rat droppings tend to taper, are unsegmented, are harder and more fibrous, and do not become powdery when crushed (unless extremely aged).

The droppings of some birds and lizards may occasionally be found along with those of bats. However, bat droppings never contain the white chalky material characteristic of the feces of these other animals.

Bat excrement produces an unpleasant odor as it decomposes in attics, wall spaces, and other voids. The pungent, musty, acrid odor can often be detected from outside a building containing a large or long-term colony. Similar odor problems occur when animals die in inaccessible locations. The odor also attracts arthropods, which may later invade other areas of a building.

Bat guano may provide a growth medium for microorganisms, some of which are pathogenic (histoplasmosis, for example) to humans. Guano accumulations may fill spaces between walls, floors, and ceilings. It may create a safety hazard on floors, step, and ladders, and may even collapse ceilings. Accumulations also result in the staining of ceilings, soffits, and siding, producing unsightly and unsanitary conditions.

Bats also urinate and defecate in flight, causing multiple spotting and staining on sides of buildings, windows, patio furniture, automobiles, and other objects at and near entry/exit holes or beneath roosts. Bat excrement may also contaminate stored food, commercial products, and work surfaces.

Bat urine readily crystallizes at room temperature. In warm conditions under roofs exposed to sun and on chimney walls, the urine evaporates so quickly it crystallizes in great accumulations. Boards and beams saturated with urine acquire a whitish, powder-like coating. With large numbers of bats, thick and hard stalactites and stalagmites of crystallized bat urine are occasionally formed.

Although the fresh urine of a single bat is relatively odorless, that of any moderate-sized colony is obvious, and the odor increases during damp weather. Over a long period of time, urine may cause mild wood deterioration (Frantz and Trimarchi 1984). As the urine saturates the surfaces of dry wood beams and crystallizes, the wood fibers expand and separate. These fibers then are torn loose by the bats crawling over such surfaces, resulting in wood fibers being mixed with guano accumulations underneath.

The close proximity of bat roosts to human living quarters can result in excreta, animal dander, fragments of arthropods, and various microorganisms entering air ducts as well as falling onto the unfortunate residents below. Such contaminants can result in airborne particles of public health significance (Frantz 1988).

Ectoparasites and other arthropods. Several arthropods (fungivores, detritivores, predators, and bat ectoparasites) are often associated with colonies of bats in buildings. Their diversity depends upon the number of bats, age, and quantity of excreta deposits, and season. Some arthropods contribute to the decomposition of guano and insect remnants but may also become a pest of stored goods and/or a nuisance within the living quarters. Bat ectoparasites (ticks, mites, fleas, and bugs) rarely attack humans or pets and quickly die in the absence of bats. Ectoparasites may become a nuisance, following exclusion of large numbers of bats from a well-established roost site. Fumigation with insecticides may be required.

Rabies. Bats are distinct from most vertebrate pests that inhabit human dwellings because of the potential for transmitting rabies. Bats are not asymptomatic carriers of rabies. After an incubation period of 2 weeks to 6 months, they become ill with the disease for as long as 10 days. During this latter period, a rabid bat's behavior is generally not normal. It may be found active during the daytime or on the ground incapable of flying. Most human exposures are the result of accidental or careless handling of grounded bats. Even less frequently, bats in this stage of illness may be involved in unprovoked attacks on people or pets (Brass, per.commun.; Trimarchi et al. 1979). It is during this stage the rabid bat is capable of transmitting the disease by biting another mammal. As the disease progresses, the bat becomes increasingly paralyzed and dies as a result of the infection. The virus in the carcass is reported to remain infectious until decomposition is well advanced.

Moles

Classification and legal status in Wyoming

Consult Wyoming Game & Fish for additional information.

Damage prevention and control methods

Exclusion – Generally not practical, except in very small, high-value areas where an above-ground and underground barrier (sheet metal, brick, wood, concrete) might restrict moles.

Cultural methods – Packing the soil destroys burrows, and sometimes moles if done in early morning or late evening. Reduction in soil moisture and food source removal by the use of insecticides discourages moles and generally results in lower populations.

Frightening – Ineffective.

Repellents – None are registered.

Toxicants – None are registered.

Fumigants – Aluminum phosphide. Gas cartridges.

Trapping (most effective control method). Out O' Sight® Trap. Bayonet trap or harpoon trap (Victor® Mole Trap). Easy-set mole eliminator. Cinch mole trap. Death-Klutch gopher trap.

Shooting – Not practical.

Damage and damage identification

Moles remove many damaging insects and grubs from lawns and gardens; however, their burrowing habits disfigure lawns and parks, destroy flower beds, tear up the roots of grasses, and create havoc in small garden plots.

It is important to properly identify the kind of animal causing damage before setting out to control the damage. Moles, voles, and pocket gophers are often found in the same location, and their damage is often confused. Control methods differ for the two species.

Moles leave volcano-shaped hills that are often made up of clods of soil. The mole hills are pushed up from the deep tunnels and may be 2 to 24 inches (5 to 60 cm) tall. The number of mole hills is not a measure of the number of moles in a given area. Surface tunnels or ridges are indicative of mole activity.

Pocket gopher mounds are generally kidney-shaped and made of finely sifted and cloddy soil. Generally, gophers leave larger mounds than moles. Gopher mounds are often built in a line, indicative of a deeper tunnel system.

Cottontail and jackrabbits

Classification and legal status in Wyoming

Cottontail Rabbits: Classified under Wyoming Game & Fish statutes as a "Small Game Animal," requiring a license to take cottontail rabbit. Contact the Wyoming Game & Fish Department for additional information.

Cottontails in rural areas spend their entire lives on a few acres; in urban areas, they may not venture far from a single backyard. Since jackrabbits reside in open rangelands, they may need to travel several miles from their dens to areas containing their preferred food.

Jackrabbits: Classified as predators and may be taken at any time in the entire state, no license required.

Economic importance

Rabbits can cause damage any time of the year. During spring, rabbits prefer young, growing vegetation, like tulips, garden vegetables (carrots, peas, beans, lettuce, beets), clover and turfgrass. In winter, rabbits gnaw through the tender bark of young trees and shrubs to eat the green, inner bark.

Prevention and Control of Damage

The presence of rabbits does not always result in economic damage to plants. Most 2- to 3-foot high shrubs can survive having most of the 1- and 2-year-old twigs removed. However, the desirable bud, flower, or fruit development may be impaired. The key to effective and economical rabbit control is being able to predict and intercept damage with methods that are relative to the predicted loss in value.

Exclusion – A 1-inch mesh fence of poultry netting (chicken wire) works well to protect gardens and perennial flower beds from rabbit damage. Bury the bottom edge of the fence about 4 inches below the ground to prevent rabbits, particularly jackrabbits, from digging under it. The buried portion should be flared outward from the protected area to better prevent digging.

Nurseries, tree farms, and other large areas can be protected with a double-strand electric fence or electrified plastic-net fence. Place electric wires at 3 to 4 inches and at 8 to 12 inches above the ground. Consult local regulations before installing electric fences.

To protect individual trees, place cylinders of black plastic drain tile, cut to length and slit down one side, around the trunks. Poultry netting supported by stakes can be placed around the trunks of young trees and shrubs. Shrub stems growing through the netting will become susceptible to damage by rabbits.

Habitat modification and plant selection – Reduce harborage for rabbits by removing brush piles and tall weeds, particularly those near new

windbreaks. Mow or spray to remove vegetation within 3 to 4 feet of recently planted trees and shrubs. Some trees and shrubs may need protection for as long as 10 years before they become mature enough to discourage rabbit feeding. Conversely, to guard against jackrabbit damage, encourage taller and denser vegetation.

Among herbaceous plants, preferred species within the rose and lily families are preferred. Horticulturists and others have compiled the following partial list of species most often eaten by rabbits.

Most often eaten:

- Annuals and Perennials
  - Aster
  - Coneflower
  - Hosta
  - Hybrid lily – Asiatic, Oriental
  - Impatiens – Young flowers on young plants
  - Pansy
  - Phlox
  - Rudbeckia
  - Tulip

- Shrubs and Young Trees
  - Acer spp. (maples)
  - Amelanchier spp. (serviceberry, juneberry)
  - Aronia spp. (black chokeberry, red chokeberry)
  - Carpinus spp. (ironwood)
  - Cornus spp. (dogwood)
  - Euonymus spp. (burning bush, wahoo)
  - Gleditsia spp. (honeylocust)
  - Hydrangea quercifolia (oakleaf hydrangea)
  - Tilia spp. (linden)
  - Malus spp., (apples, flowering crabapples)
  - Rubus spp. (raspberries and related brambles)
  - Sorbus spp. (mountain ash)
  - Spiraea spp. (spirea)
  - Pinus strobus, (Eastern white pine)
  - Populus spp. (willow, poplar, cottowood)
  - Prunus spp. (plum, cherry, almond, peach)
  - Rhus spp. (sumac)
  - Rosa spp. (rose)
  - Quercus spp. (oaks)

Plants with strong aromas and/or dense hair are typically avoided by rabbits. Some tree species rarely damaged by rabbits include black walnut, juniper, spruce, and fir. Be aware you cannot depend on rabbit-resistant plants if winter conditions are severe and food sources are limited.

Frightening devices – Scarecrows, owl, or snake effigies, spinning aluminum pie pans, and glass jars of water have been used to frighten rabbits. Commercial, water-driven scarecrows with motion detectors that spray water when movement occurs near them are available. Dogs confined by fences, tethers, or long leashes may help frighten rabbits away. In general, frightening devices may be limited in range to a few feet and provide short-lived protection because rabbits become used to them.

