UTAH STATE UNIVERSITY EXTENSION

CATEGORY 3

Ornamental and Turf Pesticide Safety Study Guide

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Contents

CHAPTER 1
INTRODUCTION

Forward 1
Introduction 1

CHAPTER 2
LAWS AND REGULATION

Learning Objectives 5
Federal Laws 5
Endangered Species Act of 1973 (ESA) 7
State Laws 7
Emergency Exemptions (FIFRA, Section 18) ... 10
Special Local Needs 24(c) Registration 11
Maintain Pesticide Application Records for 2 years 11

CHAPTER 3
PESTICIDES IN THE ENVIRONMENT

Learning Objectives 13
Introduction 14
Environmental Fate of Pesticides 14
Potential Environmental Impacts from Turf & Ornamental Pesticide Application 18
Preventing and Minimizing Environmental and Non-Target Impacts 20
Pollinator Protection Best Management Practices 29

CHAPTER 4
INTEGRATED PEST MANAGEMENT (IPM)

Learning Objectives 33
Introduction 33
Cultural Control 34
Biological Control 39
Chemical Control 40
Obstacles to Effective Chemical Control 42
Putting It All Together 43

CHAPTER 5
SITE EVALUATION

Learning Objectives 45
Introduction 45
Inspect and Document the Site 46
Document Problems, Potential Problem and Risks 49
Determine the Possible Cause of Plant Problems 50
Examine the Surrounding Area 53
Site Evaluation at Time of Application 55

CHAPTER 6
APPLICATION EQUIPMENT AND TECHNIQUES

Learning Objectives 57
Introduction 57
Equipment and Techniques for Applying Pesticide to Turf and Ornamentals 58
Ensuring Application Accuracy 64
Key Calibration Concepts 66

Calibration Examples 69
Equipment Maintenance 74
Warning Signs of Misapplication 77

CHAPTER 7
PROFESSIONALISM, SAFETY AND HUMAN HEALTH

Learning Objectives 79
Introduction 79
Professionalism 80
Communicate with Customers, Neighbors, the Public, and the Media 81
Identify and Prevent Risks 83
Prevent and Minimize Hazards to Humans and Non-target Organisms 84
Posting Requirements 87
State Posting Laws 87

CHAPTER 8
PLANT BIOLOGY BASICS

Learning Objectives 89
Introduction 89
Plant Classification 90
Plant Parts 91
Growth Cycles 95
How Plant Biology Influences Pesticide Application Success 99

CHAPTER 9
WEED MANAGEMENT

Learning Objectives 101
Introduction 101
Weed Control 103

CHAPTER 10
PLANT DISEASES AND DISORDERS

Learning Objectives 109
Introduction 109
Disease Triangle 110
What Causes Diseases and Disorders 111
Abiotic Disorder 112
Diagnosing Plant Diseases and Disorders 112
Managing Plant Diseases and Disorders 113

CHAPTER 11
INSECTS AND MITES

Learning Objectives 115
Introduction 115
Introduction to Insects 116
Turf and Ornamental Plant Pests 119
Beneficial Insects 120

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Preface

This Category 3: Ornamental and Turf Pesticide Safety Study Guide is designed for individuals preparing to take the Utah commercial and noncommercial Category 3: Ornamental and Turf Application exams.

For more information regarding certification and licensing of pesticide applicators in Utah, see the Utah Department of Agriculture and Food website.

This edition of the Category 3 Study Guide is a major rewrite of the previous manual. It represents a close cooperation with leaders in the green industries of Utah, Utah State University (USU) Extension, and the Utah Department of Agriculture and Food (UDAF), as well as with the Pesticide Safety Education Program (PSEP) from other states. This cooperative effort expands our access to a broader array of expertise and resources.

This project is facilitated by the PSEP, part of the Utah State University Extension. USU PSEP neither endorses nor opposes the use of pesticides. USU PSEP's two primary goals include helping pest managers (1) determine when to use a pesticide, and (2) develop knowledge and skills to handle pesticides legally, safely, and responsibly.

The old study materials for this category should no longer be used and should be offered for paper recycling. We plan to revise and update this study guide in future years. Feedback from manual users is the most valuable source of information for improving the manual as a training, education, and reference tool. We welcome comments from users of this manual, both what you have found useful and suggestions for improvement. Comments about this manual may be sent to:

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Major Sources

Category E: Turf and Ornamentals, Pesticide Safety Education Manual, 4th Edition, June, 2014

Turf Pest Control, Colorado Commercial Pesticide Application and Safety Training Study Guide, 3rd Edition, October 2015

Ohio Category 07, A Study Guide for Cool-Season Turfgrass Pest Management

National Pesticide Applicator Certification Manual, Second Edition 2014

CHAPTER 1

INTRODUCTION

FORWARD

Whether you are a new applicator studying for initial certification or an experienced applicator reading this Study Guide as part of your professional development, you can take pride in your contributions to the quality of life enjoyed in Utah. You keep our parks, lawns, landscapes, golf courses, and interior landscapes beautiful and healthy.

Category 3: Ornamental and Turf is the largest commercial license category in Utah. The Ornamental and Turf Category covers applications of pesticides on non-agricultural areas and for ornamental propagation of lawns, shrubs, trees and flowers for ornamental use and in ornamental areas such as residences, parks, athletic fields, golf courses, nurseries and greenhouses.

INTRODUCTION

Pesticides serve a valuable role in our world. It's important to balance the positive and negative when deciding whether or not to use pesticides or other pest management strategies by using the techniques of Integrated Pest Management. Pesticides help control exotic invasive plants and insects that harm our native plants and plant communities, such as the Japanese Beetle or Bermuda Grass. Pesticides help control plants designated as noxious weeds as well as plants and insects considered harmful to human health or as nuisance pests. Pesticides help maintain healthy plants. Many pesticides are used for aesthetic reasons, such as removing dandelions or crabgrass from lawn areas, or improving the appearance of plants, which also may improve property values. This Study Guide will provide information to help you make informed decisions on pesticide use and safety in the turf and ornamental field.

Purpose of the Study Guide

Public concern over the use of pesticides continues to grow, and the professionals who handle pesticides must prove they are capable of using these chemicals responsibly.

Applicators seeking to certify for the first time (get their license) in Category 3: Ornamental and Turf are required to take a closed book exam at a Utah Department of Agriculture and Food (UDAF) approved testing center after passing the Core test. Find locations of testing centers on the UDAF web page for a link go to shorturl.at/gCHN3

This Study Guide helps applicators prepare for the initial certification exam. Its contents were developed through adapting existing manuals and study guides from multiple states. The University of Minnesota, Ohio State, and Colorado State University graciously granted us copyright permission to use text from their materials. Additionally, Utah Department of Agriculture and Food (UDAF) and Utah State University Extension subject area experts reviewed and rewrote the materials in an effort to provide current and relevant educational materials to new pesticide applicators working in the green industries of Utah. It also forms the basis for the Category 3: Ornamental and Turf exam.

How to Use the Study Guide

This Study Guide contains materials to help you prepare for the Category 3: Ornamental and Turf Pesticide Applicator exam. In order to obtain a pesticide license Utah requires you to demonstrate your competency by passing the exam. You must also pass a separate exam for Core.

Occasionally material presented in this Study Guide is also covered in the National Core Manual, but is presented here as it applies to applicators in Category 3: Ornamental and Turf.

Because website links change, web links referred to in this Study Guide will be maintained online at: shorturl.at/gCHN3.

The Purpose of Learning Objectives

Each chapter provides a section called Learning Objectives. They identify the key concepts and outcomes you are expected to know or do after studying the chapter. Learning Objectives will help you better understand the materials in each chapter, understand pesticide labels and other resources, and better communicate with your peers in the industry as well as your customers and the general public. Use these to help you focus on what you should learn from each chapter as you prepare for the exam.

Study Tips

Everything in the Study Guide is considered testable. However,

the exam will likely include the information most important for you to know as a new pesticide applicator. The closed-book exam is composed of multiple-choice questions. You will need to study the Study Guide and learn the materials in order to pass the test.

Use these tips to help you prepare for the Category 3 exam:

- Read the Learning Objectives at the beginning of each chapter. Use them to focus on the most important material.
- As you read the chapters, take notes and/or highlight key information.

Each individual learns in different ways. If you remember things better by writing them down, take notes and review these. If you prefer visual learning, highlight the information and go over it. If you learn better by hearing things, read and repeat them to yourself out loud. Consider making flash cards of the important information. Study with a co-worker and test each other on key information and terms.

As you read the materials, keep the Learning Objectives in mind. Once you've read a chapter, go back and review them and your notes and make sure you understand each concept. Go back and review the parts of the chapter that discuss those you feel uncertain about. In education, repetition is key.

CHAPTER 2

Laws and Regulation

LEARNING OBJECTIVES

After studying this chapter, you should will able to:

1. Recognize the key elements of FIFRA.
2. Describe the Endangered Species Act and know if it applies to your pesticide application.
3. Understand the Utah Pesticide Control Act, with special attention to the Unlawful Acts, and which acts could pertain to you and your specific license.
4. Identify who needs to have a Utah Commercial or Non-Commercial Applicator's license with the Ornamental and Turf Category
5. Identify what type of applications the license with the Ornamental and Turf category will allow you to complete.
6. Describe what records of applications to keep, what information they will contain, and how long they must be stored.
7. Explain what labels must be "at hand" and in what format.
8. Describe what training your employer must provide.

FEDERAL LAWS

Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA)

FIFRA was enacted in 1947 to protect consumers from fraudulent pesticide products as manufacturers were required to register their pesticide and provide label information about the contents, directions for use, and antidotes if the chemical was ingested by humans. Because herbicides were not widely used at the time FIFRA was enacted, they are not included in the title of the Act. However, note their inclusion

under this regulation. The United States Department of Agriculture (USDA) had responsibility for its implementation and enforcement of FIFRA until the Environmental Protection Agency (EPA) was formed in 1970. At that time, responsibility for FIFRA transferred to the Office of Pesticide Programs (OPP) at EPA. Amended several time since first enacted, one of FIFRA's most important amendments passed in 1972 which led to more active regulation of product safety and an emphasis on protection of public health and the environment. Today, registration decisions are based on data which demonstrates that the pesticide will not result in "unreasonable human health or environmental effects."

3 Utah Pesticide Applicator Licenses

- Commercial
- Non Commercial
- Private

KEY ELEMENTS OF FIFRA

- EPA reviews all pesticides, as well as the use of the pesticide and approves the product label.
- All pesticides must be registered as "Unclassified (General Use)," or "Restricted Use" (RUP). If the pesticide poses a risk to the environment and/or the user could be harmed even when used as directed, it is classified at a RUP. States may classify a federally registered "General Use" pesticide as "Restricted Use" if additional concerns exist, especially to protect the environment. However, a RUP cannot be classified as a "General Use" pesticide by a state.
- FIFRA requires that anyone using RUPs must be certified as, or act under the direct supervision of, either a "Private" or "Commercial" Applicator.
    - Utah has three types of pesticide applicator licenses: Private, Commercial and Non-Commercial. One of these licenses must be obtained to purchase or use RUPs. Non-Commercial and Commercial Applicators shall not supervise the application of any RUP by unlicensed individuals.
- Makes it illegal to store or dispose of pesticides or containers in a manner other than described by regulations.
- Provides penalties for "use inconsistent with the labeling" of the pesticide and "illegal handling of containers".
- Provides civil penalties when a violation of a regulation is unintentional.
- Provides criminal penalties for knowingly violating regulations.

ENDANGERED SPECIES ACT OF 1973 (ESA)

Administered by the U.S. Fish and Wildlife Service (FWS), the Endangered Species Act (ESA) protects endangered species and their habitat. Under ESA, it is a violation of federal law to use a pesticide in any manner that may kill or otherwise harm an endangered species or adversely modify their habitat. Some pesticide labels now include an 'Endangered Species Restrictions' statement under the ENVIRONMENTAL HAZARDS section of the label.

The responsibility of protecting endangered species ultimately falls to the applicator. If the label contains an 'Endangered Species Restrictions' statement, applicators must check the EPA Endangered Species Bulletins to determine if the county (or counties) where the application will be made has any restrictions. These restrictions may be for a specific active ingredient, product, or time of application. Bulletins may be accessed up to 6 months prior to the month of intended application. For example, when making an application in June, you can access bulletins as far as 6 months prior to that application, or by January at the earliest. Access Endangered Species Bulletins links at shorturl.at/gCHN3. Applicators who work in multiple states can access information for any state from the website.

If indicated by the product label, pesticide applicators and their companies (if applicable) must check bulletins and related information on endangered plants and animals in the area where pesticides are applied. The U.S. FWS website provides information on threatened and endangered species in Utah. Find links to this information at: shorturl.at/gCHN3 and consider bulletins found on the EPA website to determine if pesticide use limitations exist in the application area.

If an active bulletin exists, applicators MUST print a copy and keep it as part of the application record. However, it does NOT need to be in possession during the application.

STATE LAWS

The Utah Pesticide Control Act (Utah Code 4-14-101) associated Rules (Utah Administrative Code R68-7-14) and Policy

The Utah Department of Agriculture and Food (UDAF) Pesticide Program administers the laws, rules, and policies associated with pesticides in Utah. UDAF issues four types of pesticide licenses: (1) Private, (2) Non-Commercial, (3) Commercial, and (4) Commercial Pesticide Business. This Study Guide will apply most to the Utah Commercial Pesticide Applicator and the Utah Commercial

A link to the full Utah Pesticide Control Act can be found at: shorturl.at/gCHN3

UDAF License Key Points

1. UDAF will not issue a Utah Commercial Pesticide Business license until at least one licensed Utah Commercial Pesticide Applicator is assigned to that business.
2. No Utah Commercial Pesticide Applicator will receive their license without first being associated with a licensed pesticide business.
3. As of 1/1/2019 no Utah Commercial Pesticide Business License will be issued until a new licensee has demonstrated that they have a qualifying party associated with the business who has been a certified licensee for qualifying party associated with the business who has been a certified licensee for at least to two years or holds a minimum of an Associate's Degree from an accredited school in a related field, as determined by UDAF. Contact the UDAF Pesticide Program for details.

Pesticide Business, but it is also applicable to those who obtain a Utah Non-Commercial Pesticide Applicator License and this category.

UDAF will not issue a Utah Commercial Pesticide Business license to a business until at least one licensed Utah Commercial Pesticide Applicator is assigned to that business. Conversely, no Utah Commercial Pesticide Applicator will receive their license without first being associated with a licensed business. As of 1/1/2019 no Utah Pesticide Business License will be issued until a new licensee has demonstrated that they have a qualifying party associated with the business who has been a certified licensee for at least to two years or holds a minimum of an Associate's Degree from an accredited school in a related field, as determined by UDAF. Contact the UDAF Pesticide Program for details..

A reason to obtain a Pesticide Applicator License in Utah is to apply RUPs. Relatively few pesticides used in this category are considered RUP so the predominant reason to obtain a license with the Ornamental and Turf category included is to apply commercially, “for hire or compensation” for a company, usually providing residential and small businesses with yard care services, but perhaps other property types like business parks, trails, public grounds, and so forth.

Generally, to assist an applicator in understanding how the rules concern them in their use of pesticides, UDAF will ask them to review the Unlawful Acts section of the Utah Pesticide Control Rule. Following is a list of the unlawful acts. For the list with comments on how commitment of these acts may affect the Ornamental and Turf category applicator see shorturl.at/gCHN3.

Any person committing any of the following acts violates Utah Pesticide Control Act or rules promulgated thereunder and is subject to penalties provided for in Sections 4-2-2 through 4-2-15:

1. Made false, fictitious, or fraudulent claims, written or spoken misrepresenting the use, effect of pesticides, certification of applicator, or methods to be utilized;
2. Applied known ineffective or improper pesticides;
3. Operated in a faulty, careless, or negligent manner;

4. Neglected or, after notice, refused to comply with the provisions of the Act, these rules or of any lawful order of the department;
5. Refused or neglected to keep and maintain records required by these rules, or to make reports when and as required;
6. Made false or fraudulent records, invoices, or reports;
7. Engaged in the business of, advertised for, or held self out as applying a pesticide for hire or compensation on the lands of another without having a valid commercial applicator's license;
8. Purchased, used, or supervised the use of, a pesticide which is restricted to use by "certified applicators" without having qualified as a certified applicator or designated as a certified private applicators agent;
9. Used fraud or misrepresentation in making application for, or renewal of, a registration, license, permit, or recertification.
10. Refused or neglected to comply with any limitations or restrictions on or in a duly issued license or permit;
11. Used or caused to be used any pesticide in a manner inconsistent with its labeling or rules of the department if those rules further restrict the uses provided on the labeling;
12. Aided or abetted a licensed or an unlicensed person to evade the provisions of the Act; conspired with such a licensed or an unlicensed person to evade the provisions of the Act; or allowed one's license or permit to be used by another person;
13. Impersonated any federal, state, county, or other government official;
14. Distributed any pesticide labeled for restricted use to any person unless such person or his/her agent has a valid license, or permit to use, supervise the use, or distribute restricted-use pesticide;
15. Applied pesticides onto any land without the consent of the owner or person in possession thereof, except, for governmental agencies which must abate a public health problem.
16. For an applicator to apply a termiticide at less than label rate.
17. For an employer of a commercial or non-commercial applicator to allow an employee to apply pesticide(s) before that individual has successfully completed the prescribed pesticide certification procedures.

18. For a pesticide applicator not to have his/her current license in his/her immediate possession at all times when making a pesticide application.
19. To allow an application of pesticide to run off, or drift from the target area to cause plant, animal, human, or property damage.
20. Refused or neglected to register a pesticide applicator business with the Utah Department of Agriculture and Food or follow the rules set forth in section R68-7-8 for licensing of a commercial business.
21. To handle or apply any registered pesticide for which the person does not have an appropriate, complete, or legible label at hand.
22. Refused or neglected to comply with the Federal Container and Containment regulations.
23. Failure to perform fumigation applications according to the standards required by this rule.
24. Failed to display business license numbers in accordance with this rule.
25. Refused or neglected to notify the customer of the application of a restricted-use pesticide and the information detailed in R68-7-10.
26. Failure of a qualifying party of the business licensee to train or prepare the applicator to comply fully with the Utah Pesticide statutes and rules and label and labeling directions.
27. Failure to fully respond in a timely way to requests by the commissioner's designated agent for information relating to training and equipping of applicators.
28. Transported, stored, handled, used, or disposed of a pesticide or pesticides container inconsistent with rules specified in section R68 7-13.

EMERGENCY EXEMPTIONS (FIFRA, SECTION 18)

Section 18 of FIFRA authorizes EPA to allow states to use a permit for an additional use (not specified by the pesticide's label), to control a pest for a limited time if EPA determines that emergency conditions exist. The uses are requested for a limited period of time to address the emergency situation only, typically for a maximum of 1 year. In addition to having the EPA-registered label, applicators must have the Section 18 use directions when applying a Section 18 pesticide.

The types of exemptions that may occur for weed control include:

- **Specific** – No registered pesticide will alleviate an identified pest situation. Use this exemption to avoid a significant economic loss. (e.g.; Spartan in Sunflowers on herbicide-resistant weeds)
- **Quarantine** – Request to use a pesticide that is not registered for the site or pest to control the introduction or spread of an invasive pest species.

SPECIAL LOCAL NEEDS 24(C) REGISTRATION

Under Section 24 of FIFRA, states can register additional uses of a federally registered pesticide. The additional uses are for distribution and use within the state to meet a "special local need" (SLN). The official request for a 24(c) registration comes from a pesticide manufacturer or formulator. The pesticide may be needed to treat a pest infestation problematic in Utah but which is not widespread enough to warrant the expense or difficulties of adding a use to a federal registration. SLNs add a special state use to the federal registration and stay active federally as long as the registrant pays the maintenance fee and does not request cancellation. An applicator must have the 24(c) Supplemental Label in their possession to apply SLN products.

MAINTAIN PESTICIDE APPLICATION RECORDS FOR 2 YEARS

Non-Commercial Pesticide applicators may keep the records with their employer, or personal records, but all parties must know their location.

Individual Commercial Pesticide Applicators must make sure the Pesticide Application Record is reported to their employer correctly, regardless of the methods used.

Application records should contain, the reason for the application, customer and business identification, time and date of application, product name, EPA registration number, application rate, and total applied. Find an example records form on the links page at: shorturl.at/gCHN3.

An appropriate label is defined in the Unlawful Acts Section of the Utah Pesticide Control Rule. "Appropriate" means the label matches the product used. Some products have more than one label. The EPA hosts a web page of pesticide labeling questions and answers: shorturl.at/gCHN3.

Non-Commercial Applicators must keep records of RUP applications, but are strongly encouraged to keep records of all applications.

Utah Commercial Pesticide Business Licensees must keep records of each and every pesticide application (not just RUP).

R68-7-10. "Responsibilities of Business and Applicator" specifies that a Business Licensee must:

1. Ensure that applicators receive the training necessary to comply with Utah Pesticide statutes, labels, rules, and law.
2. Keep records that the employee was trained, by whom, and dates and length of time of the training.
3. Include the appropriate business license numbers on invoices, reports, records, service vehicles, and so forth.
4. Notify the customer prior to the time of each Restricted Use Pesticide (RUP) application that has the Danger/Poison signal word on the label.
   a. Provide a written statement with the following:
      - i. Business name and telephone number of the licensed business
      - ii. Name and license number of the licensed applicator who will make/has made the application
      - iii. Date and time of application
      - iv. Type of pesticide application service and brand names of the products used
      - v. Instructions to the customer to contact the business telephone number if more specific information is desired regarding the pesticide product applied.

   b. The notice must be provided to the customer by:
      - i. Leaving it at the residence
      - ii. Leaving it with a property manager in the case of multiple residences
      - iii. Mailing it to the property manager if the authorized representative is not on site within 7 calendar days prior to the application.

Though the majority of the responsibility for these specific rules lies with the business, owner or principal of the entity, the individual applicator needs to know about the provisions of R-68-7-10 (B) (1): A business licensee, qualifying party and/or applicator may be held responsible for the acts or omissions of another person who is employed by the business licensee.

CHAPTER 3

Pesticides in the Environment

LEARNING OBJECTIVES

After studying this chapter, you will be able to:

1. List four (4) ways pesticides are transported (moved) in the environment.
2. List four (4) ways pesticides are transformed (changed) in the environment.
3. List three (3) ways you can control pests while preventing and minimizing negative impacts on the environment and non-target species.
4. Describe three (3) ways that pesticides may negatively impact the environment.
5. List cultural practices that can reduce pesticide use.
6. Identify the ways that pesticides may impact non-target species.
7. List common impacts of turf and ornamental pesticides on aquatic life.
8. Identify ways to minimize pesticide exposure to pollinators.
9. List two (2) general types of pollinator protection best management practices.
10. Identify three (3) challenges to pollinator health from pesticide applications.

INTRODUCTION

Pesticides can help to sustain the quality of turfgrass, ornamentals, trees, shrubs, and other landscape and indoor plants. Pesticides often reduce both labor and energy costs. Despite these cultural and economic benefits, negative environmental effects of pesticide use exist, especially with over use or improper use of pesticides. Pesticide residues resulting from overuse or improper use have been associated with adverse environmental effects, including:

- Reduction of certain bees and other pollinators and bird populations;
- Harmful effects on aquatic organisms;
- Implication of some pesticides as potential carcinogens;
- Long-term soil contamination with persistent pesticides;
- Contamination of ground and surface water;
- Harm to non-target organisms; and
- Development of pesticide-resistant weeds, insects, and diseases.

ENVIRONMENTAL FATE OF PESTICIDES

After applying a pesticide, it will meet one of the following fates:

1. Be absorbed into plants or adsorbed on the soil or organic matter
2. Move off-site (transportation)
3. Break down (transformation)

Transportation processes result in the movement of a pesticide away from its intended site of action. Leaching and runoff potential are of interest because they may affect water quality. Volatile pesticides may be carried through the air and affect an off-target area. There are several factors which influence a pesticides' potential to contaminate water:

- The ability of the pesticide to dissolve in water (**solubility**).
- How strongly it binds to soil particles (**adsorption**).
- How long it remains present and active (**persistence**).
- The tendency of a pesticide to vaporize (**volatility**).

Transformation results when a pesticide's chemical structure is altered— usually desirable because most pesticides used today become less toxic when they break down.

Transportation Processes

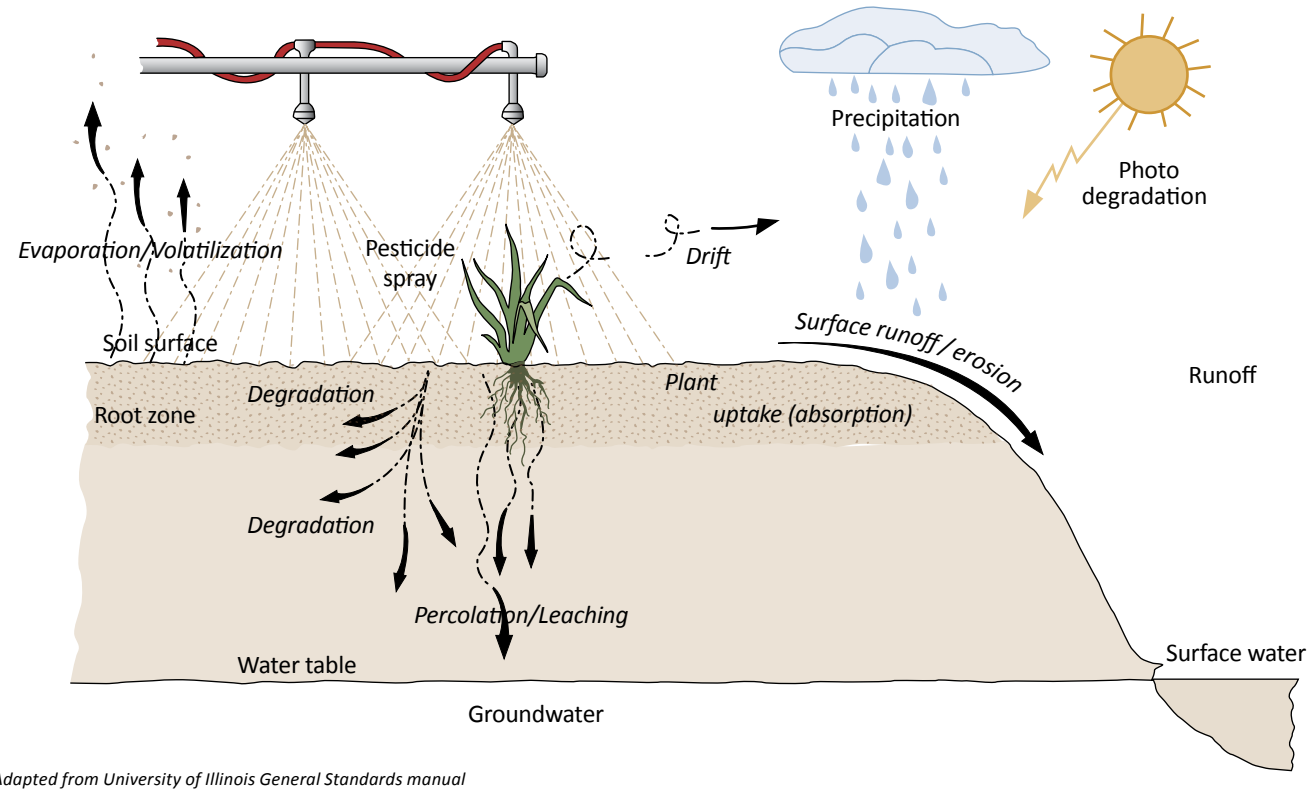
RUNOFF

Runoff occurs when the precipitation rate exceeds the rate of water infiltration into the soil, or when precipitation lands on a hard surface such as a driveway or sidewalk. Runoff is more likely in turf and ornamental pesticides applications under certain conditions, including misapplication onto hard surfaces, rain events too soon after application, over-application, and application to frozen ground. When runoff occurs from these areas, a pesticide can be carried off-site in runoff water, or, if bound tightly to soil particles, it can be carried with sediment in runoff water. The water and pollutants travel untreated through ditches or in underground storm sewer systems to rivers, lakes, streams, ponds, or wetlands.

