SM 81

Lawn and Ornamental Pest Management

BY FRED FISHEL
DEPARTMENT OF AGRONOMY

UF | IFAS
UNIVERSITY of FLORIDA

SM 81 Lawn and Ornamental Pest Management

A training manual for Pest Control Operators who want to become certified in the Lawn and Ornamental Pest Control category, as defined in Chapter 5E-9.024 of the Florida Administrative Code.

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About This Manual

This manual is for pest control operators who want to become certified as applicators of pesticides for controlling lawn and ornamental pests in the state of Florida. Several sources of information were invaluable in developing this publication. Portions of this manual are based on material from the Florida Department of Environmental Protection publication, *Florida Friendly Best Management Practices for Protection of Water Resources by the Green Industries*; Purdue Pesticide Programs; and UF/IFAS publication SM-7, *Ornamental and Turfgrass Pest Management, 2nd edition*. Other sources of information were developed by UF/IFAS faculty and published by the UF/IFAS Electronic Data Information Source (EDIS).

The material presented in this manual offers applicators of pesticides the detailed knowledge that they must have in order to be partially prepared for the Pest Control Operator's Lawn & Ornamental certification exam. In addition, an applicator may want to use this manual as a source of periodic review, general reference, or as the basis for providing training to any unlicensed pesticide handlers who work under the applicator's direct supervision.

This manual has 19 chapters:

Although the subjects are somewhat related, the manual has been designed so that each chapter can be studied independently. To aid use and study, each chapter contains:

- A table of contents,
- A set of learning objectives,
- A list of key vocabulary words, and
- A set of review questions and answers.

The subject matter and degree of detail presented in the review questions is in most cases very similar to that of the questions which make up the actual certification exam.

There are appendices at the end of this manual containing important telephone numbers; fertilizer label requirements for urban turf, sports turf, or lawns; conversion factors used in making calculations related to making pesticide applications; and references.

This project, which has the support of Florida's Cooperative Extension Service, the Florida Department of Agriculture and Consumer Services (FDACS), the USDA, and the US-EPA, represents a continuation of a long-standing effort to produce pesticide applicator training materials that are useful and that can improve the safety and efficacy of pesticide use.

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Chapter 1

Licensing of Lawn and Ornamental Applicators in Florida

In this Chapter

Learning Objectives

After you complete your study of this chapter, you should be able to:

- Know the state agency that controls licensing and regulation of people who apply pesticides to lawns and ornamental plants.
- Explain the insurance requirements of a pest control business.
- Know the cost of the following associated with being a pest control operator:
  - Pest control business license;
  - Pest control operator certificate;
  - Pest control operator certificate exam; and
  - Employee identification card.
- Describe the qualifications to be eligible for taking the Lawn and Ornamental pest control operator certificate exam.
- Understand the process of recertification to keep the following valid:
  - Pest control operator certificate;
  - Employee identification card.
- Describe the required information needed in posting a pesticide application.
- Understand your obligations for notifying your customers who are on the FDACS registry for people sensitive to pesticides.

Terms to Know

Continuing education unit (CEU): Approximately one hour of study credit used to renew pest control operator certifications.

Florida Department of Agriculture and Consumer Services (FDACS): The agency that administers the Florida Structural Pest Control Law (Chapter 482).

Florida Structural Pest Control Law (Chapter 482): The law that governs the use of pesticides by businesses and those holding a certificate in the Lawn and Ornamental category as a Pest Control Operator, Limited Lawn & Ornamental, and Limited Commercial Landscape Maintenance.

Restricted use pesticides (RUPs): Pesticide for retail sale to, and use by, only certified applicators or persons under their direct supervision and only for those purposes covered by the applicator's certification.

Unclassified (general use) pesticide: A pesticide that can be bought and used by the general public without special permits.

Pest Control Operator (PCO) – Lawn and Ornamental License (Chapter 482)

In Florida, the law that controls licensing and regulation of people who apply any type of pesticides (Figure 1.1), restricted use or unclassified (general use), to lawns and ornamental plants is the Florida Structural Pest Control Law (Chapter 482). The rules of the Florida Structural Pest Control Law are specified in Chapter 5E-14, Florida Administrative Code – Rules of the Department of Agriculture and Consumer Services. The

Figure 1.1: Applications to lawns and ornamentals are regulated by FDACS.

Florida Department of Agriculture and Consumer Services (FDACS) is the agency that administers the law and its rules. You need to become familiar with Chapters 482 and 5E-14 as there will be content questions on your certification exam. You can view them here: **http://bit.ly/LegFlUS482** (Chapter 482) and **http://bit.ly/LegFlUS5E-14** (Chapter 5E-14).

How do I know if I need a license to provide pest control in lawns and ornamentals in Florida? All persons who apply any pesticide, either restricted use or general use to ornamentals or turf associated with a building, including lawns and plant beds, must have a pesticide applicator certification issued by the Bureau of Licensing and Enforcement. General use pesticide applications made by a person to the individual's own residence or yard are exempt from this requirement. In most cases, if a person or company is providing services that only include mowing, edging, and landscaping, only a county or municipal occupational license is needed. (This does not apply to "weed and feed" or "insect control" applications.)

Lawn and ornamental areas regulated under Chapter 482, F.S., include:

- **Commercial pest control:** Pest control performed by pest control businesses and their employees on non-agricultural property.

- **Limited certificate pest control:** Pest control performed by governmental employees and/or private/commercial property owners (or their employees) on the non-agricultural property of their employer. Examples of limited pest control services performed by these individuals include ornamental pesticide applications to buildings or lawn and ornamentals associated with the following: government buildings (schools, agency offices, etc.); commercial buildings (banks, groceries, apartments, condominium common areas, hotels, restaurants, etc.).

Applications of restricted use pesticides made to athletic fields, parks, cemeteries, and golf courses also require a license obtained through FDACS Bureau of Licensing and Enforcement. These sites are considered as "agricultural sites" and are regulated under the Florida Pesticide Law (Chapter 487).

Information on how to obtain these licenses can be obtained from FDACS Bureau of Licensing and Enforcement at (850) 617-7997 or at **http://www.freshfromflorida.com/Divisions-Offices/Agricultural-Environmental-Services/Bureaus-and-Sections2/Bureau-of-Licensing-and-Enforcement.**

Qualifications and Examinations

To become a certified operator, a person must pass an examination. A person must apply to the Bureau of Licensing and Enforcement, FDACS, to take the examination. The applicant must possess one of the following minimum qualifications in order to take the examination:

- Three years employment as a service employee of a licensed business that performs lawn and ornamental pest control. One year of the employment must be in Florida within the year immediately preceding the application for the examination.

- A degree with advanced training or a major in entomology, botany, or horticulture from a recognized college or university, which includes the completion of at least 20 semester hours or 30 quarter hours of college credits in these subjects, plus one year of employment as a service employee of a licensed pest control business in Florida.

- A two-year degree in horticulture technology or the equivalent from a college or university, with advanced training of 20 or more semester hours or 30 or more quarter hours of credit in horticulture, plus one year of employment as a service employee of a licensed pest control business in Florida.

- A two-year degree in general pest control technology, or the equivalent, from a college or university, with advanced training of 20 or more semester hours or 30 or more quarter hours of credit in entomology, plus one year of employment as a service employee of a licensed pest control business in Florida.

- Twenty-four semester hours or 36 quarter hours of courses in entomology, pest control technology, agronomy, botany, horticulture, and related subjects, plus one year of employment as a service employee of a licensed pest control business.

Examination dates and locations are scheduled by the FDACS Bureau of Licensing and Enforcement, **http://www.freshfromflorida.com/Business-Services/Pest-Control/Exam-Schedule-and-Information**, or call 850-617-7997. The exam is also offered online at select UF/IFAS county Extension offices. Apply online through FDACS licensing portal located at: **https://aesecomm.freshfromflorida.com/** to qualify and then schedule the examination at an office convenient to your location.

Study Materials

The content of the exam is based upon the study materials listed in Table 1.1.

Table 1.1. Study materials for the PCO – Lawn and Ornamental exam.

Study Manuals/Reference Materials	Source
Chapter 482 F.S. The Structural Pest Control Act	FDACS Bureau of Licensing and Enforcement
Chapter 5E-14, F.A.C. Rules of the Dept. of Agriculture and Consumer Services	
Applying Pesticides Correctly	UF/IFAS Extension Bookstore **https://ifasbooks.ifas.ufl.edu**
Lawn & Ornamental Pest Control	
Identification Guide to Common Florida Lawn & Ornamental Weeds	
For questions concerning labels, a label will be included for reference during exam	Contact suppliers of pesticide products for sample labels

With this license the certified operator-in-charge may supervise an unlimited number of employees performing lawn and ornamental pest control from the business location. Each employee must have an identification card issued by the FDACS Bureau of Licensing and Enforcement. Certified operators obtain two (2) core CEUs approved for the core category plus two (2) CEUs approved for the lawn and ornamental category prior to the expiration of their annual certificate; or pass an examination. Non-certified identification cardholders are required to complete two (2) CEUs in any category to remain valid. The certified operator-in-charge cannot apply or supervise the application of pesticides on golf courses, parks, athletic fields or cemeteries.

Fees

The application to take the examination must be accompanied by a fee of $300, which includes issuance of the pest control business license. The annual renewal fee is $150. The employee identification card has an annual fee of $10 and must be renewed annually.

Each pest control business, when making application for a pest control business license or its renewal, must furnish a certificate of insurance which meets the requirements for minimum financial responsibility for bodily injury and property damage. This consists of:

- Bodily injury: $250,000 each person and $500,000 each occurrence; and
- Property damage: $250,000 each occurrence and $500,000 in the aggregate.

  Or

- Combined single-limit coverage: $500,000 in the aggregate.

Posting Notices of Lawn and Ornamental Pesticide Applications

Florida law requires pesticide applicators to post notices of pesticide applications they make to lawns and exterior foliage (ornamental plantings) when these are part of the landscape around a building. This requirement is in the Florida Structural Pest Control Law.

The posting requirement applies to pesticide applications made by the following licensed applicators:

- Commercial Pest Control Operators - Lawn and Ornamental Category
- Commercial Pest Control Operators - General Household Pest Control category, when a pesticide application is made to a lawn or exterior foliage to control certain household pests associated with the structure being treated
- Limited Certification - Lawn and Ornamental Category
- Limited Certification - Structural, when a pesticide application is made to a lawn or ornamentals to control certain household pests associated with the structure being treated
- Limited Certification - Commercial Landscape Maintenance

The posting requirement does not apply to:

- Pesticide applications made to golf courses, parks, athletic fields, and cemeteries. The Florida Pesticide Law (Chapter 487 F.S.) regulates pesticide application on these sites.

- Pesticide applications made by homeowners to the lawn and ornamentals associated with their residence.

The notice must be posted in a conspicuous location at the time of the application of the pesticide to a lawn or exterior foliage (Figure 1.2). The minimum size of the sign is 4 inches x 5 inches. It must be constructed of rigid, durable, weatherproof material with the background and lettering in contrasting colors. The business name of the licensee or the name of the limited certificate holder making the pesticide application must be clearly identified on the notice (Figure 1.3). The notice may be a part of a larger sign containing additional information.

Figure 1.2: Notices must be posted in an obvious location.

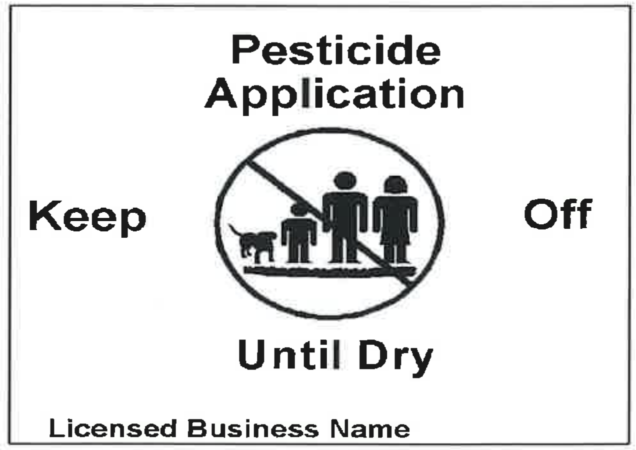


Figure 1.3: Required design of notification sign.