Repellents – Most rabbit repellents aren't registered for use on plants destined for human consumption. Repellents fall into two categories: taste and odor.

- **Taste repellents** attempt to make the plant less palatable for rabbits and are typically applied directly to the plant. Examples are those containing capsaicin or hot pepper extract (Deer-off™, Get Away™, Scoot™, Shotgun™). Their effectiveness tends to be short-lived and requires reapplication after

sprinkler irrigation, rain, or new growth occurs. The duration and effectiveness of some repellents can be extended by mixing them with an anti-transpirant, such as VaporGuard™ or Wiltpruf™.

- **Odor repellents** keep rabbits away from an area by fear or foul smell. A wide variety of active ingredients are used, including: ammonium or potassium salts of soaps (M-pede™; RoPel™), eggs (DeFence®), thiram (Spotrete™), zinc dimethyldithiocarbamate (Earl May® Rabbit Scat), predator urine (Shake-Away™), or garlic (Sweeny's® Deer & Rabbit Repellent). They are typically applied to soil in the perimeter area and/or on plant foliage to repel rabbits.

Check the label for proper application rate, method, and site before applying any repellent.

Because daffodils are poisonous to rabbits, plant them in place of tulips to ensure reliable, spring-blooming bulbs.

Toxicants – No toxicants are registered for rabbits.

Trapping or shooting – Both trapping and shooting can temporarily reduce local rabbit populations.

Integrated pest management – A combination of methods usually best controls rabbit damage, and the methods selected depend on the situation. For a windbreak in a rural area, the best combination of methods may be to plant older, less-browsed species of trees, to add a different species each year, and then apply a commercial repellent with a spreader-sticker. A spreader-sticker is a product added to the repellent to increase duration and effectiveness of the repellent. Anti-transpirants are excellent spreader-stickers. Ivory Liquid (add 1 teaspoon per gallon of mixed repellent) also acts as a spreader-sticker. Apply repellents several times during the winter during the first few years of tree growth.

For the gardener, the best approach may be to build a rabbit-proof fence to guard young sprouting plants. For perennial flower beds, the best approach may be to use motion-activated water sprays or a vigilant dog to scare rabbits. Homeowners might also resort to a low, aesthetic plastic-mesh fence as flower blossoms emerge.

For young trees and shrubs in a backyard, methods of control include low fences around clusters of plants, individual tree guards, or tree guards incorporated with chemical repellents.

Birds

Federal acts and bills related to bird damage control

The following federal acts and bills should be referenced prior to the implementation of any bird damage control program:

- USFWS Title 50, Code of Federal Regulations, Part 21, *Migratory Bird Permits*. Revised 9/14/89. 37 pp.
- *Migratory Bird Treaty Act*. (16 USC 703-711). Sec. 703: Taking, killing, or possessing migratory birds unlawful. Sec. 704: Determination as to when and how migratory birds may be taken, killed, or possessed.
- *Endangered Species Act of 1973*.(As amended by P.L. 94-325, June 30, 1976; P.L. 94359, July 12, 1976;
- P.L. 95-212, December 19, 1977; P.L. 95-632, November 10, 1978; and P.L. 96-159, December 28, 1979)
- FWS/LE Law 8, Revised 6/25/84. 36 pp.
- USFWS SO CFR Part 17. *Endangered and Threatened Wildlife and Plants*. FWS/LE Enf 4-Reg-17. (Revised 1/1/89). 69 pp.

- USFWS SO CFR Part 10. *General Provisions*. FWS/LE Enf 4-Reg-10. 15 pp.

Introduction

Birds, especially migratory birds, provide enjoyment and recreation for many and greatly enhance the quality of our lives. These colorful components of natural ecosystems are often studied, viewed, photographed, hunted, and otherwise enjoyed.

Unfortunately, bird activities sometimes conflict with human interests. Birds may predate agricultural crops, create health hazards, and compete for limited resources with other more favorable wildlife species. The management of bird populations or the manipulation of bird habitats to minimize such conflicts is an important aspect of wildlife management. Problems associated with large concentrations of birds can often be reduced through techniques of dispersal or relocation of such concentrations.

Dispersal techniques

Two general approaches to dispersing bird concentrations will be discussed in this section:

1. Environmental or habitat modifications that either exclude or repel birds or make an area less attractive, and

2. The use of frightening devices.

Habitat modifications

Habitat modifications include a myriad of activities that can make habitats less attractive to birds. Thinning or pruning of vegetation to remove protective cover can discourage birds from roosting. Most deciduous trees can withstand removal of up to one-third of their limbs and leaf surface without causing problems. Adverse effects are minimized during the dormant season. Thinning often enhances commercial timber production. Dramatic changes are not always necessary; however, sometimes subtle changes are effective in making an area unattractive to birds and causing bird concentrations to disperse or relocate to a place where they will not cause problems. Bird dispersal resulting from habitat modifications usually produces a more lasting effect than other methods and is less expensive in the long run.

Frightening devices

The use of frightening devices can be extremely effective in manipulating bird concentrations. The keys to a successful operation are timing, persistence, organization, and diversity. Useful frightening devices include broadcast alarm and distress calls, pyrotechnics, exploders, and other miscellaneous auditory and visual frightening devices. No single technique can be depended upon to solve the problem. Numerous techniques must be integrated into a frightening program.

Electronic devices. Recorded alarm and distress calls of birds are very effective in frightening many species of birds and are useful in both rural and urban situations. The calls are amplified and broadcast. Periodically move the broadcast units to enhance the effectiveness of such calls. If stationary units must be used, increase the volume to achieve greater responses. Electronically produced sounds such as Bird-X, AV-ALARM, or other sound generators will frighten birds but are usually not as effective as amplified recorded bird calls. This should not discourage their use, however. The greater the variety and disruptiveness of sounds, the more effective the method will be as a repellent.

Pyrotechnics. Pyrotechnic devices have long been employed in bird frightening programs. Safe and cautious use of these devices should be emphasized. The 12-gauge exploding shells (shell crackers) are very effective. They are useful in a

variety of situations because of their long range. Fire shell crackers from the hip (to protect the eyes) from single-barrel, open bore shotguns and check the barrel after each round to be sure no obstruction remains. Some types of 12-gauge exploding shells are corrosive, requiring that the gun be cleaned after each use to prevent rusting. Though more expensive, smokeless powder shells will reduce maintenance.

Pyrotechnics should be stored, transported, and used in conformance with laws, regulations, and ordinances.

Several devices are fired from 15-mm or 17-mm pistols are used to frighten birds. For the most part, they cover a shorter range than the 12-gauge devices. They are known by many brand names but are usually called "bangers" if they explode, and "screamers" if they do not. Both types should be used together for optimal results. Noises up in the air near the birds are much more effective than those on the ground. The use of a shotgun with live ammunition is one of the most available but least effective means of frightening birds. Shotgun fire, however, may increase the effectiveness of other frightening devices. Live shotgun shells should not be included in a frightening program unless there is certainty no birds will be crippled and later serve as live decoys. Also, live ammunition creates safety problems in urban areas and is often illegal. Rifles (.22 caliber) fired from elevated locations are effective where they can be used safely.

Rope firecrackers are an inexpensive way to create unattended sound. The fuses of large firecrackers (known as fuse-rope salutes or agricultural explosive devices) are inserted through 5/16- or 3/8-inch (8-or 9.5-mm) cotton rope. As the rope burns, the fuses are ignited. The time between explosions can be regulated by the spacing of the firecrackers in the rope. The ability to vary the intervals is an asset since birds can become accustomed to explosions at regular intervals. Burning speed of the rope can be increased by soaking it overnight in a saltpeter solution of 3 ounces per quart (85 g/I) of water and allowing it to dry. Since the burning speed of the rope is also affected by humidity and wind speed, it is wise to time the burning of a test section of the rope beforehand. Because of the fire hazard associated with this device, it is a good idea to suspend it over a barrel, or make other fire prevention provisions.

Exploders. Automatic LP gas exploders are another source of unattended sound. It is important to elevate these devices above the level of the surrounding vegetation. Mobility is an asset and will increase their effectiveness, as will changing the interval between explosions.

Other frightening materials. Other frightening devices include chemicals such as Avitrol® and a great variety of whirling novelties and flashing lights, as well as innovative techniques such as smoke, water sprays, devices to shake roosting vegetation, tethered balloons, hawk silhouettes, and others. While all of these, even the traditionally used scarecrow (human effigies), can be useful in specific situations, they are only supplementary to a basic, well-organized bird frightening program. Combining different devices such as human effigies (visual) and exploders (auditory) produce better results than either device used separately.

Bird dispersal operations

Again, the keys to successful bird dispersal are timing, persistence, organization, and diversity. The timing of a frightening program is critical. Birds are much more apt to leave a roost site they have occupied for a brief period of time than one they have used for many nights. Prompt action greatly reduces the time and effort required to successfully relocate the birds. As restlessness associated with migration increases, birds will become more responsive to frightening devices

and less effort is required to move them. When migration is imminent, the birds' natural instincts will augment dispersal activities.

Whether dealing with rural or urban concentrations, someone should be in charge of the entire operation and carefully organize all dispersal activities. The more diverse the techniques and mobility of the operation, the more effective it will be. Once initiated, the program must be continued each day until success is achieved. The recommended procedure for dealing with an urban blackbird/starling roost is given below. Many of these principles apply to other bird problems as well.

Urban roost relocation procedure

Willing and effective cooperation among numerous agencies, organizations, and individuals is necessary to undertake a successful bird frightening program in an urban area. Different levels of government have different legal responsibilities for this work. The best approach is a cooperative effort with the most knowledgeable and interested individual coordinating the program.