LEACHING

Leaching is the downward movement of pesticides and nutrients through the soil. This process carries pesticide and nutrient contaminants to groundwater resources. In determining a pesticide's potential in turfgrass to leach to groundwater, the applicator must consider the amount of product that moves down past the turfgrass root system. This depends on factors such as the solubility of the pesticide (how well it dissolves in water). Turfgrass density, depth and quantity of rooting, and thatch development can also significantly affect leaching potential. Studies from several universities have demonstrated that grass and thatch present a barrier to movement of several common turfgrass insecticides and herbicides. Though

Figure 3.1
Pesticide Movement in the Environment



Adapted from University of Illinois General Standards manual

A pesticide may volatilize from spray droplets during application or from residues on plants and other surfaces after application and move off site.

limited scientific data regarding the potential leaching of pesticides into groundwater below turfgrass areas exists, what is available is encouraging; minimal downward movement exists when pesticides are used properly.

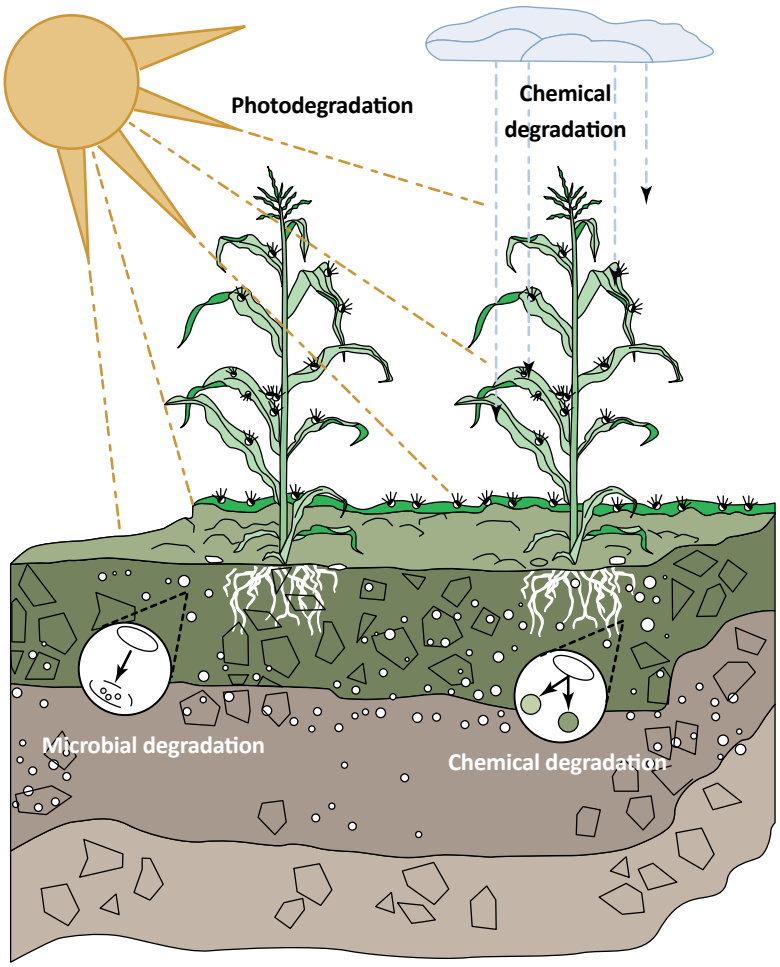
PARTICLE DRIFT

Chemical particle (spray droplet) drift may occur if spraying occurs in windy conditions or during temperature inversions when there is almost no wind. Carrying a wind meter (anemometer) helps to measure on-site wind conditions, which may differ significantly from those predicted in weather forecasts or at weather stations outside the treated area. Recording on-site readings will help you make a better choice of whether or not to spray and will provide some documentation in case of off-site damage. It is illegal to allow off-site drift of pesticides.

VOLATILIZATION DRIFT

Volatilization of a pesticide occurs when it changes from a solid or liquid phase to a gaseous phase. Broadleaf herbicides formulated as esters have a much greater tendency to volatilize than do amine formulations. Sometimes additions are made to the ester molecule to make a lower volatility ester for safer use. Ester formulations should never be used when temperatures are above 80 to 85 degrees Fahrenheit with relative humidity. Check pesticide labels for weather related use restrictions to minimize volatility problems.

Figure 3.2
Pesticide Breakdown in the Environment



OSU Pesticides and Groundwater Contamination

Transformation Processes

ABSORPTION

Absorption is the movement of pesticides into plants and, to a much lesser degree, soil microorganisms. Once absorbed, most pesticides are broken down by the plant. When the plant or plant part dies, any remaining tissue can serve as a food (energy) source for soil microorganisms.

PHOTODECOMPOSITION

Sunlight-induced transformation

can be an important fate for some pesticides. These changes generally alter the chemical properties of a pesticide, making it less toxic (sometimes less effective) and more susceptible to further breakdown by chemical or microbial processes. The dinitroaniline herbicides (for example, benefin, trifluralin, pendimethalin, and prodiamine) are susceptible to photodecomposition. However, once watered into the soil, they are less affected by further photodecomposition. Use photodecomposition to your advantage by drying your pesticide application clothes in the sun.

MICROBIAL DECOMPOSITION

The most common means of pesticide degradation is the action of microorganisms found in soil and thatch. These tiny organisms use the pesticide as a food source, resulting in pesticide degradation. Microorganisms may also alter the structure of the pesticide, usually resulting in detoxification and ultimately in further degradation.

Environmental conditions significantly affect the activity of soil microbiological populations. Warm, moist soil that is well aerated and has a pH range of 6.5 to 7.0 (neutral) encourages high microbial activity. Enhancing biological activity in the soil encourages faster breakdown and degradation of applied pesticides. It should be noted that in some uncommon cases, breakdown products may be more harmful than the original pesticide.

CHEMICAL BREAKDOWN

The hydrolysis of pesticides (that is, the way a pesticide reacts with water) also can be an important fate process. Hydrolysis of pesticides may be enhanced or reduced by the presence of mineral or organic absorbing surfaces.

In addition to these characteristics, environmental factors, such as, soil, weather, season, and distance to water sources will influence the likelihood of water contamination. Application methods and other practices associated with the pesticide use, such as storage and mixing, are also factors. You can control many of these and can prevent or minimize impacts to water. Refer to the National Core Manual for more detailed information on pesticide characteristics.

POTENTIAL ENVIRONMENTAL IMPACTS FROM TURF & ORNAMENTAL PESTICIDE APPLICATION

Pesticides used in turf and ornamental applications may be harmful to the environment, especially when not used properly.

Impacts to Surface Waters

The Utah Department of Environmental Quality, Division of Water Quality, monitors Utah's water quality for a variety of concerns, including pesticides. Find the data, reports, programs, and other information by visiting their website at: shorturl.at/gCHN3

It is not always the active ingredient that may cause damage. Glyphosate (the active ingredient in Roundup) is one of the most commonly used herbicides in Utah. Some glyphosate products are formulated with a surfactant to provide better leaf penetration and thus better control. Without a surfactant, glyphosate is labeled "practically non-toxic" to aquatic life. Certain surfactants used with glyphosate result in the product being labeled as "moderately toxic" to aquatic life. Some surfactants may damage the protective slime layer of fish, making them more vulnerable to chemicals and diseases. Use of glyphosate products with this surfactant near water or where spills or runoff may reach water may harm aquatic life. There are herbicides with the active ingredient glyphosate that are specifically formulated for use in aquatic environments. Make sure you use the correct formulations for your applications and follow label application setback requirements to protect water quality.

One source of contamination for water supplies is backflow contamination. When filling pesticide containers during mixing, it is important that you follow required procedures, or backflow may occur, contaminating the water source. See the National Core Manual for information on preventing backflow contamination.

Impacts to Non-target Species

Pesticide use has the potential to harm non-target species of plants and animals. Keep the following points in mind to prevent off-target impacts:

SHARED ROOT ZONES

One unique consideration of turf and ornamental pesticide applications are root zones shared by various plant species must be considered. Treating turfgrass in an area where trees and shrubs also exist can result in damage to the trees and shrubs. Other ornamentals with more extensive root systems may also incur pesticide damage from treating turf or other nearby ornamentals. When spraying, watch for potential points of entry, including roots growing in organic or inorganic mulch, tree trunks with thin bark, basal suckers and epicormic

sprouts (suckers or water sprouts) on trees, visible surface roots, cracks in sidewalks or driveways, permeable pavement, and parking lot islands, as well as roots growing beneath unpaved surfaces of parking lots or driveways.

Evaluate the pesticide's chemical characteristics as well as the site conditions to determine how likely it is the pesticide will move in the soil and damage non-target plants. For example, Dicamba, used for weed control in turfgrass, can harm non-target trees and shrubs because of high water soluble and low soil adsorption; therefore, it moves freely in the soil and can be taken up by their roots.

IMPACTS ON POLLINATORS

The widespread use of pesticides is one factor correlated with declining bee population. Some insecticides can be toxic to bees, either directly from spray or indirectly when they carry these chemicals with pollen back to the hive. Bees are also impacted by the use of herbicides aimed at killing blooming plants that bees use, such as clover. Some fungicides may harm bees as well by altering their foraging behavior, reducing their pollination potential, or affecting the conversion of pollen to food for bees in the hive.

IMPACTS ON AQUATIC AND OTHER LIFE

Fish and other aquatic life, such as invertebrates, are sensitive to some pesticides at certain concentrations. Other pesticides may be toxic and kill aquatic life at higher concentrations. Still others may impact their ability to reproduce or grow. Fish kills, or impacts to aquatic life, are more likely to result from a pesticide spill than from regular applications. However, use of a pesticide labeled as hazardous to aquatic life near water has the potential to harm aquatic life if misapplied.

Many common fungicides and insecticides can kill earthworms, even when applied at the recommended rate. Pesticides can also harm other beneficial insects and microorganisms.

IMPACTS INFLUENCED BY WEATHER CONDITIONS

Always consider the weather when planning a pesticide application. Weather conditions that may lead to environmental impacts include:

Wind: Drift of pesticides droplets or vapors to neighboring properties can occur, especially during windy conditions or temperature inversions.

Rain: Rain too soon after an application can wash off pesticides and also make them ineffective, leading to the need for an additional application.

Temperature and **Humidity**: High temperatures and low humidity (the typical Utah summer) may lead to volatilization of pesticides and impacts to non-target plants.

Dicamba is a synthetic auxin herbicide used to control broadleaf weeds.

Dicamba and some other pesticides are more prone to volatilization than other pesticides. Read the label for weather conditions during which these products should not be used, typically above 85 degrees Fahrenheit with low relative humidity. This is when volatilization is likely to occur. Dicamba is also highly water soluble and does not bind to soils. The high water solubility and low adsorption make it more mobile in soils, with the potential for groundwater contamination as well.

PREVENTING AND MINIMIZING ENVIRONMENTAL AND NON-TARGET IMPACTS

Turfgrass

Turfgrasses can play a significant role in reducing runoff. Water volumes running off planted groundcover areas, such as turfgrass, may be as little as 10% of rainfall, compared to 55-100% from paved areas. In fact, a thick and carefully managed turfgrass reduces runoff volume to almost zero, which is 15 times less runoff than a lower quality lawn. An average sized golf course of 150 acres can absorb 12 million gallons of water during a 3-inch rainfall. Furthermore, the turfgrass rootzone is a unique soil system. A healthy turf rootzone will help improve soil processes that facilitate the breakdown of various organic pollutants, air contaminants, and pesticides used in lawn care.

However, since most turfgrass species are not native to Utah, they require a lot of input to stay healthy. Choosing the right turfgrass variety for the site can help minimize the need for pesticides. In areas where turfgrass will not grow well, use an alternative groundcover such as mulch, shade tolerant plants, or rock. Thin turfgrass is prone to weed infestations as well as erosion of soils and nutrients, and off target movement of pesticides.

Compaction Avoidance

Many soils in developed areas are compacted either from the original construction or from equipment driving on the turfgrass. Compaction severely impairs the soil's water holding capacity and vertical drainage (infiltration). This environment restricts root growth and plants may become oxygen stressed due to lack of good drainage. Once compacted, soils can never be fully restored to their pre-compacted condition, but soil pore space and infiltration can be improved by annual or more frequent aeration. For new lawns, deep tilling followed by topsoil placement and subsoiling (breaking up soil below the topsoil and incorporating topsoil) prior to installation of turf, will greatly improve pore space and infiltration. Compaction is a concern for ornamentals as well as turf.

Organic Matter Management for Soil Health

Organic matter is anything that contains carbon formed from living plants and organisms. Organic matter contributes to good soil health and can affect the amount of nitrogen and other nutrients available to plants, soil structure, water holding capacity, and the number and types of organisms in the soil. Addition of organic matter can be beneficial to plants. It should be incorporated into the existing soils. In turf and ornamentals, this can be done through aeration.

Ornamentals

Choosing the right plant for the site will help minimize the need for pesticides. Your site evaluation (Chapter 5) will provide you information on soils, light levels, and other factors that can help you select plants suited for these conditions.

Identify potential plant stressors and match your plants to these conditions or alter them to reduce or remove the stress. A stressed plant is more prone to disease and insect damage. Stresses include compacted or poorly drained soils, nutrient imbalances, soil pH levels, air pollution, air circulation limitations, road salt, light, moisture, temperature extremes, wind, and mechanical damage.

If shade is the identified plant stress, pruning trees may reduce the stress, as well as planting shade-tolerant plants. Salt-tolerant plants utilized along the roadside will reduce damage from road salt.

Avoid using plants susceptible to disease and insect infestations to help minimize the use of pesticides. Use of disease-resistant varieties will also provide some protection.

Choose the Pesticide with the Least Environmental Impact

KNOW YOUR PEST

Pest identification is the first step to choosing a pesticide. If you don't know what disease, weed, or insect is affecting the site, you can't make informed choices. Chapter 5: Site Evaluation provides information on diagnosing plant problems and Chapters 9-11 include general information on pests. Additional guides and resources are available to help you identify the pest of concern. If you don't properly identify the pest, you may introduce pesticides into the environment unnecessarily.

RESEARCH CONTROL OPTIONS

There are usually several control options for a pest in addition to the do-nothing approach. Consider the many non-chemical approaches before reaching for a pesticide. Chapter 4: Integrated Pest Management (IPM), provides information on strategies for pest control. Using IPM is an effective way to reduce environmental impacts.

Note: In some cases, Utah state law may be more restrictive than the label. In that case, follow state law.

Always read the label on the adjuvant. In some cases, there may be some environmental hazard and toxicity that should be considered when choosing an adjuvant.

STUDY AND UNDERSTAND THE LABEL

The most important pesticide application practice for protecting the environment is to follow pesticide label directions exactly as stated. The label provides information to help you control pests and apply pesticides properly to protect non-target plants and organisms in the environment (including you). The label will indicate environmental hazards and toxicity. There may be special toxicity statements as well as general environmental statement, and wind and temperature precautions. Refer to Chapter 3 of the National Core Manual for more information on reading and understanding the label. Follow label directions for both proper mixing and for proper post-application procedures (for example, dry time, irrigation).

REVIEW SAFETY DATA SHEETS (SDS)

A review of a pesticide product's Safety Data Sheet (SDS) will provide you with information on the physical and chemical properties of a pesticide, as well as information on its toxicity. Properties such as solubility and vapor pressure will indicate how likely a pesticide is to leach or volatilize. Refer to Chapter 3 of the National Core Manual for more information on interpreting SDSs see shorturl.at/gCHN3. The old version of SDS were called Material Safety Data Sheets (MSDS).

All MSDSs were required to transition to SDSs by mid-2015. The new SDS has a standard format and new hazard communication warnings used in almost all countries of the world including the U.S. However, pesticide labels in the U.S. may not use the new hazard communication warning found on SDSs.

USE ADJUVANTS WHERE APPROPRIATE

Adjuvants are additives that increase the effectiveness of a pesticide or help with the spray/mix process. They may reduce environmental impacts in some cases either directly or indirectly. Surfactants (surface active agents) and other adjuvants may reduce the volume of pesticide used since they make pesticides more effective and may prevent the need for additional applications. Thickeners make the carrier solution more viscous and heavy resulting in reduced drift and better deposition. Spreaders and stickers increase efficiency and help pesticides adhere to leaf surfaces, resulting in less runoff.

If you want to add an adjuvant, make sure the pesticide label does not prohibit its use.

WEIGH EFFECTIVENESS VS. TOXICITY

You may think that choosing the pesticide labeled the least toxic is your best choice for protecting the environment. However, the least toxic pesticide may not be the best overall environmental choice. Consider the pesticide's effectiveness and amount of likely contamination as well as its toxicity. If multiple applications of a less toxic pesticide are needed to achieve the same control as one application of the more toxic choice, overall the less toxic chemical may

be more harmful to the environment. Read the label signal words, precautionary statements, and environmental hazard statements to evaluate the toxicity and safety of the pesticide. Find more information on pesticide labeling in the National Core Manual.

Pesticides derived from plant materials (sometimes referred to as "natural" or "botanical" pesticides) also approved for organic production may be a good option, but are not always the least toxic or safest choice. Some are more toxic than the synthetic alternative. Plant-derived pesticides are likely to break down more quickly and may need additional applications for effectiveness. Read the labels and weigh both the toxicity and other environmental hazards against the pesticide's effectiveness when making a choice to protect the environment.

Apply Pesticides Carefully

CONSIDER SITE CONDITIONS

A site evaluation (see Chapter 5) includes looking at various site factors that will affect plant health, the need for pest control, and how to apply pesticides safely to protect you and the environment.

SOIL

Soil structure will affect how pesticides move. Contamination of groundwater is more likely a concern in areas of sandy soils where leaching may occur. Pesticides are more likely to bind to high organic content and clay soils, resulting in the need to use more for effective control. In root zones with mixed plant species, high organic content and clay soils can prevent movement of pesticides to non-target plants. Do not apply pesticides or fertilizers to frozen soils.

DRAINAGE

Avoid applying fertilizer or pesticide in natural drainage areas or pathways on a property. These may not

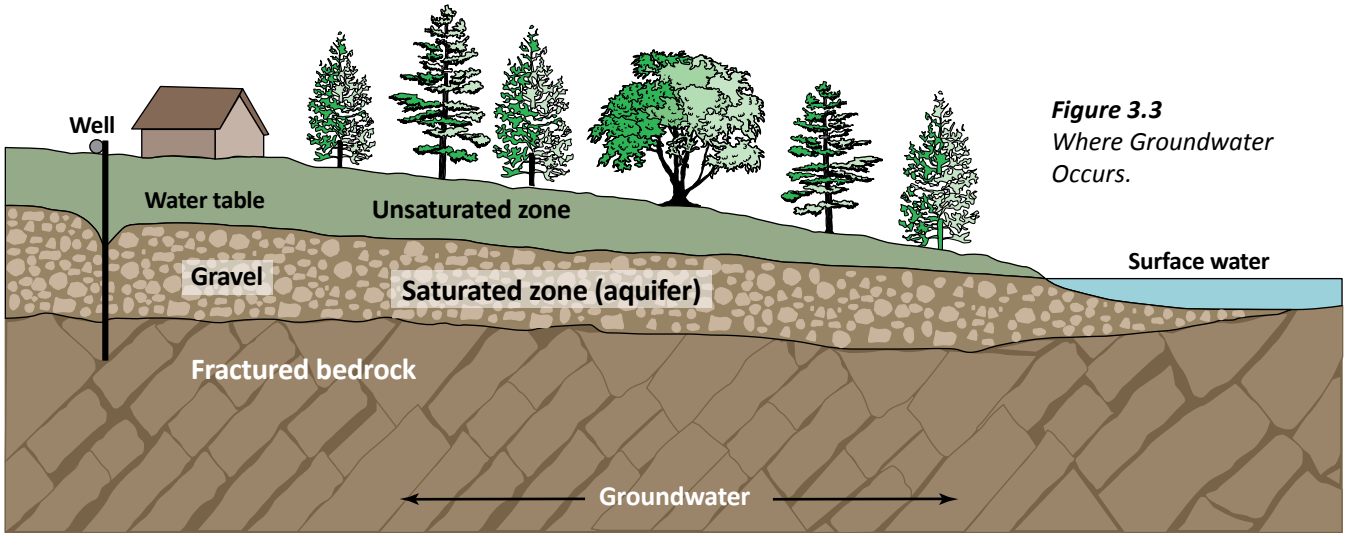


Figure 3.3 *Where Groundwater Occurs.*

Adapted from Penn State Pesticide Education Manual

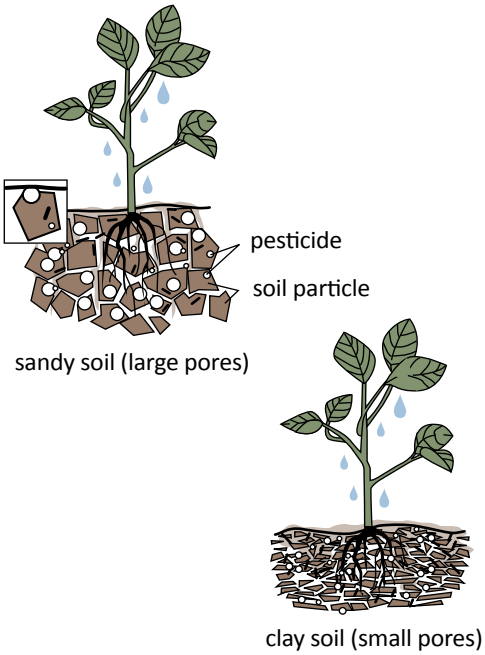


TABLE 3.1 SOIL PROPERTIES

Texture *(affects movement of water particles)*	**Organic Content** *(measures volume of water and soil's ability to adsorb pesticides)*	**Permeability** *(measures speed of water's downward movement)*
Coarse *(sand)*	low organic content = faster water flow and little adsorption of pesticides	High Permeability *(fast flow)*
Smooth *(clay, silt)*	high organic content = higher water retention and greater adsorption of pesticides	Low Permeability *(slow flow)*

OSU Pesticides and Groundwater Contamination

necessarily be hard surfaced areas. Fertilizer and pesticides can be carried directly into surface water before it has a chance to move into the surrounding turf or soil area.

WATER RESOURCES

In your site evaluation, you will have identified nearby water resources such as wetlands, ponds, streams, and lakes. If surface waters are present or nearby, take extra precautions to make sure the chemicals don't reach the water bodies. Check pesticide labels for setback requirements and allowable uses.

Temporary wetlands (vernal pools) may form from snowmelt and spring runoff. These ponds are important breeding areas for frogs and salamanders. Waterfowl also use them to feed on protein-rich aquatic insects that inhabit them. Do not apply pesticides directly to these areas, and maintain a buffer around them to ensure that pesticides do not runoff or drift into these ponds.

Never directly deposit or inadvertently apply fertilizer or pesticide materials into surface waters or onto hard surfaces which drain to surface waters. Any material that ends up on hard surfaces such as sidewalks, driveways, and streets must be cleaned up or swept back onto the application area.

For shoreline areas, leave a buffer zone of unmanaged grasses or possibly native vegetation around the shoreline. This natural area helps prevent erosion from adjacent shoreland, and may retain some nutrients or pesticides that would otherwise move into the lake.

Note: Application of a pesticide to water requires the Category of 5 (a) Aquatic Surface Water on the Commercial and Non-Commercial license.

SHARED ROOT ZONES

Before applying pesticides to a site, make sure you understand the potential for shared root zones between plant species. Below are steps you can take to minimize injury to non-target plants in a mixed landscape with shared root zones.

1. Always know the weeds that need controlling and their basic biology.
2. Consider spot treatment vs. blanket application.
3. Select herbicides with low water solubility and high soil adsorption to minimize movement into and through the soil.
4. Select herbicides with short half-lives to avoid potential long-term persistence in the soil.
5. Plan applications so that the product can fully dry onto the weed foliage, thus minimizing movement into the soil.
6. Apply herbicides just to wet the surface rather than to run off, which will minimize direct application to the soil surface.
7. Be mindful of soil structure and texture differences that impact root system locations and perhaps increase potential exposure to herbicides.
8. Note cracks in or between hard surfaces that may provide direct access to a tree's root system.
9. Check around trees and shrubs to ensure no exposed roots, root suckers or epicormic shoots hidden by the weeds.
10. Consider using contact products and spot treatment applications when treating weeds in mulched landscape beds; if only a few weeds exist, hand pull them and avoid herbicide use altogether.
11. Always read labels. Do a trial on a small area before making a large-scale introduction of new products into an established program.

Use Site Appropriate Equipment and Techniques

Each site has different characteristics. Be prepared with appropriate equipment to keep the application on target. Narrow areas such as center islands in a parking lot require equipment capable of applying a narrow band of chemical, such as a

Use a backflow device when water is pumped directly from the source.

Purdue Pesticide Programs

Purdue Pesticide Programs

Leave a distinct air gap between the hose and the surface of the pesticide mixture to prevent back-siphoning.

drop spreader. Edge or side guards should be used along sidewalks and other hard surfaces. For liquids, use appropriate nozzles for the application purpose. Spot spraying can be used instead of blanket applications in most situations. Chapter 6: Application Equipment and Techniques provides additional information on equipment for turf and ornamental pesticide application.

It is not necessary to thoroughly drench an area with an herbicide to achieve satisfactory weed control. This may be wasteful of both water and herbicide and may move the herbicide beyond the plants and into the soil making it prone to leaching. ALWAYS follow label directions for how to apply and do not apply more than the labeled rate. Follow label directions for proper mixing, water use rates, and post-application watering.

When mixing pesticides with water for application, contamination of the water source can occur due to backflow. Use an approved device to prevent backflow, especially when chemigating or using public water supplies (city water, lakes and other surface waters, ground water, and so forth). Obtain more information on back-flow prevention from Chapter 7 of the National Core Manual, including the simple method of maintaining an air gap between the discharge end of the water supply and the spray tank.

POST APPLICATION IRRIGATION

For effectiveness, move preemergent herbicides, typically used for controlling crabgrass and other annual weedy plants, into the soil surface. They affect the seed as it begins to germinate, before the plant emerges from the ground. Depending on the soil type, apply ¼-½-inch of moisture following application of these products—about 1-2 hours of irrigation with most common lawn sprinklers.