Notifying People about Pesticide Applications

Some people want to be given prior notification about pesticide applications on lawns, plant beds, trees or shrubs near their home, because they may be sensitive to certain pesticides. Florida law requires FDACS to keep a registry of these people. To enlist in the registry, a person must pay a fee of $50. The person must also provide FDACS a certificate signed by a licensed medical doctor in Florida. The certificate must identify the pesticides for which the doctor declares that prior notification is necessary to protect the person's health. In addition, the certificate must provide the distance surrounding the person's primary residence, not to exceed ½ mile, for which prior notification is required in order to protect the person's health.

The FDACS Bureau of Licensing and Enforcement must provide information from the registry (every 3 months or quarterly) to all businesses and people who have a current Chapter 482 license from the bureau. People who have limited certification licenses are included.

The information includes:

- The names and addresses of those persons currently registered;

- The pesticides for which prior notification is required; and

- The distance for which notification is required.

Licensed applicators must notify the person at least 24 hours before the application of the pesticide to a lawn, plant beds, trees or shrubs, within the area identified by the medical doctor, that surrounds the property on which the primary residence of the registered person is located. The notification must include the location where the pesticide will be applied and the type of pesticide to be used. Applicators may use the telephone, mail or hand delivery.

The notification requirement does not apply to pesticide applications made by:

- Homeowner
- Ornamental and Turf applicators or other pesticide applicators licensed under Chapter 487

Additional Information

Florida Department of Agriculture and Consumer Services
Bureau of Licensing and Enforcement
Pesticide Certification and Licensing Section
3125 Conner Blvd., Bldg. 8, L-29
Tallahassee, FL 32399-1650
Phone: 850- 617-7997
http://www.freshfromflorida.com/Divisions-Offices/Agricultural-Environmental-Services/Bureaus-and-Sections2/Bureau-of-Licensing-and-Enforcement

University of Florida/IFAS Pesticide Information Office
P.O. Box 110710
Bldg. 164
Gainesville, FL 32611-0710
Phone: 352-392-4721
http://pested.ifas.ufl.edu/

Test Your Knowledge

Q: True or False:
The Florida Structural Pest Control Law (Chapter 482) controls the licensing and regulation of people who apply pesticides to lawns and ornamental plants.
A: True

Q: True or False:
The Pest Control Operator Lawn and Ornamental certificate is for people who apply or supervise the application of any type of pesticides to golf courses, parks, sports fields, and cemeteries.
A: False

Q: Which of the following best describes where a notice of pesticide application to exterior foliage should be placed?
A. By a driveway
B. By a sidewalk leading to a front door
C. As close to the front door as possible
D. In a conspicuous area
A: D

Q: What is the maximum number of unlicensed applicators a Lawn and Ornamental pest control operator may supervise?
A. None
B. 1
C. 15
D. Any number, as long as they hold an issued identification card
A: D

Q: What is the annual renewal fee for the certified operator's certificate?
A. $50
B. $100
C. $150
D. $300
A: A: C

Q: Licensed applicators must notify persons on the FDACS registry at least _____ before the application of a pesticide.
A. 1 week
B. 48 hours
C. 24 hours
D. 12 hours
A: C

Chapter 2

Understanding the Label

In this Chapter

Learning Objectives

After you complete your study of this chapter, you should be able to:

- Explain the difference between a label and labeling.
- Understand the four major label components.
- Explain the meanings of label signal words.
- Understand the following label concepts:
  - Statement of Practical Treatment
  - Child Hazard Warning
  - Hazards to Humans and Domestic Animals
  - Personal Protective Equipment
  - Environmental Hazards
  - Use Classification
  - Brand, Common and Chemical Names
  - Ingredient Statement
  - Net Contents
  - EPA Registration Number
  - EPA Establishment Number
  - Name and Address of Manufacturer
  - Formulation
  - Physical and Chemical Hazards
  - Limited Warranty and Disclaimer
  - Directions for Use
  - Storage and Disposal

Terms to Know

Active ingredient: The substance in a pesticide product that is intended to kill, repel, or otherwise control a target pest.

Acute effect: An effect that becomes apparent soon after exposure to a pesticide occurs.

Application rate: The amount of pesticide that is applied to a known area, such as an acre.

Brand name: Name under which the manufacturer sells the product.

Caution: The signal word used on labels of the least toxic pesticides.

Certified applicator: A person who has demonstrated, through an examination process, the ability to safely handle and apply restricted use pesticides.

Chemical name: The official name given to a chemical compound to distinguish it from other chemical compounds.

Common name: The recognized, nonscientific name given to pesticides.

Danger: The signal word used on labels of highly hazardous pesticides due to serious health or environmental hazards.

Directions for use: The instructions found on pesticide labels indicating the proper procedures for mixing and application.

Establishment number: A number assigned to registered pesticides by the US EPA that indicates the location of the manufacturing or formulation facilities of that product.

Formulation: A mixture of active ingredient combined during manufacture with inert ingredients.

Inert ingredients: All materials in the pesticide formulation other than the active ingredient. Some inert ingredients may be toxic or hazardous to people.

Labeling: The pesticide label and all associated materials, including supplemental labels, special local needs registration information, and manufacturer's information. The label is a legal document.

Personal protective equipment (PPE): Devices and garments that protect handlers from exposure to pesticides. These include coveralls, eye protection, gloves, boots, respirators, aprons, and hats.

Registration number: Numbers assigned to a pesticide product to identify that the product has been approved by the US EPA.

Restricted Entry Interval (REI): A period of time that must elapse between application of a pesticide and when it is safe to allow people into the treated area without requiring they wear PPE and receive early-entry worker training.

Restricted use pesticide (RUP): Pesticide for retail sale to, and use by, only certified applicators or persons under their direct supervision and only for those purposes covered by the applicator's certification.

Sensitization: The initial exposure of an individual to a substance, resulting in an immune response; subsequent exposure results in an allergic response.

Signal word: One of three words (Danger, Warning, Caution) found on pesticide labels to indicate the relative hazard of the chemical.

Statement of practical treatment: A section of the pesticide label that provides information about treating people who have been exposed to the pesticide. This includes emergency first aid information.

Toxicity: The degree or extent that a chemical substance is poisonous.

Unclassified (general use) pesticide: A pesticide that can be bought and used by the general public without special permits.

Warning: The signal word used on labels of pesticides considered to be moderately toxic or hazardous.

Introduction

Pest problems occur in diverse settings that range from agricultural to commercial and residential. In Florida, pest control is a year-round operation and many times a pesticide will be chosen as part of the management plan for the problem. If a pesticide will be part of the management plan, understanding the contents of the pesticide label is essential for the product's safe, effective, and legal use.

The pesticide label is a very expensive document. The information on the pesticide label represents the research, development and registration procedures that a pesticide must undergo before reaching the consumer at the market, frequently at a cost of millions of dollars to the manufacturer. The US Environmental Protection Agency (EPA) requires a manufacturer to submit data from nearly 150 tests prior to that product's approval for use, including toxicity, environmental persistence, and many other factors that may affect how the pesticide will be safely and effectively used. The pesticide use information obtained in this process is referred to as the label or labeling, two similar words with very different meanings.

The label is the information printed on or attached to the pesticide container; it has several interpretations. To the manufacturer, the label is the product's clearance to sell to applicators of pesticides. To governmental agencies, including the EPA, the label is a way to control the distribution, storage, sale, use, and disposal of the product. To the buyer or applicator, the label should be considered the main source of information on how to use the product correctly, legally, and safely.

Labeling refers to all the information that you might receive from the company, their sales representatives, or a local pesticide dealer about the product. This information may include brochures, flyers, and other information accompanying the product. The focus of this chapter will be on the pesticide label.

Properly interpreting the pesticide label is crucial to selecting the most appropriate pesticide products for use and therefore receiving maximum benefit from their use (Figure 2.1). The length of a pesticide label can vary widely, ranging from one to many pages of very fine print. And although labels contain all the required EPA information, the order in which a manufacturer chooses to present that information can vary. While the label may seem overwhelming at first, it does not require a great amount of time to understand the information once the general format is recognized. Label content for a single product changes frequently—applicators of pesticides should review the labels of products they use on a regular basis.

You should read the pesticide label:

- Before purchasing the pesticide to ensure that it is the correct one for the job;
- Before mixing the pesticide to ensure the proper pesticide concentration;
- Before applying the pesticide to ensure proper use; and
- Before storing the excess pesticide or disposing of the empty container.

Information contained on most labels can be divided into four major categories: safety, environmental, product, and use. This chapter discusses the contents of these categories and provides interpretations. Sample labels are available from pesticide dealers and manufacturers or online at **http://www.cdms.net/Label-Database**. Several questions on your certification exam will ask you for specific information by referring to a product label. A fictitious label is available at the conclusion of this chapter for use with the practice questions. The superscripted number beside most subsection titles is identified on the sample label.

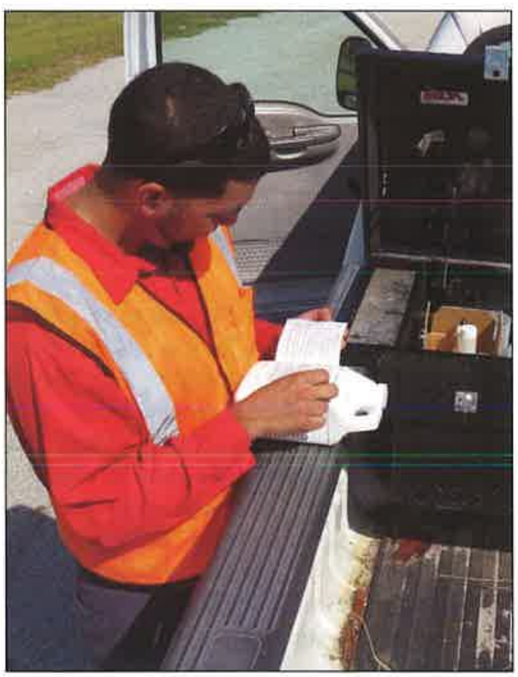


Figure 2.1: Proper interpretation of the pesticide label is crucial. Credit: Don Rainey, UF/IFAS

Safety Information

[1]Child Hazard Warning

The front panel of every pesticide label must bear the statement, "KEEP OUT OF REACH OF CHILDREN." Although pesticides are not the top substances in the U.S. causing exposure incidents in children, they do rank among the top ten. According to the American Association of Poison Control Centers, pesticide exposure incidents occur in greater frequency to children under the age of six years than to older children, teens, and adults on an annual basis.

[2]Signal Word

A signal word (Table 2.1) is displayed in large letters on the front of the label to indicate approximately how acutely toxic the pesticide is to humans by ingestion. The signal word is based on the entire contents of the product; not the active ingredient alone, but also the inert ingredients. The signal word does not indicate the risk of delayed or allergic effects.

Table 2.1. Acute toxicity label signal words.

Signal word	Category	Oral lethal dose[1]
DANGER – POISON (skull and crossbones)	I Highly toxic	A few drops to a teaspoonful
WARNING	II Moderately toxic	Over a teaspoonful to one ounce
CAUTION	III Slightly toxic	Over one ounce to one pint
CAUTION (or no signal word)	IV Relatively non-toxic	Over one pint to one pound
[1]Based on a 150-pound person.		

All highly toxic pesticides that are very likely to cause acute illness through oral, dermal, or inhalation exposure have DANGER as their signal word, and will carry the word POISON printed in red with the skull-and-crossbones symbol. Products that have the DANGER signal word due to skin and eye irritation potential will not carry the word POISON or the skull-and-crossbones symbol (Figure 2.2).

KEEP OUT OF REACH OF CHILDREN

DANGER-POISON

PELIGRO

Figure 2.2: Example of a "Danger" pesticide label signal word.

[3]Statement of Practical Treatment

The labels for all highly toxic pesticides (signal word DANGER, Category I) must provide information to medical professionals should an exposure occur. Examples of wording found in this section:

- "If swallowed: Immediately induce vomiting by touching back of throat with finger. Drink one or two glasses of water and induce further vomiting. Call a physician or poison control center immediately."
- "If in eyes: Hold eyelids open and flush with a steady, gentle stream of water for 15 minutes. Get medical attention."
- "If on skin, wash skin with soap and water. Get medical attention."