Public relations efforts should precede an urban bird-frightening effort. Federal, state, and/or local officials should explain to the public the reasons for attempting to relocate the birds. Announcements should continue during the operation and a final report should be made through mass media. These public relations efforts will facilitate public understanding and support of the program. They will also provide an opportunity to solicit citizen involvement. This help will be needed when the birds scatter all over town after one or two nights of frightening. Traffic control in the vicinity of the roost is essential. Consequently, police involvement and that of other city officials is necessary.

The public should be informed that the birds may move to a site less suitable than the one they left and that, if disturbed in the new roost site, they are likely to return to the original site. Sometimes, it is wise to provide protection for a new, acceptable roost site once selected by the birds. One can predict with some certainty blackbirds and starlings will move to one of their primary staging areas if that area contains sufficient roosting habitat. Fortunately, if the birds occupy roost sites where they still create problems, a continuation of the frightening program can more easily cause them to move to yet another site. With each successive move, the birds become more and more responsive to the frightening devices. Habituation is uncommon in properly conducted programs, especially if sufficient diversity of techniques and mobility of equipment is maintained.

Birds are much easier to frighten while they are flying. Once they have perched, a measure of security is provided by the protective vegetation and they become more difficult to frighten. Dispersal activities should end when birds stop moving after sunset. A continuation of frightening will only condition birds to the sounds and reduce responses in the future. With blackbird/starling roosts, all equipment and personnel should be prepared to begin frightening at least 1-½ hours before dark. The frightening program should commence as soon as the first birds are viewed. Early morning frightening is also effective. This requires only about ½ hour and should begin when the first bird movement occurs within the roost, which may be prior to daylight. This movement precedes normal roost exodus time by about ½ hour.

On the first night of a bird-roost frightening program, routes for mobile units should be planned and shooters of exploding shells should be placed so as to build a wall of sound around the roost site and saturate the roost with sound. Shooters should

be cautioned to ration their ammunition so they do not run out before dark. The response of the birds is predictable. As flight lines attempt to enter the roost site in late afternoon, they will be repelled by the frightening effort. A wall of birds about 1/4 mile (0.4 km) from the roost site will mill and circle almost until dark. At that time, virtually all of the birds will come into the roost site, no matter what frightening methods are employed.

By the second and third nights of the frightening program, flexibility will be necessary in adapting dispersal techniques to the birds' behavior. As larger numbers of birds are repelled from the original roost site, they will attempt to establish numerous temporary roosts. Mobile units armed with pyrotechnics and broadcast alarm and distress calls should be prepared to move to these areas, disturb the birds, and send them out of town. Frightening efforts by residents should be encouraged through mass media. Efforts must continue each morning and evening in spite of weather conditions. Complete success is usually achieved by the fourth or fifth night.

A bird-frightening program can be used to deal with an immediate bird problem, but it can also be an educational tool that prepares individuals or municipalities to deal with future problems in an effective manner. Those interested in resolving the problem should bear part of the financial burden of the bird-frightening program. This requirement will immediately eliminate imagined bird problems. When a city or individual is willing to pay a part of the bill for a bird frightening operation, it is obvious a genuine problem exists.

Summary

Large concentrations of birds sometimes conflict with human interests. Birds can be easily dispersed by means of habitat manipulation or various auditory and visual frightening devices. Timing, persistence, organization, and diversity are the keys to effective bird dispersal programs. The proper use of frightening devices can effectively deal with potential health and/or safety hazards, depredation, and other nuisances caused by birds.

Pigeons (rock doves)

Classification and legal status in Wyoming

Classified under the *Wyoming Game & Fish Commission Chapter 52: Non-game Wildlife Regulation* as non-game wildlife and may be taken as provided for in the appropriate federal laws. Feral pigeons are not protected by federal law, but may be protected within municipalities.

See the *Wyoming Game & Fish Commission Chapter 52: Non-game Wildlife Regulation, Section 6. Birds* at https://wgfd.wyo.gov/Regulations/Regulation-PDFs/Regulations_Ch52.pdf for additional information.

Damage prevention and control methods

Exclusion – Screen eaves, vents, windows, doors, and other openings with 1/4-inch (0.6-cm) mesh hardware cloth. Change angle of roosting ledge to 45° or more. Install porcupine wires (Cat Claw™, Nixalite™), ECOPIC™, or Bird Barrier™ to roosting sites. Construct parallel or grid-wire (line) systems.

Habitat modification – Eliminate food supply. Discourage people from feeding pigeons in public areas. Clean up spilled grain around elevators, feed mills, and rail car clean-out areas. Eliminate standing water.

Frightening – Visual and auditory frightening devices are usually not effective over long periods of time. Avitrol® (a chemical frightening agent).

Repellents – **tactile**: Various nontoxic, sticky substances (4-The Birds™, Hotfoot™, Tanglefoot™, Roost No More™, and BirdProof'™).

Odor: Naphthalene flakes.

Toxicants – oral: DRC-1339, used under supervision of USDA-APHIS-Wildlife Services only. Avitrol®, depends on bait concentration.

Fumigants – Generally not practical.

Trapping – Several live trap designs are effective.

Shooting – Where legal.

Other control methods – Nest removal.

Damage and damage identification

Pigeon droppings deface and accelerate the deterioration of buildings and increase the cost of maintenance. Large amounts of droppings may kill vegetation and produce an objectionable odor. Pigeon manure deposited on park benches, statues, cars, and unwary pedestrians is aesthetically displeasing. Around grain handling facilities, pigeons consume and contaminate large quantities of food destined for human or livestock consumption.

Pigeons may carry and spread diseases to people and livestock through their droppings. They are known to carry or transmit pigeon ornithosis, encephalitis, Newcastle disease, cryptococcosis, toxoplasmosis, salmonella food poisoning, and several other diseases. Additionally, under the right conditions, pigeon manure may harbor airborne spores of the causal agent of histoplasmosis, a systemic fungus disease that can infect humans.

The ectoparasites of pigeons include various species of fleas, lice, mites, ticks, and other biting insects, some of which readily bite people. Some insects that inhabit the nests of pigeons are also fabric pests and/or pantry pests. The northern fowl mite found on pigeons is an important poultry pest.

Pigeons around airports can also be a threat to human safety because of potential bird-aircraft collisions and are considered a medium priority hazard to jet aircraft by the US Air Force.

House or English sparrows

Classification and legal status in Wyoming

House or English Sparrows are classified under yoming statutes as predacious birds allowing for control of these birds in the entire state at any time during the calendar year. In addition, it is also legal to destroy the nest and eggs of predacious birds. Federal law does not protect House or English sparrows because they are an introduced species. Many listings for various other species of sparrows are classified under the *Wyoming Game & Fish Chapter 52 Regulations* as non-game wildlife and may or may not be protected under federal law.

See the *Wyoming Game & Fish Commission Chapter 52: Non-game Wildlife Regulation, Section 6. Birds* at https://wgfd.wyo.gov/Regulations/Regulation-PDFs/Regulations_Ch52.pdf for additional information.

Damage prevention and control methods

Exclusion – Block entrances larger than 3/4 inch. Design new buildings or alter old ones to eliminate roosting and nesting places. Install plastic bird netting or overhead lines to protect high-value crops.

Cultural methods – Remove roosting sites. Plant bird resistant varieties.

Frightening – Fireworks, alarm calls, exploders. Scarecrows, motorized hawks, balloons, kites. 4-Aminopyridine (Avitrol®).

Repellents – Capsicum. Polybutenes. Sharp metal projections (Nixalite® and Cat Claw®).

Trapping – Funnel, automatic, and triggered traps. Mist nets.

Shooting – Air guns and small firearms. Dust shot and BB caps.

Other methods – Nest destruction. Predators.

Damage and damage identification

House sparrows consume grains in fields and in storage. They do not move great distances into grain fields, preferring to stay close to the shelter of hedgerows. Localized damage can be considerable since sparrows often feed in large numbers over a small area. Sparrows damage crops by pecking seeds, seedlings, buds, flowers, vegetables, and maturing fruits. They interfere with the production of livestock, particularly poultry, by consuming and contaminating feed. Because they live in such close association with humans, they are a factor in dissemination of diseases (chlamydiosis, coccidiosis, erysipeloid, Newcastle's, parathypoid, pullorum, salmonellosis, transmissible gastroenteritis, tuberculosis, various encephalitis viruses, vibriosis, and yersinosis), internal parasites (acariasis, schistosomiasis, taeniasis, toxoplasmosis, and trichomoniasis), and household pests (bed bugs, carpet beetles, clothes moths, fleas, lice, mites, and ticks).

In grain storage facilities, fecal contamination probably results in as much monetary loss as does the actual consumption of grain. House sparrow droppings and feathers create janitorial problems as well as hazardous, unsanitary, and odoriferous situations inside and outside of buildings and sidewalks under roosting areas. Damage can also be caused by the pecking of rigid foam insulation inside buildings. The bulky, flammable nests of house sparrows are a potential fire hazard. The chattering of the flock on a roost is an annoyance to nearby human residents.

Nestlings are primarily fed insects, some of which are beneficial and some harmful to humans. Adult house sparrows compete with native, insectivorous birds. Martins and bluebirds, in particular, have been crowded out by sparrows that drive them away and destroy their eggs and young. House sparrows generally compete with native species for favored nest sites.

European starling

Classification and legal status in Wyoming

Starlings are classified under Wyoming statutes as "predacious birds" allowing for control of these birds in the entire state at any time during the calendar year. In addition, it is also legal to destroy the nest and eggs of predacious birds. Federal law does not afford protection to starlings.