CLEAN UP MISAPPLICATIONS AND SPILLS

Misapplication of pesticides is both illegal and likely to cause contamination of surface water. Use of a rotary or broadcast spreader without edge guards or in an area smaller than the spread width, such a parking lot island, can result in spreading of granular pesticides onto hard surfaces. Misapplication of liquid pesticides onto hard surfaces can also result in these chemicals being carried into surface waters. Finally, misapplication can falsely lead an applicator to assume a product did not work.

Sometimes it is not practical to carry several types of spreaders and your broadcast spreader applies material to the sidewalk in addition to the turf. Use a backpack blower or sweep up material that ends up on hard surfaces.

Clean up any spills. Fill spreaders on a hard surface where spill clean up is easily and make sure to close the gate when filling or crossing hard surfaces. NEVER wash fertilizer spills into the street or other hard surface areas where fertilizer can enter storm sewers and ultimately surface water.

Except for special situations (such as golf greens), return grass clippings to the turf area to decompose, thereby recycling nutrients back to the turf. Clippings sprayed with certain herbicides may harm other plants when used as mulch. Since grass clippings are a source of nutrients, particularly nitrogen, do not blow them into street gutters, or on sidewalks or driveways where they can be carried by runoff to surface waters, or be blown directly into surface water areas. If they get into the surface water, nutrients will be released to the water environment when they decompose, creating nutrient enrichment—a prime cause of undesirable algae and vegetative growth. Pesticide residues may also end up in water along with the clippings.

Use Fertilizers Responsibly

Few soils have enough fertility to indefinitely maintain the level of turfgrass quality expected by most property owners and managers. For that reason, fertilizing turfgrass is a common management practice, the most common practice after mowing. However, improper management of turfgrass fertilizers can contribute to pollution of rivers, lakes, and groundwater.

To protect water resources, follow these precautions when using fertilizer:

- Avoid over-application by applying lawn fertilizer according to Utah State University Extension recommendations, and a current soil test.
- Do not apply fertilizer to paved surfaces such as sidewalks, driveways, and streets. If accidently applied or spilled on paved surfaces, clean fertilizer up immediately to avoid washing it away during the next storm or irrigation event.

Protect Pollinators

Pollinators, primarily bees, have seen significant population declines, with many accompanying news reports. The work that you do may contribute to this decline. This section will offer tips on minimizing impacts to pollinators. Many pesticides, particularly insecticides, now specify certain steps that must be taken to protect pollinators as a requirement of the labeling.

IMPORTANCE OF INSECT POLLINATORS

More than one-third of the world's crop species, such as alfalfa, sunflower, and numerous fruits and vegetables, depend on bee pollination, an ecological service valued in North America alone at $20 billion a year. Without pollinators, the choices you have at the grocery store and of other products would be greatly reduced. Moreover, a

far wider range of plants rely on pollinators to produce seed, including plants we commonly use in our gardens, lawns, and landscape. While managed honey bees pollinate most of our crops, native bees and other insects are also important pollinators. Bees ensure garden plants, ornamentals, and wildflowers get adequate pollination.

COMMON INSECT POLLINATORS OF UTAH

In Utah, there are probably close to 900 different species of bees. The majority of which are not honey bees or bumblebees. Social bees, bumblebees (native to the United States) and honey bees (introduced from Europe), work together in a colony. The remaining species are mostly solitary bees that live on their own, not in colonies with a queen and workers like honey bees and bumblebees. They build their own nest, collect pollen and nectar, and lay eggs without any help from other bees. Some solitary bees may nest in large groups, but they do not actively help each other. Butterflies, ants, wasps, beetles, and moths are also insect pollinators. For more information Utah native bees and management for bees go to: shorturl.at/gCHN3.

IMPORTANCE OF URBAN LANDSCAPES TO POLLINATORS

Urban landscapes also provide habitat for insect pollinators. Gardens with blooming flowers and flowering trees provide nectar and pollen for pollinators. Solitary bees make use of cavities in wood or open soil as nesting areas. Pesticide applicators need to be aware of the importance of urban and suburban landscapes for native pollinators and the growing number of hobby and other beekeepers and hives in Utah.

Local ordinances cannot have stricter pesticide requirements than state law. However, some cities do have ordinances specific to beekeeping. Examples include permits, signage, barriers or location of hives, and so forth.

CHALLENGES TO POLLINATOR HEALTH FROM PESTICIDE APPLICATION

Honey bees have been pushed to the tipping point by the disruption of natural habitats leading to lack of "bee flowers," the widespread use of pesticides, lack of genetic diversity, bee management practices, and numerous bee diseases and parasites. This honey bee crisis is broadly termed Colony Collapse Disorder, a phenomenon in which worker bees disappear abruptly from a beehive. Our native bees are also in decline due to unprecedented habitat loss, pesticide contamination, and their own diseases.

DIRECT AND INDIRECT

Use of pesticides, more specifically insecticides, is one of the many suspected contributing causes of the decline in bee populations. Both direct spray and indirect contact with pesticide residues on plant surfaces after foliar applications harms bees. Pollen with pesticide residues is carried back to the hive where it can harm the hive. Bees can also ingest residues in nectar and pollen when

a pesticide is applied as a seed or soil treatment, tree injection, or foliar application. Some fungicides, although not toxic to bees, can be harmful to bees indirectly by reducing their resistance to the parasite implicated in colony collapse disorder.

Herbicides kill the weedy flowers that provide nectar and pollen for bees. The desire for weed-free landscapes results in use of herbicides to control plants such as clover and dandelion, plants commonly visited by bees.

PESTICIDES HARMFUL TO BEES

Insecticides harm bees more than fungicides and herbicides. Insecticides kill insects and, depending on active ingredient, formula, and concentration, can harm or kill bees and other beneficial insects. Fungicides may have detrimental effects on bee nutrition if they destroy beneficial yeasts and microorganisms in bees' guts.

Certain insecticide classes (for example, neonicotinoids) are more harmful to bees than others. The neonicotinoid compounds imidacloprid, clothianidin, thiamethoxam, and dinotefuran are highly toxic to bees. Imidacloprid is the most widely used neonicotinoid insecticide for controlling sucking insects in home landscapes. Acetamiprid and thiacloprid are also neonicotinoids, but are less toxic to bees than imidacloprid. Neonicotinoids may also be connected to colony collapse disorder. While colony collapse disorder appears to have multiple interacting causes, including pathogens, a range of evidence points to pesticide exposures as an important contributing factor. Neonicotinoids are a particularly suspect class of insecticides, especially in combination with the dozens of other pesticides found in honey bee hives.

POLLINATOR PROTECTION BEST MANAGEMENT PRACTICES

Protect and Encourage Pollinator Habitat

Native bees have two basic habitat requirements: a diversity of flowering plants and egg-laying or nesting areas. You can help protect pollinators by protecting their nesting areas and food sources.

Honey and native bees use many flowering plants to gather nectar and pollen, but some are especially attractive to pollinators, such as bee balm (*Monarda* or *Monardella spp.*), some blazing stars (*Liatris spp.*), and sunflowers (*Helianthus spp.*). You can find a link to publications on bee-friendly flowers on the USU Cooperative Extension's web page at shorturl.at/gCHN3.

When you plan a pesticide application on a site, inquire about the existence of bee-friendly plants on the property and nearby. Consider communicating with any known nearby beekeepers to let them know of an application.

Plants such as clover, often controlled with herbicides, are important pollen sources for bees. Property owners may be willing to accept clover if they understand its value for bees. You have the opportunity to talk with them about leaving some clover on their property, possibly in an area in back of a building where it is less visible.

Most native bees (between 60-70%) dig burrows in the ground. These bees prefer dry, sandy soil bare of vegetation, often on hillsides. The other 30-40%, the cavity-nesting bees, use hollow plant stems or holes in wood left by wood-boring beetles, instead of digging their own tunnel in the ground. Avoid spraying near these areas if you observe bees.

Pollinators need water, whether from a bird bath, a dog dish, or a puddle, especially on very hot days. Take reasonable measures to keep these water sources clean.

Choose Pesticides Carefully

Follow Bee Mandatory and Advisory Statements.

For neonicotinoid pesticides used outdoors as foliar applications that are directly or indirectly toxic to pollinating insects, a bee hazard statement must appear on the pesticide label under Environmental Hazards. The statement differs depending on the toxicity of the active ingredient, and if extended residual activity is displayed. Some additional application restrictions may appear in the "Directions for Use." Here is an example of a bee hazard statement: *"This product is highly toxic to bees and other pollinating insects exposed to direct treatment or residues on blooming crops or weeds. Do not apply this product or allow it to drift to blooming crops or weeds if bees or other pollinating insects are visiting the treatment area."*

Note: The US EPA is in the process of identifying chronic toxicity label statements for pollinator protection.

Bee Advisories will appear on other labels as EPA works with manufacturers.

LEAST HARMFUL PESTICIDE

Consider the following factors when choosing a pesticide to minimize impacts on insect pollinators:

- Toxicity: When more than one pesticide meets your needs, choose the pesticide least toxic to bees.
- Exposure: Think about how bees and other pollinators may come into contact with the pesticide you selected. A pesticide with a somewhat higher toxicity but resulting in a significantly lower exposure rate may be less harmful to pollinators.
- Persistence: Choose a formulation with low persistence and short residual activity.
- Formulation: Use granules, solutions, emusifiable concentrates, and soluble powders instead of dusts or wettable powders.
- Effectiveness: Choose an effective option without the need for multiple applications. Use the lowest effective rate listed on the pesticide label.

Application Method and Timing

Spot spraying vs. broadcast or blanket spraying will minimize the potential for off-target impacts. Avoid spraying near blooming plants. If bees are present, do not spray near them. Avoid spraying when bees are actively foraging. Bees are most active a little after dawn until dusk with peak activity occurring in the morning and late afternoon. Try to spray a site with blooming flower gardens at a time other than when bees are most active. Night is the best time to spray to avoid bees, after the sun sets. Of course, this is not the ideal time for you as pesticide applicators. On very hot days, bees may seek shade in the afternoon or be out searching for a water source.

Many bee species are active with temperatures above about 50 degrees Fahrenheit, and clear, calm days, not too hot or humid, are ideal for bee activity. Bee activity is unlikely in heavy rain.

Leave Buffer Zones

Leave areas of untreated vegetation between the treated area and bee foraging area (blooming vegetation). This will provide a safety margin in case of drift and will help protect the pollinators visiting the area.

CHAPTER 4

Integrated Pest Management (IPM)

LEARNING OBJECTIVES

After studying this chapter, you will be able to:

1. Identify the three approaches to pest control.
2. Explain why cultural practices are key factors in pest management.
3. Describe proper cultural practices for healthy turfgrass.
4. Explain the phrase, "Healthy turfgrass is tolerant turfgrass."

INTRODUCTION

The goal of most turfgrass care programs is to achieve and maintain healthy, vigorous, attractive turfgrass with a minimum of pest problems. Reaching this goal, whether on the home lawn, golf course, or commercial complex, requires the long-term use of a combination of reliable control methods. In addition, determining the necessity and timing of control requires monitoring pest populations.

Integrated pest management (managing with a combination of control methods) relies on cultural, biological, and chemical controls. However, we must evaluate these methods before use for their potential effectiveness as well as their cost and environmental consequences.

Integrated Pest Management (IPM) is based on several key premises:

1. No single pest control method will be successful over the long term.
2. Evaluate the status of pests and the turfgrass requires continuous monitoring.
3. The mere presence of a pest does not justify taking action for control.
4. Eradication (complete elimination) of pests is not necessary and is generally impossible.
5. Healthy turfgrass can withstand greater damage or pressure from pests and recovers more quickly when problems do occur.

Successful turfgrass management requires an additional component, a professional manager. A professional manager must have the knowledge and skills to carry out a number of key tasks:

- Maintain the turfgrass properly
- Identify problems correctly
- Decide upon required action
- Select the appropriate control method(s)
- Determine the correct timing of control method(s)
- Use the control method(s) properly

Find extensive and useful information on managing turf on the USU Extension web page shorturl.at/gCHN3.

In this chapter, we will look at the three general control methods: cultural, biological, and chemical.

CULTURAL CONTROL

The Essential Tasks

Cultural control entails manipulating the planting, growth, and maintenance of turf or a landscape to make it less attractive to a pest and reduce pest activity. The goal of cultural control is to keep the desirable turfgrasses healthy so that weeds, diseases, and other pests have trouble gaining a foothold. Vigorously growing turf masks pest activity that does occur. Healthy turfgrass is tolerant turfgrass. That is, healthy turfgrass can withstand some pest problems without losing its quality and attractiveness. Healthy turfgrass is also more capable of recovering when problems do occur. Proper care of turfgrass can actually reduce pest problems. Likewise, turfgrass may become more susceptible to problems when it does not receive basic care.

Healthy turfgrass begins with the selection of high-quality turfgrass seed or sod well-suited to the site, followed by sound planting practices. After that, proper cultural practices such as mowing, watering, aerating, and fertilizing are essential to maintaining attractive, healthy turfgrass.

Choosing the Turfgrass

As a turfgrass manager, you often have not had the opportunity to control grass selection. However, when establishing or renovating, you may get your chance. Carefully consider the best turfgrass to meet the environmental and site conditions as well as the probable level of maintenance. Each turfgrass species suits a specific environment.

EXAMPLES

- Ryegrasses and Kentucky bluegrasses do best in full sun. They become susceptible to disease in heavily shaded areas.
- Fine (red) fescue tolerates shady, cool areas. However, it rapidly becomes stressed in hot, sunny areas and may be attacked by chinch bugs.
- Improved turf-type tall fescues grow well in sun and shade and tolerate drought as well as the wear and tear of human activity.

Each turfgrass species has many cultivars selected for specific uses. Cultivars are types of plants, including turfgrasses, developed through extensive breeding programs and designed for insect and disease resistance. Selection of resistant cultivars can reduce or almost eliminate the chances of certain insect or disease problems.

Going one step further, some perennial ryegrasses and turf-type tall fescues have a built-in defense mechanism called an endophyte. Endo means within, and -phyte means plant. Endophyte, then, refers to a turfgrass plant incorporated with a fungus toxic to some insects. Turf stands with 40% or more endophytic stems have been shown to eliminate problems from most surface insects such as chinch bugs, billbugs, and sod webworms.

When purchasing seed, the package often contains a mix of several species and cultivars. Carefully read the label for the germination rate, date of test, percentage of weed seed, and percentage of other crop seed. Cheap seed is never a bargain. Never purchase a mix containing more than 2% inert matter, or any noxious weed seeds. Avoid grass seed mixes with annual ryegrass, which germinates and grows quickly but usually die over the winter.

Certified seed is a specific variety or varieties of turfgrass. Buying certified seed from the seller guarantees that you will get the variety of seed listed on the label. Similarly, only purchase high quality, certified sod free from noxious weeds and excessive amounts of other crop or weed plants.

Proper Planting Practices

Once you have chosen your turfgrass, prepare the soil for planting. When a new home is built, the topsoil usually is scraped off, leaving the subsoil. In addition, trucks and machinery at the site can compact the subsoil, making it hard and unsuitable for planting. The subsoil also lacks the nutrients and organic matter necessary for healthy turfgrass growth.

To provide a good home for turfgrass roots, perform the following tasks before planting:

- Use a rotary tiller to cultivate the soil.
- Add topsoil if needed.
- Add organic matter.

Once the seedbed is properly prepared, seed at the proper rate or lay high-quality sod. Then fertilize and water to start the young plants growing.

Proper Cultural Practices

Once you have selected and planted the proper turfgrass, follow proper cultural practices to keep it healthy.

MOWING

Proper mowing is critical to healthy turfgrass. Two key factors to consider when mowing include cutting height and frequency.

The cutting height depends on the time of year and the species of turfgrass. Raise the cutting height during hot, dry weather when turfgrass is stressed. Taller turfgrass helps avoid drought stress by increasing the humidity and keeping temperatures at the soil level cooler. The taller turf that results from higher mowing also shades out germinating weeds and sun-loving insects. Proper mowing encourages deeper rooting and denser turfgrass, which chokes out weeds.

Mow turf grass so that you remove no more than ⅓ of the leaf blade. For example, turfgrass grown to three inches should have no more than 1 inch removed, and would now be at least two inches in length. Scalping, or mowing too short, weakens the turfgrass and makes it more susceptible to disease and other stresses. Find suggested mowing heights based on season and location shorturl.at/gCHN3. For best results, keep mower blades should and properly set.

WATERING

Monitor your turfgrass. Do not wait until it turns brown to water it! The first sign of drought is a loss of springiness and a wilted, generally dull appearance. Light, frequent watering encourages shallow roots, incapable of supporting the turfgrass plant during dry periods. Additionally, waterings that keep moisture only on the leaf surfaces encourage disease.

MANAGING THATCH

Thatch is a layer of living and decomposing turfgrass roots, stems, and leaves on the soil surface. Turfgrass clippings do not contribute significantly to thatch if the turfgrass is properly mowed. A thin layer of thatch (less than ½ inch) causes no serious problem. However, excessive thatch can cause problems.

Proper watering means watering deeply,

- 1-3 times per week as follows:
- 1-1 ½ inches in spring and fall
- 2-2 ½ inches in summer
- Water less frequently in cooler seasons.

EXAMPLES

- Thick thatch provides a hospitable environment for surface insects such as chinch bugs, billbugs, sod webworms, and cutworms.
- Thick thatch can lead to disease problems such as “patch” diseases.
- Growing on thick thatch, turfgrass becomes shallow-rooted and more susceptible to drought.
- Thatch can interfere with pesticide applications by preventing the pesticide from reaching soil pests, such as grubs.

You can prevent thatch problems by selecting turfgrass types not prone to developing thatch. Core aeration also will help by encouraging healthy plant growth and the breakdown of thatch. In addition, fertilize at the proper rate. Over-fertilizing can increase thatch.

MANAGING COMPACTION

Compaction of the soil is caused by excessive traffic on the area. This can be foot traffic caused by athletes using sports fields or people frequently walking on a given area (not staying on a sidewalk). Sometimes the use of machinery on an area can cause compaction, especially under wet soil conditions. Although compaction may not immediately kill the turfgrass, it does restrict the growth and weakens the plant making it more vulnerable to other problems such as weeds, insects, and diseases.

General problems caused by compaction may include the following items:

- Decreased water infiltration and percolation into and through the soil
- Poor soil drainage
- Lower oxygen levels in the soil
- Reduced microorganism activity in the soil
- Reduced turfgrass root growth
- Reduced wear tolerance of the turfgrass
- Greater difficulty establishing new turfgrass stands
- Slower recovery from injury

Look for these symptoms of soil compaction in turfgrass:

- Shallow roots
- Reduction of growth
- Thinning of turf stand
- General yellowing of turf
- Invasion of weeds adapted to compacted soils (for example, knotweed, crabgrass, annual bluegrass, goosegrass, and clover)

Use aeration to alleviate soil compaction and reduce thatch. Aeration is the process of removing plugs of soil from the turf area. Aerators use hollow tines (usually 3-4 inches in length and 1⁄4 to 3⁄4 inches in width) to remove plugs from the soil.

Perform aeration during periods of cool weather (early to mid-spring or late summer to early fall) to ensure rapid recovery of the grass. Aerating requires adequate moisture for penetration of the aerator tines and for removal of the plugs. The plugs are broken apart and left on the surface after they have dried.

FERTILIZING

How much and when to fertilize are two key questions you should ask yourself. The answers depend on:

1. Type of turfgrass. Improved kentucky bluegrass a high-performance turfgrass, may require more fertilizer.
2. Soil conditions. Sandy soils may allow nutrients to leach away. That means the soil may require more fertilizer.
3. Time of year. Use a heavier rate when fertilizing in the late fall. Late-fall fertilization encourages root growth. A stronger root system will better support the

plant and add to its overall health. Use a lighter rate when fertilizing in the spring and summer. A lighter rate enhances top growth, keeping the turfgrass green, healthy, and attractive.

4. Level of maintenance. Golf courses may require more fertilizer to keep the turfgrass healthy and attractive. Certainly, the level of maintenance required for turfgrass on a prestigious golf course will be different than that for a public playground.

Proper fertilization encourages good root and top growth, resulting in healthier, thicker turfgrass, less prone to pest and environmental problems.

BIOLOGICAL CONTROL

Using Natural Defenses

The biological approach to control uses living organisms or their products to reduce pest populations. The turfgrass environment contains many naturally occurring insects, mites, nematodes, bacteria, and fungi that naturally reduce turfgrass pests. These organisms act as predators, parasites, or disease agents of the pests. Turfgrass managers have two options in terms of biological control.

1. Enhance or preserve the effects of natural enemies that already exist in the turfgrass.
2. Introduce commercially produced biological organisms into the turfgrass system.

Enhancing and Preserving Natural Enemies

How can turfgrass managers strengthen natural control? First, correctly identify and monitor pests and their natural enemies, and second, eliminate unnecessary use of pesticides. Chemicals may harm beneficial organisms as well as target pests.

Several diseases that attack insects may be found in the soil and turfgrass canopy. Beauvaria, a fungal disease found in the soil, often attacks chinch bugs, sod webworms, and billbugs and can significantly reduce their numbers. In years with above average rainfall, conditions are prime for the development of this fungal disease, and chinch bugs and sod webworms rarely reach pest status. Monitoring the pests is the key. No chemical control is necessary if the natural enemy Beauvaria is attacking the pests.

Not all insects cause damage. The harmless big-eyed bug often is confused with the damaging chinch bug. Big-eyed bugs prey on the chinch bug. The presence of these predators means control of chinch bugs. If the big-eyed bugs are misidentified, controls might be applied that will harm them. In their absence, a real pest problem could develop.

Ground beetles and rove beetles readily attack turfgrass caterpillars, as well as the eggs of sod webworms and white grubs. Using chemical controls before warranted may kill these natural predators. Indiscriminate or preventive pesticide use also may kill these "natural defenses" and allow reinfestation of pests.

Using Commercially Produced Biological Controls

More and more commercially produced biological controls are becoming available for managing turfgrass insects. The bacterium *Bacillus popilliae* Dutky causes milky spore disease in Japanese beetle grubs. In certain areas where this disease has been established, Japanese beetle grubs are suppressed and often do not reach damaging levels. More recently, insect parasitic nematodes (microscopic worms) have been selected and are commercially available for control of a variety of turfgrass insect pests.

Effective use of biological controls requires skill, however. Many conditions must coincide for this approach to work. Additionally, biological controls are very specific.

The biological-control approach can become costly when so many conditional requirements exist for its effectiveness. When failure occurs, expensive reapplications may be necessary.

CHEMICAL CONTROL

A Tool to Use Wisely

Chemical controls include not only pesticides that kill pests, but also repellents, attractants or pheromones, and insect growth regulators. Currently, few of these latter controls are registered for use on turfgrass, but in the future we have access to more of these tools. The wise turfgrass manager knows when and how to use the chemical approach effectively and keeps up with current information on chemical controls.

Preventive vs. Reactive Applications

You can use two approaches to control a pest problem with pesticides. The approach you use depends on the specific problem.

1. Preventive Application. Prevent a pest outbreak by making an application before the problem appears.
2. Reactive or Curative Application. "Cure" a pest problem after the problem is noticed.

Preventive

Often, preventive applications occur before any observable damage. Therefore, it is harder to justify the decision to use this approach when using pure IPM. At the very least, before using a preventive application, be certain that conditions exist that would favor the pest's development. Turfgrass with a recent history of an insect or disease problem is a reasonable candidate for the preventive approach. Certain annual weeds and some diseases are best controlled with pesticides.

EXAMPLES

- Control crabgrass before it germinates and becomes visible.
- Keep diseases from invading turfgrass plants because control is almost impossible once infection has occurred (the damage is already done).
- Some fungicides and insecticides (for example, imidacloprid or halofenozide) are more effective when used as preventive applications.

Reactive

Where possible, using reactive treatments is the more desirable approach. When using reactive treatments, ensure you have a pest present and in high enough numbers to justify chemical use.

EXAMPLES

- Most insects can be adequately controlled after they are discovered, but before they cause significant damage.
- Dandelions are controlled when they are young and actively growing.

OBSTACLES TO EFFECTIVE CHEMICAL CONTROL

Consider these three obstacles to effective control before choosing a chemical control:

1. Presence of turf grass thatch,
2. poor timing of chemical control, and
3. pest resistance to the chemical control.

Thatch

The presence of dead and living shoots, stems, leaves, and other organic material (thatch) in turfgrass can present problems.

Proper cultural practices to reduce thatch will improve the performance of some pesticides.

EXAMPLES

- Some pesticides adsorb (attach) to the thatch and are inactivated.
- Some pesticides adsorb to the thatch and do not reach the pest.

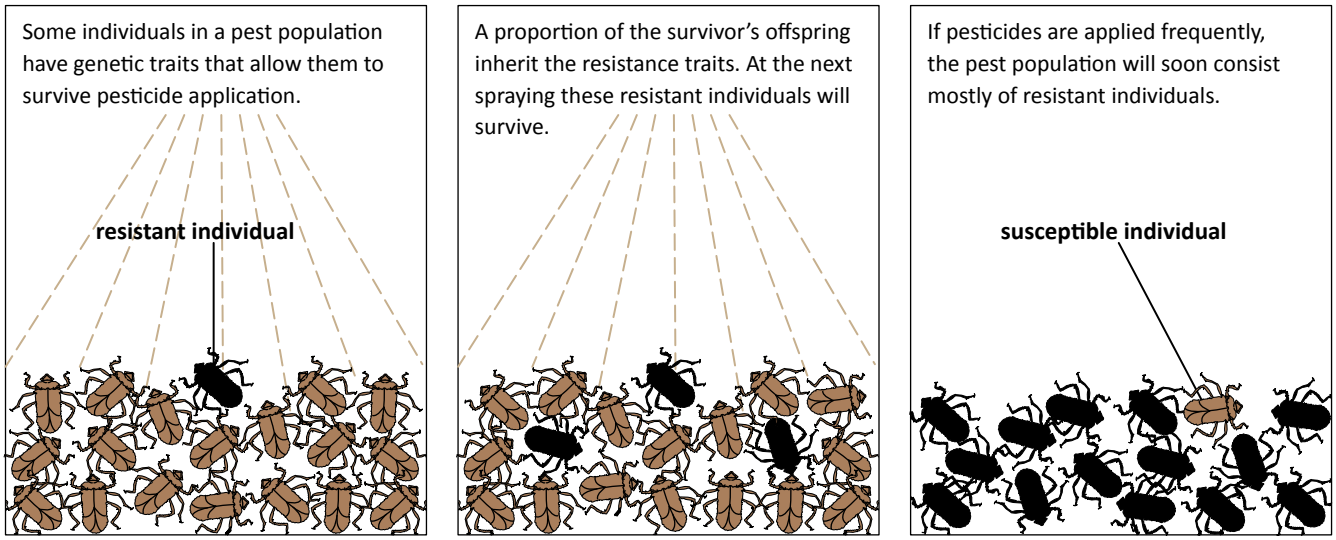
Poor Timing

Examples of poor timing of chemical control are applying pesticides when a disease is already visible, when white grubs are large and nearly mature, or when weeds have gone to seed. Under these conditions, control is nearly impossible.