It is in this section that proper antidotes and treatment are recommended for medical personnel treating a victim. For this reason, the pesticide label should always be taken to the emergency medical facility when an exposure occurs. Products labeled DANGER also bear an 800 telephone number that physicians may call for further treatment advice at any time. Often labels for less toxic pesticides will also provide first-aid instructions.

[4]Hazards to Humans and Domestic Animals

This part of the label includes precautionary statements indicating specific hazards, routes of exposure and precautions to be taken to avoid human and animal injury. The label will contain statements that indicate which route of entry (mouth, skin, eyes, and lungs) that must particularly be protected and what specific action is needed to take to avoid acute effects from exposure to the pesticide. Examples of such statements seen in this section include:

- "Causes eye and skin irritation. Harmful if swallowed, inhaled or absorbed through skin."
- "Do not get on skin or on clothing."
- "Avoid breathing vapor or spray mist."
- "Avoid contact with eyes."
- "Prolonged or repeated skin contact may cause allergic reactions in some individuals."
- "Wash thoroughly with soap and water after handling."

Pesticides that the EPA considers to have the potential to cause delayed effects must have label statements warning the user of that fact. These statements will indicate whether the product has been shown to cause problems such as tumors or reproductive problems in laboratory animals. Additional information in this section will alert users if the product has the potential to cause allergic effects, such as skin irritation or asthma. Sometimes the labeling refers to allergic effects as "sensitization."

[5]Personal Protective Equipment

Most pesticide labels contain specific instructions concerning the type of clothing that must be worn during the handling and mixing processes. This information is usually found following the statements regarding acute, delayed and allergic effects. Some labels may list this information after the signal word.

Examples of some common statements from pesticide labels regarding personal protective equipment include:

- "chemical-resistant footwear plus socks;"
- "long-sleeved shirt and long pants;"
- "waterproof gloves;"
- "protective eyewear" and many other similar statements.

The personal protective equipment listed is the minimum protection that should be worn while handling the pesticide (Figure 2.3). Sometimes the statements will require different personal protective equipment for different pesticide handling activities, usually with greater safety equipment emphasis on operations that involve handling concentrated products. In some cases, reduced personal protective equipment is allowed when you will be applying the pesticide in safer situations, such as enclosed cabs.

Personal Protective Equipment (PPE)

Some materials that are chemically resistant to this product are listed below. If you want more options, follow the instructions for **Category A** on an EPA chemical-resistance category selection chart.

Mixers, loaders, applicators, and other handlers must wear:

- Long-sleeved shirt and long pants
- Chemical-resistant gloves made of any waterproof material
- Shoes plus socks

Figure 2.3: PPE listed on the pesticide label is the minimum protection.

Environmental Information

[6]Environmental Hazards

This section of the label explains the nature of potential hazards and the precautions needed to prevent injury or damage to nontarget organisms or to the environment (Figure 2.4). Some general statements appear on practically every pesticide label; for example, most pesticide labels will warn the user not to contaminate water sources when applying the pesticide, cleaning application equipment or disposing of pesticide wastes. It is also in this section that information can be found if the product poses a threat to groundwater. Instructions will be provided to minimize such impacts. Some labels will mention endangered species concerns in this section. Warnings of potential toxicity to honeybees may also be stated in this section.

Examples of environmental hazard statements include:

- "This product is highly toxic to honeybees."
- "This product is extremely toxic to fish and aquatic invertebrates."
- "Do not apply where runoff is likely to occur."

Environmental Hazards

This product is toxic to aquatic organisms. For terrestrial uses. **DO NOT** apply directly to water, or ares where surface water is present, or to intertidal area below the mean high water mark. **DO NOT** contaminate water when disposing of equipment washwater or rinsate.

Figure 2.4: Practically all labels carry concerns about water contamination.

Product Information

[7]Use Classification

The EPA is required to classify pesticides for either general use or restricted use. In classifying a pesticide, the EPA considers:

- the toxicity of the pesticide;
- the way in which the pesticide will be used; and
- the effect of the pesticide on the environment.

When a pesticide is classified as restricted, the label will state "Restricted Use Pesticide" at the top of the front panel. Below this heading may be a reason for the restriction (Figure 2.5). Although there is a federal list of restricted active ingredients determined by the EPA, some states have their own lists of restricted products. Florida follows the federal guidelines for determining if a product is restricted. To purchase and apply restricted use pesticides, a person must be certified and licensed in the state of Florida.

RESTRICTED USE PESTICIDE

Due to Toxicity to Fish and Aquatic Organisms

For retail sale to and use only be Certified Applicators or persons under the direct supervision of a Certified Appliator and only for those uses covered by the Certified Applicator's certification.

Figure 2.5: Example of restricted use classification on a pesticide product label.

A "general use pesticide" is defined as one that will not harm the applicator or the environment to an unreasonable degree when used according to label directions. General use pesticides are available to the general public for use according to label directions. Applicators in Florida who perform structural pest and mosquito control are required to be certified and licensed regardless of pesticide classification.

[8]Brand (Trade) Name

Each manufacturer has a brand name for each of its products (Figure 2.6). Different manufacturers may use different brand names for the same pesticide active ingredient. For example, Pendulum and Prowl are trade names for the same herbicide active ingredient, pendimethalin. However, it is not legal to use different brand-name pesticides interchangeably even if they contain the same active ingredient. Pendulum is the product approved for use on lawns and ornamentals, whereas Prowl is approved for use in crops. Each product label will state specifically the sites to which it may be applied. The brand name is shown plainly on the front panel of the label.

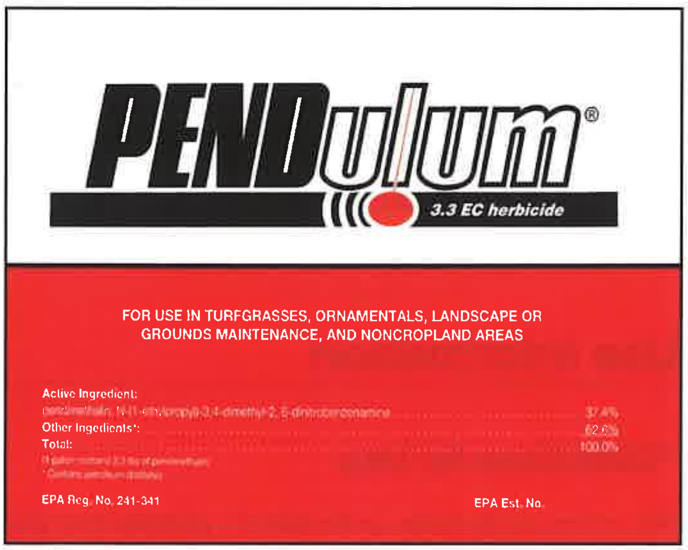


Figure 2.6: The product's brand name is displayed prominently. Credit MDMS.

[9]Ingredient Statement

This statement, normally on the front panel of the label, identifies the name and percentage by weight of each active ingredient. Identified by chemical or common name, the active ingredients are the components of the product that affect the target pest. The chemical name is often complex. For example, the chemical name for pendimethalin is N-(1-ethylpropyl)-3,4-dimethyl-2,6-dinitrobenzeneamine. To aid communication, EPA-approved common names may be substituted for chemical names—in this case, pendimethalin. Usually following the list of ingredients, the amount of active ingredient is expressed as a percentage by weight for both liquid and dry formulations of pesticides. For liquid pesticides, the number of pounds per gallon of active ingredient will be given in this section as well (Figure 2.7).

ACTIVE INGREDIENTS:

2,4-Dichlorophenoxyacetic acid* 13.8%

2,4-Dichlorophenoxyacetic acid, butoxyethyl ester* 24.5%

OTHER INGRIDEDIENTS: 61.7%

TOTAL: 100%

*Total 2,4-Dichlorophenoxyacetic acid equivalent 30.8% by weight or 2.8 lbs./gal. Isomer specific by AOAC method No. 978.05

Figure 2.7: Example of ingredients statement on a pesticide product label.

Inert ingredients allow active ingredients to be formulated into many different products, and make the product safer, more effective, and easier to handle. As part of the formulation, they also determine a product's handling properties. Inert ingredients that are not considered to be toxic need not be named on the label, but the label must show what percentage of the total contents they make up.

[10]Net Contents

The front panel of the pesticide label states how much of the product is in the container. This can be expressed as pounds or ounces for dry formulations and as gallons, quarts, pints, or fluid ounces for liquids.

[11]EPA Registration Number

This number identifies a specific product and signifies that the product has met federal registration requirements through all of the testing phases. This number must have a minimum of two sets of digits, one for the manufacturer, and one for the product. For example, if the EPA registration number is 901-358, "901" indicates the manufacturer, and "358" is the specific number issued to identify the product. Sometimes there will be a third set of numbers to identify the distributor.

Some states require that some registration numbers carry a set of letters in this code as well.

[12]EPA Establishment Number

This number identifies the facility that formulated the product. In the event of questions or concerns regarding a product, the facility that made the pesticide can be determined. Although not common, quality control problems have been tracked to the facility that formulated the product when problems with a specific product were identified.

[13]Name and Address of Manufacturer

The law requires the maker or distributor of a product to put the company name and address on the label. This enables consumers to know who made or sold the product. In many cases, the manufacturer will also list a telephone number and/or web address where users of the product may seek technical advice.

[14]Formulation

The front panel of some pesticide labels will describe the product formulation. The formulation name may be either spelled out or designated by an abbreviation, such as G for granular materials, WP for wettable powders, D for dusts, or DF for dry flowables, also known as dispersible granules. There are other formulations, but these are some of the more common ones. This information is helpful for practical purposes because it provides insight about the type of application equipment that will be needed and the product's handling properties. However, the labels for some lawn and ornamental pesticides do not clearly state the formulation. For more information, you will need to contact the manufacturer.

[15]Physical and Chemical Hazards

This section will tell of special fire, explosion, or chemical hazards the product may pose. For example, it will alert you if the product is so flammable that you need to be especially careful to keep it away from heat or open flame, or if it is so corrosive that it must be stored in a corrosion-resistant container. This section is not always found in the same location within the labeling. Some labeling will identify physical and chemical hazards in a designated box, while other labeling may list them on the front panel beneath the signal word. Others may list hazards under headings such as "Note" or "Important." Examples include wording such as:

- "Do not use or store near heat or open flame."

Some products will include statements concerning the diluted product, such as:

- "Spray solutions of this product should be mixed, stored and applied using only stainless steel, aluminum, fiberglass, plastic or plastic-lined steel containers."

Many other hazard warnings may be found in this section.

[16]Limited Warranty and Disclaimer

This statement conveys the manufacturer's assurance that the product conforms to the chemical description on the label and that it is fit for label purposes if used according to directions under normal conditions. The warranty does not extend to any use of the product contrary to label instructions, nor does it apply under abnormal conditions such as drought, tornadoes, hurricanes, or excessive rainfall. Applicators who violate label instructions assume all liability associated with the product.

Use Information

[17]Directions for Use

This section usually makes up the bulk of a pesticide label and begins with the wording: "It is a violation of federal law to use this product in any manner inconsistent with its labeling" (Figure 2.8). Products intended for use in agriculture will have an Agricultural Use Requirement box included in this section. It will contain the statement: "Use this product only in accordance with its labeling and with the Worker Protection Standard, 40 CFR part 170." The purpose is to inform those handling the product that the Worker Protection Standard applies to the product. When the Worker Protection Standard applies, a statement regarding information on employee notification of restricted entry intervals and applications, proper training, decontamination, emergency assistance, and personal protective equipment is stated here. The Worker Protection Standard does not apply to applications made to lawns and ornamentals. The directions for use section will contain information such as:

- Sites, objects, animals, plants or areas where the product may be applied.
- The amount of product to use. This may be expressed as an amount per unit area, such as per acre or per 1,000 square feet. It may also be listed as an amount to mix per unit volume of water.
- A description of how the product should be applied and by which type of application equipment it is most effectively applied.
- The timing and frequency of application. For example, a label may state specific time intervals between applications, such as "allow 10 or more days between applications."

Directions for Use

It is a violation of Federal law to use this product un a manner inconsistent with its labeling.

Read all Directions for Use carefully before applying.

Do not apply this product in a way that will contact workers or other persons, either directly or through drift. Only protected handlers may be in the area during application. For any requirements specific to your state or tribe, consult the agency responsible for pesticide regulation.