Damage prevention and control methods

Exclusion – Close all openings larger than 1 inch. Place covering at 45° angle on ledges. Porcupine wires on ledges or rafters. Netting to prevent roosting on building beams or to protect fruit crops. PVC or rubber strips to cover door openings; netting where frequent access is not needed.

Cultural methods and habitat modification – Reduce availability of food and water at livestock facilities: remove spilled grain and standing water; use bird proof feeders and storage facilities; feed livestock in open sheds; where appropriate, feed in late afternoon or at night; lower water level in waterers. Modify roost sites by closing buildings; exclude from roost areas with netting (for example, under roof beams); modify specific perch sites. For tree roosts, prune branches of specific trees or thin trees from groves.

Frightening – Frightening devices include recorded distress or alarm calls, various sound-producing devices, chemical frightening agents (Avitrol®), lights, and bright objects. Use with fruit crops and starling roosts. Also useful at livestock facilities in warm climates and at facilities located near major roosts.

Repellents – Soft sticky materials (polybutenes) discourage roosting on ledges. Starling repellent is under development: methyl anthranilate (grape flavoring). If successful, it may be useful for protecting fruit and as a livestock feed additive.

Toxicants – Starlicide (USDA Wildlife Service only licensed applicant): toxic bait for use around livestock facilities and, in some situations, at roost sites. Toxic perches: can be useful for certain industrial and other structural roost situations.

Fumigants – None are registered.

Trapping – Nest-box traps, for use during nesting season. Decoy traps may be useful around orchards or livestock facilities. Proper care for trap and decoy birds is necessary.

Shooting – Helpful as a dispersal or frightening technique. Not effective in reducing overall starling numbers.

Damage and damage identification

Starlings are frequently considered pests because of the problems they cause, especially at livestock facilities and near urban roosts. Starlings may selectively eat the high protein supplements often added to livestock rations.

Starlings may also be responsible for transferring disease from one livestock facility to another. This is of particular concern to swine producers. Tests have shown that the transmissible gastroenteritis virus (TGE) can pass through the digestive tract of a starling and be infectious in the starling feces. Researchers, however, have also found healthy swine in lots with infected starlings. This indicates that even infected starlings may not always transmit the disease, especially if starling interaction with pigs is minimized. TGE may also be transmitted on boots or vehicles, by stray animals, or by infected swine added to the herd.

Although starlings may be involved in the spread of other livestock diseases, their role in transmission of these diseases is not yet understood. Starlings can cause other damage by consuming cultivated fruits such as grapes, peaches, blueberries, strawberries, figs, apples, and cherries. They were recently found to damage ripening (milk stage) com, a problem primarily associated with blackbirds. In some areas, starlings pull sprouting grains, particularly winter wheat, and eat the planted seed. Starlings may damage turf on golf courses as they probe for grubs, but the frequency and extent of such damage is not well documented.

The growing urbanization of wintering starling flocks seeking warmth and shelter for roosting may have serious consequences. Large roosts that occur in buildings, industrial structures, or, along with blackbird species, in trees near homes, are a problem in both rural and urban sites because of health concerns, filth, noise, and odor. In addition, slippery accumulations of droppings pose safety hazards at industrial structures, and the acidity of droppings is corrosive.

Starling and blackbird roosts near airports pose an aircraft safety hazard because of the potential for birds to be ingested into jet engines, resulting in aircraft damage or loss and, at times, in human injuries. In 1960, an Electra aircraft in Boston collided with a flock of starlings soon after takeoff, resulting in a crash landing and 62 fatalities. Although only about 6% of bird-aircraft strikes are associated with starlings or blackbirds, these species represent a substantial management challenge at airports.

One of the more serious health concerns is the fungal respiratory disease histoplasmosis. The fungus *Histoplasma capsulatum* may grow in the soils beneath bird roosts, and spores become airborne in dry weather, particularly when the site is disturbed. Although most cases of histoplasmosis

are mild or even unnoticed, this disease can, in rare cases, cause blindness and/or death. Individuals who are weakened by other health conditions or who do not have endemic immunity are at greater risk from histoplasmosis.

Starlings also compete with native cavity-nesting birds such as bluebirds, flickers, and other woodpeckers, purple martins, and wood ducks for nest sites. One report showed that, where nest cavities were limited, starlings had severe impacts on local populations of native cavity-nesting species. One author has speculated that competition with starlings may cause shifts in red-bellied woodpecker (*Melanerpes carolinus*) nesting from urban habitats to rural forested areas where starling competition is less.

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Section 11 - Appendices

Appendix A. Wyoming Statute 23-1-101: Definitions of wildlife.

(a) As used in this act:

(i) "Big game animal" means antelope, bighorn sheep, deer, elk, moose or mountain goat;

(ii) "Exotic species" means any wild animals, including amphibians, reptiles, mollusks, crustaceans or birds not found in a wild, free or unconfined status in Wyoming;

(iii) "Furbearing animal" means badger, beaver, bobcat, marten, mink, muskrat or weasel;

(iv) "Game bird" means grouse, partridge, pheasant, ptarmigan, quail, wild turkey and migratory game birds;

(v) "Game fish" means bass, catfish, crappie, grayling, burbot, northern pike, perch, salmon, sauger, sunfish, trout, walleye or whitefish unless the species is otherwise designated by the commission in specific waters through rule and regulation;

(vi) "Migratory game bird" means all migratory game birds defined and protected under federal law;

(vii) "Predacious bird" means English sparrow and starling;

(viii) "Predatory animal" means:

(A) Coyote, jackrabbit, porcupine, raccoon, red fox, skunk or stray cat; and

(B) Until the date gray wolves are removed from the list of experimental nonessential population, endangered species or threatened species in Wyoming as provided by W.S. 23-1-108, "predatory animal" includes wolves. After that date, "predatory animal" shall include any gray wolf within areas of the state where the state of Wyoming has jurisdiction for wildlife management, but not within an area of the state in which the gray wolf is:

(I) Designated as a trophy game animal under subdivision (xii)(B)(I) or (II) of this subsection.

(II) Repealed by Laws 2012, ch. 25, 2.

(ix) "Protected animal" means black-footed ferret, fisher, lynx, otter, pika or wolverine;

(x) "Protected bird" means migratory birds as defined and protected under federal law;

(xi) "Small game animal" means cottontail rabbit or snowshoe hare, and fox, grey and red squirrels;

(xii) "Trophy game animal" means:

(A) Black bear, grizzly bear or mountain lion; and

(B) From and after the date gray wolves are removed from the list of experimental nonessential population, endangered

species or threatened species in Wyoming as provided by W.S. 23-1-108:

(I) "Trophy game animal" shall include any gray wolf within those tracts of land within the following described area: northwest Wyoming beginning at the junction of Wyoming Highway 120 and the Wyoming-Montana state line; southerly along Wyoming Highway 120 to the Greybull River; southwesterly up said river to the Wood River; southwesterly up said river to the Shoshone National Forest boundary; southerly along said boundary to the Wind River Indian Reservation boundary; westerly, then southerly along said boundary to the Continental Divide; southeasterly along said divide to the Middle Fork of Boulder Creek; westerly down said creek to Boulder Creek; westerly down said creek to the Bridger-Teton National Forest boundary; northwesterly along said boundary to its intersection with U.S. Highway 189-191; northwesterly along said highway to the intersection with U.S. Highway 26-89-191; northerly along said highway to Wyoming Highway 22 in the town of Jackson; westerly along said highway to the Wyoming-Idaho state line; north along said state line to the southern boundary of Yellowstone National Park; east and north along said boundary to the Wyoming-Montana state line; then east along said state line to Wyoming Highway 120;

(II) "Trophy game animal" shall include any gray wolf located, from October 15 through the last day of February in the subsequent year, within the following described area: beginning at the boundary described in subdivision (B)(I) of this paragraph, where the Bridger-Teton National Forest boundary intersects U.S. Highway 189-191 at Hoback Rim; westerly and then southerly along said forest boundary to its intersection with USFS Road 10125 (McDougal Gap Road); westerly along said road to USFS Road 10138 (Grey's River Road); southerly along said road to Sheep Creek; westerly down said creek to Grey's River; southwesterly up said river to Bear Creek; southwesterly up said creek to the hydrographic divide between Bear Creek and Willow Creek; west from said divide to USFS Road 10080 (Willow Creek Road); northwesterly along said road to Lincoln County Road 123; southerly along said road to USFS Road 10081 (Grover Park Road); southerly then westerly along said road to Lincoln County Road 172; westerly along said road to the junction with Wyoming Highway 237; westerly along said highway to Wyoming Highway 238; southerly along said highway to Lincoln County Road 134; westerly along said road to the Wyoming-Idaho state line; north along said state line to Wyoming Highway 22 where the boundary described in this subdivision will rejoin the boundary described in subdivision (B)(I) of this paragraph.

(xiii) "Wildlife" means all wild mammals, birds, fish, amphibians, reptiles, crustaceans and mollusks, and wild bison designated by the Wyoming game and fish commission and the Wyoming livestock board within Wyoming.

Appendix B: Descriptions of vertebrate pesticides[1]

ALUMINUM PHOSPHIDE

Chemical name
Aluminum phosphide

Trade names
Phostoxin®, Delta®, Rotox®, Gastoxin®, PhosTek®

Use
A fumigant for certain burrowing rodents and moles, it is also used to control insects in stored products.

History
Aluminum phosphide was introduced as a fumigant for stored products in the early 1930s by Dr. Werner Freyberg, Chemische Fabrik. It being formulated into molded tablets or pellets is a rather recent development. This material was registered for mammal control in 1981, although the compound has been used for this purpose in some other countries for a much longer time.