Pest Resistance

When you use pesticides, you put pressure on a pest population to survive. Under severe pressure, those pests that survive can pass on their ability to survive to future generations. Eventually, the pest population may contain individual pests that can survive or "resist"

Figure 4.1
Pesticide Resistance



Adapted from U. of C. The Safe and Effective Use of Pesticides

Follow these guidelines to reduce the risk of developing resistant pest populations:

- Use pesticides sparingly.
- Select short-residual pesticides.
- Rotate or alternate pesticides that target a different mechanism of action.

the chemical's effect. When this happens, the chemical fails to provide adequate control and is no longer useful.

Pesticides that last a long time (have a long residual) and are used repeatedly tend to cause development of resistance.

The mechanism of action is defined as the biochemical site within a pest which a pesticide directly interacts.

The term site of action is sometimes used instead of mechanism of action. The group number on the label will indicate the pesticide's mechanism(s) of action. Pesticides with the same mechanism of action are assigned the same group number.

By following these guidelines you will have many more options to choose from when using chemical control.

PUTTING IT ALL TOGETHER

What Is Integrated Turfgrass Management, and What Does It Look Like?

Just knowing all the general turfgrass management tactics does not establish a good turfgrass management program. An integrated turfgrass management program uses the basics of IPM and applies it to turf. An IPM turf program includes cultural, biological, and chemical controls to manage a pest population.

CHAPTER 5

Site Evaluation

LEARNING OBJECTIVES

After studying this chapter, you will be able to:

1. List three (3) pieces of information to obtain from the site owner.
2. List five (5) things to observe when walking the site.
3. List key steps in determining the cause of a plant problem.
4. Understand pest diagnosis well enough to recognize a potential misapplication.
5. Understand how the site location itself can affect plant health.
6. Identify cultural practices and abiotic stresses that impact plant health.
7. List weather conditions that could postpone a pesticide application.
8. Identify cultural practices that can impact pesticide application effectiveness.

INTRODUCTION

Conducting a site assessment of any new site can help you identify important site-specific conditions and information for increasing effectiveness of pest management while minimizing problems with pesticide applications. Understanding the size of the site, the maintenance history, adjacent properties, and the customer or supervisor's expectations will help you do your job more effectively and efficiently. Create a standard form you can complete for each property and keep in the file for future work. You can make use of technology such as digital notepads to record this information as well as photos if

desired. Many of the items you assess may not have a direct relationship to pesticide application, but will relate to plant health. Ensuring that the site has healthy turfgrass and healthy plants will reduce the need for pesticide use. Choosing the right plant for the right area is a big factor in plant health. In addition to an initial site evaluation, each time you schedule a pesticide application, some site evaluation should occur.

Tools

Make up a checklist of things to include in your site evaluation. You can include a list of common insects, weeds, and diseases to check if noted on the site. Several phone or tablet Apps or other computer programs are available that will make this information easier to manage.

INSPECT AND DOCUMENT THE SITE

Gather Information from Customer and Document Findings

LOT BOUNDARIES

Determine the boundaries of the property. Obtain this information from the customer, property records, and several on-line sources. Often, county property tax sites have maps overlain on aerial photography which provide the boundaries as well as measurements. Boundaries will be important not only to determine the size of the site, but to make sure that no pesticides are applied offsite.

CONCERNS AND EXPECTATIONS

One of the most important things to gather during a site evaluation is the expectations for the site. Future maintenance relies on this information. Talk to your customers or supervisors and determine their expectations for the property. Expectations will likely vary for the front of the building and the back area. Rarely used areas in a park may require minimal care. People are often willing to accept some weeds. Many people would like to see fewer chemicals used on the property. The input required for different expectation levels varies substantially, with high quality landscapes requiring significantly more input in time, resources, and money.

Map out the property and the management goals for different areas of the property. If questions arise in the future about weeds or insect damage in a low maintenance area, the management plan agreed upon with the property manager will help you explain pests in an area and why other areas have no pests.

PAST TREATMENT AND CULTURAL PRACTICES

Talk to the customer about past site maintenance. What maintenance was performed on the site in the past? If irrigated, what is the schedule? When was the last pesticide treatment and for what?

IRRIGATION PRACTICES

Whether or not a site is irrigated will make a difference in how you treat it. Adjust irrigation schedules and time pesticide applications to avoid washing off the chemicals following a treatment. For preemergent pesticides, irrigation following the application is recommended to move the pesticides into the soil. Irrigated sites will require more fertilizer and other cultural practices than non-irrigated sites.

EXISTENCE OF POLLINATOR GARDENS

Verify with the property owner or manager whether or not there are butterfly or bee gardens on the property. They also may be aware of nearby pollinator gardens or hives. As you develop a management plan for the site, you will need to take precautions around these areas. Herbicide applications may harm bees and other pollinators. Find information on pollinator protection in Chapter 3: Pesticides in the Environment.

Walk the Site and Document Findings

AREA

Often the engineering department of government properties will have mapping capabilities and can provide measurements for various areas. For contractors, obtain this information through purchased on-line programs. Some county government offices have mapping programs you can access. Some even have the ability to provide area measurements.

If you do not have access to this information, use a measuring wheel to measure the property and calculate areas. The property size is needed for calculations such as the amount of herbicide needed for a lawn treatment.

PLANTS AND TURFGRASS

Take an inventory of the existing plants, or areas of plants. Note the type and size of trees as well as their condition. It is also important to identify the species of turfgrass, since maintenance requirements and pesticide options will differ. Document any noxious weeds or invasive species found and the location and extent of the problem.

SLOPE

Is the property relatively flat or are there some hills? Will it be prone to runoff and erosion? Are there concerns for equipment use on steep slopes or equipment access issues?

ASPECT

What direction do the areas to maintain face? This will be important to gauge wind conditions as well as sunlight.

IRRIGATION

Is the site watered regularly or is there an irrigation system? Are the irrigation heads in working condition? Are the heads the proper type for the area and adjusted to water the turf and not hard surfaces? Is there a rain or moisture sensor or smart irrigation system?

DRAINAGE

Where does the site drain to when it rains? Is there a nearby pond, stream, lake, or wetland that may be affected? Is there a swale that directs water through the turf? Note the nearest storm drains. Any spills or chemical that reaches the storm drain will wash into surface water.

LIGHT

Identify the light exposure conditions on the property, whether full sun, partial sun, or shade. Several different conditions may exist on the property. A shady area where turfgrass is not growing well will be prone to weeds. Rather than using repeated applications of pesticide and never getting dense turfgrass growth, another more shade-tolerant planting or mulch.

SOIL PROPERTIES

Identify the texture of the soil on the property as coarse (sands, loamy sands, and sandy loams), medium (loams and silt loams) or fine (clay loams, silty clay loams, and silty clays). A soil probe is a useful tool for evaluating soil conditions. Is the soil compacted? Try using a soil probe or inserting a screwdriver into the ground to determine compaction. If you can't insert it more than an inch or two after an irrigation event, it is likely compacted. Bulk density measurements precisely indicate compaction. These measurements help when doing soil injection. Figure bulk density by dividing the dry weight of the soil divided by the soil volume.

For turfgrass, collect a soil sample and send it to the USU Analytical Laboratories (USUAL) shorturl.at/gCHN3 or a private laboratory. In most cases, the basic soil test will do. A soil test will give you information on soil texture, nutrient needs, pH, and organic matter content.

Soil traits will also be useful in identifying how pesticides may move in the soil. Soil type and texture will influence the ability of a plant to grow well. Clay soils will limit root penetration and are often poorly drained. Sandy soils dry out quickly. Higher organic content soils will hold more water and also act as a reservoir for plant nutrients. Soils with a high clay or organic content will adsorb more pesticides, and pesticide concentrations will be lower in the soil solution.

Soil pH is often included in the basic soil test. The optimum soil pH for most plants is between 6.0 and 7.0. Higher or lower values can affect the availability of several plant nutrients, activity of soil microorganisms, and the ability of soil to hold plant nutrients. Soils that are too acidic (low pH) or alkaline (high pH) will affect plant growth. Utah typical soil pH is between 7.0 and 8.5.

ADJACENT SITES

Identify property concerns adjacent to the customer's property. Record this information on a map of the site. Take note what is located downwind of the property. Take special precautions when nearby properties include daycare center

or home with children playing, or if the neighbor next door is growing bee-friendly plants or prize-winning flowers and expresses concerns with pesticide applications on neighboring properties. If someone with a sensitivity to certain pesticides lives nearby, note this in the file.

ENVIRONMENTAL AND NON-TARGET CONCERNS

Each site has different features that may make it more sensitive to environmental concerns. Take notes on potential environmental and non-target species concerns. For example, if you noted the soils were coarse in the soil assessment, the site is more likely sensitive to groundwater contamination. Observations of steep slopes, drainage ways, on-site or nearby wetlands, lakes, or streams may make the site more sensitive to contributing to surface water contamination. Woodland areas may host a lot of birds that could be harmed by pesticides. Bare eroding soils can contribute sediment and attached pollutants to water.

Document the potential for non-target impacts such as nearby pollinator habitat, or wildlife that use the site. Note and document bee, butterfly, and other pollinator gardens located nearby, as well as any known beekeepers in the vicinity of the property. Bees fly up to two miles or more to gather nectar and pollen. Many commercial and industrial and townhome developments have stormwater treatment ponds located on site. Birds, frogs, and other wildlife use these created ponds for food and habitat. Note where they are located on the property and avoid treating areas near the water's edge just as you would with natural streams, lakes, and wetlands.

Identify shared rootzone concerns and note the presence of potential pesticide points of entry.

The fate of pesticides in the environment and methods to reduce environmental impacts are discussed in Chapter 3 of this study guide as well as in Chapter 7 of the National Core Manual.

DOCUMENT PROBLEMS, POTENTIAL PROBLEM AND RISKS

Measure and Map Affected Areas

Document any plant problems you find during the assessment and determine the extent of the problem. Measure the affected area, or inventory plants affected in the case of indoor sites or trees. This will help you plan for future treatments if needed. Gather and document the following information.

Area and Number of Plants

Measure the square footage of the affected area(s). If there are individual trees or shrubs, take a count of the affected plants. You may need to measure tree diameter for pesticide application. The usual measurement taken is the diameter at 4 1/2 feet trunk height (about breast height for many people, sometimes stated as DBH). Document this information on a site map. Note if the problem occurs in a specific environment, such as shade or a wet area.

Don't start pesticide treatment or corrective measures until you have completed a thorough and accurate diagnosis of the problem.

DETERMINE THE POSSIBLE CAUSE OF PLANT PROBLEMS

Once a problem is documented, you will need to determine its cause in order to choose the best management option. You are probably familiar with how a doctor looks at symptoms and talks to patients about medical issues. You will need to take some of the same steps to diagnose plant problems. Diagnostics include a combination of examining the plant and surrounding areas as well as speaking to the property owners or others that could offer clues about timing of the problem, how the site has been treated, and other events and practices that influenced the condition of the plants. A little detective work may solve a problem. It is not a guessing game, but rather a systematic process. Look for clues to help determine the cause of the plant problem. The more you practice, the better you will get at diagnosing plant problems.

A good diagnostician has the following characteristics:

1. Broad knowledge of plants
2. Access to relevant resources, such as books and websites
3. Knowledge of diagnostic techniques
4. An inquiring, open, logical mind
5. Patience and thoroughness

Identify the Affected Plant

Identifying an affected plant is one of the important clues to help you identify the pest or problem. Recognizing the appearance of a healthy plant helps you identify abnormalities. Pathogens (disease-causing agents) only attack certain plants (known as a host range). If you identify a plant, you can eliminate all pathogens or insects that don't cause disease or damage on that plant. The host range varies from very small for some insects, such as the sawfly that

feeds on species of pine, too large for the Brown Marmorated Stink Bug, which feeds on many different types of plants. Identifying the plant will help you narrow your choices of possible pathogens or insects.

Once you've identified the plant, you can also look up some of the common problems known to affect that plant. Use references such as those listed in Chapters 9–11 as well as on-line tools to help you narrow your choices.

Describe the Symptoms

EXAMINE THE PLANT

Closely examine the affected plants and its affected parts. Remember to examine all parts of the plant, not just the part with obvious symptoms (response or alteration of appearance due to a pest or problem). For instance, symptoms such as wilting leaves might indicate a problem blocking water movement in the stems or roots. Look at both surfaces of the leaves. Examine several plants. Use a hand lens or magnifier for closer examination. This will allow you to see smaller insects, mites, spores, and so forth. A microscope may help identify some diseases or insects. Slicing the plant open will help you identify pests when there are exit holes, unknown galls, wilts, or dieback, or when you see no visible symptoms.

IDENTIFY THE PATTERN OF THE PROBLEM

What type of damage occurs on the individual plants? Note if the damage affects the whole plant, just the leaves, or other parts. Note if the damage is limited to one species or if it affects several species, and if so, identify those species. This type of information will help you diagnose the problem.

PROGRESSION OF THE PROBLEM OVER TIME

Talk to the property owner and determine when the symptoms first appeared. Determine the problem's spread or reach. Identify the area on the plant where the problem appears. For example, on a tree, diseases of leaves often start in the lower inner canopy, where humidity is low, and grow upward. Insects often disperse throughout the plant.

Abiotic (non-living) disorders often occur following an event, such as frost, flooding, or an herbicide application. Sometimes the symptoms appear soon after the event, but in some cases, the symptoms may not appear for years, as in the case with construction. Talk to the property manager to determine if an event occurred that caused or contributed to the problem.

Key steps for diagnosing plant problems:

- Identity the plant
- Describe the symptoms
- Look for signs of pests
- Examine the surrounding area
- Use reference materials to identify the pest

Look for Signs of the Pest

The pest may be present on the plant. Closely examine the plant for the pest or signs of the pest. Signs may include fungal spores, bacterial ooze, insect droppings, exit holes, tunneling, and so forth. Look for signs such as dark discolored areas, bore holes, and sap or resin along the stem. You may get lucky and spot the pest itself. When pests are not visible and there is wilt, dieback, or marginal tissue death, slicing the plant open may help you identify the pest. This also helps when no visible symptoms on the branches or trunk of a tree, or you find an unknown gall, exit holes, or frass (insect excrement).

Use reference materials to verify if the pest you identified causes the type of damage observed see shorturl.at/gCHN3.

Points to Remember

A wide variety of visible signs and symptoms indicate when plants are in trouble. A professional pesticide applicator should become an expert at diagnosing plant health problems in an ongoing learning process.

During a diagnosis, keep the following points in mind:

1. Location of initial symptoms provides a useful diagnostic tool. For example, most leaf spot diseases show up on the lower inner branches first because of higher humidity and lower airflow there. In contrast, vascular wilts and root problems (abiotic or pathogenic) show up first in the upper canopy where sun and wind rapidly deplete water and nutrients at a rate that the damaged roots or blocked vascular system cannot replace.
2. If injury shows up on top or on external portions first, look for environmental factors first (air pollution, salt spray damage, cold injury). Other possibilities include some herbicide injury, some nutritional disorders, and some insect or disease pests.
3. Presence of an insect does not necessarily mean it is caused the observed damage. Ask yourself: What is the insect? What damage does it seem to be causing? Are there enough insects to cause the visible damage?
4. Absence of an insect or disease sign does not necessarily indicate that these did not cause the damage. An insect may leave feeding damage and migrate to another plant or change to another state (egg, pupa). A disease organism may not have progressed sufficiently to show spore bodies and other signs.
5. Always check growth rate. Compare current growth with previous growth history. Sometimes this provides clues to past cultural practices.

EXAMINE THE SURROUNDING AREA

What Is the Pattern?

As you continue your examination of the plant, also consider the surrounding area and whether you can detect any pattern. Is more than one type of plant affected? Are all of the plants affected related or are many different types of unrelated plants affected? If a variety of plants are affected, this might indicate a pest with a very broad host range causing the problem, or that an abiotic problem, like drought, is affecting many of the plants. If only one type of plant is affected, this could indicate a plant particularly sensitive to an abiotic problem or that a pest or pathogen with a narrow host range is causing the problem. For example, white pines are very sensitive to air pollution and will show damage when other plants do not.

Consider Cultural Practices and Other Abiotic Stresses

Improper cultural practices, such as excess irrigation, excess fertilizer, mowing too short or too tall, mechanical damage (trimmers/mowers), improper planting, and pesticide damage, may lead to poor plant health and disease. Mowing too short often leads to thin turf and weed invasion. Frequent, light irrigation leads to short root systems and weak turfgrasses. This makes the turf at risk for insects, weeds, and diseases. Lack of fertilizer can lead to thin turf and weed invasion.

The most common abiotic stresses are water (too much or not enough) and temperature (too low or high). Water-stressed turf is more susceptible to insect pressure and leads to thin turf which encourages vouneralbility to weed invasion. Too much water, however, can make plants more susceptible to diseases. Wind and fire are less common abiotic stressors.

Location

Consider the site conditions: soil type, light, exposure, wind, moisture, and drainage. Compare the conditions at the site to the preferred growing conditions for that particular plant. A drought tolerant plant may do poorly planted at the base of a rain spout where a water loving plant may thrive. The same two plants will have the opposite response in a dry exposed site. Ask yourself: How much sun or shade does the plant receive and require? Is the plant well protected or is it exposed to wind or other elements? How much water does the plant receive and require?

Soil condition can greatly affect a plant's appearance. Compacted soils and poor soils may restrict root growth, and a root's ability to take up oxygen and nutrients. Slow

growth, dieback, and discolored foliage all result from poor soils. What is the soil type and the pH? If a pin oak is placed in soil with too high a pH, it will be unable to take up iron, which will result in chlorosis. A soil test from USUAL can provide details on pH. Is the soil well drained? Water that doesn't drain well could suffocate roots and favor root-rotting pathogens.

Road Salt

Road salt application is a common abiotic stressor to turfgrass and other landscape plants, especially along streets, sidewalks, and roadways. Damage can occur from salt spray as well as from salt that ends up in the soil. On busy streets and high-speed roads, damage is most severe within about 60 feet of the road. Salt spray on deciduous trees can kill twigs and buds. A common symptom is a "witch's broom," where new spring growth appears as a cluster of twigs. On evergreens, salt spray can cause yellowing or browning of needles and twig dieback, usually affecting the side facing the road. Symptoms of excess soil salt include browning of leaf edges, stunted growth, and fewer or smaller leaves, flowers, and fruit. If you suspect high soil salt, a soil test will help confirm this.

Use Reference Materials to Identify the Pest or Problem

Now that you've gathered information on the problem including location, symptoms, patterns, and possible causes, use reference materials to help you identify the pest or problem. Use references to match the signs and symptoms you observed with the specific description of the pest. Reference materials include books, keys, Utah State University Extension staff, websites, and the Plant Disease Diagnostic Clinic. Refer to Chapters 9– 11 for more information on weeds, insects, and diseases. One good local source of diagnostic help is the USU County Extension Master Gardener volunteers. Locate volunteers at shorturl.at/gCHN3.

Tips for Using Reference Materials

First, look for the host plant or suspected pest in the table of contents or index. Don't try to just flip through photos; you're not likely to find what you need. The index will give you a list of pages to locate your host plant often divided by symptoms, pests, or diseases, which can narrow your list even more. Many books further divide into groups of diseases (fungal diseases of asters, leaf spots on tomatoes, viral diseases of hostas).

Do your preliminary examination of the sample to make decisions about the problem. Take notes and then read the descriptions that go with each possible disease and see if the symptoms fit. Remember symptoms develop over time with a disease. Photos can be taken with different lighting and background, of different cultivars, and maybe of a different plant. Weather conditions make the

disease and the plant look different. Rely on the written description of the symptoms to help you out, not just the photos.

If you are unable to identify the pest, contact the USU Plant Pest Diagnostic Lab. See shorturl.at/gCHN3. The laboratory can give you instructions on what materials must be submitted for them to identify the pest.

SITE EVALUATION AT TIME OF APPLICATION

Weather Conditions

Review the forecast prior to deciding to apply pesticides. If rain is predicted soon after application, delay the application. Refer to the label for information on how long before rain the pesticide must be applied.

Utah does not require weather information be recorded for pesticide applications, but, it has been the experience of UDAF Pesticide Program Inspectors that the more information that is recorded with the application records the less problems arise from complaints about the application. This seems to be a logical business practice of anybody applying pesticides in the Ornamental and Turf Category. An example of this could be if the weather information was written down and a complaint entered that the applicator was spraying a volatile formulation on a hot and windy day. When the UDAF inspector addresses the complaint, they usually will accept the weather information as long as acceptable methods and instruments were used to gather it. If the information was in the parameters required by the label directions then there will not be a violation. If the complaint results in a civil matter because of damage, the applicator can use the information and demonstrate the methods to seek relief from paying damages. Methods to acquire the data, such as smart phones are better than not recording the data, but remember these methods and instruments are not specific to the application site but rather from weather stations in the area.

Cultural Practices

If you also mow the property, make sure that you do not mow 1-3 days before or 1-2 days after an herbicide application, or it may affect the effectiveness of the treatment. If someone else mows the property, communicate with them prior to the application so you can schedule an herbicide application with the appropriate time between mowings.

Adjust irrigation systems so they don't wash off herbicide applications; or make owners aware for those herbicides that require watering-in.

When to postpone an application:

- Forecasted rain
- Windy conditions
- Temperature above 80°F with low humidity

Presence of People and Pets

Before starting a pesticide application, check the area to see if any humans or pets could be exposed to pesticides. If present, notify them so they can leave the area prior to the application. Your company should have a policy on this. Here is an example policy.

Knock on customer's door (for residential only). If no one is home, proceed with the visual inspection of the property, looking for the following:

- Open windows (if spraying)
- Vehicle in way of application
- Pets, people, or children in yard
- Neighbors present (if spraying)

If people are present in the yard, ask them to go inside. Ask them to resolve any of the concerns noted in the visual assessment. If no one is home and windows are open, call the customer on the phone and inform them of the need to reschedule. In the case of townhomes, you may need to skip an area and note it on the work order.

CHAPTER 6

Application Equipment and Techniques

LEARNING OBJECTIVES

After studying this chapter, you will be able to:

1. Explain the importance of calibrating your application equipment.
2. Understand common calibration methods used in ornamental and turf applications.
3. Explain the relationship between equipment speed and application rate.
4. Explain the relationship between pressure and application rate.
5. Calculate the area of a rectangle, a triangle, and a circle.
6. List the three (3) key considerations to a calibration check.
7. Know common signs of possible past misapplications.
8. Identify six (6) major types of pesticide application equipment for outdoor application.
9. Identify when to complete equipment maintenance.

INTRODUCTION

The function of any application equipment is to deliver the proper rate of chemical and to apply it uniformly to the target area. Your equipment choice will be influenced by many factors, including :

- Type of application equipment used
- Pesticide formulations
- Type of area for treatment
- Frequency of applications

Large, power-driven equipment works well for some jobs, while small, portable or hand-held equipment works best for others. Calibrate all pesticide application equipment regularly and be kept it clean and in good working order. Applicators must read the pesticide label to determine if restrictions exist for certain application methods.

EQUIPMENT AND TECHNIQUES FOR APPLYING PESTICIDE TO TURF AND ORNAMENTALS

Most pesticides are applied as liquids using sprayers of different types and sizes, varying from hand-operated units to machines with 100-foot booms. The following paragraphs describe sprayer components and some common types of sprayers.

Types of Sprayers

Liquid sprayers make spot, band, or broadcast treatments. Water is the most frequently used carrier. The spraying system forces the pesticide solution through at a specific pressure and sprayer speed. The sprayer may have one or several nozzles. Liquid sprayers are usually powered and towed, self-propelled, or mounted on other equipment, including aircraft. However, for small jobs, a hand-carried compressed air or knapsack (backpack) sprayer is often used.

A backpack sprayer is a type of hydraulic sprayer.

Larry Schulze, University of Nebraska

Low pressure sprayers, the most commonly used sprayers for residential and commercial lawns, normally deliver low to moderate volumes at a system pressure of 15 to 80 psi. Most are hand sprayers used while walking and carrying a long hose from a truck mounted tank system. Low pressure sprayers are used on large turf areas such as golf courses, sports fields, and general grounds. High pressure sprayers can deliver up to 50 gallons of spray per minute and operate at pressures up to 800 psi. The high pressure spray can penetrate dense foliage and provide thorough coverage even in tall tree canopies, but the fine droplets produced are susceptible to drift. High pressure sprayers are used on shade trees, ornamental plants, and in orchards. Most are truck-mounted sprayers, but backpacks can be used for hard-to-reach areas.

BACKPACK AND HANDHELD SPRAYERS

Backpack or handheld sprayers are small liquid sprayers used to treat individual plants, small areas, or hard-to-reach areas. Hand sprayers use compressed air to force the spray liquid through the nozzle(s). These sprayers may be used with single or multiple nozzle systems. A handheld sprayer is carried via the pump handle on top and is equipped with a hose and wand. The capacity of hand

sprayers generally ranges from 0.5 to 3 gallons. Small, handheld sprayers work well for indoor plants.
A backpack sprayer is a type of small capacity sprayer equipped with shoulder straps to carry the tank on the applicator's back. Many are operated by a hand pump to maintain pressure. They hold about 2.5 gallons to 5 gallons of liquid and can weigh 30 to 40 pounds. Shake backpack and handheld sprayers frequently (every 30 to 60 seconds) to mix.

You may experience difficulty maintaining even pressure using a hand pump, resulting in over or under-application of pesticide in different areas depending on the pressure. When using this type of sprayer, pump frequently (every few seconds) to maintain pressure as evenly as possible. The addition of a pressure regulator will help provide constant flow and even application of pesticide.

One of the advantages of powered sprayers includes maintaining the pressure more evenly. They also require less effort from the applicator. Gasoline powered, rechargeable electric, and CO_2 regulated backpack sprayers are available.

RIDE-ON SPRAYERS

Ride-on sprayers may include a specific piece of equipment manufactured for spraying, or an all-terrain vehicle equipped with a tank and sprayer. Ride-on sprayers may include a boom sprayer as well as a wand. Depending on the type of vehicle, the applicator is either seated or standing during the application.

TRUCK-MOUNTED SPRAYERS WITH HOSE REEL

Truck-mounted sprayers with hose reels provide a larger capacity tank for use on large areas or multiple sites accessible from a road or drive.

PULL-BEHIND AND THREE-POINT MOUNTED SPRAYERS

Pull-behind and three-point mounted sprayers are pulled behind a vehicle and generally have a tank capacity of up to 200 gallons. The pump is powered by an electric or gasoline engine. They are equipped with boom sprayers and/or hose reels and guns.