Agricultural Use Requirements

Use this product only in accordance with its labeling and with the Worker Protection Standard, 40 CFR Part 170. this Standard contains requirenments for the protection of agricultural workers on farms, forests, nurseries, and greenhouses, and handlers or agricultural pesticides. It contains requirements for training, decontamenation, notification, and emergency assistance. it also contains specific instructions and exceptions pertaining to the statements on this label about personal protective equipment (PPE), and restrited-entry interval. The requirements in this box only apply to uses of this product that are covered by the Worker PRotection Standard.

Do not enter or allow worker entry into treated areas during the restricted entry interval (REI) of 48 hours.

Figure 2.8: The directions for use usually make up the bulk of the label.

- Limitations on reentry to treated areas. These will be given in specific terms. The reentry intervals may be very specific and given in terms of hours or days or they will simply state "do not enter or allow others to enter the treated area until sprays have dried."
- The pests that the product controls. The user assumes all risks for applying the product to control a pest that is not listed on any given product's label.
- Any number of various limitations associated with the product, including application intervals, crop rotation restrictions, animal restrictions, and warnings about the use on certain sites.

[18]Storage and Disposal

Most, if not all, pesticide labels will contain a general statement in this section to the effect, "do not contaminate water, food, or feed by storage, disposal, or cleaning of equipment" and "store in original containers only." Label information about storage generally includes temperature requirements. In many cases, minimum and maximum storage temperatures will be provided in specific terms. Some pesticides become ineffective if they are not stored under suitable temperatures; other pesticide labels may indicate that if freezing occurs and crystals form, then the product may be reused if it is warmed up. Moisture is a critical concern with dry pesticides, including granular materials and wettable powders, which have a strong affinity for water. When this is the case, the label may have the statement, "store in a dry place."

Labels include information on disposal of pesticide containers as well as excess quantities of diluted pesticide mixtures. The label will inform users that leftover mixtures that can't be applied to a labeled site may be disposed of in an approved waste disposal facility that is in accordance with appropriate federal, state, and local procedures. With disposal of liquid pesticide containers, the triple-rinse procedure will be stated in this section of the label and options such as recycling or disposal of punctured containers in a sanitary landfill will be given. Manufacturers of returnable and refillable containers will remind the user to return the containers promptly and intact to the point of purchase. The label will state that bags containing dry pesticide products should be emptied thoroughly into the application equipment and incinerated or discarded into a sanitary landfill. Although burning of pesticide containers is legal in Florida, some counties and municipalities have enacted ordinances which prohibit such activities. Applicators should consult their local authorities to determine burning regulations.

Test Your Knowledge

Using the accompanying label on the next page, answer the following:

Q: What is the brand name of this product?
A: Weeds-Away

Q: Who is the manufacturer of this pesticide?
A: Optimal, Inc.

Q: What does this pesticide control?
A: Weeds

Q: What is the common name of the active ingredient in this product?
A: Killzdamine

Q: What is the application rate of the product for a preemergence application for control of crabgrass?
A: 0.25 to 0.50 fluid ounces/1,000 ft^2

Q: What is the signal word listed on the pesticide container's label?
A: CAUTION

Q: Is it safe to apply this product to surface water such as ponds?
A: No, it is toxic to fish.

Q: What is the EPA registration number of this product?
A: 910-358

Sample Label

[7]Restricted Use Pesticide
(TOXIC TO FISH)

For sale and use only by Certified Applicators or persons under their direct supervision and only for those uses covered by the Certified Applicator's certification.

[8]Weeds-Away 4L[14] Herbicide

(For use in lawns)

[9]Active Ingredient:
Killzdamine (2,4-butyl-p-methylamine)..24.5%
Inert Ingredients.......................................75.5%
1 gal contains 4.0 lb. killzdamine

[10]NET CONTENTS 1.0 GAL.
[11]EPA REG.# 910-358
[12]EPA EST.# 901-FL-3

[3]Statement of Practical Treatment
If swallowed, do not induce vomiting. Call a physician or Poison Control Center immediately.
If in eyes, flush with plenty of water.
If on skin, wash with plenty of soap and water.
NOTE TO PHYSICIAN: vomiting should only be induced under professional supervision.

[2]CAUTION

[1]KEEP OUT OF REACH OF CHILDREN

[17]Directions for Use
It is a violation of federal law to use this product in a manner inconsistent with its labeling.

Preemergence Application

Grass species	Rate (fl oz/1,000 ft^2)
Crabgrass	0.25 – 0.50
Foxtails	0.25 – 0.50
Goosegrass	0.50 – 0.75

Postemergence Application

Grass species	Rate (fl oz/1,000 ft^2)
Crabgrass	0.50 – 0.75
Foxtails	0.50 – 0.75
Goosegrass	0.75 – 1.00

[4]Hazards to Humans and Domestic Animals
Harmful if absorbed through skin. Causes minor skin irritation.

[5]Personal Protective Equipment (PPE):
- Applicators and other handlers must wear:
- Long-sleeved shirt and long pants
- Chemical-resistant gloves
- Shoes plus socks

[6]Environmental Hazards
This product is toxic to fish. Do not apply directly to water or to areas where surface water is present.

[15]Physical and Chemical Hazards
Do not use or store near heat or open flame.

[18]Storage and Disposal
Storage: Do not contaminate water, food, or feed by storage or disposal. Store at temperatures above 32° F.
Pesticide Disposal: Wastes resulting from the use of this product may be disposed of on-site or at an approved waste disposal facility.
Container Disposal: Triple rinse (or equivalent). Then offer container for recycling or puncture and dispose in sanitary landfill or by incineration.

[16]Warranty
Optimal Inc. warrants that this herbicide conforms to the chemical description on its label. When used in accordance with label directions under normal conditions, this herbicide is reasonable fit for its intended purposes. The user assumes all risk of any such use, including the use of this product on weed species not recommended on this label.

[13]Optimal, Inc.
2738 Washington Hwy.
PO BOX 4603
Tampa, FL 64208-603

Chapter 3

Introduction to Best Management Practices to Reduce Pollution and Conserve Water

In this Chapter

Learning Objectives

After you complete your study of this chapter, you should be able to:

- Describe the four major goals of Green Industries Best Management Practices.
- Explain the cause of nonpoint source pollution.
- Describe the benefits provided by a healthy and vigorous turf and its root zone.
- Name the most important factors in planning a lawn and landscape.
- Describe the importance of educating your customers about wise cultural practices.
- Describe why proper cultural practices, including irrigation, fertilization, mowing and pruning, aeration and dethatching can reduce the need for pesticides.
- Describe the importance of adequate employee training and your role as supervisor.

Terms to Know

BMPs: Best management practices. Procedures to reduce nonpoint source pollution and promote the efficient use of water.

Evapotranspiration: Water loss from plants and soil.

FYN: Florida Yards and Neighborhoods. A statewide public education and outreach program for homeowners offered through most UF/IFAS Extension offices.

Green Industries: The people who work mowing, pruning, planting, weeding, fertilizing, watering, taking care of pest problems, and teaching customers how to properly care for their lawns.

IPM: Integrated pest management. The use of all suitable pest control methods to manage a pest population. Biological, cultural, physical or mechanical, and chemical controls are all IPM practices.

Nonpoint source pollution: Contamination that comes from a widespread area, such as a pesticide entering ground water from a large-scale application.

Introduction

The protection of water resources is enhanced through turf- and landscape-care practices that make the best use of technology and the practical experience of professionals. These practices address specific concerns, including the protection of water resources where pesticides and nutrients enter ground water and surface water as a result of nonpoint source pollution.

University studies throughout the country, including Florida, have shown that properly managed turfgrass and landscapes do not significantly contribute to nonpoint source pollution. Pollution occurs when less-than-adequate management techniques are used. Developing low-risk irrigation, fertilizer, and pesticide programs, and ensuring that these programs are properly administered and periodically reviewed, reduces the possibility of nutrient movement off-site. Whenever possible, professionals should educate their clients on landscape best management practices (BMPs) that encourage water conservation and pollution prevention.

What, exactly, is meant by the phrase *"the Green Industries?"* Simply put, only you, the people working every day, mowing, pruning, planting, weeding, fertilizing, watering, taking care of pest problems, and teaching your customers how to properly care for their lawn, can make a difference in the effects our landscapes have on our natural resources (Figure 3.1). Governments can regulate and educators can teach, but only the individual working in the yard can actually make a difference.

In the summer of 2000, a group of industry associations met with government and university representatives to discuss developing standards of environmental responsibility for their industry. The goals of Green Industries Best Management Practices (GI-BMPs) are to reduce nonpoint source pollution and promote the efficient use of water, as follows:

- Reduce the off-site transport of sediment, nutrients, and pesticides through surface water or ground water.
- Use appropriate site design and plant selection.

Figure 3.1: The green industries are comprised of people who do a wide variety of tasks in landscapes.

- Use appropriate rates and methods of applying fertilizer and irrigation.
- Use integrated pest management (IPM) to minimize pests and apply chemicals only when appropriate.

BMPs should integrate selection, irrigation, fertilization, and pest management in a manner that minimizes environmental impacts, yet meets clients' and customers' expectations. Irrigation practices influence how often we need to fertilize, and this can affect the occurrence of pest problems. Weigh these and other factors when making landscape management decisions.

Environmental Issues

Many areas of the state are running low on freshwater supplies. Water conservation is one of the most crucial issues facing Florida in the future, and applying the BMPs described in this manual will help to conserve our precious fresh water (Figure 3.2).

Figure 3.2: Using BMPs will help conserve water.

Since the passage of the Clean Water Act and the formation of the U.S. Environmental Protection Agency, tremendous strides have been made in cleaning up our air and water. Most of this cleanup has been accomplished through permitting and the regulation of point sources of pollution such as factory smokestacks and sewage discharges.

In contrast, nonpoint source pollution comes from diffuse sources and is associated with the long-term effects of everyday activities. It is carried primarily by rainfall and irrigation water, which cause pollutants that have accumulated on the land surface to run off into surface waters or to leach into ground water. Water is the primary mechanism for the transport of dissolved chemicals through the soil. Nonpoint source pollution may not be obvious until a rainfall event occurs, leading to stormwater runoff from roads, parking lots, suburban areas, and farms. As Florida's population has soared, this type of pollution has become an increasingly important issue in the state.

Many of Florida's water resources are particularly susceptible to pollution because of the state's unique geology and climate. Floridians obtain most of their drinking water from ground water via wells. Ground water supplies often lie near the surface and may be covered by nothing but sandy soil. Surface waters in Florida are very sensitive to even small additions of pollution, which have caused widespread ecosystem changes in our sensitive estuaries, lakes, rivers, and wetlands.

In order to prevent potential leaching and runoff; users of fertilizers and pesticides need to consider the weather conditions, proper application rates of products and calibration of equipment, soil properties, the distance to the water table, the slope of the land, and the distance to surface waters and storm drains; all of this, in addition to plant nutrition, disease, and pest factors.

Importance of Maintaining Healthy Landscapes and Turf

Well-planned, healthy landscapes designed with Florida-friendly landscape practices usually include trees, ornamentals, and a lawn of turfgrass or other ground cover (Figure 3.3). Native and well-adapted, noninvasive ornamentals contribute beauty and balance to a property, provide shade and wildlife habitat, and help to control erosion by diminishing the force of rainfall. Both the lawn and other landscape plantings reduce noise and glare, and modify temperatures.

Figure 3.3: Landscape participating in Florida-friendly practices.

A healthy and vigorous turf with good plant density provides many benefits. Healthy grass is viewed as an aesthetic asset, and a growing body of evidence points to the positive health and environmental contributions made by lawns and other turf areas. Turfgrass plays a significant role in reducing water runoff in urban and suburban environments that have significant areas of impervious surfaces, such as parking lots, sidewalks, and driveways. Dense turf reduces the velocity of runoff and allows greater infiltration into both the thatch and root zone, where microbes can begin breaking down the water contaminants. The turfgrass root zone is a unique soil system. A healthy root zone does the following:

- Improves soil structure and reduces soil compaction, allowing greater infiltration of rain or irrigation water;
- Improves soil processes that facilitate the biodegradation (breakdown) of various types of organic pollutants, air contaminants, and pesticides used in lawn care;
- Encourages soil-building processes through the decomposition of organic matter and formation of humus, and contributes to easier lawn care with fewer weeds and insects and less disease.