Properties
Aluminum phosphide form dark gray or yellowish crystals. For mammal control, it is formulated into 3-g tablets or 600-mg pellets. A typical formulation contains 56% to 57% active ingredient plus 26% ammonium carbamate, 3% paraffin, and 14% to 15% aluminum oxide. Aluminum phosphide reacts with atmospheric moisture to release phosphine (PH_3) gas, the active ingredient. Phosphine is colorless and has a slight carbide-like odor. At some concentrations it is flammable or explosive. In formulations that contain ammonium carbamate, this compound hydrolyzes to release C02 and ammonia. Aluminum phosphide should be stored in its original metal container until used.

Toxicity
Phosphine gas is a potent mammalian toxicant. At a concentration of 1,000 ppm, it is lethal to humans after a few breaths. At 400 ppm, it is lethal in 30 minutesa. It is immediately dangerous to life or health at 200 ppmb. At a concentration of 1 ppm, it can be lethal to some rats within 24 hoursc. [aSpencer 1981,bBerg 1983,cLewis 1979].

ANTICOAGULANTS

Chemical name
See below.

Trade names
See below.

Use
Anticoagulants are a group of widely used rodenticides; an estimated 95% of all commensal rodent control is conducted with anticoagulants. They are separated into two functional groups, first-generation and second-generation anticoagulants. Those of the second generation have the ability to control warfarin-resistant rats and house mice, and they are also considered single-feeding anticoagulants. First-generation anticoagulants are also used for the control of certain field rodents, including ground squirrels, pocket gophers, and voles. Some field rodent and rabbit registrations are specific to local

1 Compiled by Robert M. Timm. *Description of Active Ingredients. Prevention and Control of Wildlife Damage - 1994*. Cooperative Extension Division, University of Nebraska, Lincoln. Pages G-23 - G-60.

needs of various states, and they are extensively used to protect agricultural crops and forest trees. At present, none of the second-generation anticoagulants are registered for control of field rodents or rabbits.

History

Warfarin, the first anticoagulant rodenticide, had its beginning in 1943 when Dr. Karl Paul Link and his coworkers of the Biochemistry Department, University of Wisconsin, were attempting to determine the cause of "Sweet Clover Disease" in cattle. Moldy sweet clover hay was found to contain a powerful anticoagulant. The first result of the research was the development of dicumarol, which is used to prevent the formation of blood clots in humans. Dr. Link's staff continued the line of research and synthesized warfarin (Compound 42), which is a much more potent anticoagulant than dicumarol. In April 1948, J.A. O'Connor described the first successful use of an anticoagulant compound, dicoumarin, for controlling rats under field conditions.

Pindone, coumafuryl, and valone soon followed warfarin on the market, with diphacinone and chlorophacinone marketed somewhat later. The last two compounds were, by far, more toxic than the earlier materials; hence, the concentration in baits was reduced by some fivefold. Of the earlier anticoagulants, coumafuryl (Fumarin®) and valone (PMPR) are no longer marketed.

The second-generation anticoagulants, bromadiolone and brodifacoum, were developed some years later specifically to combat warfarin resistance. The newest of the second-generation anticoagulants, difethialone, has been in development for a number of years and is nearing registration in the United States.

Characteristics

Anticoagulants used as rodenticides are chemically separated into two general groups: the hydroxycoumarins (such as warfarin) and the indandiones (pindone, valone, diphacinone, and chlorophacinone). The second-generation materials (bromadiolone, brodifacoum, and difethialone) are closely akin to the hydroxycoumarin group.

All first-generation anticoagulants, also known as multiple-dose rodenticides, relied on their cumulative toxic effect. They were substantially more toxic if consumed in small doses over a period of several days than if consumed in one large amount (for instance, the 5-day cumulative LD50 is substantially lower than the acute LD50). The baits are formulated so rodents have to feed a minimum of 3 to 5 days before a lethal dose is achieved; death follows after several additional days.

To achieve this multiple feeding, the bait must be made available on a continuous basis until the desired control is reached. Prior to the development of anticoagulants, all rodenticides were acute (single dose) materials; hence, the introduction of warfarin required a whole new concept of bait application. Bait trays or bait boxes had to be designed to hold substantial amounts of baits and strategically located so all rodents in an area had access to ample bait for repeated feedings until death.

Bromadiolone, brodifacoum, and difethialone, all second-generation materials, are much more potent, with relatively low acute LD50s for rodents, making them effective for the control of warfarin-resistant rats and mice. When formulated at their current concentrations, they have the ability to kill a high percentage of the rodent population in a single feeding, hence their designation as a single-feeding anticoagulants. The effects of these compounds are also cumulative and will result in death after several feedings of even small amounts.

As in the case of all anticoagulants, death is delayed for several days following the ingestion of a lethal dose. This delayed action has a decided safety advantage because it provides time to administer the antidote and save pets, livestock, and of course, people who may have accidentally ingested the bait. Vitamin K1 is the antidote for anticoagulants and, if administered soon enough after intake, can reverse the action of the anticoagulant. Diphacinone, chlorophacinone, and all of the second-generation materials persist in animals and will often require prolonged veterinary or medical treatment.

The slow action of anticoagulant baits has another great advantage in that the target animal is unable to associate its illness with the bait eaten. Bait shyness or toxicant shyness does not occur.

More of the anticoagulant baits used today are commercial ready-to-use baits; very few individuals prepare their own baits from concentrates as they commonly did 20 years ago. Ready-to-use bait increases the cost of rodent control but avoids past problems of incorrect bait concentrations and poor bait formulation, which often led to poor control.

Some anticoagulants are available as tracking powders and others as sodium salts that are water-soluble, allowing their use as water baits.

In the early 1960s, the practice began of mixing anticoagulant grain baits with melted paraffin and molding it into cans or cartons to form block-type paraffin baits. These became commercially available a few years later and were promoted for sewer rat control or for other rodent-infested areas with moisture and high humidity. Now there are molded or extruded paraffin-type baits made from most of the current anticoagulants. Block-type baits have several advantages: they confine multiple feedings of bait into one unit; if permitted by the label, they can be placed in strategic locations where bait boxes with loose grain or pelleted bait would be difficult to place; and bait deterioration from insects and molds is retarded.

Anticoagulant resistance

The resistance of rats to warfarin was first noted in Scotland in 1958, some years following its repeated use. Shortly thereafter, anticoagulant resistance was identified in rats and house mice in other European countries. It was identified somewhat later in the United States, where it has since been demonstrated in many regions and major cities. All three species of commensal rodents are implicated. Resistance arises from genetic mutation or recombination, sometimes of a single gene, and levels of resistance vary among individual animals. A high degree of resistance will render control with warfarin virtually impossible. Rats and mice that are resistant to warfarin also show some resistance to all first generation anticoagulants. Where resistance is apparent, switch to a second generation anticoagulant or to another rodenticide with a different mode of action.

Whether resistance will eventually extend to all second-generation anticoagulants remains to be seen; some isolated instances of resistance to bromadiolone have been reported.

Pharmacology

All anticoagulants have two actions; they reduce the clotting ability of the blood and cause damage to the capillaries (tiny blood vessels). The rate of blood clotting gradually decreases and blood loss leads to an apparently painless death.

Animals killed by anticoagulants often have no color in the skin, muscles, or viscera. Evidence of hemorrhage may be found in any part of the body, but usually only in one location. The blood that remains in the heart and vessels is very thin and forms a poor clot or no clot. The animal exhibits increasing weakness though appetite and body weight are not specifically affected. Hematoma (a

local swelling or tumor filled with blood) formation beneath the skin is often more common than free hemorrhage.

Repeated daily doses of the anticoagulants greatly increases their effective toxicity. Feeding does not have to be on consecutive days, but several feedings should occur within a 10-day interval with no longer than 48 hours between feedings. Plenty of bait must be made available at all times to achieve adequate control.

Toxicity

The susceptibility to anticoagulants varies considerably among species and among anticoagulants. For this reason, generalizing often leads to erroneous conclusions. Since all anticoagulants are cumulative in toxicity, they have the ability to kill any warm-blooded animal if consumed in sufficient amounts for a long enough period. Materials with the highest toxicity and the longest half-lives present the greatest lethal potential with fewer feedings.

Compounds with the longest half-lives need not be consumed daily; a lapse of several days between feedings will not alter the outcome.

Many drugs increase the effects of anticoagulants; among these are the broad-spectrum antibiotics, the barbiturates, and the salicylates. Observations of rats treated with chlordane and DDT show the opposite effect; they stimulate the metabolism of warfarin, thus decreasing its toxicity. Susceptibility to anticoagulants seems to increase with age.

Anticoagulants tend to accumulate in the liver and gradually dissipate over a period of time, depending on the initial accumulations and successive doses. Where large doses of anticoagulants are ingested, substantial amounts may pass through the animal unassimilated.

Precautions should be taken to prevent children, pets, and livestock from gaining access directly to anticoagulant bait. Baits should be placed in areas inaccessible to nontarget animals or in tamper-resistant bait stations. A single substantial ingestion of diphacinone, chlorophacinone, or any of the second-generation anticoagulants baits may, for example, place a dog in jeopardy, requiring veterinary attention. When used according to label instructions, there is little potential hazard to nontarget species.

Secondary hazard associated with predator or scavenger animals consuming rodent carcasses is minimal in commensal rodent control. It can be of somewhat greater concern when anticoagulants are used for field rodent control. Occasionally a farm dog is known to consume fresh vole or ground squirrel carcasses over several days and begin to show signs of anticoagulant intoxication. With quick and proper veterinary attention, the dog can usually be saved. Although secondary poisoning has been demonstrated in the laboratory for various species, its occurrence in the wild appears very low, with few documented cases where use recommendations were followed.