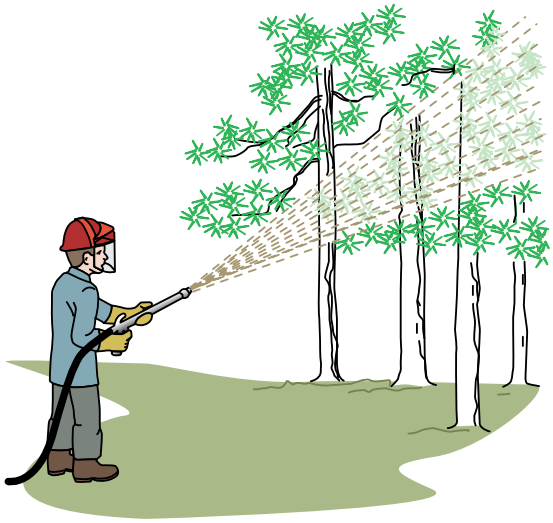


Figure 6.1
Foliar application

AIR-BLAST SPRAYERS

Air-blast sprayers, as the name indicates, use a blast of air to propel sprays. They provide good coverage and penetration but produce spray susceptible to drift. Air-blast sprayers work effectively in orchards and on shade trees.

Mist blowers are specialized air-blast sprayers with air velocities of 120 to 200 mph. They produce a fine spray that allows for lower water volumes than the standard air-blast sprayer.

Spray Output Equipment

SPRAY GUNS

Spray guns are handheld devices attached to a hose and tank, and equipped with a trigger to regulate the application of the liquid from the tank. Spray guns deliver pesticides through a single nozzle designed for treating ornamentals. They are not ideal for spraying turf due to the likelihood of non-uniform coverage. Metered spray guns, calibrated to deliver a precise volume of spray with each pull of the trigger, work well for spot spraying, especially in nurseries and greenhouses.

SPRAY WAND

A spray wand is a long rigid tube between the hose and the nozzle used for accurate low-volume spot treatments. The wand allows the applicator to deliver the material closer to the target, thus reducing the likelihood of drift. Spray wands work well with ornamentals as well as smaller turfgrass areas.

SPRAYER BOOM

Booms provide spray coverage over a large area. The length of the boom and the height from the ground determines the swath width. They range from small hand-operated versions to large tractor-mounted units. They can be fitted with different nozzles to control the spray pattern, angle, and discharge rate. Some nurseries use a single nozzle called a boom buster that creates a wide spray similar to that from a boom sprayer.

CONTROLLED DROPLET

Controlled droplet applicators, have a spinning cup with small grooves that spiral up the inner wall. The nozzles are gravity-fed from the spray tank and are powered by small electric motors. Centrifugal force moves spray solution in the spinning cup up the grooves. When the spray solution reaches the edge of the cup, it sprays out in a hollow pattern. The spray droplets fall nearly vertically onto the target. The droplet size varies with cup diameter, speed, and flow rates. Large truck-mounted and small hand-held models are available. Controlled droplet applicators are capable of low volume delivery, but more susceptible to drift because of small droplet sizes.

Spreaders

When applying granular pesticide formulations or fertilizers, the most common devices include drop (gravity) spreaders and rotary (broadcast) spreaders. Both types normally consist of three main components: a hopper to hold the materials, a mechanical agitator at the base of the hopper to provide a uniform and continuous feed, and some type of metering device, usually a slit gate, to regulate the flow of granules.

ROTARY SPREADERS

Rotary spreaders distribute granules to the front and sides of the spreader, usually by means of a spinning disc or fan. Power, hand-pushed, and pull-behind or power takeoff (PTO) models are available. Most

rotary spreaders produce a swath width of 6 to 12 feet, so they cover areas faster than drop spreaders. Rotary spreaders are less precise in uniformity and distribution than drop spreaders. Additionally, they are more sensitive to ground speed, physical characteristics of the granules, and environmental factors such as wind, temperature, and humidity. A change in ground speed changes the distribution pattern, throwing the granules further at a faster speed—or not as far at a slower speed. Heavy granules will travel further than light granules, and drift may be a problem with fine particles. The shape of the granule and environmental conditions may also affect the distribution pattern. Some drop spreaders have a means of shutting off one side of the spreader for edging a driveway or sidewalk.

Bob Wolf, Kansas State University

A rotary spreader.

Rotary spreaders may be push-type applicators pushed in front of the body, belly grinders (sometimes referred to as monkey grinders) strapped over the shoulders with the product dispensed by turning a handle, handheld grinders held freely from the body, or larger units carried (or pulled) by a vehicle.

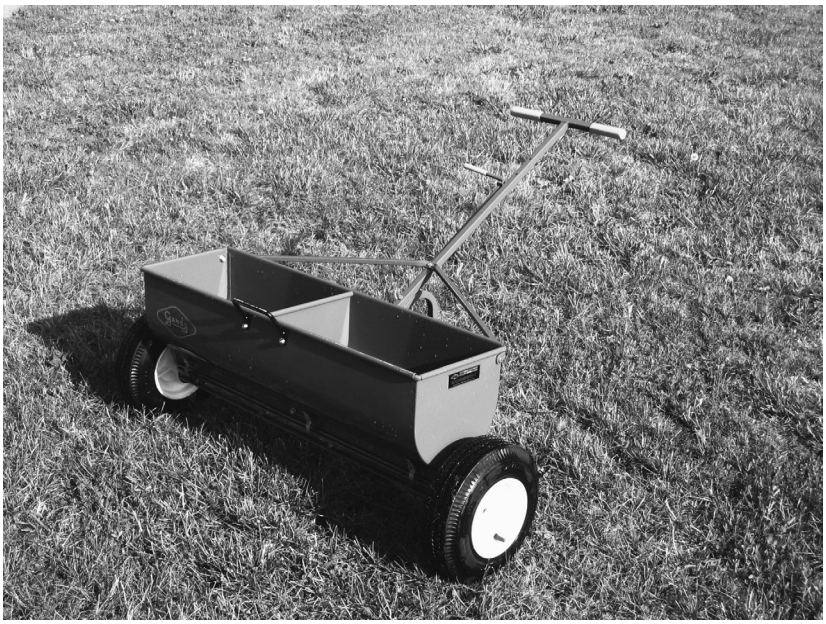
DROP SPREADERS

Drop spreaders, also called gravity spreaders, apply uniformly sized dry particles to soil, water, and sometimes foliage. An adjustable sliding gate opens the outlet holes and the granules flow out by gravity feed. A revolving agitator activates when the spreader is in motion to ensure uniform dispensing.

Generally more precise, relatively simple and lightweight drop spreaders deliver a better pattern than rotary spreaders. Larger vehicle-mounted models are also available for treating vast areas. Since the granules drop straight down, there is good control, with minimal chemical drift and little chance of applying pesticide to non-target areas.

Since the edge of a drop spreader pattern is sharp, any steering error will cause missed or doubled strips. For this reason, rotary spreaders are generally best for large area applications and drop spreaders work best for small, narrow area applications. Also, the amount of material flowing from the spreader does not change proportionally with

A drop spreader.



Bob Wolf, Kansas State University

changes in speed, so a constant ground speed maintains uniform application rate. Consequently, uniform coverage can be difficult to achieve with a drop spreader. Keep in mind also that some drop spreaders will not handle large granules.

CALIBRATION OF SPREADERS

Spreaders (rotary and drop) must be calibrated to each individual applicator due to differences in each person's gate and pace.

Tree Injection

Trees may be treated by injecting liquid pesticide or encapsulated pesticide implants. These options have several advantages over sprays and soil treatments, including: 1) using a much lower amount of pesticide, 2) applying the pesticide into the tree, targets the organism in its location, 3) it is away from people and non-target wildlife and insects, 4) availability for use on windy or rainy days, and 5) it is less likely to reach surface or groundwater or other non-target areas.

Tree injectors inject pesticide into the trunk of the tree. Equipment used includes a drill and bits, a syringe, and a tee which connects to tubing. Most often, the tree injection will be made near the root flare. A hole is drilled into the active xylem of the tree (near the first few rings) and a pesticide injected or an implant pounded into that hole. The pesticide moves systemically through the tree from the injection location site upwards to the top of the tree's stems and leaves (through the vascular system). This type of application usually uses a higher concentration of pesticide than used for foliar treatments. Often insects are targeted by this type of treatment; though some fungicides are also used to treat diseases. Injections can be done as macro or micro injections. Macro injections are typically used for oak wilt and Dutch elm disease, while micro injections are most commonly used for emerald ash borer.

Trunk injections can be used in sensitive areas where spray drift needs to be avoided; however, this type of treatment can cause wounds on the plant. If injections are made more frequently than the tree can heal, the tree may become permanently damaged or die. Trunk injections may work more quickly than soil injections, providing a better choice in saturated soils.

Timing is important for tree injections. It is important to understand the life cycle of the pest in order to treat the tree while the pest is at its most vulnerable phase, and before the tree experiences irreversible damaged. This method should not be used if the tree stem is wet.

Monitor the tree injection site to make sure children and pets do not go near it and ensure the equipment functions properly.

Bark Spray and Stump Treatments

Bark spray and stump treatments are used for treating woody plants.

BARK SPRAY

A bark spray, also known as basal bark treatment, is applied directly to the bark on the tree stem on the bottom 4 to 5 feet of the tree usually with a backpack or handheld sprayer equipped with a solid cone or flat fan nozzle. Use a low volume sprayer to prevent damage to the tree, bounce back, and drift. Cover the entire stem, root collar, and any exposed roots must be fully covered. Add an oil carrier to help penetrate the bark. This method is generally used for thin-barked trees less than 6 inches in diameter (DBH), or on vines such as grapevine.

STUMP TREATMENTS

Stump treatments are completed by first cutting the tree down and treating the exposed stump with an herbicide immediately after cutting. Herbicide should be applied to the cambium and the outer 2 inches of the sapwood (xylem) around the entire circumference of the tree. For small stems (less than 3-inch diameter), treat the entire cut. Apply herbicide to the stump using a spray or wick type applicator.

The invasive plant, Russian olive, is often controlled using bark spray or stump treatments. They are good methods for selectively removing trees within a wooded area. For both basal bark and stump treatments, addition of a tracer dye to the herbicide helps you visually determine adequate coverage with the herbicide.

Soil Injection

Soil injections require specialized equipment to inject pesticide into the soil in multiple locations within the root zones of trees and shrubs. Large injectors, some hand held, can make a variety of patterns. Others are connected to truck-mounted tanks that run with a high pressure pump. The injector can be calibrated to inject the same amount of chemical with each injection. Take care so that the pesticide does not splash back when making an injection (especially in hard, dry soil). It is important that the technician remain onsite to monitor the injection until completed. Refer to the pesticide label for instructions on application. Some insecticides require moist soils for optimum control and may have instructions on keeping the area moist for a period beyond the treatment.

Do not apply soil drenches to highly-saturated, frozen, or compacted soils.

Soil Drench

Soil drenches are used on trees and shrubs. The soil drench is poured around the base of the tree and taken up by the tree roots. This type of application requires no specialized equipment however, remove any mulch, dead leaves, plastic, or landscape fabric from the base of the tree before applying the pesticide to encourage root absorption. Mix the insecticide in a pitcher, bucket, or other container and pour it around the base of the tree or shrub. Avoid sloped areas where the pesticide could drain away from the base of the tree. A shallow trench dug around the base of the tree or shrub can help keep the pesticide from moving away from the target plant. If the soil is dry, irrigate lightly prior to applying the drench to improve absorption of the pesticide.

Wick or Wiper Applicators

Wick or wiper applicators provide ideal foliar treatment in ornamental beds. A non-selective herbicide can manage a variety of weeds surrounding an ornamental garden while avoiding the risk of herbicide drift. Apply the herbicide directly to the leaf of the weed or cut stump using a sponge or wick attached to a tube which contains the desired herbicide.

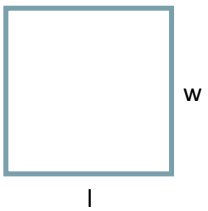
ENSURING APPLICATION ACCURACY

Whenever you use a pesticide or fertilizer, the product label provides instructions for applying the chemical. The label lists the application rate necessary to prevent or control certain pests on specific sites. For some products, the application rate is straightforward and simple. Many pesticide labels, however, provide very specific directions regarding application rates.

When you are using a product with very specific application rate directions, follow these steps to be sure you are applying the right amount of pesticide:

Calculate the Target Area

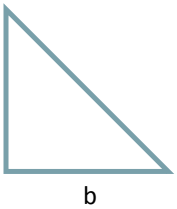
Measure the dimension of the site, using the same measuring units as the pesticide label directions (see Read the Label, below). Use the following formulas to calculate the size of the area.



SQUARE OR RECTANGLE

For a square or rectangular site, multiply the length (l) by the width (w).

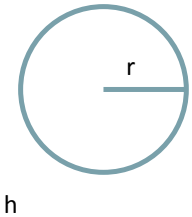
area = l x w



TRIANGLE

For a triangle, multiply the length of the base by the height, and divide by two.

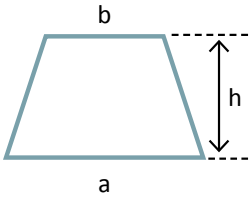
area = (b x h)/2



CIRCLE

For a circular site, multiply the square of the radius (r x r) by 3.14 (pi or π).

area = (r x r) x π



TRAPEZOID

If the site is a trapezoid shape, multiple the average length of the parallel sides (a + b)/2 by the height (h).

area = (a + b)/2 x h

IRREGULAR SHAPE

For areas with irregular shape, try to visually break the area into regular shapes and measure the areas accordingly.

Keys to applying pesticides at the correct rate:

- Calculate the size of the target area;
- Use the label directions to calculate the amount of pesticide you need to apply; and
- Calibrate your application equipment.

Follow Label Directions

Label application rates may be provided in any combination of ounces, pints, pounds, quarts, or gallons of product per square foot, 100 square feet, 1,000 square feet, or acre. Do not confuse dry ounces (16 oz. per pound, a weight measurement) with fluid ounces (128 fl. oz. per gallon, a volume measurement).

Examples:

- 10 oz./1,000 ft² (ten ounces per one thousand square feet)
- 2 lbs./acre (two pounds per one acre)

Rates may also vary due to differences in pest susceptibility, growth stage, and infestation levels. The application method may affect the application rate as well. Follow the label directions carefully, and calibrate your application equipment properly.

Why Calibrate?

Calibration should not be considered optional. This vital step ensures you apply the appropriate rate of a chemical. Calibration is simply determining the product delivery rate of your application equipment. You may have the latest and greatest equipment but if you don't calibrate, you don't know the actual rate of application. Regular calibration ensures that your equipment applies the correct amount of pesticide over a given area. Without proper equipment calibration you could make costly or even dangerous mistakes in the application rate of a chemical.

You will need to calibrate your equipment on a regular basis, even if your equipment supplier provides charts and tables to help you determine equipment setup and delivery rates. Charts and tables cannot account for equipment wear, or for inaccurate gauges and speedometers. How often is regular? You should calibrate each year at a minimum and with equipment changes, such as boom height, pressure, and nozzles that may affect the application rate. For granular materials, calibrate for different products since they differ in size and active ingredient percentages.

KEY CALIBRATION CONCEPTS

Relationships

There are several key relationships to understand in calibration. The amount of material applied will vary with speed, pressure, and height above ground (or distance from target).

SPEED AND RATE

Generally, the faster you walk or drive, the lower the application rate (note: some sprayers can automatically compensate for this by increasing pressure as you drive faster). The speed determines the area you cover over time. When you

move slower, more material will be applied over an area than when you move faster. Base calibration on the speed at which you plan to operate the equipment. Ideally, calibrate the equipment for the individual using it so their actual walking speed is used. Calibrate driven equipment for a range of speeds as well as settings. Maintain a steady speed to ensure even application of material.

PRESSURE AND RATE

The higher the pressure, the more material you will apply (higher the rate). When you calibrate a piece of equipment, you will calibrate for different pressure settings since each will provide a different output. It is important to maintain steady pressure while applying pesticides or you may under or over-apply these products.

HEIGHT ABOVE GROUND AND SPRAY PATTERN

The closer to the ground your sprayer, the tighter the spray pattern and the higher the rate. As you raise the height of your spray bar, the spray pattern will be wider and the rate lower. Complete calibration with the spray bar at the height used for the application, or for various heights if it will be changed for different applications. The higher or farther the nozzle is from the target, the wider the spray pattern.

Volume per Unit Area

Pesticide labels will specify a volume of product to use for a specified area. For example, a label on a liquid product may state, use 6 fluid ounces of this product per gallon of water to treat 1000 square feet. The unit area may be listed as acres or square feet. For granular products, the product will be listed by weight (pounds or ounces).

Some products have annual use limits. For example, insecticides used to treat emerald ash borer have an annual volume or weight per acre limit. For trees, determination of insecticide volume is based on tree diameters. You may find it impossible to treat all the trees on the property before exceeding the limit.

Calibration Chart

Document equipment calibration for the range of settings on the equipment. Create a chart that shows the results and keep a copy with the equipment as well as a copy at the office. Refer to the calibration chart and adjust the settings, pressure, and nozzles as needed for each individual and product.

Prevent Drift

Drift of pesticides to non-target areas is illegal in Utah. See the Unlawful Acts Section of the Utah Pesticide Control Rule see shorturl.at/gCHN3. Therefore, it is critical that applicators take steps to prevent drift. Droplet size will influence the likelihood that both particle and vapor drift will occur. Type of nozzle and the nozzle pressure affects droplet size. Each nozzle produces a range of droplet sizes. The nozzle droplet size is determined based on the

median (middle) size of the droplets produced. Droplet size decreases with increasing pressure. You can increase the droplet size by lowering the nozzle pressure.

Coarse droplets are larger, heavier and have less surface area to catch the air resulting in less drift. Coarse droplets may not provide even coverage needed for effective pest control, while fine (small) droplets provide better coverage on plants they are more prone to drift.

Large droplets also have much less surface area for the same amount of spray liquid than small droplets, greatly reducing both vaporization and evaporation. As spray droplets evaporate they shrink in size and become more prone to drift.

Equipment manufacturers often provide charts that indicate the droplet size for different nozzles and pressure settings. Use these recommendations on the label to determine the appropriate nozzle to provide adequate coverage while preventing drift.

Spray booms can be fitted with drift reduction skirts to minimize drift and keep the spray on target. And a smaller cone-like guard can be added to a backpack sprayer wand to confine the spray to a smaller area and minimize drift. This is useful for applications such as under and around shrubs or along sidewalks.

Accounting for Overlap

Overlap enables even coverage of granular or liquid pesticides. When applying granular herbicide to turfgrass using a rotary spreader, the amount of herbicide spreads in an uneven pattern. To compensate for the uneven application pattern, you will need to overlap your spreader passes. This is called a “wheel to wheel” application. Determine how much material your spreader applies using a series of pans set out on a hard surface and weighing product in each pan after passing your spreader over them. If you spread back to your wheel path, you will generally get an even coverage.

When trimming the edges, use an edge guard or side shield and close off one of the holes (if your equipment allows) in the bottom of the spreader, or adjust the setting to reduce the amount of material coming out.

When using liquids, overlap can ensure even coverage. Each piece of equipment and each operator’s technique is different. How much area is covered using a hand wand will differ somewhat for each applicator. Practice your technique and overlap pattern using water in the sprayer. Overlap the spray one-half swath width when using showerheads. This is often accomplished by overlapping back to your footsteps. Trim the edges at half rate. When using a boom sprayer, you may have to shut off valves when trimming edges and around trees and other obstacles.

Spraying Turf vs. Spraying Landscape Plants

Spraying turf differs from spraying landscape plants. With turfgrass applications, you work with a relatively flat surface. Pesticides are applied on a volume per area basis. Turf is easily treated because of an even surface, good access, and large equipment can cover the area quickly.

With ornamental plants, the landscape is three-dimensional. Depending on the product, you may apply a volume of pesticide to get adequate coverage rather than using a rate per area. To get adequate coverage for foliar applications, you must apply the pesticide over the entire plant canopy. The label will provide instructions on coverage, such as: "use adequate spray volume to wet the leaves and stems," "apply sufficient volume for thorough coverage," "spray to wetness," or "spray to runoff." Mix the pesticide to the concentration specified on the label. Smaller equipment is often used for these applications.

For trees and shrubs treated with drenches and injections, the tree diameter or height determines the amount of pesticide to use. The pesticide label may provide directions on how to calculate the application rate. Measure tree diameter at 4 1/2 feet above the ground, known as diameter at breast height (DBH). Calculate application rate based on fluid ounces per inch in diameter. For shrubs, which are multi-branched, measure the tallest branch. Application rate is calculated as weight or volume per foot or per 10 foot of height.

CALIBRATION EXAMPLES

This section can only offer suggestions on calibrating some common application devices. Many different types of equipment are available for pesticide application, and many different methods of calibration can be used effectively. Check with your equipment dealer, your chemical dealer, or your county or state extension educator for additional calibration information.

Preparing for Calibration

Your equipment should be in good working order before calibrating it. Use the following guidelines to prepare your equipment for calibration.

1. Use the correct sprayer nozzle tips for the spray application you want to make. Consult the nozzle manufacturer's recommendations and the pesticide label.
2. Clean and inspect all nozzles, nozzle tips, and screens. Use a soft brush, not wire or any hard material. Add water to the spray tank and visually check nozzle output during sprayer operation. Discard and replace nozzle tips that produce distorted spray patterns.
3. Check all the pressure gauges. Replace rusty or inaccurate gauges.

Sprayer calibration results are valid only for the speed, nozzles, pressure, and spray width (nozzle spacing) used during the calibration process.

4. Check the spray volume output of all nozzles. Replace any nozzle tips that differ from the average output of all nozzles by more than 10%. If more than one nozzle varies seriously from the average, replace all the nozzles.

Boom Sprayers

Significant changes in any one of these factors will require another calibration check. Also keep in mind that equipment under heavy use can be jostled out of alignment, so it's a good idea to calibrate your sprayer every few days during periods of heavy use.

A hydraulic sprayer with a spray boom.

Larry Schulze, University of Nebraska

One simple method of calibrating a boom sprayer is to fill the tank with water and spray an acre. Then measure, in gallons, how much water it takes to refill the tank. If you need 32 gallons to refill the tank, then your delivery rate was 32 gallons per acre. Alternatively, you could spray a fraction of an acre and multiply your findings as needed to calculate the area's needs.

The following procedure is more complex, but probably faster.

1. Determine a travel speed. Select a reasonable operating speed for the spray equipment, taking into account the terrain and soil conditions. Simulate real application conditions by filling the tank at least half full with water and by conducting the calibration on a natural surface (to account for wheel slippage). Record the tachometer or speedometer readings and the gear setting used to maintain the selected speed.
2. Verify the travel speed. Time the spray equipment over a set distance (for example, 200 feet). Time equipment in both directions and calculate the average time. Use the following formulas to calculate speed in miles per hour (mph):

$$\frac{\textbf{distance in feet}}{\textbf{time in minutes}} = \textbf{feet per minute}$$

$$\frac{\textbf{feet per minute}}{\textbf{88}} = \textbf{miles per hour}$$

3. Determine nozzle output. Select and record the spray pressure for operating the system (check label and nozzle recommendations for guidelines). Adjust to the desired pressure while the pump operates at normal speed with water flowing through the nozzles. Collect and measure spray from nozzles (in ounces) at the pressure used for a time interval easily converted to one minute (that is, if you collect spray for 30 seconds, you can multiply by 2 to convert to one minute). The more nozzles you collect from, the more accurate the calibration. Calculate the average output from the nozzles sampled. Convert to gallons per minute (if you collected spray for 30 seconds, multiply average output by two).
4. Measure nozzle spacing. Measure the distance between two nozzles, center to center, in inches.
5. Calculate the gallons per acre (GPA) or gallons per 1000 square foot delivery rate. Use the following formula by inserting speed in mph, nozzle spacing in inches, and the average gallon per minute output of a nozzle:

$$\frac{\textbf{gallons per minute x 5,940}}{\textbf{mph x nozzle spacing}} = \textbf{gallons per acre}$$

$$\frac{\textbf{gallons per minute x 136}}{\textbf{mph x nozzle spacing}} = \textbf{gallons per 1000 ft2}$$

A Procedure for Calibrating Compressed Air Sprayers

Most compressed air sprayers are small, hand-operated units. Keep in mind that factors such as speed, spray width, and pressure will vary with each person who operates the device.

1. Measure and mark a square area 18.5 ft. x 18.5 ft., preferably on a surface that will easily show the spray pattern width (such as a paved parking lot).
2. Starting with an empty liquid spray tank, and using a container graduated in ounces, add 2 quarts (64 oz.) of water to the spray tank.

$$\frac{\textbf{distance in feet}}{\textbf{time in minutes}} = \textbf{feet per minute}$$

$$\frac{\textbf{feet per minute}}{\textbf{88}} = \textbf{miles per hour}$$

3. Pressurize the sprayer and spray the area within the marked square. Maintain uniform operator walking speed, nozzle height, and tank pressurization.
4. Depressurize the spray tank by opening the filler cap; drain the spray wand back into the tank by holding the spray wand above the tank and opening the spray valve on the wand.
5. Using a container marked in ounces, determine the number of ounces remaining in the sprayer.

$$\frac{\textbf{gallons per minute x 5,940}}{\textbf{mph x nozzle spacing}} = \textbf{gallons per acre}$$

$$\frac{\textbf{gallons per minute x 136}}{\textbf{mph x nozzle spacing}} = \textbf{gallons per 1000 ft}^2$$

6. Calculate the number of ounces sprayed by subtracting the number of ounces left in the sprayer from the 64 ounces originally added to the spray tank.
7. The number of ounces sprayed on the defined area equals the gallon per acre delivery of that sprayer. For example, using 36 ounces to cover the marked area, the sprayer delivers about 36 gallons per acre.
8. Adjust the delivery rate as required. If your sprayer is delivering less than or more than enough spray to each acre, you can change the rate by using one of these methods:
   a. Change the nozzle. The larger the hole in the nozzle tip, the more spray delivered. This is usually the preferred method when making substantial changes in sprayer output.
   b. Change the speed of the sprayer. Slower speed means more spray delivered over the area—fast speed means less spray delivered over the area. Doubling the ground speed of the sprayer reduces the sprayer delivery rate by one-half, except for wheel-driven sprayers. Speed changes may be practical for small adjustments in delivery rate, but not for large adjustments.
   c. Change the pump pressure. Lower pressure means less spray delivered—with higher pressure, more spray is delivered. This is usually not a good method for large adjustments because large changes in pressure will alter the nozzle pattern. To double output, you must increase the pressure fourfold.

A Procedure for Calibrating Granular Spreaders

The delivery rate of granular spreaders can be altered by a number of circumstances, including temperature, humidity, rate adjustments, and differences in the size or type of granule. Even a different lot number of the same granular formulation can make a difference. Recalibrate your spreader any time any of these conditions changes. The operator of the spreader also affects the delivery rate, so the calibration procedure should be performed by the person who will operate the device.

When using a spreader regularly, calibrate the device weekly, even if none of these conditions change, because the delivery rate will gradually change due to everyday use of the spreader.

1. Measure a known area. Use the formulas covered in Calculate the Target Area. For calibrating granular spreaders, a rectangular target area works best.
2. Set up a collection device. This can be a tarp laid out over the target area or a catch container mounted on the spreader. If you use a catch container, ensure the device does not interfere with the

delivery rate. You may also select a target area with a smooth, clean surface (such as a parking lot or driveway) and simply sweep up the granules and measure them.