Cultural Practices for Healthy Landscapes

Plant selection and location are the most important factors in planning a lawn and landscape. After weather, cultural practices are the biggest factors in determining how well an agronomic or horticultural program performs. The amount of pesticides, fertilizers, and water required often directly correlate with cultural practices and how well they are carried out.

Landscape professionals have a responsibility to supply their customers with educational material on their role in keeping turf and other landscape plants healthy. This includes (as appropriate) information on irrigation, mowing, plant selection, aeration, and traffic control. Few landscaping and lawn care companies have total control over all aspects of the properties they maintain. It is not uncommon for mowing, fertilization, pest management, and irrigation maintenance to be performed by two or more companies, and the homeowner may do one or more jobs themselves. It is of the utmost importance to educate customers about wise cultural practices so they can see that they are performed properly (Figure 3.4).

Cultural practices include irrigation, fertilization, mowing and pruning, aeration and dethatching. When each of these is performed properly, the need for pesticides is reduced because plants and turfgrasses are healthier and more resistant to pest problems.

The concept of Integrated Pest Management (IPM) emphasizes proper cultural practices along with selecting plant species, varieties and cultivars that are less susceptible to insects, nematodes, and diseases, and best adapted to the environmental conditions of the site and geographic part of the state. An entire chapter of this publication will be devoted to discussing IPM.

Mowing height has a tremendous impact on the severity of weed, insect, and disease pests. In general, lowering mowing height increases weed, insect, and disease pressure on turfgrasses by causing turf stress. There are exceptions: dwarf varieties, centipedegrass and improved bermudagrasses have lower mowing heights than the standard often used for lawn and commercial turfgrasses (Figure 3.5). Still, even these lower-growing varieties will suffer stress if mowed too short.

Figure 3.5: Centipedegrass has lower mowing heights.

Figure 3.4: Educating the customer is key to keeping plants healthy. Credit: UF/IFAS Image Database.

Pruning is an important task in maintaining a landscape. Through the selective removal of shoots and branches, pruning a plant can improve its health, control its growth, and enhance its fruiting, flowering, or appearance (Figure 3.6). Improper pruning, on the other hand, may weaken a plant, open it to invasion by disease or insect pests, or even lead to premature death of the plant. Incorrect disposal of material may lead to the spreading of diseases or pests, or of the spreading of invasive species.

Figure 3.6: Pruning can enhance flowering.

Time fertilizer applications to maximize plant use and minimize adverse environmental impacts (Figure 3.7). Plants use the most nitrogen during periods of high growth, and less when dormant. However, it is important to avoid fertilizer applications if heavy rain is expected before the nutrients are immobilized. In theory, frequent, very light applications or "spoon feedings" of turf and landscapes are ideal to avoid leaching a large amount at one time due to a heavy rain event, but this is difficult to achieve safely without special management, such as for golf course greens. Slow release fertilizers attempt to match this ideal profile. Both quick- and slow-release fertilizers have a place in a sound management program.

Figure 3.7: Properly fertilized St. Augustinegrass lawn.

Fertilization of plants can result in additional growth and production of leaves, stems, branches and roots. However, additional growth can result in more maintenance and yard trimming, so it is important to determine if heavy growth is the desired result. Fertilization is usually desirable when trying to establish newly installed landscape plants. In addition, adding fertilizer can help plants get off to a quick start so they fill the planted area.

Inadequate nutrition results in thin, weak plants that may be more susceptible to insects, weeds, and diseases. In addition, weakened plants do not hold the soil as well as healthy dense stands and can lead to soil erosion and water pollution. Certain diseases, such as rust and dollar spot, can occur in turf maintained under low-nutrient conditions. Under-fertilized landscape plants may require a higher than normal rate of nitrogen or other nutrients in order to return to a healthy condition.

Over-fertilization can also enhance plant susceptibility to pests and diseases. Several pesticide applications may be required to alleviate problems that would not have been as prevalent under a proper nutrition program.

Remember that plants don't waste water, people do. In a typical urban environment where soils and habitat have been modified, supplemental irrigation is necessary for the survival of many turf and ornamental plants during periods of severe moisture deficiency. However, overwatering may increase insect, weed, and disease pressures. For example, excessive moisture encourages the development of dollarweed and fungal pathogens. Conversely, some weeds such as spurge and Florida pusley thrive under dry conditions and can outcompete turfgrass suffering from drought stress. A balance is necessary to keep the landscape strong and healthy.

The average volume of rainfall in Florida ranges from 40 inches annually in Key West, to about 53 inches in the central and northern peninsula, and over 60 inches in the Panhandle west of Tallahassee and along the southeast coast south of Lake Okeechobee. In parts of the central and southern peninsula, more than half of Florida's total annual rainfall is concentrated between June and September. During the winter and spring, or during severe drought years, the lack of rainfall may seriously compromise plant health. Landscape plants, including turfgrass, that are growing in soils with a limited capacity to retain moisture can benefit from supplemental irrigation during periods of low rainfall. Even during the rainy season, evapotranspiration (water loss from plants and soil) occurs between showers and may necessitate supplemental watering while plants are becoming established.

Determining and controlling the rate, amount, and timing of irrigation can minimize soil erosion, runoff, and fertilizer and pesticide movement. The irrigation system should be designed to have an application rate that is less than the infiltration capacity of the soil so that no surface pooling occurs and water percolates with maximum efficiency. Rain sensors or soil moisture sensors eliminate irrigation when nature has supplied sufficient water. A correctly installed and operating rain sensor, which is required by law on all systems installed after 1991, can save up to 30% or more over a timer-only system. If you notice a defective rain sensor while performing other work on a property, try to notify the owner so they can get it repaired.

Figure 3.8: The use of pesticides is an important component in managing landscapes.

The use of pesticides for controlling pests remains an important part of landscape plant management in Florida (Figure 3.8). The key to reducing pesticide use is to combine genetic, cultural, and biological management practices into an IPM program that focuses on the prevention of pest problems. When suppression is necessary, it is easier to suppress a pest when conditions exist that do not favor its development. For example, diseases can be hard to manage during periods of heavy rains but if overwatering is promoting disease, cutting back irrigation will help suppress fungus much more effectively than fungicide applications alone.

BMPs to protect water quality can be affordable and easily implemented, and are effective in reducing the off-site transport of sediment, nutrients, and pesticides. Select pesticides that are the least toxic, least water soluble, least volatile, and most effective. The best defense against the movement of pesticides and fertilizer nutrients off-site or through the soil is a thick, vigorously growing stand of turf or other landscape plants.

Pesticides must be correctly applied. Spray when conditions for drift are minimal, avoid application when heavy rain is expected, and irrigate with appropriate volumes of water per label instructions. Granular applications should be targeted away from impervious surfaces and bodies of water. The landscape manager should check the proper calibration of equipment before every pesticide application.

Always follow the label directions for disposing of pesticide containers.

Employee Training

The effectiveness of any program is only as good as the understanding of the personnel responsible for final application. BMPs are no exception. For BMPs to be effective, the technicians in the field must understand their role in protecting our water resources. This understanding can only come from the development and implementation of employee-training programs.

Employees should be given pertinent information relating to their job duties, especially job safety. The Green Industry is very diverse. Companies range in size from one or two individuals to very large corporations. Firms of any size may choose to avail themselves of horticultural and practical training available through professional associations, governments, or the Cooperative Extension Service.

In addition to the BMPs, it is recommended that managers, salespeople, and supervisors take advantage of Florida Yards and Neighborhoods (FYN) training events where they are provided by their local UF/IFAS Extension office. While consistent with the Green Industry BMPs, FYN training is geared to homeowners, and in some areas to retailers and homebuilders. While FYN is the "homeowner" BMP guide and applies to maintenance of all types of yards found in Florida, it also addresses design of diverse landscapes that minimize use of irrigation, supplemental fertilizers, and corrective pest control. FYN classes also focus considerable attention on specific plant selection, placement, and care. This information is tailored to local conditions and soils, topics beyond the scope of this manual. There is a growing demand for people to install and service these yards properly, and this may provide an opportunity to expand your client base. More information about GI-BMP employee training is available at **http://ffl.ifas.ufl.edu/professionals/BMP_overview.htm**.

If you are doing planting or irrigation work, or any other digging, find out where utility lines are buried before you dig in order to protect yourself and your crew from injury and prevent damage to underground utility lines. Train your employees that a call to 811 starts the process of getting underground utility lines marked for free. Calling 811 in Florida routes you to Sunshine State One Call. Utility companies then send a professional locator to the location to mark underground lines within two full business days. Once the lines are marked, you will know the approximate location of the utility lines and can dig more safely (Figure 3.9). However, One Call member utilities typically locate only those underground facilities they own. Customer wiring and piping within the lot are not marked by One Call.

Figure 3.9: Marked underground utility lines help prevent accidents from activities such as core aeration.

Employees whose job duties include activities related to BMPs should be properly trained to perform those activities before going in the field. Applicable personnel at all levels of responsibility should receive refresher training annually on the general components and goals of the BMPs, job safety, and the specific BMPs that apply to their jobs.

Documenting an employee's participation is an integral part of a successful training program. Employee training should be documented in an employee training log. This documentation provides the business with a tool to ensure the effective delivery of BMPs. It not only allows the company to track an employee's education and competence, but also provides a record in case of accident to show that the company provided the employee with the proper training to do his or her job. Records should have the name and signature of the employee, the provider or trainer, subject, date, and hours (time in/ time out).

In 2009, the Florida Legislature enacted s.403.9335-9338, and s.482.1562 Florida Statutes, providing for fertilizer ordinances and requiring training and certification for commercial fertilizer applicators by 2014. Many local governments have ordinances that also regulate institutional and non-commercial fertilizer applicators and landscape workers. Many of these ordinances require education in these BMPs in order to obtain an occupational license or to provide services to the public. Maintaining training records shows that your business meets these requirements.

Remember . . .

- Train employees about BMPs and job safety.
- Retrain annually and when changes are made.
- Train employees to document and retain records of activities.

Finally, consider the real nature of your business. It is probably not the sale of pesticides, fertilizers, or gasoline. It is more likely that your real business is maintaining your customers' yards at a level that pleases them, at the lowest expense to you. Do not spend money applying materials that are not needed, or that are wasted by poor application practices or improper equipment calibration. Do not waste materials and time fighting the symptoms of problems you have no control over. Collaborate with other trades that have expertise you do not provide, such as an irrigation contractor. Then, if the irrigation system is causing fungal problems and dry spots, you can provide the customer with repairs; fix the real cause of the trouble; and save money on pesticides, fertilizer and labor. Using Best Management Practices minimizes both the environmental and financial costs of maintaining a healthy and attractive landscape.

Test Your Knowledge

Q: What are the four major goals of the Green Industries Best Management Practices? (Select all that apply)
A. Reduce the off-site transport of sediment, nutrients, and pesticides through surface water or ground water.
B. Use appropriate site design and plant selection.
C. Use appropriate rates and methods of applying fertilizer and irrigation.
D. Use integrated pest management (IPM) to minimize pests and apply chemicals only when appropriate.

A: A, B, C, D

Q: True or False:
Nonpoint source pollution comes from distinctly identified sources and is associated with the long-term effects of everyday activities.

A: False

Q: What are the benefits provided by a healthy turfgrass root zone?
A. Improves soil structure and reduces soil compaction, allowing greater infiltration of rain or irrigation water
B. Improves soil processes that facilitate the biodegradation (breakdown) of various types of organic pollutants, air contaminants, and pesticides used in lawn care
C. Encourages soil-building processes through the decomposition of organic matter and formation of humus, and contributes to easier lawn care with fewer weeds and insects and less disease
D. All of the above

A: D

Q: What is the most important factor in planning a lawn and landscape?
A. Plant selection
B. Location
C. Proper watering
D. Plant selection and Location

A: D

Q: After weather, what are the biggest factors in determining how well an agronomic or horticultural program performs?
A. Pesticide selection
B. Cultural practices
C. Pest identification
D. Use of biological control

A: B

Q: True or False:
For BMPs to be effective, the technicians in the field must understand their role in protecting our water resources.