AVITROL

Chemical name

4-aminopyridine

Trade name

Avitrol®

Use

Avitrol® is a bird management chemical registered for use as a flock-frightening repellent. It is usually formulated as a grain bait. Treated bait is diluted with untreated bait so only a few birds in a flock ingest a treated particle of bait. Affected birds emit distress cries and/or perform visual displays that

often frighten the other birds in the flock, causing them to leave.

Avitrol® has been used for feral pigeons, house sparrows, and for certain blackbirds and cowbirds in and around structures. In agricultural situations, crows, starlings, grackles, cowbirds, and blackbirds are most frequently the targeted species.

Avitrol® products are for use by or under the supervision of government agencies or certified control operators. Avitrol® is not for sale to the public.

History

Avitrol® is the registered trademark of the Avitrol Corporation for the chemical 4-aminopyridine. The synthesis of this chemical was first reported in 1931, and its unique action on birds was reported in 1964 by Goodhue. Its utility for controlling damage by birds in some situations was demonstrated in 1965 by Goodhue and Baumgartner.

Characteristics

4-aminopyridine is a white crystalline, odorless, water-soluble material. It is stable in light and melts at 159°C.

Pharmacology

Avitrol® is an acutely toxic substituted pyridine that affects the nervous system in a manner similar to that of organophosphates and carbamates; however, Avitrol® is not a cholinesterase inhibitor. In most bird species, a lethal dose of Avitrol® is necessary to produce distress behavior.

Toxicity

Birds and mammals appear equally sensitive to Avitrol® intoxication. LD50 values are generally less than 10 mg/kg. Birds ingesting the material become disoriented, emit distress calls, and exhibit erratic flight, tremors, and convulsions before death. Distress usually begins in about 15 minutes and last 20 to 30 minutes in most species. Some species, such as pigeons, do not emit distress calls.

In mammals, the following symptoms are produced: hyper-excitability, salivation, tremors, muscular incoordination, convulsions, cardiac or respiratory arrest, and death. Initial effects are usually noted in 10 to 15 minutes and death often occurs 15 minutes to 4 hours later. Occasionally, the tremor and/or convulsive stages are accompanied by audible vocalizations produced by strong, involuntary contractions of the diaphragm.

Documented reports of secondary poisoning following Avitrol® use have been very limited. When birds are offered undiluted Avitrol® baits, there may be potential hazards to dogs, cats, and raptors that consume unassimilated Avitrol® in gut contents. In field use, only individual scavengers such as magpies and crows appear to have been impacted.

GAS CARTRIDGES

Chemical components

Variable, depending upon type of gas cartridge.

Trade names

US Department of Agriculture Gas Cartridge, Giant Destroyer® Smoke'Em®, GopherGasser®, Dexol Gasser®, and others.

Use

Gas cartridges are incendiary devices designed to give off carbon monoxide and other poisonous gases and smoke when ignited. They are used to fumigate burrows of certain rodents and other mammals (coyotes, skunks).

History

Gas cartridges were developed by the former Bureau of Biological Survey more than 70 years

ago. One type is manufactured and supplied by the Pocatello Supply Depot, USDA-APHIS-Animal Damage Control, Pocatello, Idaho. Other types were developed and are manufactured and sold by private commercial establishments.

Properties

The current USDA gas cartridge was developed for control of woodchucks, ground squirrels, prairie dogs, and pocket gophers. It contains sodium nitrate, charcoal, and inert ingredients. A similar cartridge was developed and registered by USDA for fumigating coyote and skunk dens. Most gas cartridges are made of cardboard or paper and are ignited with a fuse. Care should be taken to avoid fire hazards at locations of use. Dry grasses, and methane or natural gas, which may be present in or around structures, can make using gas cartridges a potential fire hazard.

Pharmacology

Gas cartridges give off smoke and toxic gases when ignited. Carbon monoxide gas is a major product. In humans, the first stage of carbon monoxide poisoning produces a feeling of tightness across the forehead, headache, throbbing at the temples, dizziness, weariness, nausea, vomiting, collapse, and unconsciousness. In the second stage, the blood pressure falls, muscular control is lost, intermittent convulsions may occur, and the victim's breathing becomes shallower, slower, and finally stops. Presumably, carbon monoxide acts similarly on other animals.

Toxicity

Two hundred parts per million of carbon monoxide in inhaled air may produce symptoms of poisoning in a few hours, and 1,000 ppm can cause unconsciousness in 1 hour and death in 4 hours.

METHYL ANTHRANILATE

Chemical names

Methyl anthranilate, o-aminobenzoic acid methyl ester, o-carbomethoxyaniline

Trade name

ReJeX-iT®

Use

Because methyl anthranilate is broadly (if not universally) repellent to birds, it has many potential applications. The development of several of these applications has begun, and the formal registration of a few is imminent. The manufacturer (PMC Specialties Group) anticipates the registration of methyl anthranilate as a bird repellent additive to standing water at airports. The company also anticipates registration of methyl anthranilate as a bird repellent additive to Concover® (Newastecon, Inc.), a product designed as a thin cover for landfill operations. Gulls and crows refuse to forage in areas sprayed with Concover®/methyl anthranilate.

History

Methyl anthranilate is a GRAS (Generally Recognized As Safe) food flavoring that is approved by the Food and Drug Administration as an additive to both human foods and livestock feeds. This chemical occurs naturally and is the characteristic odor of Concord grapes. The major US producer is PMC Specialties Group. The company synthesizes the chemical as a precursor ingredient for the manufacture of calcium and sodium saccharin.

The first publication on the bird repellency of methyl anthranilate appeared in Poultry Science (Kare and Pick 1960). The following year, methyl anthranilate was patented as a bird repellent. For reasons still not completely understood, methyl anthranilate is a chemical irritant to birds, much as ammonia, formaldehyde, and black pepper are irritants to mammals. Every avian species

tested to date, including laughing gulls, ring-billed gulls, starlings, sparrows, waxwings, red-winged blackbirds, grackles, cowbirds, mallards, Canada geese, snow geese, crows, chickens, guinea fowl, pheasants, bobwhite quail, and turkeys will avoid normally preferred foods when these foods are adulterated with methyl anthranilate at concentrations ranging from 0.5% to 1.0% by weight.

Properties

Methyl anthranilate at room temperature is an oily, yellowish liquid. It has a fruity or grape-like odor and occurs in neoli, ylang-ylang, bergamot, jasmine, other essential oils, and in grape juice. It can be obtained synthetically by esterifying anthranilic acid with CH30H in the presence of HCL. Methyl anthranilate is only slightly soluble in water but is freely soluble in alcohol or ether. It has a boiling point of 256°C, a melting point of 24°C, and a specific gravity of 1.168. It has a vapor pressure of 1 mm at 20°C.

Pharmacology

According to the Materials Data Safety Sheet, the pure substance may be harmful if inhaled, ingested, or absorbed through the skin. The vapor or mist from the concentrated compound can be irritating to the eyes, mucous membranes, and upper respiratory tract. It can cause skin irritation.

Toxicity

Methyl anthranilate is not fundamentally toxic to mammals or birds. It may, however, be moderately toxic to fish.

STARLICIDE

Chemical name

3-chloro-p-toluidine hydrochloride

Other names

3-chloro-4-methyl benzylnamine hydrochloride, CPTH, DRC-1339

Use

Starlicide® is a slow-acting avicide registered for the control of starlings, blackbirds, pigeons, gulls, ravens, crows, and magpies.

History

This chemical, originally coded DRC-1339 and evaluated by the Denver Wildlife Research Center, was found to be an excellent toxicant for starlings and blackbirds when formulated as a Starlicide® pellet. It received federal registration in 1967 for feedlot uses. Starlicide® is manufactured and distributed by the Purina Mills Company. Registration of a DRC-1339 concentrate has been maintained by USDA-APHIS for use against starlings, blackbirds, and gulls, with additional approvals granted for use against pigeons in 1992 and against ravens, crows, and magpies in 1993. Use of the DRC-1339 concentrate is restricted to USDA-APHIS personnel.

Properties

The technical compound is a pale yellow, crystalline solid material very soluble in water and other highly polar solvents; it sublimes at 220°C. If formulated with many grains, potency of the compound may decline significantly when stored. Commercial Starlicide® pellets retain their potency for 6 to 12 months.

Pharmacology

Starlicide® is a slow-acting and apparently painless toxicant in birds and mammals. In sensitive bird and mammal species, death results primarily from uremia (a buildup of uric acid in the blood). Death occurs without convulsions or spasms and is the result of generalized circulatory impairment in the liver and kidney, and congestion of the major organs. At death, victims' feathers are usually

fluffed and their feet tucked inside the feathers of the lower breast.

In most mammals and nonsensitive birds, death results from methemoglobinenimia (a buildup of methemoglobin in the blood). Mammals become listless and comatose before death.

Birds and mammals appear to metabolize or excrete Starlicide® completely within a matter of hours, and the excreted metabolites are nontoxic to birds and mammals. Because the Starlicide® and its metabolites are excreted while birds are still alive, there is no secondary toxicity to any scavengers eating dead birds.

Toxicity

In birds, the average time between ingestion and death is 36 to 60 hours, depending on the amount ingested. Even when the lethal dose level is exceeded many times, death still takes many hours. Death occurs in 3 to 12 hours in most mammals.

The toxicity of Starlicide® varies considerably between bird species. Starlings, blackbirds, and crows are among the most sensitive birds; house sparrows and hawks are nonsensitive. Mammals are generally not sensitive to the toxic effects of Starlicide®.