3. Apply at proper speed and gate setting. The rate at which granules flow out of the spreader depends on the size of the gate opening. A larger opening allows more granules to flow, so changing the size of the gate opening significantly increases or decreases the delivery rate. The speed at which the spreader moves also affects the delivery rate. When travel speed increases, less material is applied per unit area, and with reduced speed, more material is applied.
4. Collect and weigh the amount of chemical applied over the target area. The delivery rate equals the weight of material collected per the size of the target area. For example, a target area of 300 square feet with 2.5 ounces of chemical applied means, the delivery rate is 2.5 oz./300 ft^2.
5. Convert the delivery rate to the units specified on the label. Using the example described above, a delivery rate of 2.5 oz./300 ft^2 converts to 8.3 oz./1000 ft^2 or 22.6 lbs./acre.
6. Adjust the gate setting or speed to achieve the desired delivery rate. For small changes, simply alter the speed at which the spreader travels. For larger changes, adjust the size of the gate opening to increase or restrict the flow of granules.

EQUIPMENT MAINTENANCE

Proper maintenance of your equipment helps to ensure safe and effective pesticide application. It will also significantly reduce repair costs and prolong the life of the equipment.

Before Applying Pesticide

- At the beginning of each season, thoroughly rinse the applicator with clean water.
- On boom sprayers, make sure all nozzles are the same type, size, and fan angle (color coded nozzle caps and nozzles provide a reliable and quick way to assure compatibility).
- Ensure nozzles with check valves work properly (check valves prevent dripping when flow to the nozzle drops below a certain pressure).
- Check the applicators for leaks and uniform output. If a sprayer nozzle's output is 10% more or less than the average, change that nozzle. If more than one nozzle varies by 10%, the entire nozzle system is probably wearing out, so replace all the nozzles.

Granular applicators may get chips that cause leaks or over application. Check the opening for uniform output.

- Replace damaged or deteriorated strainers. Place strainers on the filler opening, on the suction or supply line to the pump, between the pressure relief valve and the boom, and on the nozzle body. As the mixture moves through the system, strainer openings should be progressively smaller. Strainer mesh is described by the number of openings per linear inch; a high number indicates a fine screen.
- Replace hoses at the first sign of surface deterioration. Use weather-resistant hoses and other equipment parts with a burst strength greater than peak operating pressure of your sprayer. Choose synthetic rubber or plastic that resists oil and solvents present in the pesticides.
- Check the nozzle height by measuring the distance between the nozzle tip and target. Check the nozzle manufacturer's recommendations for nozzle spacing, alignment, and boom height, and adjust the boom accordingly. Boom height is very important in broadcast application because it affects the uniformity of the spray pattern.
- Level the tank during filling so it indicates amounts correctly. Know the true volume levels of your equipment. Factory sight gauges and volume markers are often incorrect, resulting in miscalibration and misapplication.
- Make sure that ducts in the chemigation equipment are clear and fluid can freely move through the system. Sometimes particles in the water or the chemical may clog the ducts.
- Make sure to clean up any chemical spills that occur during preparation. Spills must be reported to local law enforcement if assistance is required for containment and cleanup.

During Application

- Prevent drift of pesticide. Make sure the nozzle selection, pressure, flow rate, boom height, application speed, and weather (wind speed, temperature, and humidity) are optimal for application.
- Check the pressure gauge and tachometer frequently while spraying. The sprayer should always operate at the same pressure and speed used during calibration. Reasonable speeds ensure spray booms don't bounce or sway excessively.
- Periodically check hoses and fittings for leaks. Keep hoses from being kinked or worn.
- Check nozzles for unusual patterns.
- Check pressure gauges frequently for accuracy. If the gauge does not zero properly, replace it.
- Always wear adequate protective clothing, particularly label designated gloves, if emergency repairs or adjustments are necessary in the field. When

applying granular products or using back-pack sprayers, it is likely the product will be distributed in front of the body. If this is the case, it is important to wear long-sleeved shirt, long pants, and chemical resistant boots to protect the skin.

- Never use metal wire to unclog a nozzle, it may distort the nozzle opening and change the spray pattern and output. Use an old clearly labeled toothbrush instead.
- Never operate a sprayer pump at speeds or pressures above those recommended by the manufacturer.
- Never allow the pump to run dry. Pumps depend on the spray liquid for lubrication and removal of friction heat. Pumps will be damaged if run dry or if they have a restricted inlet or outlet.
- Prevent drift when applying chemicals in any form.

After Application

All equipment and equipment parts exposed to a pesticide normally have some residue, including sprayer pumps, tank, hoses, and boom. Wear label designated gloves and a long-sleeved shirt and pants to prevent skin contact with these residues. Some labels may require more personal protective equipment.

- Always flush the spray system, inside and out, with water after each use to prevent chemical buildup. Make the initial tank rinse at the application site. Apply the rinsate on the site to reduce the generation and concentration of wastes at the clean-up area. You will need extra water on-site (saddle tank or truck). See the National Core Manual for more information on cleaning procedures and use of rinsates.
- Clean the inside and outside of the equipment thoroughly before switching to another pesticide and before doing any maintenance or repair work.
- Rinse hoses often, inside and out, to prolong life. Store them out of the sun.
- Clean strainers after each use.
- Look over all equipment to ensure good working order after use and before the next application treatment.

Storage of Equipment

- Clean equipment thoroughly before storing for the season.
- When cleaning sprayers, add 1 to 5 gallons of lightweight emulsifiable oil (depending on the size of the tank) to an equal volume of clean water. Flush the entire system with the oil and water mixture. As the mixture is pumped from the sprayer, the oil will leave a protective coating on the inside of the tank, pump, and plumbing. As you flush the system with the oil and water mixture, ensure you discharged it in an manner that will not contaminate surface or groundwater.
- Drain all tanks and hoses.

- Remove, clean, and place all nozzles and screens in a dry place to prevent corrosion.
- Cover the nozzle openings in the sprayer boom with tape to keep dirt out.
- When storing for the winter, drain water from pumps to keep them from freezing and cracking (if not stored in a heated building). As an added precaution, pour one tablespoon of radiator rust inhibitor antifreeze into the pump inlet. Turn the pump several revolutions to coat the internal surfaces.

Calibration Checks

Once you've calibrated your equipment, periodic checks will verify proper calibration. Equipment wear and repairs can alter how much material is delivered. You should know ahead of time how much product you plan to use at a site to get the proper application rate and monitor product usage. As you conduct the application, check to make sure you use the right amount of product for the amount of ground you have covered. For example, if you have completed an application on one-fourth of the site, you should have used one-fourth of the pesticide. Ensure correct techniques and equipment settings.

Documenting Calibration

After you've calibrated the equipment, keep a written or electronic recording of the calibration. The documentation should include information such as the date of calibration, equipment type, specific equipment identifier, operator name, name of the individual completing the calibration, and the calibration chart. Keep the calibration chart with the equipment for accessibility to the equipment operator. After any work on the equipment, it may require recalibration.

WARNING SIGNS OF MISAPPLICATION

As a professional pesticide applicator, you must apply pesticides carefully and follow the law. However, on occasion, a misapplication may occur. You may not always realize it has occurred at the time of the application, but the effects may show up later. Potential signs of misapplication include damage to non-target plants, damage to target plants due to use of the wrong herbicide or wrong concentration, death of bees nearby, and granular pesticide visible on hard surfaces adjacent to the application area. Uneven coverage is indicated by control of some weeds or pests, but lack of control of others, usually in a swath missed by the applicator due to poor overlap, clogged nozzles, or other equipment issues. Misapplication also includes lack of control of the pest due to not applying enough herbicide or using the wrong product.

CHAPTER 7

Professionalism, Safety, and Human Health

LEARNING OBJECTIVES

After studying this chapter, you will be able to:

1. Identify common pesticide safety risks turf and ornamental applicators face and how to minimize those risks.
2. Identify common pesticide safety risks customers and the public face and how to minimize those risks.
3. Describe technical and ethical standards of professionalism.
4. List four (4) aspects of professionalism.
5. List where to find pesticide application posting requirements.

INTRODUCTION

A professional must be prepared to answer questions about health and safety, the environment, laws and regulations, and other issues that arouse public concern over the use of pesticides. Your ability to answer your customers' questions and to address community concerns over your work can make a very good impression—or a very bad impression. If you study the other chapters of this Study Guide, you will have the basic knowledge you need to educate your customers and others concerned about pesticides in their community. This chapter prepares you for some of the more common questions you will be asked.

PROFESSIONALISM

What Is Professionalism?

According to the Merriam-Webster dictionary, professionalism is "the skill, good judgment, and polite behavior that is expected from a person who is trained to do a job well." Professionalism applies to you as a pesticide applicator.

Your employer expects you to act professionally, especially while working with customers and in front of the public. You become a professional by educating yourself about the work you do; knowing how to minimize risks to yourself, your co-workers, and the public; staying current on industry changes; knowing the laws that apply to your work; learning how to communicate appropriately with your customers and the public; and representing your profession well.

As a pesticide applicator, you are out in the public on a daily basis. Whether you know it or not, people are watch you. The actions you take will leave an impression of not only you, but also your company and the pesticide applicator profession.

Follow and Demonstrate Professional Ethical Standards in Your Work

A professional demonstrates good ethics while working. This means taking shortcuts that may impact your customers, the public, or the environment–you give the customer what he or she paid for, providing good service. You offer honest and knowledgeable advice on how best to maintain a landscape or site. You follow appropriate safety standards when handling or applying pesticides to protect yourself, your coworkers, your customer, the public, and the environment.

IPM will help you make sound pest management decisions to avoid applying unnecessary pesticides and better protect people and the environment.

Keep Current on Regulations, Equipment, Safety, and Environmental Concerns

A number of federal, state, and local regulations apply to pesticide application. Your responsibility includes knowing the regulations and safety procedures for your work. These regulations may change and you should keep up to date on changes that affect your work.

Regulations protect you, your co-workers, the public, and the environment. The federal laws are covered in detail in Chapter 2 of the National Core Manual. You or your employer should check to see if any local rules or regulations apply to the areas where you work. For example, local regulations may differ in posting requirements.

Remember, "the label is the law" for pesticide application. Read and make sure you understand and follow the label and label restrictions, requirements, and safety and environmental precautions for the pesticide use.

For example, if the label instructions state "… for use only by certified applicators or those under their direct supervision." In Utah, Commercial and Non-Commercial Applicators cannot supervise the application of a Restricted Use Pesticide (RUP) by anyone other than another licensed applicator with the same type and category of license.

Utah Commercial Applicators must be licensed to apply any pesticide used commercially (for hire or other compensation).

Non-RUP can be used under the supervision of Non-Commercial Pesticide Applicators when applying in a non-commercial application.

Being a professional includes not only following laws and the pesticide label, but also being aware of best practices and using these in your work.

Sometimes state laws are stricter than the label. In that case, follow the state law.

COMMUNICATE WITH CUSTOMERS, NEIGHBORS, THE PUBLIC, AND THE MEDIA

Your customers or those who use your parks or other facilities question pesticide applications. Be prepared to explain the principles of plant health care and answer their questions. How a customer mows and waters turfgrass for example, may affect what you can do to manage their pests. If they don't understand how their maintenance practices can affect plant quality, they may be disappointed with the results of your work.

You may need to assure your customers that the presence of a minor pest problem does not necessarily require any pesticide treatment at all. The benefit of pesticides includes stopping an out-of-control pest (weed, insect, or disease) problem threatening the health of plants in the landscape. Helping your customers understand how to correct problems using IPM strategies will create a good impression of you and your company.

The simplest way to minimize risk is to limit your exposure to pesticides. Your customers need to understand the reentry intervals for the pesticides you apply so they can avoid exposure. If you are applying granular pesticides that need to be watered in, make sure your customer understands this. Explain that people and pets should stay off the treated area until it is completely dry. If any special label directions exist, inform your customer and provide a copy of the label.

Serious pest problems indicate that the plants in a landscape have unmet needs. In these cases, the pest is just a symptom of an underlying cause. Pesticides will not provide a long-term solution unless the underlying cause is corrected.

General Use and Restricted Use

Your customers may not understand the difference between general-use and restricted-use products. Be ready to briefly explain FIFRA and the role of the EPA and UDAF in pesticide regulation and enforcement. If you apply restricted-use pesticides, be ready to explain why you chose that product and why the product is restricted. It is always a good idea to provide your customers with information about the chemicals you apply, particularly any cautions associated with the products, even when using general-use pesticides.

Handling Customer Complaints

Sooner or later you will find yourself on the receiving end of a customer complaint. Your main objective should be to turn an unhappy customer into a happy one. Personal feelings must not enter into the situation regarding the value or service the customer received. Make a judgment according to company policy and, if this does not satisfy the customer, politely refer the matter to your manager. If manage or own the business, you will need to make the final decision. The following guidelines may help you diffuse a potential or actual conflict between the business and a paying customer.

1. Listen attentively to the customer. Don't look down at the floor, over at the shelves, or past a person's head. Look into the person's eyes and look interested.
2. Show sympathy and understanding by nodding your head occasionally and by the tone of your voice.
3. Avoid justifying. The customer is not interested in excuses like "the computer failed" or your problems: "We were too busy to spray those plants." All the customer wants to know is what you will do about the problem.
4. Ask questions. Probe the situation with open questions to obtain facts, such as, "How much water did you give it each week?" Be careful not to antagonize, however. Do not lead a customer into increased anxiety with phrases like, "You claim you watered the granules in, but…"
5. Agree to a course of action. This will depend on many factors including company policy, the customer's attitude, terms of the sale, and so forth.
6. Inform all others on staff who need to know. You don't want to further frustrate the customer with double billings or other misunderstandings.
7. Keep a record. For future reference, record the details of each complaint relative to who, what, how much, and the date.
8. Never, never argue. It may sometimes challenge you to stay calm, but losing your temper means losing a customer and perhaps your job.

Media

Make sure you know your company or organization's policy for talking to the news and other media. Many larger companies or municipalities designate an individual to speak to the media. Be careful what you say and do with media representatives present. You want to leave a positive impression about your profession.

Make Good Judgments When No Clear Answer or Solution Exists

Sometimes there is no easy or clear answer to a problem. As a professional, you must make judgments based on your experience with the information you have or can access. It may make sense to call a supervisor in some cases. They generally have more experience in dealing with difficult situations.

Your decisions should always consider safety for humans and animals, and minimizing environmental risks before making a profit or getting the job done. If an unsafe condition or potential environmental risk exists, it is better to postpone the application.

Refer to the National Core Manual for detailed safety and health information for pesticide applicators.

IDENTIFY AND PREVENT RISKS

You work in close proximity to pesticides during mixing, loading, application, and cleanup. Identify and mitigate risks to you and your co-workers early and take precautions to minimize your exposure to pesticides. You should also recognize that during mixing and loading you are working with the most concentrated version of the product and thus your risk is at its highest.

Working in Areas with Applied Pesticides

Schedule your work on a site so that the pesticide application is the last thing you do. When working in areas where pesticides have recently been applied, check the label ensure you wear the appropriate personal protective equipment (PPE). Wear clothing that protects your body from pesticide residues, such as long pants, long-sleeved shirts, gloves, and chemical resistant work boots and gloves.

Overhead Applications

Overhead applications, such as occurs with trees and tall shrubs, require extra precaution and PPE. Consider potential exposure to your co-workers, customers, and yourself, and minimize exposure keeping all at a safe distance during applications.

Tree Injections, Soil Drench and Injection, and Other Specialty Applications

Some of the operations you do may interest the public or your customers and they may want to observe. Make sure they maintain a safe distance from the application. Your company may have a policy on this to follow.

PREVENT AND MINIMIZE HAZARDS TO HUMANS AND NON-TARGET ORGANISMS

Follow Your Employer's Policies on Pesticide Use

Your employer may have some policies, in addition to the pesticide label requirements and state law, that will help you do your job safely. These policies should be written and discussed with each employee.

Recognize "Sensitive Sites" for Pesticide Application

Sensitive sites have particular vulnerabilities because of potential exposure to humans or animals. Facilities such as schools, daycare centers, healthcare facilities, playgrounds, and other recreation areas are considered sensitive due to potential exposure to children, the elderly or sick, and animals. Chapter 5: Site Evaluation provides information about evaluating your application site. As part of this assessment you will have identified sensitive areas. These include areas such as surface waters, flower gardens, and areas with foraging bees. Use this information to plan your application and minimize risks to these areas. Consider shared root zones when spraying sidewalks, driveways, and streets with cracks which will allow the pesticide to reach roots.

If you are aware of individuals in the area that are sensitive to pesticides, notify them of the application timing. The municipality may have a list of these individuals that you can access.

Secure Pesticide Products from People and Pets

Lock pesticides in an enclosed area secured from public access. Also secure empty containers and containers used for mixing, loading and applying pesticides. You will not always be within view of your vehicle. Keep it locked and all chemicals secured.

Residences

Using pesticides in a residential setting can pose some challenges. Verify that no people and pets are in the vicinity of the application before using pesticides on the site. Do a visual assessment of the property to look for the following:

- Open windows
- Vehicle in the way of the application
- Pets, people, or children in the yard
- Pools or bird baths in the yard
- Laundry on a line
- Personal property in the yard
- Neighbors present

If people or pets are present in the yard, ask them to go inside and bring pets inside. Move personal items located within the application area, to avoid contamination or wait to apply in the area after you have spoken with the property owner. If no one is home and windows are open or clothes are out on the line, call the customer to let them know you will need to reschedule. For townhomes, you may have to skip spraying that part of the property if a window is open or other safety issue is present.

Business and Commercial Sites

If possible, complete applications of pesticides on business and commercial sites when no one is around. If you must treat during business hours, block off the area to

Sensitive area—apiary. *Scott Bauer, USDA ARS*

Sensitive area—wildlife habitat. *USFWS*

Sensitive area—playground. *C. Randall, MSU*

Avoid pesticide effects on non-target plants. *Edward Crow, Maryland Department of Agriculture*

keep people out during the pesticide application and the appropriate time following the application, as indicated on the label.

Parks and Public Spaces

When spraying pesticides in parks and other public spaces, you should avoid spraying during peak visiting times. Morning is usually the best time to spray. Extra signage at entrances is a good idea to make sure people avoid the area and are aware of the use restrictions. Cities often receive calls from residents about spraying the parks. Make sure you keep good records of the applications and are prepared to respond to questions.

Golf Courses

Pesticide applications on golf courses can pose challenges. The bottom line is: the "label is the law." Applicators on golf courses must be aware of the potential exposure to workers, players, and neighboring properties.

A golf course is a huge piece of property used by many individuals for recreation and relaxation. Theses tracts of land need to be protected from disease and insect damage to ensure a viable destination for activities. Many clubs post a blanket notice in the clubhouse or at the first and tenth tee boxes notifying players that, "plant protectants are used periodically upon this property. For answers to your questions please contact the Golf Course Superintendent." However this does not preclude the club from responsible application techniques that will limit exposure to workers, players, and adjoining properties.

Keeping well ahead of play is of paramount importance. This allows the plant protectant time to dry upon the target plants and limits exposure to humans. Some courses schedule their applications during pre-dawn hours, course closures, or even at night. Every course schedule varies so applicators must think ahead in order to limit impact upon play.

Record keeping, including details of all pesticide applications, is also very important and a best practice. Utah Commercial Pesticide Businesses are required to keep records of every pesticide application. Utah Non-Commercial Pesticide Applicators are only required to keep records for RUP applications. Regardless of the type of license, if any, it is highly recommended to keep records of all pesticide applications on a golf course due to public exposure to pesticides. It is the experience of the UDAF Pesticide Program Inspectors, that recording weather information is highly beneficial. Keeping good record information is highly beneficial to the applicator, golf course and UDAF inspector if there is a complaint.

Whether you work for a park system, commercial application company, or maintain business landscapes, clear communication of agronomic and good pesticide use practices is important. Educate every employee on company policies on how to respond to questions and who to contact for questions they cannot answer.

On golf courses, notify the pro shop and clubhouse staff prior to applying products and the reason for the application. Knowing and articulating why a material is being introduced into the environment is very important.

Pesticides are necessary to maintain a golf course to meet the expectation of today's players. When applied correctly and with thoughtfulness, the chance of unintended exposure can be limited if not eliminated.

POSTING REQUIREMENTS

Label

Some pesticide labels may require posting of pesticide applications.

Remember, the label is the law. Applicators must read and follow the label directions.

STATE POSTING LAWS

Turf

The Utah Department of Agriculture and Food (UDAF) Pesticide Program does not require posting of Ornamental and Turf applications, unless applying a Restricted Use Pesticide (RUP) or if the label instructions require it. Utah licensed pesticide applicators may have other notification requirements and should refer to the responsibilities of businesses and applicators in the Utah Pesticide Control Rule, R-68-10 (D) (1) which states:

Prior to the time of each application of a restricted-use pesticide with a Danger/Danger-Poison signal word, the licensed commercial applicator or an employee of the licensed pesticide business shall provide the customer with a written statement containing the following information:

1. Business name and telephone number of the licensed business.
2. Name and license number of the licensed applicator who will make the application
3. Date and time of application.

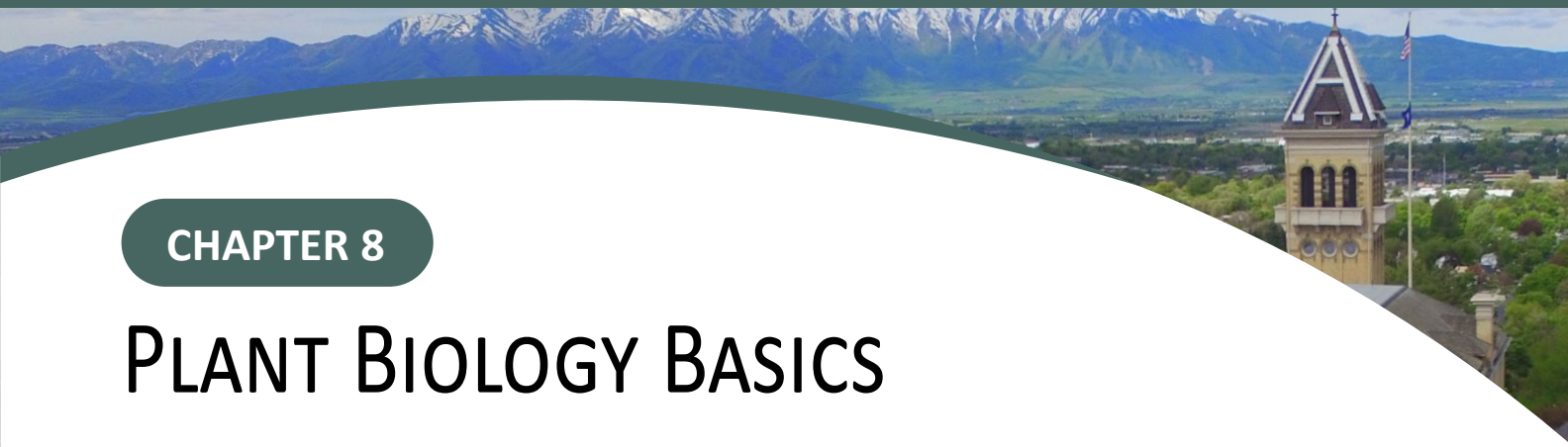
Posted field during the restricted-entry interval.

4. Type of pesticide application service and brand name of pesticide(s) applied.
5. Instructions to the customer to contact the business telephone number if more specific information is desired regarding the pesticide product applied.

The written statement required in subsection (1) shall be provided to the customer by any of the following means:

- Leave notice at the residence
- In the case of a multiunit residence, leave notice with the property manager or his/her authorized representative
- Mail notice to the property manager (or their authorized representative if management is located at a location other than the pesticide application site) within seven (7) calendar days prior to the date of the pesticide application

Many labels require that an applicator observe “Agricultural Use Requirements” and “Non Agricultural Use Requirements” and the respective “Restrictive Entry Interval” (REI) for the product applied. Sometimes this not only includes people, but pets. Applications done at hours without people present meet these restrictions. Putting up signs restricting access may also help in meeting REI requirements. If more restrictive instructions for posting exist on the label of the pesticide used, follow the label instructions.



CHAPTER 8

Plant Biology Basics

LEARNING OBJECTIVES

After studying this chapter, you will be able to:

1. List the six (6) basic requirements for plant growth.
2. Describe how pesticides are transported within plants.
3. Describe how leaf structure can affect pesticide uptake by plants.
4. Describe the difference between annuals, biennials, and perennials.
5. Identify the location meristems (rapidly multiplying plant tissues) in plants.
6. Explain what makes the meristems susceptible to chemical damage (intended and unintended damage).

INTRODUCTION

Every business, profession, and trade has its own set of terminology or "jargon." The green industries are no exception. To become a successful pesticide applicator, you will need to understand the terminology of the industries you serve. Understanding the terminology will help you prepare for the exam and to communicate effectively with other green industry professionals. In this chapter, you will learn the basic terms of the plant sciences. You will also learn plant biology which will help you succeed with your pesticide applications.

PLANT CLASSIFICATION

There are several different ways plants are classified from both a scientific perspective and a more practical perspective.

At the top are the seed forming and non-seed forming plants. The non-seed forming plants include ferns, mosses, liverworts, horsetails, and hornworts. The seed-forming plants are further divided into the flowering and non-flowering plants.

Flowering Plants (angiosperms)

Within the flowering plants there are monocots (plants with one seed leaf or cotyledon) and dicots (plants with two seed leaves or cotyledons).

Non-Flowering Plants (gymnosperms)

The non-flowering plants include the conifers, such as pines, spruces, firs, and junipers. They often have needle-like or scale-like leaves.

Growth Habits

WOODY PLANTS

Woody plants produce wood from xylem as their structural tissue. Most woody plants produce new layers of wood each year. The wood is generally covered in protective bark. Trees, shrubs, and vines are considered woody plants. Trees are plants that grow with a single trunk and are more than 20 feet tall. Shrubs are plants with more than one stem at the ground level and not taller than 20 feet. Woody plants are generally perennials and have living stems that remain above ground throughout the winter.

HERBACEOUS PLANTS

Herbaceous plants have leaves and stems that die back at the end of each growing season. Herbaceous plants do not have a woody stem. They generally grow fast and produce flowers and many seeds in a short time. Examples of herbaceous plants include hostas, daylilies, begonias, and spider plants.

TURFGRASS

Turfgrass is any of various species of grasses grown to form turf. In Utah, most turfgrasses used are classified as cool-season species. This means they actively grow in the spring and fall and are naturally dormant in summer and winter. Irrigation is required to keep them green in the summer. Common Utah grasses include bluegrasses, fescues, and ryegrasses

Scientific and Common Names

We tend to use common names for plants, but for clarity when referring to a certain plant, use scientific names. A specific plant (correctly described by only one scientific name) may have a number of common names. Scientific names include two parts, the genus and the species name (in Latin) and

are italicized in print. For example, American linden has the scientific name *Tilia americana*. The genus name describes the kind of plant (for example, maple, oak, or sumac). The species name describes the individual type within the genus (for example, red maple, white oak, staghorn sumac). The only way to assure accurate information about a specific plant is including the scientific name in its description.