A: True

Chapter 4

Best Management Practices for Design and Installation of Landscapes

In this Chapter

Learning Objectives

After you complete your study of this chapter, you should be able to:

- Name the first and second steps in selecting plants for a landscape.
- Know the nine principles of Florida-friendly landscaping as defined by Florida law.
- Describe the general process for properly transplanting a plant into the landscape.
- Describe the factors affecting selection of a turfgrass at any given site.
- Be able to discuss the following characteristics for bahiagrass, Bermudagrass, centipedegrass, seashore paspalum, St. Augustinegrass, and zoysiagrass:
  - Area of the state to which it's adapted
  - Mowing height
  - Soil requirements
  - Leaf texture
  - Salt tolerance
  - Shade tolerance
  - Wear tolerance
  - Drought tolerance
  - Nematode tolerance
  - Maintenance level
  - Establishment methods
- Be able to associate specific cultivar names for Florida's major turfgrass species.
- Describe the logical step-by-step process for preparing to plant a lawn.
- Name three practices that reduce environmental stresses to Florida lawn grasses.
- Name six management practices to produce better turfgrass growth in shaded situations.

Terms to Know

BMPs: Best management practices. Procedures to reduce nonpoint source pollution and promote the efficient use of water.

FYN: Florida Yards and Neighborhoods. A statewide public education and outreach program for homeowners offered through most UF/IFAS Extension offices.

Hydrozone: An area of an irrigation system where all the factors that influence the watering schedule are similar.

Photosynthesis: The process by which plants convert sunlight into energy.

Phytotoxicity: Herbicide injury to plants.

Rhizome: A specialized primary stem, which grows horizontally at the ground surface or underground.

Stolon: A specialized horizontal aboveground stem that takes root at the nodes.

Introduction

Bare soils and slopes without proper plant cover are highly susceptible to erosion. Sediment resulting from erosion is the leading cause of waterbody impairment and pollution. Sediment destroys fish-spawning beds, reduces useful storage volumes in reservoirs, and increases filtration costs for municipal water supplies. Pesticides and nutrients such as nitrogen and phosphorus can bind with sediments and be moved by running water. A healthy stand of turf and/or other landscape plants can help to control erosion and reduce runoff, but must be properly established and maintained to protect water quality.

It is important to design the landscape before installing the irrigation system. This allows the irrigation system to be designed to meet the needs of the plants instead of the other way around.

In many communities, construction and design documents and permits require the signature and seal of a design professional. To protect the public, landscape architects and professional engineers are licensed by the state. Contact your local authorities if you are not sure what is required. For more information on landscape architecture, see **http://www.myfloridalicense.com/dbpr/pro/larch/**, or to learn more about engineering services go to **http://www.fbpe.org/**.

Site Evaluation and Landscape Design

The long-term value of a landscape depends on how well it performs for its particular objectives. Performance is often directly related to matching a site's characteristics and a client's desires with plant requirements. Therefore, the first step in selecting plants for a landscape is to conduct a site evaluation, which may consist of studying planting site characteristics such as the amount of sun or shade, salt spray exposure, soil type, pH, soil compaction, slope and water drainage (Figure 4.1). These characteristics will most likely differ between areas on the same property. For example, the area on one side of a structure may have significantly different light conditions than an area on the other side. Construction activities may have produced severe compaction, and non-native soils may have been used as fill in some areas. Such soils may need aerification or amendment to be suitable for planting. The second step is to select plants with attributes that match the characteristics of the planting site (Figure 4.2). The design professional should always provide the owner with a drawing identifying each plant or bed and the recommended irrigation requirements.

For more information, see UF/IFAS Circular 536, *Basic Principles of Landscape Design*, at **http://edis.ifas.ufl.edu/MG086**.

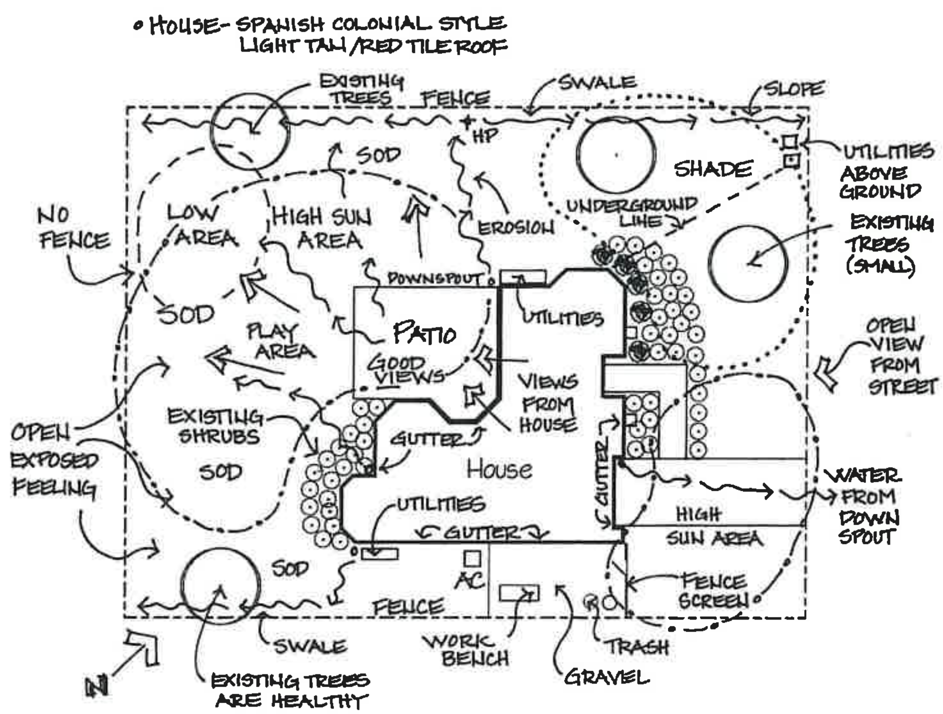


Figure 4.1: Sketching a map will help to identify site conditions prior to installing the landscape. Credit: UF/IFAS EDIS Document ENH1165.

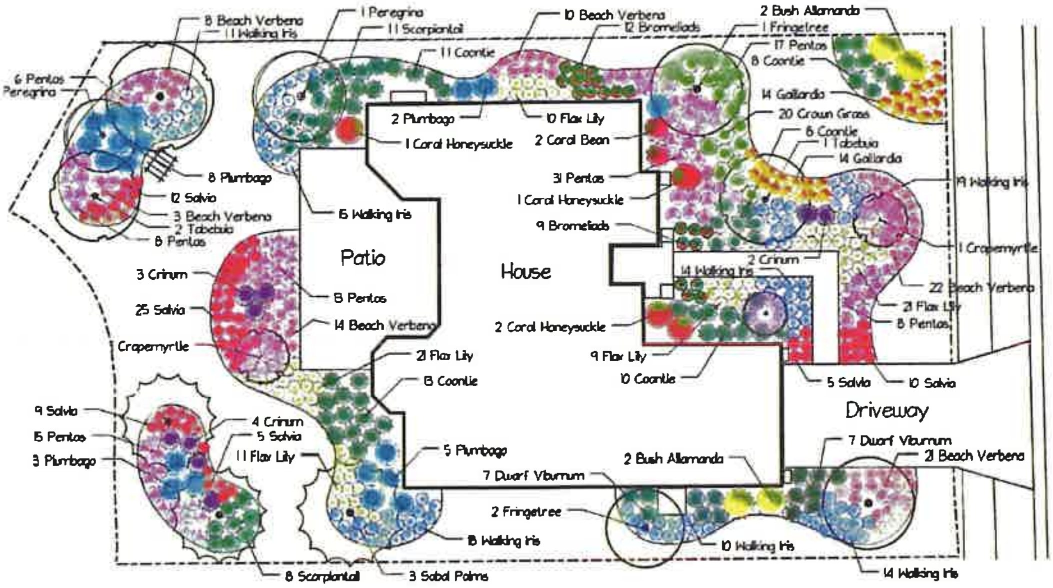


Figure 4.2: Landscape map showing placement of plant selections. Credit: UF/IFAS EDIS Document ENH1195.

Florida Friendly Landscape Design Standards

In 2004, the Florida legislature created section 373.228 Florida Statutes, directing the Department of Environmental Protection, the Water Management Districts, and several stakeholder groups to devise standards for Landscape Irrigation and Florida-Friendly landscape design. These standards were adopted in December 2006. Local governments must use these standards when adopting local ordinances after that date. Florida-Friendly Landscape Design Standards state:

- Low-impact site design practices, such as preserving existing native trees and vegetation, shall be used if feasible. Where established natural vegetation is incorporated into the landscape design, irrigation of those areas shall not be required.
- The plant palette and irrigation system shall be appropriate for site conditions, taking into account that, in some cases, soil improvement can enhance water use efficiency.
- Plants shall be grouped together by irrigation demand.
- The percentage of landscaped area in irrigated high water-use hydrozones should be minimized. Local government ordinances shall address the percentage of irrigated landscaped area that may be included in high water-use hydrozones. These high water-use limits should not apply to landscaped areas requiring large amounts of turf for their primary functions, e.g., ballfields and playgrounds.

Florida law defines the nine principles of Florida-friendly landscaping to include 1) planting the right plant in the right place, 2) efficient watering, 3) appropriate fertilization, 4) mulching, 5) attracting wildlife, 6) responsible management of yard pests, 7) recycling yard waste, 8) reduction of stormwater runoff, and 9) waterfront protection. Additional components of Florida-friendly landscape include planning and design, soil analysis, the use of solid waste compost, practical use of turf, and proper maintenance.

This BMP manual for professionals and the Florida Yards and Neighborhoods (FYN) programs for homeowners, homebuilders and developers, and retailers are based on these nine principles, differing only in focusing on the needs of their target audience. All are part of the Florida Friendly Landscaping TM program, a partnership between the Florida Department of Environmental Protection, UF/IFAS' Environmental Horticulture Department and the Center for Landscape Conservation and Ecology, and the five water management districts.

Selecting Trees, Shrubs, and Groundcovers

The plants selected should be suited to the characteristics of the site that were determined during an earlier site analysis. Good landscape design requires that plants serve particular functions. They should reduce cooling and heating costs and improve the appearance or usefulness of the landscape. Plants should be selected and positioned to provide a transition between the structure and the landscape, a screen for privacy, shade for comfort, and wildlife habitat, or to direct traffic flow onto and within the property. Select plants that will not outgrow their allotted space. Even though smaller cultivars of landscape plants may take longer to reach the desirable size, they will not have to be pruned as frequently and are less likely to need replacing in a few years. See **http://hort.ifas.ufl.edu/woody/index.html** for information on individual plants.

Landscape Plant Installation

Before digging the hole, 1) remove all soil from above the topmost root, and 2) measure the distance between the topmost root and the bottom of the root ball. Dig the hole about 10 percent shallower than this depth and as wide as possible (at least one and a half times the width of the ball and even wider in compacted soils). The root ball should be positioned in the hole shallowly enough so that the finished grade of the backfill soil and landscape soil is lower than the top of the root ball. In other words, leave the upper portion of the sides of the root ball exposed to the air. Then apply mulch so that it covers the sides of the root ball. Be sure that when you are finished planting, there is NO SOIL, and little or no mulch, over the top of the root ball. Soil (as well as thick mulch layers more than three or four inches deep) over the root ball can prevent water and air from entering the root ball.

When finished planting, you should be able to see the topmost root in the root ball originating from the trunk at the soil surface. In other words, the trunk flare (root flare) should be visible. Soil should be packed firmly between the root ball and existing soil to eliminate air pockets where roots can dry out. Air pockets can be removed when planting large specimens by inserting a running hose between the root ball-soil interface several times until all the soil settles around the root ball.

Care During Plant Establishment

Even the healthiest landscape plants installed in the most ideal circumstances may need a substantial amount of time, care, and proper irrigation to become established. During the establishment period, the roots are expanding out into the landscape soil, and the shoots and trunk grow more slowly than they did before transplanting. In most instances, established, drought-tolerant landscape plants have a root system substantial enough to keep them alive with little or no supplemental irrigation. Establishment occurs more rapidly when irrigation is supplied in the correct quantity and frequency.

In addition to requiring special attention to irrigation, during their establishment period trees benefit from mulching and may require staking or guying. Pruning and fertilizing may also benefit landscape plants while they are becoming established.