STRYCHNINE

Chemical Name

2,4a,5,5a,7,8,15, l5a,l5b,l 5c-dechydro-4,6-methano-6H, l4H-indolo (3,2,l-ij)oxepino(2,3,4-de) pyrrolo(2,3- h)quinolin- 14-one

Use

Strychnine is a widely used toxicant registered for use in controlling certain rodent and depredating bird species. In the past, strychnine was commonly used for controlling rodents, depredating birds, and mammals such as skunks and coyotes. Above-ground uses were halted by court action in 1988, but it remains registered and used below-ground for control of pocket gophers and, in some states, other species.

History

Strychnine is one of the alkaloids processed from raw dried ripe seed of Strychnos nux vomica, a small tree native to India, North Australia, Vietnam, and Ceylon. This alkaloid was discovered by Pelletier and Caventon in 1817. There is 2.0% to 2.7% total alkaloid found in the seeds, which were used to kill dogs, cats, and birds in Europe at least as early as 1640.

Properties

Strychnine, a white crystalline powder, is available in an alkaloid form; the sulfate form previously used is no longer registered. Strychnine has a bitter taste. It is almost entirely insoluble in water and very stable (unless exposed to heat and light); however, it is subject to acid-salt formation, which renders it water soluble and subject to leaching in acid soils.

Pharmacology

Strychnine acts the quickest of the commonly used rodenticides. It is not stored in body tissues nor absorbed through normal intact skin. It has a very slight odor, very high toxicity, and acts somewhat variably on target animals. Strychnine enters the blood very rapidly and acts on the central nervous system. The time of action depends on whether the stomach is empty or full and the nature of the food present. Animals with little in their stomachs react more quickly to strychnine than those that have fed recently. Symptoms may appear from 5 to 30 minutes after ingestion.

Intoxicated animals have frequent tetanic convulsions interspersed with quiescent periods. Ultimately these convulsions lead to death through

respiratory failure. Strychnine is not assimilated into tissues or bone; however, residues in the gastrointestinal tract of animals poisoned with lethal doses are known to be potentially hazardous if the gastrointestinal tract is consumed. With its current below-ground application pattern, secondary poisoning is unlikely.

Toxicity

LD50 values range between a low of O.70, 0.75 and 1.5 mg/kg for coyotes, desert kit foxes, and black-tailed prairie dogs, respectively, and 16.0 mg/kg for chukar partridge and 24.7 mg/kg for ring-necked pheasants. LD50s for mallards, Canada geese, golden eagles, and house sparrows fall within an approximate range of 3.0 to 5.0 mg/kg.

Livestock are about as sensitive to strychnine as rats. Horses, hogs, geese, and ducks show no hesitation in eating strychnine baits. Cattle and sheep are more reluctant to accept baits. Gallinaceous game birds and most domestic poultry, however, are less susceptible to strychnine than most rodents.

Antidote

The use of general antidotes is feasible and often successful if treatment is initiated soon after exposure. Sodium pentobarbital and sodium amytal both act to reduce the severity of convulsions in humans (see J. Am. Med. Assoc. 100:548-551). Emetics such as 1% to 2% tannic acid are useful but should only be used after the convulsive stage is past. Prompt administration of methocarbamol is useful in treating poisoned dogs. Prognosis: if the patient lives for 24 hours, he or she probably will recover.

ZINC PHOSPHIDE

Chemical name

Zinc phosphide

Use

Zinc phosphide, at concentrations of O.75% to 2.00/o on grain, fruit, or vegetable baits, has been used successfully against such species as meadow mice, ground squirrels, prairie dogs, and Norway rats. In some areas, zinc phosphide baits have been partially or completely rejected by ground squirrels and meadow mice and at times control has been erratic.

History

Zinc phosphide appears to have been first synthesized by Marggral in 1740 and was first used as a rodenticide by the Italians in 1911. Extensive use of zinc phosphide in the United States did not occur until 1942, when the availability of strychnine became uncertain due to the war.

Properties

Zinc phosphide is a heavy, finely ground gray-black powder that is practically insoluble in water and alcohol. When exposed to moisture, it decomposes slowly and releases phosphine gas (PH_3). Phosphine, which is highly flammable, may be generated rapidly if the material comes in contact with diluted acids. Zinc phosphide concentrate is a stable material when kept dry and hermetically sealed.

Although zinc phosphide baits have a strong, pungent, phosphorous-like odor (garlic-like), this characteristic seems to attract rodents, particularly rats, and apparently makes the bait unattractive to some other animals. For many uses of zinc phosphide formulated on grain or grain-based baits, prebaiting is recommended or necessary for achieving good bait acceptance.

In general, zinc phosphide is less toxic than Compound 1080 or strychnine and is slower-acting than either of these compounds.

There is only a small amount of deterioration of zinc phosphide on baits due to the evolution of phosphine gas; dry baits must be considered to be toxic indefinitely and must be used accordingly. Lecithin-mineral oil, added to zinc phosphide to adhere it to grain bait, offers protection against moisture, and may increase its stability. Under field conditions, zinc phosphide baits may remain toxic for several months until baits are eroded by weathering, the carrier decomposes, or the grain is removed by insects. Physical erosion does not seem to occur rapidly. In one instance, zinc phosphide-treated bait exposed in the field for 2 to 3 months and subject to 10 to 12 inches (25 to 30 cm) of rain continued to maintain some toxicity.

When zinc phosphide is dusted onto wet baits, such as meats or cubed fresh fruits and vegetables, it breaks down within a few days and the baits soon lose their attractiveness.

In soil, zinc phosphide breaks down rapidly to phosphine, which is either released into the atmosphere or converted to phosphates and zinc complexes.

Translocation of phosphine gas has been demonstrated, but it is rapidly converted to harmless phosphates. There is no evidence that hazards exist via this route when grain baits are used in growing vegetables.

Pharmacology

When zinc phosphide comes into contact with dilute acids in the stomach, phosphine (PH_3) is released. It is this substance that probably causes death. Animals that ingest lethal amounts of bait usually succumb overnight with terminal symptoms of convulsions, paralysis, coma, and death from asphyxia. If death is prolonged for several days, intoxication occurs that is similar to intoxication with yellow phosphorous, in which the liver is heavily damaged. The surface of the liver will be spotted and discolored. Prolonged exposure to phosphine can produce chronic phosphorous poisoning.

Early symptoms of zinc phosphide poisoning are nausea, vomiting (yielding black stomach contents and the smell of phosphine), abdominal pain, chest tightness, excitement, and a feeling of coldness. In fatal cases, there is liver, kidney, and heart damage. The time between ingestion and death is frequently about 30 hours. Victims who are alive after 3 days are said to recover completely. Mild poisoning from breathing minute amounts of phosphine gas can be mistaken for food poisoning because of the diarrhea and stomach pains produced.

Zinc phosphide-poisoned rats show no signs of distress until a short terminal death agony occurs. They typically die in a prone position with their legs and tails outstretched.

Because zinc phosphide is not stored in muscle or other tissues of poisoned animals, there is no secondary poisoning with this rodenticide. The bait, however, remains toxic up to several days in the gut of a dead rodent. Other animals can be poisoned if they eat enough of the gut contents of rodents recently killed with zinc phosphide.

Toxicity

Zinc phosphide is poisonous to some degree to all animals. Supposed safety factors such as the odor and dark color may be of little deterrence in situations. As little as a teaspoonful of bait containing zinc phosphide could cause toxic symptoms in a child to whom the color and odor may not be disagreeable. Around dwellings, bait should be exposed only in situations that will

prevent pets and children from coming into contact with it.

Use extreme care in handling zinc phosphide concentrate and treated bait. If zinc phosphide baits are prepared in the open air, phosphide generated from the moist bait offers little hazard. When quantities of bait are prepared within a bait mixing plant, safeguards against continued exposure to low concentrations of phosphide must be taken. Zinc phosphide dust created by the preparation or handling of baits is also hazardous. Personnel working indoors should wear appropriate respirators and work under exhaust fans. Zinc phosphide baits should not be mixed or distributed with the bare hands. Oils, liquid or semisolid, are used in some preparations. Because phosphorous is soluble in certain fatty oils, it may be absorbed in small amounts through the skin. Continued exposure to phosphorous absorption may result in toxic manifestations at some later time. Rubber or synthetic gloves are preferable when handling dry zinc phosphide bait formulations but cotton or leather gloves are acceptable.

Zinc phosphide can be used for rat control on almost any food product; however, it (or any other acute toxicant) should not be used on bait materials recognizable as food in the home environment. Do not use on such foods as tomatoes, apples, oranges, or bread, unless they are made unrecognizable by rolling or cubing them.

Appendix C: DEFINITIONS

Acceptance: Refers to the palatability of baits and toxicants.

Acclimation: Process of adaptation by an individual organism to a new situation.

Acute Rodenticide: A chemical that only requires a single dose to kill the target animal.

Adaptation: The fitness of an organism within its genetic structure for its environment, or the process (acclimation) by which it becomes fit.

Adult: Sexually mature; an animal that has or is capable of contributing new individuals to a population.

Age Composition: The arrangement of age classes in a population, which describes the relative strengths of the age classes. Synonym, age structure.

Aggressive Behavior: Includes both combat and aggressive display to drive the stimulus object away or otherwise modify it by intimidating, injuring, or even killing it.

Agonistic Behavior: Aggressive behavior associated with conflict or fighting between two individuals.

Animal Unit: A measure for converting types of animals to the forage resources, based on the equivalent of the forage required by a mature cow of about 1,000 pounds.