Cultivars, Varieties, and Hybrids

The word cultivar is a contraction of the term "cultivated variety," describing a plant produced with human intervention. Cultivar names are always capitalized and are either set off in single quotation marks or preceded by the abbreviation "cv." Boulevard linden (*Tilia americana* 'Boulevard') is a cultivar of our native *American linden*.

The term variety or botanical variety refers to a naturally-occurring variation of a plant. Variety names are italicized and often preceded by "var." For example, honey locust (*Gleditsia triacanthos*) has a naturally-occurring variety that is thornless (*Gleditsia triacanthos* var. *inermis*) and a cultivar of that variety called Skyline (*Gleditsia triacanthos* var. *inermis* 'Skyline').

A hybrid is produced by crossing two or more species or cultivars and can occur naturally or through plant breeding. Common naturally-occurring hybrids are often renamed and preceded by an x, such as the cross between *Acer rubrum* and *A. saccharinum* called *Acer x freemanii*. When parentage becomes complex, the cultivar name is preceded by a capital X which designates its hybrid status (for example, *Malus* X Prairiefire, or Prairiefire crabapple). Cultivars and hybrids are bred to get plants with desirable characteristics.

PLANT PARTS

The Cell

The basic unit or building block for plants is the cell. It is the site of all physiological processes within the plant associated with growth. Groups of cells related in structure or function are called tissues. Tissues that occur in certain combinations or arrangements form the organs of a plant; for example, stems, leaves, roots, and reproductive structures.

The Stem

The stem is the site of attachment for leaves, flowers, and fruits. It also provides a path for the transport of carbohydrates, water, and minerals, (and pesticides when applied) between the roots and the tops of the plant. Observing and feeling whether a stem is woody or herbaceous can help in identifying a plant.

Nodes and Internodes

The point of attachment of the leaf is called the node. The portion of the stem between two leaves is the internode.

Buds

Buds are embryonic stems enclosed by scalelike leaves called bud scales. When a bud begins to open and grow, the bud scales peel away and leave a series of concentric lines or scars (bud scale scars) around the stem. The distance between the tip of the stem and the first set of bud scale scars back from the tip is a measure of the current year's stem growth. The bud at the apex or tip of a stem is called the terminal bud. Buds along the stem are called lateral or axillary buds.

Meristem

Meristems are the zones of actively dividing cells where growth occurs. There are three meristematic regions in a plant: apical meristems, secondary meristems, and marginal meristems.

APICAL MERISTEMS

Apical meristems (growing tips) are located at the tip of the stem of woody plants and some herbaceous plants and also at the root tip. The growth in length of the stem (primary growth) originates from the apical meristem.

SECONDARY (OR LATERAL) MERISTEM

Growth in stem diameter (outward growth) comes from the secondary (or lateral) meristem. It produces secondary xylem, phloem, and bark. When a wound is made in the bark of a tree or when a branch is cut off, the cambium in the area of the wound is triggered into rapid growth, producing the callus that eventually closes the wound.

MARGINAL MERISTEMS

Marginal meristems are located near nodes and areas of leaf attachment. Common in monocots such as grasses help in regenerate parts lost to activities such as mowing.

Xylem

Conduction (movement) of water and dissolved minerals occurs in the xylem, which is also known as the "sapwood." The xylem is the primary route for translocation of herbicides from roots to shoots in plants. Merely girdling the stem can interrupt all conduction, effectively killing shoot growth above the injured area.

Phloem

Carbohydrates (sugars), other organic compounds produced in the leaves, and mobile inorganic nutrients are translocated or moved through the plant via the phloem. Some herbicides, such as auxinic herbicides like 2,4-D and dicamba, are translocated through the phloem to the meristems after transfer from the xylem.

Leaves

Leaves normally consist of a blade, a petiole, and stipules. The blade is the main body of the leaf. Stipules are small leaflike appendages found at the base of the petiole. The petiole (stalk attaching the leaf to the stem) transports materials to and from the leaf (some leaves attach directly to the stem and have no petiole or stipules). When applying contact herbicides, leaves are a primary application target.

EPIDERMIS

Each leaf has an outer protective layer or layers of cells called the epidermis, which is covered by a waxy layer called the cuticle. The cuticle can affect the ability of pesticides to penetrate the plant.

STOMATA

Among the epidermal cells are small pores called stomata. Stomata are surrounded by a pair of cells known as guard cells, which regulate the opening and closing of the stomata. Stomata serve as sites for the exchange of gases and water vapor. Drought conditions can cause the stomata to close and reduce water and herbicide translocation.

MESOPHYLL

The area between the upper and lower epidermis is the mesophyll. Veins for the conduction of materials to and from leaves are present in the mesophyll.

Leaf Types

Leaf type and arrangement are good features to use to identify plants. To determine if a leaf is simple or compound, examine the leaf from its tip to where it attaches to the stem. The point of attachment to the stem is determined by the presence of a bud either in the leaf or beneath the petiole. If the leaf blade is composed of a single unit, the leaf is a simple leaf; when it has two or more leaflets, it is called a compound leaf. Leaf placement along the stem also provides a good identifying feature. Leaf arrangements include alternate, opposite, and whorled.

Roots

The root is an organ, typically situated below ground, which anchors and supports the plant and absorbs moisture and inorganic nutrients (minerals) from the soil. The root also stores carbohydrates (sugar used for energy) produced in the leaves in late summer or fall. In spring, the sugars are translocated (moved) back to the buds to provide energy for spring growth. Herbicides applied to the soil enter through the roots and root hairs; those applied to the leaves translocate to the roots.

ROOT GROWTH

After a seed germinates, it begins to grow above-ground vegetation. The roots are also grow rapidly.

ROOT SYSTEMS

Most turfgrasses and common nursery plants have a fibrous root system as opposed to a tap root system. A fibrous root system consists of many fiber-like, branching roots, with no one root being more prominent than the others. A tap root system consists of one main root that grows directly downward from which branch roots extend. Tap roots penetrate more deeply than fibrous roots, making tap-rooted trees (such as butternut, oak, and hickory) more difficult to transplant.

RHIZOMES

Rhizomes are horizontal underground stems that can produce both shoots and roots from nodes. They sometimes have thickened areas for storage of starch. Lily of the valley and quackgrass are examples of rhizomatous plants. Many invasive plants have rhizomes which allow them to spread easily.

ADVENTITIOUS ROOTS

Certain stems will produce roots if separated from the plant or if injury occurs. Known as adventitious roots their structure makes it possible to grow root cuttings.

Flowers

The flower is the reproductive organ of angiosperms (flowering plants). The major function of flowers is pollination. Insects and birds pollinate flowers of some plants, and others are wind pollinated. A typical flower is a modified stem. The club-like structures or stamens are the pollen bearing (male) component of the flower. In the center of the flower is a flask-like structure called the pistil, the female component of the flower which receives the pollen.

Fruits

The botanical term “fruit” refers to the mature (ripened) ovary. The fruits contain the seeds of the plant. Other flower parts associated with it may include the receptacle as well as withered remnants of the petals, sepals, stamen, and stylar portions of the pistil.

Seeds

A seed is a miniature plant in a dormant state. Structurally, the seed is a matured ovule, although various parts of the ovary may be incorporated in the seed coat. Seeds are composed of a seed coat, an embryo, and usually a storage structure (cotyledon) for food reserves.

Since seeds are really whole plants in a miniature (embryo) form and in a dormant state, it is understandable why seeds lose viability and will no longer grow. If the embryo outgrows its dormant period without the conditions required for continued growth, it dies. Plants may stay alive in the dormant (seed) stage for only a few hours or for many years. Proper care of seed lengthens its life considerably.

GROWTH CYCLES

Plants are classified according to their life cycles and growth habits.

Annuals

An annual plant completes its life cycle in one year. Annuals grow vegetatively from seed, form flowers and produce seed, and then die, all in a single growing season (annually). Examples of annuals are cereal grains, beans, garden peas, marigolds, and petunias. Summer annuals germinate in the spring and flower that same growing season. Winter annuals germinate in early winter and bloom by late winter or spring. They require a period of cold temperatures in order to flower.

Biennials

Biennials plants generally need two growing seasons to complete their life cycle. During the first season, the seeds germinate and the subsequent plants produce only vegetative growth (often a rosette). These plants need exposure to the prolonged cold of winter in order to flower. In the second season, the plants produce flowers and fruits, and then die. Not as common as annuals and perennials, examples of biennials include foxgloves, parsnips, hollyhocks, and money plants. Garlic mustard is an example of a non-native invasive biennial you may encounter in wooded areas.

Perennials

Perennials are plants that live from year to year. They may be either herbaceous or woody. Herbaceous perennials die back to the ground each year, but their crowns survive. Each season, new vegetative growth arises from the crown system. Examples of herbaceous perennials are daffodils, hostas, irises, and peonies. Woody perennials have persistent stems that remain for many years. Examples of woody perennials include maples, forsythias, pines, and rhododendrons.

Woody perennials are further categorized based on leaf retention, height, and growth habit. Plants such as sugar maples, that lose all of their leaves at the end of the growing season, are deciduous plants. Woody plants that do not lose their leaves (needles) all at once are conifers.

How Plants Grow

Plant growth and development involves many chemical and physiological processes controlled by environmental factors such as light, water, temperature, oxygen, and carbon dioxide.

Reproduction

SEXUAL

Sexual reproduction involves pollen from the stamen of one plant or flower fertilizing the pistils of

another. This is desirable because it combines characteristics to create offspring different from each parent (a major component of the process of evolution) and also makes hybridization possible. Flowers are either self-pollinated (pollen from same species and same plant) or cross pollinated (pollen from same species but different plant).

ASEXUAL

Asexual reproduction is the formation of new individuals from the cell(s) of a single parent. New plants may also be started from adventitious root or shoot pieces (cuttings). Once roots have been initiated and expanded to allow water and nutrient uptake, the cutting becomes self-sustaining. Pulling a dandelion often results in a piece of root left behind. This can form new plants via asexual reproduction. Stolons (above-ground stems) can produce new plants asexually, as occurs with strawberry plants. Rhizomatous plants also can reproduce asexually.

Seed Germination

Growth of a new plant often starts with seed germination. The embryo is completely dependent upon the stored food in the cotyledon(s) or endosperm until the first true green leaves emerge and begin active photosynthesis. Then, water and mineral uptake must actively occur through the roots. If proper environmental conditions exist, the seedling becomes self-sustainable at this stage.

Photosynthesis

Photosynthesis, the conversion of light to energy, may be the most important chemical process on earth. Leaves and other green tissues in the plant absorb sunlight and CO_2 (carbon dioxide) and convert it to chemical energy for use by the plant. The products of photosynthesis are converted to starch and stored or transformed into sugar providing food for the plant.

Converting Food to Energy

The plant must convert sugars and starch (food) produced via photosynthesis into usable energy in order to synthesize all the compounds required to maintain life. The process by which this occurs is called respiration. Aerobic (requiring oxygen) respiration happens continuously, in light or dark, day or night, in all living cells, in all parts of the plant.

Growth

Plants take the food and energy produced and use them to grow. Growth occurs through cell division, cell enlargement, and cell differentiation.

PLANT GROWTH HORMONES

To produce the typical structures and functions required for plant growth, the plant must control cell division, enlargement, and differentiation. The plant produces chemicals, “plant growth hormones,” to regulate and control its own growth. These

compounds are effective in very small quantities, and they can translocate (move) from the site of production to where they are needed.

Basic Requirements for Plant Growth

Controlling plant growth by modifying environmental factors (such as light, water, temperature, and nutrients) is critical to profitable nursery and landscape management. Plants under long-term water stress or plants that receive inadequate nutrition will be less vigorous and may become susceptible to pest attack. Even a short-term environmental stress can prevent a plant from reaching its full potential if it occurs at a critical stage in that plant's development.

NUTRIENTS

Three nutrients or essential elements fertilize plants: nitrogen (N), phosphorus (P), and potassium (K). These elements are the primary macro-nutrients. Though many other elements are necessary for proper plant growth, all except these three are usually provided in sufficient quantities by soil processes.

NITROGEN

Nitrogen (N) helps plants to grow and to develop a healthy, dark green color. Nitrogen in the soil becomes available for use by plants as lawn clippings, plant roots, and other organic matter are decomposed by soil microorganisms. Before the nitrogen in organic matter can be taken up by plant roots, the organic nitrogen must be broken down to ammonium or nitrate. Nitrate is not tightly held by the soil particles and is soluble in soil water. In sandy soils with excessive rain or watering, nitrate can move with the water to depths below the root zone. In clay soils with excessive rain, nitrate can also leach below the root zone or convert to a gas, lost to the atmosphere. Ammonium can also convert to ammonia gas which can be lost through volatilization. The amount of nitrogen required varies with maintenance practices, but you will usually need to add nitrogen-containing fertilizer to maintain the vigorous growth desired for turf and ornamentals; the nitrogen provided by natural soil processes is generally insufficient.

PHOSPHORUS

Phosphorus (P) stimulates early root growth and promotes early plant vigor. Phosphorus moves very little in the soil due to binding tightly to soil particles. Soils naturally high in phosphorus normally provide sufficient phosphorus for vigorous turf growth for many years without adding phosphorus in fertilizers. Excess phosphorus harms lakes and streams; take care when adding phosphorous to soils. Conduct a soil test to assess the need for phosphorous, and then add the recommended amounts based on the results of the soil test.

POTASSIUM

Potassium (K) is important for plant growth and survival. It aids a plant's tolerance to stress such as cold or hot temperatures, drought,

damage and pest problems. Potassium deficiencies in lawns can lead to increased incidence of turf diseases and reduced tolerance to environmental stress. Potassium movement in soils varies by soil type, with coarse-textured soils most prone to potassium leaching. Where soils are high in native potassium, supplemental potassium fertilization may be unnecessary.

SECONDARY MACRO AND MICRONUTRIENTS

In addition to the major nutrients discussed above, plants may require additional nutrients. Often these are present in sufficient quantities in the soil. Secondary macronutrients include calcium, magnesium, and sulfur. The term micronutrient refers to elements present in lower quantities in plant tissues. The essential micronutrients include boron, chlorine, copper, iron, manganese, molybdenum, nickel, and zinc. A soil test will help you determine the potassium and phosphorus levels as well as secondary and micronutrients, and the need to supplement these with fertilizers.

WATER AND HUMIDITY

Plants require a certain amount of water for growth and health. Too little or too much water stresses plants and makes them more susceptible to insect and disease problems. For turfgrass, watering should follow seasonal growth patterns to encourage root growth. In the spring and fall, water deep and infrequently. In drier summer conditions when the grass roots are short, water shallow and more frequently.

Relative humidity measures the amount of moisture in the air. As the temperature increases the air can hold more water. Plants take up water through their roots and transpire (release) it through the leaves.

TEMPERATURE

Temperature influences a number of plant processes and needs. Temperature can trigger activities such as blooming or dormancy. Temperature is also dictates humidity and water loss. Measuring soil temperature can indicate time of germination. Colder soil temperatures can limit nutrient and uptake of other chemicals. Use soil temperatures to help time applications of pre-emergence herbicides and fertilizers.

SPACE

Plants require enough space for the roots to expand as well as enough overhead space for the plant to reach its maximum height. Overcrowding can stress a plant. Weeds in turf and ornamentals will compete for space. Non-vegetated areas are prone to weed invasion while dense, healthy turfgrass or mulched plantings can outcompete or minimize weeds.

AIR

Plants need air to complete their biological processes, both above and below ground. Air circulation

and soil aeration are also important for plants. Too little air circulation can result in overly damp conditions which may lead to disease. Too much wind can dry out plants or damage delicate plants. Roots need oxygen from the soil also. Continuously saturated soil creates deficiencies in oxygen, causing the majority of landscape plant problems in Utah.

HOW PLANT BIOLOGY INFLUENCES PESTICIDE APPLICATION SUCCESS

Understanding a little about plant biology helps to provide more efficient and effective control of weeds while protecting non-target plants and organisms.

Plant Classification

Distinguishing between monocots and dicots will help in deciding the correct herbicide to use on a site. Selective herbicides used in turfgrass, such as dicamba and 2,4-D, control broadleaf weeds (dicots) like dandelions, but not grasses (monocots). Herbicides that work selectively on grasses (monocots) can often be used in ornamental broadleaf (dicot) plantings to control unwanted grasses.

Life Cycle (Growth Stage)

Knowing the life cycle of a weed and its susceptibility to herbicide application will help you achieve better control. Some herbicides will affect only the seeds, some will affect the newly sprouted seedlings, and others affect actively growing larger weeds. If you are able to identify a plant as an annual, you will know that treating it after it goes to seed provides no long-term benefit.

Some weeds are more effectively controlled prior to emergence. Crabgrass, for example, can be controlled with a preemergence herbicide because of this warm-season annual's fairly predictable germination. To treat at the correct time, track soil temperature and apply just before germination.

Leaf Penetration

Some leaf shapes have more surface area, which provides a larger area for herbicide penetration. A waxy cuticle or leaf hairs can minimize the success of a contact herbicide application by limiting contact on or penetration into the plant tissue. Use of a surfactant (surface active-agent) may be necessary to provide better absorption into the leaf.

Meristem Susceptibility to Chemical Damage

As the actively growing areas of plants, meristems are good target areas for herbicides. Mobile (systemic) herbicides will move through the plant to the growing points, the area where you will most likely see injury. Non-mobile, or contact, herbicides must thoroughly cover the plant to get adequate contact for control.

Pesticide Transportation and Translocation

Pesticides can enter plants below ground through the roots and above ground through the leaves. Since plants store food as carbohydrates in their roots, the best time to treat many perennial plants is in the fall. Herbicides applied at this time will more likely be translocated down to the roots and provide more long-term control.

CHAPTER 9

Weed Management

LEARNING OBJECTIVES

After studying this chapter, you will be able to:

1. List the five (5) categories of weeds.
2. Select five (5) cultural practices that minimize weed growth.
3. Identify the importance of indicator weeds.
4. List seven (7) characteristics to consider when selecting an herbicide.
5. Describe the damage weeds can cause in a landscape.
6. List what weed growth stages provide the greatest level of herbicide control for annual and perennial species.
7. Identify where Utah Noxious Weed information is posted.

INTRODUCTION

When Is a Plant a Weed?

Simply defined, weeds are unwanted plants. Any plant interfering with the growth or aesthetic appearance of desirable turf or ornamental plants may constitute a weed. Even desirable ornamental plants can become troublesome weeds if they spread into unwanted areas. However, many Utah landscapes host traditional weed species. These plants typically adapt well to local climates, soils, and other external conditions successfully compete with cultivated plants. Many weeds produce large quantities of seeds, even under stressful growing environments. Other weeds are capable of reproducing through vegetative structures, so cultural

activities such as hoeing or mowing can facilitate the reproduction of the plant by dividing roots and stems.

The State of Utah Noxious Weed List includes plants legally declared weeds in Utah. For a link to the list, see shorturl.at/gCHN3. According to Utah Law, these weeds must be cut and controlled so that seed production does not occur. The plants on this list must not be sold, transported, or planted in Utah. The majority of noxious weeds in Utah were planted as ornamental plants and escaped to the environment where no natural enemies exist to assist in control. Local governments usually also require the control of plant overgrowth, especially weeds, in their jurisdictions to avoid many problems associated with weeds, fire, health, aesthetic, and valuation concerns. Additionally, some local governments require control of certain problem weeds in the local area.

NOTE: RIGHTS OF WAY (CATEGORY 6)

Applicators using pesticides in maintaining public roads, electric power lines, pipelines, railway rights-of-way, or other similar areas is a separate category and must be on the license of Commercial and Non-Commercial Applicators in these areas.

Damage Caused by Weeds

Weeds compete with turf and ornamental plants for water, nutrients, light, and space. They can also interfere with management practices such as planting, transplanting, thinning, and harvesting. Some weeds produce growth inhibitors that retard the development of desirable plants (allelopathy), and some produce substances that irritate or even poison people and animals.
Other weeds are invasive and will outcompete for native habitat and adversely affect not only the native plants, but also the wildlife that need those plants to survive.

Why Manage Weeds

The various reasons for managing weeds include including state law requirements, removal of invasive or aggressive weeds, and improvement of the aesthetics of a landscape.

INVASIVE OR AGGRESSIVE PLANTS

Some invasive or aggressive plants have no legal requirements for control. Control makes sense when one plant takes over an area where other plants are desired. For example, in woodland areas, invasive Amur maples may warrant control to maintain the native plant community. Native bee balm is often aggressive in some areas and may dominate an ornamental planting. Control of this plant may be needed to keep it confined to the desired area.

AESTHETICS

Weeds are often controlled for aesthetic reasons. Each property owner has a different tolerance level for weeds. Plants such as dandelions are often controlled in turfgrass

because many consider the yellow flowers or seed heads unsightly. Ornamental plantings infested with weeds can leave a bad impression.

Keeping the plant beds free from weeds improves the aesthetics of the landscape.

WEED CONTROL

For effective weed control, you must first identify the weeds, when they occur, and their life cycle; try to determine why the weeds invaded the area and correct the problem. If you determine a need for chemical control, identify the appropriate herbicide to manage the weed problem.

Identify Weed Types

In order to control weeds, you must identify them. You need knowledge of basic characteristics of different weed groups and information about their life cycle to help you choose the best control method. Make use of plant identification keys and other resources to determine what weeds you have to manage.

Turfgrass weeds can be classified into two major groups: grassy (grasses, sedges) and broadleaf weeds (herbaceous and woody). Grassy weeds are monocots, and are identified at emergence as having only one leaf. Broadleaf weeds are dicots, emerging with two leaves. Dicots have relatively broad (wide) leaves and branching (net-like) veins. Find additional information on monocots and dicots in Chapter 8: Plant Biology Basics.

The two major weed groups include five types or categories of weeds: grasses, sedges, mosses/algae, herbaceous broadleaves, and woody broadleaves.

GRASSES

Grasses have relatively narrow leaves with parallel veins. They can be categorized as either cool-season or warm-season species based on their photosynthetic system and adapted regions. Examples of grassy weeds include crabgrass, quackgrass, and tall fescue.

SEDGES

Sedges may be considered weeds when in lawns or other landscaped areas. Sedges are grass-like plants. Most have triangular stems and the majority grow in wetlands or moist soils. Many consider a common sedge called yellow nutsedge a weed in turfgrass and landscape plantings.

MOSSES AND ALGAE

Mosses are small, generally short, soft, flowerless, seedless, and mat-forming plants. They tend to grow in patches in shady, moist locations where grass will not grow. However, they will sometimes grow in drier locations under low fertility conditions. Other favorable

conditions for moss growth include compacted, acidic, or poorly drained soils, and areas with excessive thatch. Usually considered unacceptable in turfgrass, mosses typically pose a minor problem in Utah and occur in shady areas with high humidity.

WOODY BROADLEAF WEEDS

Herbaceous and woody plants fit within the broadleaf group. Woody broadleaf weeds are easily identified by their woody stems. They include trees, shrubs, and some vines. Russian olive, tamarisk, and Siberian elm are examples of woody broadleaf weeds.

HERBACEOUS BROADLEAF WEEDS

Herbaceous broadleaf weeds include a large variety of plants with broad leaves and branching veins without woody stems. Examples include dandelion, plantain, and knotweed.

The simplest way to begin to identify some common weeds involves comparing specimens with photographs and drawings or using identification keys. An online resource, Common Weeds of the Yard and Garden, exists from USU Extension. Find it at shorturl.at/gCHN3. If unable to identify a weed, you may need the help of a plant specialist. Contact your county or regional extension office.

Life Cycle

Weeds can also be classified by their life cycle. Knowing how long the plant lives, when it germinates, grows, and how it reproduces helps in controlling it. The three life cycles to consider are annuals, biennials, and perennials. Both cultural and chemical control strategies should take into account the life cycle of the weeds. Find more information about life cycles in Chapter 8: Plant Biology Basics.

Annuals reproduce from seed and live for only one year. In order to reproduce and survive, they produce a lot of seed which can remain viable for several years in the soil. Annuals can further be classified as either summer (germinating in spring and dying in the fall) or winter (germinating in the fall and dying in the spring).

Biennials also reproduce from seed. However, they must survive over the winter. They do this by producing a taproot. Biennials often produce only a rosette of vegetation and store up food reserves (energy) the first year and then flower and produce seeds and die in the second growing season. All biennial weeds are broadleaves. Achieve the best control for biennials at the rosette stage.

Perennials survive and often reproduce from both seed and vegetatively. They produce a root structure (taproot, tuber, bulb, or corm) that allows them to survive from year to year. Difficult to control, creeping perennials spread by rhizomes (below-ground stems) and/or stolons (above-ground stems) as well as tubers, bulbs, and seed. To control these, you must destroy the above- and below-ground parts of the plant.

Determining Why Weeds Invaded and Correcting Problems

INDICATOR WEEDS

The presence and type of weeds can help you identify problems on the site. Correcting the problem will likely control the weeds and minimize or eliminate pesticide use. If you don't correct the conditions resulting in weed growth, the weeds will likely return.

MAINTAIN VIGOROUS TURFGRASS

Healthy turfgrass provides the best defense against weeds. Dense growth of turfgrass will minimize the area available for weed infestation. An unhealthy lawn thins out, resulting in exposed soil which provides more opportunity for weed infestation. Maintain healthy turf through good cultural and nutritional practices.

ESTABLISH AND MAINTAIN GOOD CULTURAL PRACTICES

Good cultural practices will reduce the number of weeds, and thus the need for weed control. Having the right turf species for the site conditions will result in healthy, dense turfgrass less prone to weed invasion. Practices such as mowing at proper heights, fertilizing according to plant needs, and aerating will promote healthy, dense turf with no room for weed invasions. Overseeding will also help maintain healthy turf. Controlling weeds by mechanical methods before they grow too large or spread will help you stay ahead of them and minimize the need for pesticides. For smaller areas, such as in ornamental plantings, hand pulling weeds effectively removes them with an environmentally safe approach. Choosing the right plant for the site conditions will help minimize weeds in ornamental plantings as well as turfgrass. Plants grown in the proper setting will be healthier and more likely to outcompete or shade out weeds.

MULCH AROUND ORNAMENTALS

A planting of shrubs or herbaceous plants with bare soil between plants will be much more prone to weed invasions than a dense planting or mulched planting. Maintaining a 2 to 3-inch layer of mulch around ornamentals in a planting will help control weeds. Mulching around trees will help prevent weeds as well as protect the trunks from equipment damage. Add mulch periodically as it biodegrades. Rock provides an alternative form of mulch that does not require replacement, but is not as healthy for the plants. Plastic often used under the rocks prevents infiltration of water into the soil.

PREVENT WEED SEED DISPERSAL AND VEGETATIVE PROPAGATION

Weeds should be removed before they disperse their seeds; ideally before setting seed. Seed dispersal occurs by various means, including wind, water, on animals and on humans. If weeds already produced seeds using an herbicide will not provide effective control long-term. If herbicides are used when seeds are forming, the plants may still produce seeds which can germinate in the future.

Learn which plants reproduce by vegetative propagation. These plants can grow from just a small piece. Tilling practices may increase these plants; for example, field bindweed. Control may be accomplished by removing all the underground parts. If using an herbicide apply a systemic herbicide on young plants for effective control.