For more information, see the following:

- UF/IFAS Publication ENH 860, *Fertilization and Irrigation Needs for Florida Lawns and Landscapes*, at **http://edis.ifas.ufl.edu/EP110**.
- UF/IFAS Publication ENH 857, *Irrigating Landscape Plants During Establishment*, at **http://edis.ifas.ufl.edu/EP113**.
- UF/IFAS Circular 853, *Pruning Landscape Trees and Shrubs*, at **http://edis.ifas.ufl.edu/MG087**.
- UF/IFAS tree pruning website, *Pruning Shade Trees in the Landscape*, at **http://hort.ifas.ufl.edu/woody/pruning/**.

Table 4.1. Characteristics of turfgrasses for the Florida lawn.

	Bahiagrass	**Bermudagrass**	**Centipedegrass**	**Seashore Paspalum**	**St. Augustinegrass**	**Zoysiagrass**
Area adapted to	Statewide	Statewide	N. FL and Panhandle; One cultivar adapted to S. FL	Statewide	Statewide	Statewide
Mowing height	3–4”	Cultivar dependent 0.75–1.5”	1.5–2.5”	0.5-2”	Cultivar dependent 2-2.5” or 3.5-4”	1.5-2.5”
Soil	Acid, sandy	Wide range	Acid, infertile	Wide range	Wide range	Wide range
Leaf texture	Coarse-medium	Cultivar dependent Fine-medium	Medium	Fine-medium	Cultivar dependent Coarse-medium	Cultivar dependent Fine-medium
Salt tolerance	Poor	Good	Poor	Excellent	Good	Good
Shade tolerance	Poor	Poor	Fair	Poor	Good	Good
Wear tolerance	Poor	Good-excellent	Poor	Good-excellent	Poor	Good-excellent
Drought tolerance	Excellent	Good	Medium	Good	Fair	Medium
Nematode tolerance	Very good	Poor	Poor	Good	Good	Good
Maintenance level	Low	Cultivar dependent Medium-high	Low	High	Medium	Medium-high
Establishment methods	Seed, sod	Sod, sprigs, plugs, seed	Seed, sod, sprigs, plugs	Sod, plugs, sprigs, seed	Sod, plugs, sprigs	Sod, plugs, sprigs, seed

Selecting a Turfgrass for a Florida Lawn

Selecting the correct grass is critical to maintaining a lawn successfully. Table 4.1 can help you choose the grass that is best suited to a particular customer, location, and use. To select the right grass, the following questions should be asked:

- ***What type of lawn is desired or expected and what level of maintenance can be provided?*** The level of maintenance required is closely related to cost and time, with high-maintenance turf costing the most and taking the most time to maintain. Homeowners should understand realistically what their options are and what each entails.

- ***What are the environmental conditions at the planting site?*** Most importantly, what are the soil type, pH, drainage, and other soil characteristics? Has it been compacted by construction activity? Does the site contain low fertility subsoils brought in for fill? Is the site irrigated? Can it be easily mowed? Is it shaded or in full sun (Figure 4.3)? Will it be shaded in a few years? What is the quality and the expected quantity of the water available for irrigation? What pests are prevalent in the area? Are pest-resistant cultivars available? Reclaimed water may contain high levels of chloride, leading to salt accumulation in the soil. When planning or renovating a landscape, check with the reclaimed water provider regarding chloride levels, and if necessary choose plants that are salt-tolerant.

Bahiagrass

Bahiagrass was introduced from Brazil in 1914. It was originally used as a pasture grass on the sandy soils of the southeastern United States. Additional varieties have been introduced since that time for use as lawn grasses. Bahiagrass is a low-maintenance lawn grass that does well with limited water and fertilizer inputs (Figure 4.4). Varieties currently available do not produce a carpet-like, dense lawn like some other warm-season lawn grasses.

Bahiagrass forms an extensive, deep root system. It sustains better than other grasses in infertile, sandy soils and does not require high inputs of water or fertilizer. This makes it a good choice for home sites on large lots or acreage or for anywhere

Figure 4.3: The sunlight pattern of a site is an important factor in selecting a turfgrass.

that there is no irrigation system. It should be noted that during extended drought periods, bahiagrass will go into a drought-induced dormancy and turn brown until conditions become favorable for regrowth.

Bahiagrass can be found throughout the state, but prefers acidic soils. It does not form excessive thatch. It may be grown from seed, which is abundant and relatively inexpensive, but may take some time to germinate and provide cover. It may also be established from sod. If left unmowed, bahiagrass can reseed itself from the seed heads that it produces, especially during the long days of summer. It has relatively few disease and insect problems.

Bahiagrass forms tall, unsightly seed heads throughout the spring, summer, and fall months that many find objectionable. This necessitates regular mowing to keep the stalks from becoming too tall. The seed stems are tough and can wear out mower blades, requiring frequent sharpening. Bahiagrass has few insect problems, but it is susceptible to mole crickets. It does not have good tolerance for shade, traffic, or saltwater. Bahiagrass grows in an open growth habit, which can result in weed encroachment into sparse areas. It has a coarse leaf texture and provides less cushioning for recreational activities than some other species. Bahiagrass does best in full sun.

Figure 4.4: Bahiagrass maintained in a parking lot island.

Bahiagrass Cultivars

Common. Common bahiagrass is a coarse-textured, light-colored bahiagrass. It has an open and sparse growth habit and is very susceptible to cold temperatures. It is not normally recommended for use as a lawn grass.

Argentine. Argentine forms a relatively dense sod and has a dark green color, making it acceptable for lawn use in many situations. It has wider leaf blades than Pensacola bahiagrass. It has good insect and disease resistance and tolerates cold temperatures well.

Pensacola. Pensacola bahiagrass was selected in Pensacola, Florida, in 1935 and is the most widely grown bahiagrass today. It has an extensive root system, which imparts excellent stress tolerance. It tolerates both hot and cold temperatures well. It produces more seed heads than Argentine, which reduces its desirability for use as a lawn grass but makes it suitable for roadside plantings. It has longer and narrower leaf blades than Argentine.

Bermudagrass

Bermudagrasses are among the most widely used warm-season grasses. Improved, fine-textured bermudagrasses are used throughout the South on golf courses, athletic fields, and in high-profile residential and commercial landscapes where a fine-textured, dense ground cover is desired. Because of the high maintenance requirements of the improved bermudagrasses, however, they are not generally recommended for use as a home lawngrass. Common bermudagrass varieties are often found as pasture and roadside grasses; these coarse-leaved varieties do not provide the high quality nor do they require the high maintenance of the fine-textured types.

Bermudagrass produces a vigorous, medium green, dense turf that is well adapted to most soils and climates found in Florida (Figure 4.5). Bermudagrass has excellent wear, drought, and salt tolerance. It establishes rapidly and is able to outcompete most weed species. It is readily available as sod or plugs, and some improved cultivars are available as seeded varieties. Improved bermudagrasses require high levels of maintenance. They have poor tolerance to many insect, disease, and nematode pests, which limits their use in home lawn sites. They grow very aggressively from stolons (aboveground stems) and rhizomes (belowground stems) and can rapidly invade flower and landscape beds. This aggressive growth also fosters thatch buildup. Bermudagrasses generally have poor

Figure 4.5: Bermudagrass produces a vigorous, dense turf. Credit: UF/IFAS Image Database.

to medium cold tolerance and relatively poor shade tolerance. Since bermudagrass performs best with higher levels of fertilizers and chemicals than other Florida lawngrasses, a professional lawn care company may best handle maintenance of this species.

Vegetatively Propagated Bermudagrass Cultivars

Tifway, TifGrand, and TifSport. These hybrid cultivars are commonly used in golf and athletic fields. These cultivars will require increased levels of maintenance (i.e., greater nutrition and plant protectant chemicals, increase mowing frequency, etc.) and may be best managed by professional lawn care companies. TifGrand requires fewer hours of direct sun and is less sensitive to the Tawny-mole cricket compared to Tifway and TifSport.

Latitude 36. Latitude 36 is a relatively new hybrid cultivar developed at Oklahoma State University. It is noted for its ability to survive colder climates compared to other bermudagrasses. It is also more resistant to spring dead spot. Latitude 36 is available in Florida and is performing well. It is not as aggressive as other bermudagrasses.

TifTuf. This is a new hybrid cultivar from the University of Georgia. This bermudagrass is very drought tolerant but will require levels of maintenance similar to Tifway, TifGrand, and TifSport. TifTuf is also proving to retain color longer into the fall, and its shade response is similar to TifGrand.

Celebration. Celebration bermudagrass is a versatile variety that is used on golf courses, athletic fields, and home lawns. It has a fine leaf texture and quality but does not require as much maintenance as some of the other fine textured bermudagrass cultivars. It has good tolerance to traffic and will tolerate slightly more shade than other bermudagrasses. Celebration can be mowed at 1–2 inches for lawn use and a rotary mower can be used. Mowing at heights > 2 inches may result in an uneven appearance.

Bimini. Bimini bermudagrass is very new to the Florida market. Its growth habit is intermediate between Celebration and the hybrid cultivars. It has been well received in the golf market, but early evidence supports its use in a variety of applications: golf, athletic fields, and home lawns. Mowing requirements will be similar to Celebration.

Bermudagrass Seeded Cultivars

Retail stores routinely sell seeded cultivars of common bermudagrass. Two seeded varieties that have performed well throughout Florida are Princess 77 and Sultan. You often find blends of two or three varieties that may include cultivars such as Arizona Common, Riviera, Cheyenne, Sahara, Sundevil, Jackpot, and others. The varieties contained in these seed packages can change from year to year based on seed availability. These improved seeded varieties have a darker green color, deeper roots, more shoot density, and a less coarse leaf texture than older selections of common bermudagrass (e.g., Arizona Common). While these varieties are suited for lawns, sports turf, parks, or roadsides, their performance and overall quality are generally lower than the vegetatively propagated cultivars. It is worth noting that the performance of these blends of bermudagrass have not been evaluated by the University of Florida.

Centipedegrass

Centipedegrass was introduced into the United States from southeastern Asia in 1916. It is well adapted to the climate and soils of central and northern Florida and is the most common home lawn grass in the Florida Panhandle. There is now one cultivar adapted to south Florida conditions.

Centipedegrass is a slow-growing grass with low fertility requirements when compared to other Florida lawn grasses. Centipedegrass grows close to the ground, is medium textured, and is naturally lighter in color than other lawn grasses. Overfertilizing with nitrogen to obtain an unnaturally dark green color reduces its cold tolerance, increases long-term maintenance problems, and is believed to contribute to centipedegrass decline, a disease complex that produces patches of dead turf in the spring.

Centipedegrass does very well in acidic (pH 4.5–6.5) and infertile soils. It has fair shade tolerance and survives drought conditions by going dormant, which results in brown turf. It can be established from seed, sod, or plugs, and it spreads by its aboveground stolons. Maintenance and fertility requirements are low compared to other turfgrasses.

Centipedegrass is highly susceptible to damage from plant-parasitic nematodes (especially ring nematodes) and the scale insect known as ground pearls. Historically, nematode damage limited the use of centipedegrass in South Florida's sandy soils. Most centipedegrass cultivars have a naturally pale yellow-green color and are prone to iron chlorosis, which yellows the blades. It has poor salt, wear, and freeze tolerance. Centipedegrass stolons have high lignin content and contribute to a heavy thatch layer, particularly when high nitrogen fertilization rates are applied. The grass is often subject to centipedegrass decline, a fungal disease. The decline is influenced by improper management practices, particularly high nitrogen fertility. Intensive management over a period of multiple years may result in root dieback in the spring. This root dieback then reduces shoot growth and results in the death of large patches of the lawn. This condition is aggravated by thatch accumulation, resulting in new stolons growing several inches above the soil surface. Management practices that can encourage root growth include irrigating properly, maintaining a mowing height of 1.5–2.5 inches, preventing thatch accumulation, and ensuring low nitrogen fertility rates.

Centipede Cultivars

Common. Common centipedegrass is a term used to describe an undeveloped and unimproved population of centipedegrass. This variety can be established by seed or vegetative means and is available from many sod producers. It grows slowly and in a prostrate manner.

Covington. Covington centipedegrass is a new proprietary selection from Sod Solutions, Inc. Covington's leaves, stems, and seedheads are uniformly emerald green in color. Covington has good fall color retention and stays green several weeks longer than other centipede varieties.