Anticoagulants: Compounds that reduce the clotting ability of blood. Vitamin K is usually an antidote for anticoagulant poisoning.

Avicides: Usually a lethal agent used to destroy birds, but also refers to other materials or means of repelling or mitigating birds.

Bait Extender: An edible or non-edible material added to increase the bait's bulk to dilute the concentration, or make the bait easier to handle.

Balance of Nature: The relationship of the population densities of the diverse species of organisms that make up an ecologic community.

Biological Control of Vertebrates: An attempt to reduce the population density of a pest species (i.e., increase mortality, reduce natality, or cause a significant emigration), either by increasing predation, manipulating the conditions of the habitat, introducing or stimulating epizootics (diseases), or by the application of antifertility agents.

Bait Shyness: A learned aversion to both toxicant and food items of a toxic bait.

Buffer Crops: Crops deliberately planted to take the feeding pressure of vertebrate pests off more valuable crops.

Buffer Species: An animal species constituting food for predators to the benefit of game or domestic stock; a comparatively undesirable animal species that lessens or neutralizes the effects of predators on a desirable species.

Carnivore: An animal whose principal diet is meat.

Carrying Capacity: The maximum density of a particular species of animal that can be maintained in a given ecosystem on a sustained basis without deteriorating the habitat, i.e., the number of

individuals that a habitat can maintain in a healthy condition.

Chemical Toxicant: Any chemical substance, which, when ingested, inhaled, or absorbed, or when applied to, or injected into the body in relatively small amounts, may cause significant bodily malfunction, injury, or death to animals or man by its chemical action.

Chemosterilant: A chemical substance that causes sterilization or prevents effective production.

Chronic Rodenticide: A chemical that may require more than one dose to kill the target animal. Many of the available anticoagulant rodenticides fall into this category.

Climax: A community in a state of relative ecologic equilibrium with its habitat because it is no longer in process of further successional changes. Climatic climax is an equilibrium with the general climate. Edaphic climax is modified by substrate where topography, soil, or water are such that the climatic climax cannot develop.

Conservation: The maintenance of a species at a desired level and/or the perpetuation (not preservation per se) and wise use of natural resources and conservative use of non-renewable resources, such as natural gas, oil, and minerals.

Cumulative Poison: A chemical that is not excreted from the body and causes damage over a period of time resulting in death.

Cyclic: A population with great variation between high and low densities (excluding seasonal fluctuations), that occur with cyclic regularity.

Deprivation: Withholding food, water, sexual contact, etc.

Ecology: Derived from the Greek oikos, meaning house or place to live. A branch of biology that is concerned with organisms in relation to environment.

Economic Control: The reduction or maintenance of a pest density below the economic-injury level, or any attempt to reduce a pest population to the economic threshold.

Economic Threshold: The density at which control measures should be determined to provide the necessary time to initiate control to prevent an increasing pest population from reaching the economic-injury level.

Ecosystem: It includes an ecological community (of organisms) together with its habitat (climate and physical features of the environment).

Endangered Species: A species whose prospects for survival and reproduction are in immediate jeopardy due to loss of habitat, change in habitat, over-exploitation, predation, competition, or disease.

Endemic: A disease caused by an indigenous pathogen.

Environment: All the organic and inorganic features that surround and affect a particular organism or group of organisms, i.e., both the biotic and physical factors of the habitat.

Eradicate: Often used to imply the local extermination of a species (best stated as local eradication).

Exotic: An organism that is not native to the region in which it is found.

Extinction: The disappearance of a species, due to the remaining individuals of that species being incapable of maintaining a viable population.

Feral: An organism that has escaped from cultivation or domestication and is established in a wild state.

Food Chain: A sequence of species within a community, each member of which serves a food for the species next higher in the chain.

Fur Bearer: Any animal sought for its fur.

Game Management: The art of making land produce a sustained crop of wild game for recreational purposes.

Graminivorous: An animal that eats grass.

Habitat: It is the environmental situation (usually only climate and physical features of the environment) in which or on which any community, species, or individual lives.

Herbivore: An animal whose principal diet is plants.

Home Range: The area over which an individual animal habitually travels while engaged in its daily activities.

Immunity: Following repeated exposures to pesticides, drugs, or pathogens, the organism acquires the ability to resist the agent or infection.

Indicators: Indicator species of plants or animals often recur again and again in widely separated ecosystems of similar types and serve as an indicator of certain general characteristics of the environment.

Integrated Control: Is a management system which, within the area of associated environments and population dynamics of the pest species, uses all suitable techniques and methods in as compatible a manner as possible to maintain pest populations at levels below those causing economic injury.

Invasions: Spread of a species into a community where it was not formerly represented.

LD50: the amount of a chemical necessary to kill 50% of a population. Usually expressed in milligrams of toxicant per kilogram of body weight, (mg/kg).

LD100: the amount of toxicant needed to kill 100% of a population. Usually expressed in milligrams of toxicant per kilogram of body weight, (mg/kg). LD100 means that a chemical is highly toxic.

Learning: The process that produces change in individual behavior as the result of experience.

Life Cycle: The stages an organism passes through from the fertilized egg to death.

Limiting Factors: Any environmental factor that limits the distribution and/or the size of a population.

Marginal Habitat: Where individuals or populations live a tenuous existence and seldom successfully reproduce.

Multiple Use: Harmonious use of land for more than one of the following purposes: grazing of livestock, wildlife production, recreation, watershed, and timber production; but not necessarily the combination of uses that will yield the highest economic return or unit output.

Natality: Birth rate.

Natural Control: The maintenance of a more or less fluctuating population density with certain definable upper and lower limits over a period of time by the combined actions of abiotic and biotic elements of the environment.

Niche: The portion of the habitat the species concerned occupies for shelter, for breeding sites, and for other activities; the food that it eats, and all the other features of the ecosystem that it utilizes.

Non-Cumulative Poison: A chemical that is excreted from the body over a relatively short period of time.

Omnivore: An animal whose principal diet is meat and plants.

Overpopulation: A population level that the habitat cannot sustain indefinitely.

Pesticide: A substance or mixture of substances intended for destroying, repelling, or mitigating any vertebrate or invertebrate pest or preventing the species from becoming a pest.

Placebo: An inactive substance; in a test bait that contains all the same ingredients except the toxic or test material.

Plague:

1. A drastic increase in the population and "outbreak" as a plague of mice or locusts.

2. Commonly used in reference to the disease, bubonic plague, caused by Yesinia (Pasteurella pestis).

Pollution: Environmental (air, water, land, cities, etc.) contamination.

Polyandry: The mating of a single female with several males.

Polygamy: The mating of one male with several females.

Predacide: Chemical substance used to poison predators.

Predatory Animal: Any mammal, bird, or reptile that habitually preys on other animals.

Primary Poisoning: Poisoning of the target species by the direct effect of toxicants causing sickness, pathological changes, or death resulting from ingestion or absorption.

Raptor: A bird of prey.

Rodenticide: A pesticide applied as a bait, dust, or fumigant, to destroy or repel rodents and other animals, such as moles, rabbits, and hares.

Secondary Poisoning Effect: The result attributable to a chemical toxicant which, after being ingested, inhaled, or absorbed by or into, or when applied to or injected into a mammal, bird, or reptile, is retained in its tissue, or otherwise retained in such a manner and quantity the tissue itself or retaining part, if thereafter ingested by man or animal, produces the effects of a chemical toxicant.

Selective Pesticide: A pesticide which, while killing the pest individuals, spares much or most of the other fauna, including beneficial species, either through differential toxic action or through the manner in which the pesticide is used, (formulation, dosage, timing, etc.).

Scavenger: An animal that feeds principally on carrion (dead animals) or garbage.

Social Behavior: Activities elicited by other members of the same species, but in some cases of another species, that have some effect on other individuals.

Species: A group of interbreeding populations (actually or potentially) reproductively isolated from other such groups.

Succession: The replacement of one community by another.

Synergistic Effects: Where the degree of control achieved by a combination of methods exceeds the sum of the independent effects of each method.

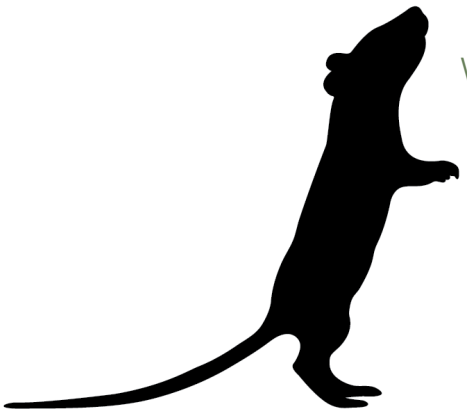
Territory: That portion of a home range that is defended against trespass by other members of the same species.

Tolerance: An organism's ability to endure a pesticide or drug without ill effect; for example, the state of the innate resistance or acquired immunity.

Trap Night: Used to express the ratio of individuals captured, depending on the number of traps and length of time they were set. One trap night equals one trap set for one night.

Vertebrate Control Objectives: To accomplish the desired effect with a maximum of safety to man and to forms of life useful or of neutral value to him, and that it be carried out with a minimum of disturbance to the biotic community. It is the alleviation of the problem to a tolerable level, not the destruction of vertebrates.

Vertebrate Pest: Any native or introduced, wild, or feral species of vertebrate animal that is currently troublesome locally or over a wide area, to one or more persons, either by being a health hazard, a general nuisance, or by destroying food, fiber, or natural resources. A pest to one person may at the same time have aesthetic or recreational value to others.



Wyoming Ornamental and Turf Pest Categories: All 903 Categories

MP-127.903 • December 2017

University of Wyoming Extension