HERBICIDE USE

Choosing the right herbicide requires some knowledge about the different types of herbicides as well as knowledge about the target weeds.

FOLLOW LABEL DIRECTIONS

Follow label instructions; the label is the law. Match an herbicide effective on the weeds you need to control and labeled for use on the given turfgrass type. Heed mixing instructions and precautions to prevent exposure to people and the environment. Find more detailed information in Chapter 3 of the National Core Manual.

CONTROL WEEDS AT SUSCEPTIBLE STAGES

More effective control occurs on small, immature plants than on large, mature plants.

You will have the best success in controlling weeds if you treat them at their most susceptible stage. Depending on their life cycles, they may be more susceptible at different times of the year.

Knowing the life cycle and biology of the weed will help you decide the best time of year to control it. For example, dandelion, (a perennial) is most effectively controlled in the fall when the herbicide is translocated down into the root system.
If your site has a lot of dandelions, a fall treatment provides more effective control. If needed, conduct spot treatments in the spring. Note that generally, controlling perennial grassy weeds requires using a nonselective herbicide and replanting the area.

Select Appropriate Chemical (Herbicide Types)

PREEMERGENT/POSTEMERGENT

Some annual grasses are more effectively controlled before they germinate. A preemergence herbicide is used to control annual grasses such as crabgrass. To be effective the herbicide must be applied at the right time, before the plant germinates, but not too soon or it will lose its effectiveness. Crabgrass germinates as soil temperatures reach 60 degrees Fahrenheit, so make applications prior to this soil warming. An inexpensive soil thermometer inserted about 1 inch into the ground will help you determine the appropriate time for applying preemergence herbicides. Remember that edges near streets or sidewalks generally warm up earlier than the middle of a turf area. Watch for environmental indicators of time to apply preemergents for crabgrass, such as when the forsythia blooms and lilacs nearly bloom.

Postemergence herbicides are used after the plant emerges from the ground. Apply this herbicide

to the plant rather than the soil. Spot treatment of weeds is the best approach to minimize use of herbicides.

SELECTIVE/NON-SELECTIVE

Selective herbicides control certain types of plants. For example, a broadleaf herbicide can be used in turfgrass to kill broadleaf weeds, such as chickweed and common mallow without harming turfgrasses. However, even selective herbicides can harm non-target plants when applied improperly. Follow label directions to minimize off target damage. Non-selective herbicides such as Glyphosate (Roundup) can kill most plants when applied at adequate rates.

CONTACT

Contact herbicides don't move within the plant so good spray coverage is needed for effective control. They only scorch or chemically burn the parts that are treated and are most effective against annual weeds. Many certified organic herbicides fit into this category.

SYSTEMIC

Systemic herbicides are absorbed by roots or leaves and then translocated to other parts of the plant. Systemic herbicides are effective on annuals and perennials, and often provide excellent control of perennial weeds.

MODES OF ACTION

There are 27 different herbicide modes of action or sites of action as grouped by the Weed Science Society of America. Each herbicide is classified under one of these groups. For example, some herbicides such as pre emergence products interfere with seedling growth, while others inhibit photosynthesis or synthesis of plant compounds. Repeated use of pesticides with the same mode of action can lead to resistant species. Information on methods to prevent occurrence of pesticide resistance is found in the National Core Manual.

Adapted from Penn State Pesticide Education Manual

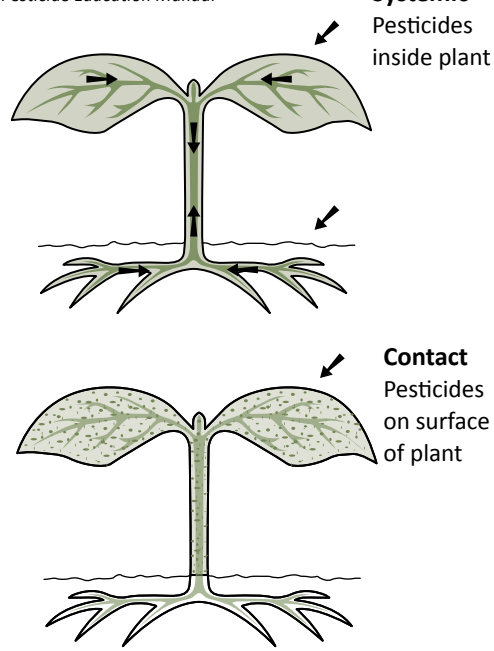


Figure 9.1
Systemic and Contact Pesticides on Treated Plants.

Amines vs. Esters

Some postemergence herbicide, such a broadleaf weedkillers' active ingredients, are manufactured in either amine or ester formulations. Ester formulations are often more effective at lower temperatures, but have a higher potential to volatilize during hot, dry weather. Volatilization is the process of a liquid or solid turning into a gas. When this happens, these herbicides can drift in the wind for long distances and damage other plants. Some ester products are formulated as having lower volatility. Always exercise caution using either during hot weather, and always consult the label.

> Amine formulations are less volatile and are often safer to use in landscape settings and warmer weather.

COMBINATION PRODUCTS

Combination products mix two or more herbicides. Depending on the number of active ingredients,

they are colloquially referred to as three-way or four-way products. You can mix these types of products on your own also, but make sure to use compatible products with labels that do not expressly forbid it. Combination products are used to control difficult, perennial weeds. Fertilizer and pesticide combinations are also available. However, they usually work best where weed pressure is low.

USE OF ADJUVANTS

An adjuvant is an additive to a pesticide to increase effectiveness, safety, or compatibility or other reason. Examples include surfactants, wetting agents, spreaders, stickers, crop oils, anti-foaming materials, and buffering agents.

Using more than one adjuvant can meet a specific need. Some herbicide labels recommend using adjuvants to improve the pesticide's performance by reducing surface tension. This helps the product more effectively penetrate through the waxy cuticle or leaf hairs.

Drift retardants help keep applications on target by increasing the droplet size. Compatibility agents aid in mixing multiple pesticides or fertilizer-pesticide combinations, resulting in more uniform mixtures.

Examine the pesticide label before using an adjuvant. Use only adjuvants recommended or not restricted by the label and at the recommended concentrations. The adjuvant label should also have instructions on how and where to use it safely and effectively. Find more information on adjuvants in the National Core Manual.

CHAPTER 10

Plant Diseases and Disorders

LEARNING OBJECTIVES

After studying this chapter, you will be able to:

1. Identify the conditions that cause a plant disease or disorder.
2. List the types of plant pathogens (according to their biology).
3. List four (4) disease management strategies.

INTRODUCTION

A plant disease or disorder is a harmful change in the growth or function of a plant. The causes of plant diseases and disorders divide broadly into two basic groups: abiotic and biotic.

Abiotic (non-living) disorders are caused by unfavorable growing conditions and poor cultural practices, such as too little or too much water or fertilizer, improper light, temperature extremes, or injury from machines or chemicals.

Biotic (living) diseases are caused by plant pathogens, such as fungi, bacteria, nematodes, viruses, and phytoplasmas that can multiply and spread from plant to plant.

This chapter introduces some common plant disease and disorders. For additional information, including color photographs of diseased plants, visit the USU Extension Utah Pests plant diseases page. Find a link at shorturl.at/gCHN3.

DISEASE TRIANGLE

The disease triangle model demonstrates three requirements that must be present for a biotic disease to develop. The components of the disease triangle include a causal agent (a pathogen), a susceptible host, and favorable environmental conditions. A disease will not develop unless all of these occur simultaneously for a specificied time. This information can be utilized to manage plant disease. One side of the triangle can be changed or removed and disease will not develop. Fungicides prevent fungal pathogens from starting infections, resistant varieties can replace susceptible varieties, and cultural practices can be used to change environmental conditions.

Susceptible Host Plants

Most plants are susceptible to attack by pathogens. Pathogens cause disease in a group of host plants known as the pathogen's host range. Some pathogens have a very broad host range. Plants outside of a pathogen's host range are not infected by the disease. For example, the bacterial disease *Erwinia amylovora* commonly causes tree death in Utah orchards, affecting plants in the rosacea family. Apple and pear trees are susceptible to this pathogen as are Hawthorne, Lilac, and Rose. Peaches, plums, and cherries are resistant to this disease and are not able to contract or spread the disease.

Many pathogens primarily cause disease in stressed plants. Stressors include drought, improper mowing and pruning, nutrient deficiencies, excess fertilizer, poor planting practices, low light, poor air circulation, cool temperatures, mechanical damage, and others.

Favorable Environmental Conditions

Environmental conditions like light, temperature, and moisture influence the growth and development of plants and pathogens. Disease-causing bacteria must have water to infect plants, reproduce, and spread. Moisture is necessary for the reproduction, spread, germination, and infection of many disease-causing fungi. With some exceptions, fungi prove more damaging to turfgrass plants during wet weather, or when moisture from rain, irrigation, or dew remains on the leaves for a long time, than during dry weather. Fungi also have specific temperature ranges within which they are active. The fungi that cause snow mold are active mainly during cold weather, whereas the fungi that cause dollar spot and red thread are most active during warm weather.

WHAT CAUSES DISEASES AND DISORDERS

Diseases

PATHOGENS

The causal agents, or pathogens, of plant diseases include fungi, bacteria, viruses, phytoplasmas, and nematodes. The naked eye cannot see most of these small pathogens.

FUNGI

Fungi cause the most common diseases of turfgrasses and ornamentals. Fungi grow in long filaments and reproduce by forming spores spread by wind, water, mowers, and other equipment, and by infected plant parts such as grass clippings. Symptoms of fungal infections vary depending on the type of plant and the plant part affected. Diseases caused by fungi include rust, powdery mildew, and dollar spot.

BACTERIA

Bacteria are single celled microbes that reproduce asexually. They typically infect plants at the sites of wounds or natural openings (such as stomata). Bacteria spread by splashing water, wind, equipment, animals, and soil. Some common plant bacterial diseases in Utah include fire blight, various bacterial leaf spots, and crown gall on a variety of woody ornamentals.

VIRUSES

Viruses are infectious particles comprised of genetic material surrounded by a protein coating. They require a host and can multiply only inside living cells. Mosaic (a mixture of dark and light green areas), flecking, and ring-spotting are foliar symptoms typical of viruses. Viruses also cause stunting and unusual, distorted, or malformed growth.

Viruses spread from plant to plant by a vector, an organism that can carry and transmit a pathogen from one host to another, usually through saliva. Many sap-sucking insects like aphids and thrips serve as viral vectors, but nematodes, and mites vector as well. Some viruses are transmitted by equipment such as pruning tools, plant-to-plant contact, and on workers' hands in the case of tobacco mosaic and others.

Viruses survive from season to season in perennial plants, insects, nematodes, and seeds. Once infected, a plant cannot be cured. Removal is recommended to prevent spread to healthy plants. Diseases caused by viruses include rose mosaic and impatiens necrotic spot.

PHYTOPLASMAS

Phytoplasmas are very small bacteria that live within a plant's vascular system and spread from plant to plant by an insect vector such as leafhoppers or psyllids. The insect vector is specific to the phytoplasma for example, aster yellow phytoplasma spreads only by the aster leafhopper. The phytoplasma enters the insect as it feeds. After it grows within the insect, it is injected into the phloem of a plant through the insect's saliva. Common

symptoms of phytoplasma diseases include leaf yellowing, reduced leaf size, stunting, and growth of axillary buds (witch's broom). Infected plants are not curable, and should be removed and destroyed to stop the disease from spreading.

NEMATODES

Nematodes are tiny non-segmented roundworms so small that most cannot be seen with the naked eye. Some nematodes are plant pathogens. Most nematodes live in soil and feed on roots and other underground plant parts, but some move above ground and feed on leaves, stems, and other plant parts. Many do not survive the winter or periods of drought. Foliar nematodes live in above-ground plant parts. Recognizable symptoms such as a wedge-shaped area of discolored cells between leaf veins indicate foliar nematodes. Galls are symptoms of seed gall nematodes, while stunting and distortion are symptoms of stem and bulb nematodes. Common symptoms of root feeding nematodes include wilting, stunting, yellowing, and symptoms of nutrient deficiency. Nematodes are transferred through insect vectors, machinery or boots, propagative parts, and water or movement through water films. Diseases caused by nematodes include root-knot nematode, pine wilt nematode, and foliar nematode.

ABIOTIC DISORDER

Pathogens do not cause most plant problems in Utah. Many abiotic factors exist that cause plant problems and can be prevented with proper knowledge and implementation of good cultural and management practices.

DIAGNOSING PLANT DISEASES AND DISORDERS

In order to properly diagnose any plant disorder, you must first identify the cause. Refer to Chapter 5: Site Evaluation for the steps on diagnosing plant problems. Multiple disorders and diseases cause similar symptoms. It is imperative to obtain an accurate diagnosis to choose the best management measures.

Tolerance

As an applicator discuss the potential harm from the disease or disorder and determine the client's pest tolerance level. These decisions should guide management actions. Tolerance of the disease or disorder will differ depending on the potential harm it may cause and on the opinions of individuals affected. If

the pest damage does not affect the overall health of the plant and the use of the site or plant, and the owner or manager accepts the level of damage caused to the property, doing nothing and tolerating the damage comprises a good strategy. Powdery mildew is an example of a disease where doing nothing and tolerating the damage can be an acceptable strategy.

MANAGING PLANT DISEASES AND DISORDERS

Once you identify the pathogen responsible for causing disease and determine it requires management, several options are available. Use the plant disease triangle to help understand disease management. The triangle states that all three factors must be present in order for a disease to occur. Therefore, if you eliminate one factor the disease will not occur. Disease management can be achieved from any side of the disease triangle. Use IPM strategies along with the disease triangle to manage diseases. IPM strategies include doing nothing, cultural control and sanitation, physical or mechanical control, biological control, chemical control, and genetic control (resistant varieties). Chapter 4: Integrated Pest Management (IPM) provides additional information on these strategies to consider.

Resistant Varieties

Resistant plants have characteristics that allow the plant to defend itself against the pathogen or that prevent infection. Find out what diseases are common in the area, and whenever possible, choose plants with disease resistance in mind.

Cultural Control

Some maintenance tasks help prevent diseases and disorders. Examples include pruning to allow more sunlight and circulation, adequate plant spacing, proper fertilizing, disinfecting tools, protecting plants from winter injury, proper irrigation, and keeping maintenance equipment from damaging woody plants.

Sanitation

Good sanitation includes removal of diseased plant material, and can greatly reduce current and future disease problems. Diseased plant should be sent to the landfill, burned, buried, or properly composted.

Pathogens can survive on pots, trellises, stakes, and garden tools. These can all be disinfected with a 10% bleach solution (using a registered pesticide bleach product) before using them again.

Pesticides

CHEMICAL PESTICIDES

Pesticides are products applied to a plant in order to prevent, suppress, or kill a pest or otherwise prevent

the pest from causing damage. Fungicides manage fungal pathogens. A few products manage bacteria, occasionally called bactericides. Nematicides kill nematodes. Viral pathogens or phytoplasmas do not respond to control.

Most fungicides are preventive and protective. They block new infections, but cannot cure established infections. A few fungicides kill fungal tissue on the outer surface of the plant, and some have "kick back action" that can stop recently formed infections. Fungicides are used to protect healthy plant tissue.

BIOCONTROL/BIOPESTICIDES

Biological control uses a beneficial organism to control a pest. Most biological control organisms are fungi and bacteria. These are commonly isolated from natural sources like plant, soil, and water environments.

Biological control products for disease control are often sold as a pesticide with the organism's scientific name listed as the active ingredient. Read and follow the instructions on the label.

Because these control organisms are alive they often have special storage and application requirements. Many will not survive extreme heat or cold, and typically have very short shelf lives.

CHAPTER 11

Insects and Mites

LEARNING OBJECTIVES

After studying this chapter, you will be able to:

1. Describe five (5) types of insect pests (according to the type of feeding and damage they cause).
2. Identify the two major insect life cycles.

INTRODUCTION

Nearly a million species of insects have been identified in the world; the total number of species is believed to be as high as two to five million. Fortunately, the majority of these insects are not pests. Out of all these different species, only about 1% are considered pests. Insect pests cause damage to plants in a variety of ways, including:

- Chewing plant parts
- Tunneling or burrowing into plants
- Sucking plant sap
- Causing galls
- Transmitting diseases

You should recognize common insect pests and protect non-target organisms while controlling pests.

This chapter provides introductory information about some common insect pests in turf and landscape. This knowledge will help you make the best use of the detection and diagnostic procedure described in Chapter 5: Site Evaluation, and Chapter 4: Integrated Pest Management.

Access pest identification resources from USU Extension at shorturl.at/gCHN3.

Only about 1% of the insects on the planet are considered pests.

INTRODUCTION TO INSECTS

Insect Development

Insects change in form and size during their lives, and this is called metamorphosis. It may be gradual, involving little more than an increase in size, or it may be a very dramatic one in which the adult looks nothing like the young (for example, a caterpillar changing to a butterfly). Often juvenile forms of insects do the most damage to plants.

Life Cycles

INCOMPLETE METAMORPHOSIS

In incomplete (i.e., simple, gradual) metamorphosis, the insect that hatches from the egg looks very similar to the adult except it is smaller and lacks wings. The juvenile forms are called nymphs. As the nymphs feed and grow, wings form on the outside of the body. Insects which have incomplete metamorphosis include grasshoppers, thrips, true bugs, aphids, and leafhoppers.

COMPLETE METAMORPHOSIS

Most insects undergo complete metamorphosis, which involves more dramatic changes. Insects with complete metamorphosis go through four distinct stages: egg, larva, pupa, and adult. A larva hatches from the egg. We have different names for the larvae of different groups of insects; for example, caterpillars (moths and butterflies), grubs (beetles), and maggots (flies). As the larva grows, it molts several times and finally changes into an intermediate form called a pupa. The pupa may be exposed or it may be contained in a capsule or in a silken cocoon. The pupa remains in a resting stage; it does not feed and usually does not move. During this stage, a number of fundamental changes occur and when completed, the adult insect emerges. Insects which have complete metamorphosis include beetles, moths and butterflies, flies, bees, lacewings, wasps, sawflies, and ants.

Insect Form and Structure

Within the animal kingdom, insects and their relatives belong to a group called Arthropoda. All arthropods are invertebrates (that is, they have no spinal columns). They have a segmented external skeleton or covering (exoskeleton) and they have paired jointed legs or appendages. The external skeleton is rigid and provides both protective covering and support.

The group Arthropoda is divided into several classes, including the class Insecta (true insects) and the class Arachnida (mites, ticks, and spiders). The wings and mouthparts are the most important features to consider when you identify a particular insect. Adult insects usually have two pairs of wings, although one pair's modifications may make them not easily recognized. Also, one group has only one pair of wings, and others may have none at all. The head bears the mouthparts and some of the sensory organs (eyes and antennae). Insects with chewing mouthparts

(for example, grasshoppers, beetles, and caterpillars) have jaws that bite or tear leaves or other plant parts. Those with piercing-sucking mouthparts (for example, true bugs, aphids, scale insects, leafhoppers, thrips) have needlelike structures capable of penetrating plant tissue. Keep in mind that mouthparts differ in the juvenile and adult forms of the same species.

Major Insect Orders (Insect Classification)

One of the ways that entomologists describe arthropods is by "Class" and "Order." All insects belong to the Class Insecta, while spiders and ticks belong to the class Arachnida. These classes subdivided into "Orders" that describe insects or arachnids with similar physical characteristics. Some of the more common orders are described in the following paragraphs.

ORTHOPTERA (GRASSHOPPERS, CRICKETS, AND KATYDIDS)

Members of the Orthoptera have chewing mouthparts, and back legs enlarged for jumping. Immature orthopterans resemble adults. Though many adult insects in this Order have wings, most do not fly well. A few are wingless. All undergo incomplete metamorphosis.

HEMIPTERA (TRUE BUGS)

This order includes lace bugs, plant bugs, stink bugs, and boxelder bugs. Pest species of true bugs produce one or more generations each year. Nymphs and adults have needle-like (piercing-sucking) mouthparts and feed on plants by puncturing stems, foliage or flowers, and sucking the sap. True bugs attack many kinds of herbaceous and woody ornamental plants. Plant injury is characterized by mottled whitish or yellowish discolorations on foliage, deformed buds, loss of vitality, wilting, and, in severe infestations, death. Some true bugs inject toxins into plants that cause further damage. Not all true bugs feed on plants, some also prey on other insects, such as damsel bugs and assassin bugs. All undergo incomplete metamorphosis.

HEMIPTERA (APHIDS, PSYLLIDS, SCALES, MEALYBUGS, LEAFHOPPERS, AND SPITTLEBUGS)

This diverse group of generally soft-bodied insects were formerly considered a separate order in the Homoptera but are now part of the Hemiptera. Most are winged, although some have unwinged forms. They all have piercing-sucking mouthparts. Hemipterans pierce plant tissues and suck out liquids. Feeding can cause deformity of leaves, loss of plant vigor, stunted growth, and dieback of plant parts. Some of these insects, for example, aphids and soft scales, excrete a sticky substance called honeydew that supports the growth of black sooty mold fungi. Some species transmit pathogens (disease-causing substances) to host plants. All undergo incomplete metamorphosis.

THYSANOPTERA (THRIPS)

Thrips consist of tiny, elongated insects with two pairs of wings. Their wings have a fringe-like appearance. Thrips have modified puncture and

Note: License Category 8 - Public Health

State, federal, or other government employees must have this category on their licenses to apply restricted-use pesticides in public health programs for controlling pests of medical and public health importance.

sucking mouthparts. Thrips puncture the surface tissue of tender buds, flowers, and leaves, and then suck the plant juices. All undergo incomplete metamorphosis.

COLEOPTERA (BEETLES AND WEEVILS)

Adult coleopterans range from "pinhead size" to several inches in length, depending on the species. Adults are recognized by their elytra, the hardened first pair of wings that usually completely covers the abdomen and hides the insect's second pair of wings when not flying. Larvae are very diverse in appearance, but all undergo complete metamorphosis. Both larvae and adults have chewing mouthparts. Their habits vary, but many species attack plants.

LEPIDOPTERA (MOTHS AND BUTTERFLIES)

Moths and butterflies are distinguishable from other insects by their large, scale-covered (and sometimes brightly colored) wings and their coiled tube-like mouthparts which they can extend to suck up liquids. Larvae are caterpillars and have chewing mouthparts. They possess two to five sets of prolegs (fleshy leg-like appendages on the abdomen). The larvae nearly always feed on plants, causing extensive damage. All undergo complete metamorphosis.

DIPTERA (FLIES, MOSQUITOES, GNATS, AND MIDGES)

Adult dipterans are easily distinguished from other winged insects because they only have one pair of wings; in place of the second pair are halteres, small club-like organs believed manage balance. Larvae are usually wormlike, often called maggots, and undergo complete metamorphosis. Most adults have a variety of mouthparts for sucking, such as lapping-sucking, sponging-sucking, and piercing-sucking. Injury to plants is characterized by wormy or decayed seeds, stems, and roots; wilted foliage; stunted growth; or death of the plant.

HYMENOPTERA (SAWFLIES, WASPS, BEES, AND ANTS)

Adults typically have four fly-like wings. They also have chewing mouth parts. Some larvae (the sawflies) are caterpillar-like and have six to ten pairs of prolegs. Sawflies feed on plants, especially defoliating deciduous and coniferous trees and shrubs as well as herbaceous plants. Other Hymenopotera larvae are predaceous (wasps and ants) or pollen feeders (bees). The Hymenoptera develop by complete metamorphosis.

ARACHNIDA (SPIDERS, TICKS, AND MITES)

Arthropods in this order include spiders, ticks, and mites. While not insects, arachnids are closely related to them. You can usually tell them from insects without great difficulty. Remember that they usually have four pairs of legs instead of three and they never have wings. Mites are tiny and usually soft-bodied. Nymphs and adults have sucking mouthparts; some species attack plants while others attack animals. Mites are usually very tiny.

TURF AND ORNAMENTAL PLANT PESTS

Another way to classify insects is by the damage they cause to plants.

Leaf-Chewing Insects

Insect pests with chewing mouthparts eat all or portions of leaves. Skeletonizing is a particular type of feeding where insects feed on the leaf tissue between veins. Some insects feed on one layer of leaf tissue between the veins, which is called windowpane feeding. Leafminers are insects that feed literally inside the leaves. Some species of leaf chewing insects common to Utah include tent caterpillars, pear, and birch leafminers, and grass hoppers.

Sucking Insects and Mites

Insects with piercing-sucking mouthparts remove plant juices (sap and/or cell contents). You may confuse symptoms of their feeding with those caused by plant disease agents. Symptoms include yellowish or whitish mottled leaves and misshapen foliage. Others may cause scarring from laying eggs. Common sucking pests of Utah include aphids, leafhoppers, plant bugs, scales, and spider mites.

Gall Forming Insects and Mites

A gall is abnormal growth of leaf, stem, twig, or flower tissue caused by the presence of a gall-making organism such as an insect, mite, or fungus. Most galls occur during late spring on new growth, and do not cause serious damage to the host plant. Oaks commonly have galls. Other trees and shrubs commonly prone to galls include maples, hackberry, ash, viburnum, and spruce. Under most circumstances, management of galls is not recommended. Insects produce many galls; they move to trees as new growth develops. Management is very challenging as pesticides need to be timed when the insects or mites are laying eggs. Once galls form, it is too late to treat them and pesticides will not control the gall makers inside their gall.

Root-Feeding Insects

Scarab beetle white grubs, Japanese beetle grubs, and some weevil larvae can attack the roots of turfgrass, causing root damage and deterioration of plant health. Grass generally turns brown and can die.

Shoot, Stem, Branch, and Trunk Borers

Any insect that feeds inside the trunk, branches, or roots of a plant constitutes a borer. The general life cycle of many borers starts in the spring when eggs are laid on the bark or stem. The eggs hatch and the larvae penetrate the stem or bark or tunnel underneath the bark and into the wood. Larvae usually molt several times as they develop, and then pupate inside the plant. When the adults emerge, they eat through the stem or bark to the

outside of the plant. Exit holes made by the adults often help diagnose a borer infestation. Depending on the specific site of attack, borers can weaken plants and even kill them by interfering with water and nutrient transport, disrupting the production of new growth, or allowing entrance of rot-causing organisms. Borers can also weaken the structure of a plant and increase its susceptibility to storm damage and disease. Examples of Utah borers include the bronze birch borer, poplar or aspen borers, greater peach tree borer, shot hole borer, flat headed borer, ash-lilac borer, and others.

BENEFICIAL INSECTS

The vast majority of insects are beneficial or benign. Insects such as bees, flies, beetles, and butterflies serve as pollinators. Most of our flowering plants are pollinated by insects. Insects provide natural control of other organisms, especially other insects. The two types of natural control include predators and parasitoids. Predators capture and quickly devour their prey; examples include lady beetles, ground beetles, lacewings, and assassin bugs.

Parasitoids (sometimes referred to as parasites) lay their eggs on or in the bodies of their hosts. The larvae hatch slowly consuming their host until it eventually dies. There are many species of parasitic wasps and flies that are present in the landscape.

Pesticide applicators need to be aware of non-target insects and avoid killing them when possible.

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