Santee. Santee is another proprietary selection from Sod Solutions, Inc. Santee also features good fall color retention and spring green-up.

TifBlair. TifBlair was released by the University of Georgia in 1997. It has good cold and freeze tolerance and can be propagated by seed or vegetative means. It has a slightly faster rate of growth than other centipedegrass cultivars. TifBlair was licensed to The Turfgrass Group, Inc. for sod production and is available only from qualified, licensed producers.

Seashore Paspalum

Seashore paspalum is native to tropical and subtropical regions worldwide and is thought to have been introduced into the U.S. through maritime travel. It grows naturally in coastal environments, often in brackish marsh water or in close proximity to ocean waters. It also grows in areas that receive extended periods of heavy rains and low light intensity. Its best growth occurs in response to warm temperatures and long day lengths.

Seashore paspalum produces a dense, dark green turfgrass with relatively low fertility inputs. It's important that homeowners realize that seashore paspalum is not a miracle grass and that it will not perform better than currently available grasses in all environments. Although it has good drought tolerance, it still requires water to remain green, just like any other turfgrass. It does have characteristics that make it tolerant to a wide range of stresses and it does have the ability to survive in harsh environmental conditions. Some of its stress tolerance advantages include excellent salt and wear tolerance and tolerance to a wide pH range and extended periods of low light intensity.

Some of its disadvantages include poor shade tolerance, requirement to mow frequently to avoid scalping, sensitivity to many herbicides, and a tendency to become thatchy.

Figure 4.6: St. Augustinegrass has better shade tolerance than other warm-season turfs. Credit: UF/IFAS Image Database.

Seashore Paspalum Cultivars

Salam. Salam is a proprietary cultivar grown by Southern Turf Nurseries. It was released in the 1990s and is suited for athletic, golf course, and landscape use. It has many qualities similar to Sea Isle 1.

Sea Isle 1. This cultivar was released by the University of Georgia in 1999. It is a fine-leaved, dense-growing selection from Argentina, intended for commercial or residential landscapes or athletic use in fairways or sports fields. It produces a dark green, dense grass with excellent salinity tolerance and good tolerance to drought and wear. Problems have been reported with diseases in Sea Isle 1, particularly *Helminthosporium*, *Fusarium*, and take-all. Fungicides can control these diseases after diagnosis. The primary insect problems of Sea Isle 1 are caterpillars, including sod webworms and fall armyworms.

Sea Lawn. Sea Lawn is a proprietary cultivar produced in Florida by Environmental Turf Solutions. There are other seashore paspalum cultivars available that are intended primarily for golf courses, athletic fields, or roadside utilization.

St. Augustinegrass

St. Augustinegrass is widely adapted to the warm, humid regions of the world. It is believed to be native to the coastal regions of both the Gulf of Mexico and the Mediterranean. St. Augustinegrass is the most commonly used lawn grass in Florida.

St. Augustinegrass produces a green to blue-green dense turf that is well adapted to most soils and climatic regions in Florida. It has relatively good salt tolerance, and certain cultivars have better shade tolerance than other warm-season grass species (Figure 4.6). St. Augustinegrass establishes quickly and easily and may be planted as sod, sprigs, or plugs.

St. Augustinegrass, like most turfgrasses, has certain cultural and pest problems. It requires water to remain green and healthy and may require supplemental irrigation during extended dry periods. It has poor wear tolerance and does not hold up to repeated foot or vehicular traffic. It goes into winter dormancy in parts of the state and turns a brown or tan color until springtime. It produces thatch under high fertilization and irrigation regimes, which may become a health problem for the grass. It has coarse, wide leaves and stems and therefore does not grow as densely as some other species. The major insect pest of St. Augustinegrass is the southern chinch bug, which can cause considerable damage if not treated. Some cultivars are also susceptible to diseases, such as gray leaf spot, large patch, and take-all root rot. Chemical weed control can be challenging, particularly when trying to control persistent, grassy weeds, for which there are few herbicide options for use on home lawns.

Standard St. Augustinegrass Cultivars

Bitterblue. Bitterblue was selected in the 1930s. Bitterblue has a relatively fine, dense texture and dark blue-green color. It has good cold and shade tolerance and is well adapted for use throughout the state. It should be mowed to a height of 3.5 to 4 inches.

Classic. Classic is a proprietary cultivar released in the early 2000s by Woerner Turf. It has good cold tolerance and is used throughout Florida and other states. Shade tolerance has not yet been verified by university research, and there is no evidence that it is superior to other cultivars. It should be mowed to a height of 3.5 to 4 inches. It has a dark green color.

DeltaShade. DeltaShade is a proprietary release from Environmental Turf in 2005. University research shows that DeltaShade has good shade tolerance, but not as good as the dwarf varieties. It appears to have good cold tolerance, although no university studies have been done to verify this. In some landscapes, it tends to have a lighter green color than some cultivars. It should be mowed to a height of 3.5 to 4 inches.

Floratam. Floratam is an improved St. Augustinegrass that was released jointly in 1973 by the University of Florida and Texas A & M University. Floratam is the most widely produced and used St. Augustinegrass in Florida. It is a coarse-textured cultivar that has poor cold and shade tolerance relative to other St. Augustinegrass cultivars. It does not persist well in environments that receive less than six hours of sunlight daily. It grows vigorously in the spring and summer. When first released, it had UF-documented chinch bug resistance, although that has largely been lost over time and chinch bugs are now a major pest of Floratam. It also is susceptible to gray leaf spot and other diseases. Floratam is not tolerant of herbicides that contain atrazine when applied at temperatures above 85°F. It should be mowed to a height of 3.5 to 4 inches.

Palmetto. Palmetto was a selection found by a Florida sod grower in 1988 and released in the mid-1990s. It is sometimes referred to as a "semidwarf cultivar" with a shorter growth habit and internodes than many other cultivars, but it is slightly larger than the dwarf St. Augustinegrass cultivars. It does well in full sun or partial shade, but not in dense shade. It is sometimes referred to as drought-tolerant, but research has not shown that it has any greater degree of drought tolerance than other St. Augustinegrass cultivars. It is not resistant to insects and sometimes has problems with disease, particularly in Florida's humid environment. It tends to have a lighter green color than many other cultivars. It should be mowed to a height of three to four inches.

Raleigh. Raleigh is a cold-hardy cultivar released by North Carolina State University in 1980. It has a medium green color and a coarse texture. It is susceptible to chinch bugs and large patch disease, but is used in northern Florida due to its tolerance to lower temperatures. It is highly susceptible to gray leaf spot. During peak summertime heat, Raleigh has been noted to yellow and grow less aggressively than it does at cooler temperatures. Supplemental iron applications can reduce this yellowing tendency. Raleigh is best adapted to the heavier clay soils with medium to low soil pH of north and northwest Florida.

Dwarf St. Augustinegrass Cultivars

Captiva. Captiva was released by the Florida Agricultural Experiment Station in 2007. It has dark green, short, narrow leaf blades and reduced vertical leaf extension, making it a slower-growing cultivar. It exhibits improved tolerance to chinch bugs compared to other commercially available cultivars. It is somewhat susceptible to diseases such as large patch and take-all root rot, particularly if it receives excess fertilizer or irrigation. Although it has not been officially evaluated for shade tolerance, the dwarf St. Augustinegrass cultivars all have better tolerance to shade than the standard cultivars. It should be mowed to a height of 2 to 2.5 inches.

Delmar. Delmar is often sold as sod or plugs. It has good shade tolerance and also does well in full sun. It has short internodes, a dark green color, and good cold tolerance. Delmar is susceptible to chinch bugs, tropical sod webworms, and large patch disease. Like the other dwarf cultivars, it has a tendency to become thatchy. It should be mowed to a height of 2 to 2.5 inches.

Sapphire. Sapphire has a blue-green leaf color, purple stolon color, and long leaf blades that remain folded, giving the grass a fine leaf appearance. It spreads rapidly and grows aggressively during the growing season. It is susceptible to most major pests associated with St. Augustinegrass. Sapphire should be mowed to a height of 2 to 2.5 inches.

Seville. Seville is a fine-leaved variety with a dark green color and a low growth habit. It is susceptible to chinch bug and webworm damage. Like the other dwarf cultivars, Seville tends to be prone to thatch. Seville performs well in both shade and full sun, but is cold sensitive. It is not as common as Delmar, but is also a good choice for shady sites. Seville should be mowed to a height of 2 to 2.5 inches.

Zoysiagrass

Zoysiagrasses were introduced into the United States from Asia and provide attractive turf throughout much of the United States. In recent years, dramatic improvements in zoysiagrass have been made by turfgrass breeders. These improvements include insect resistance, accelerated establishment, and overall performance. Zoysiagrasses are adapted to a variety of soil types and have good tolerance to shade, salt, and traffic. They provide an extremely dense sod that resists weed invasion, but certain pests can be problematic. Zoysiagrass maintenance is different from that of other Florida lawn grasses. When improper maintenance practices are followed, undesirable results are likely to occur.

There are three species of Zoysiagrass. *Zoysia japonica* was introduced into the United States in 1895 and is commonly called Japanese or Korean lawn grass. Cultivars from this species are generally coarse-textured grass with hairy, light green leaves. Of all the zoysiagrasses, this species has a faster growth rate and exhibits excellent cold tolerance. *Zoysia japonica* is the only zoysiagrass for which seed is commercially available; however, the seeded varieties generally do not produce as high-quality turf as do the sodded or plugged varieties. They can be used for lawns or general turf areas where convenience of establishment by seed is more important than quality. *Zoysia matrella*, also called Manilagrass, was introduced into the United States in 1912 from Manila. It produces a finer and denser turf than *Zoysia japonica,* but is less winter hardy and slower growing. Manilagrass resembles bermudagrass in texture, color, and quality and is recommended for a high-quality, high-maintenance turf where a slow rate of establishment is not a disadvantage. *Zoysia tenuifolia*, also called Mascarenegrass or Korean velvet grass, is the finest-textured and densest zoysiagrass available. It has good wear tolerance but poor cold tolerance and is only adapted to the central and southern areas of the state. It also produces an excessive thatch, giving it a puffy appearance. This species is often used for low-growing, ornamental specimen plants, especially in Asian-themed gardens.

Zoysiagrass Cultivars

De Anza. De Anza is a medium- to small-leaf zoysiagrass patented by the University of California in 1995. It has good shade and drought properties and retains color longer than most zoysiagrasses during the fall. De Anza ranked favorably in the National Turfgrass Evaluation Program.

Diamond. Diamond is an improved *Zoysia matrella* that is vegetatively propagated. It was released from Texas A&M University in 1996. Diamond is distinguished from other zoysiagrasses by its fine texture and excellent salt and shade tolerance. It performs best when mowed at a height of ½ inch or less. In fact, Diamond has been planted on several experimental golf greens mowed at ¼ inch or lower. Like other zoysiagrasses, it has poor cold tolerance, which may limit its use in northern parts of the state, and it is highly susceptible to tropical sod webworms.

El Toro. El Toro is an improved *Zoysia japonica* released in 1986 from California. It has a faster establishment rate, improved cool-season color, better cold tolerance, and less thatch buildup than Meyer zoysiagrass. El Toro is also reported to have early spring green-up, more shade tolerance, and improved resistance to rust disease. El Toro performed well in the NTEP trials conducted in Gainesville, Florida, and the greater Pensacola, Florida, area from 1997 to 2000.

Emerald. Emerald zoysiagrass is a selected hybrid between *Zoysia japonica* and *Zoysia tenuifolia* developed in Tifton, Georgia, and released in 1955. This hybrid combines the winter hardiness, color, and faster growth rate of one parent with the fine texture and density of the other parent. Emerald resembles Manilagrass in color, texture, and density, but is faster spreading and has a wider adaptation. Emerald zoysiagrass is highly recommended for top-quality lawns where time and money allow for adequate maintenance. Emerald produces an excessive thatch layer and is susceptible to dollar and leaf spot. Large (brown) patch disease also can occur.

Empire. Empire Zoysia® brand zoysiagrass cultivar SS-500 is gaining popularity in Florida. It is similar in texture to El Toro and has a very dense growth habit. It maintains a nice green color and, compared to other new zoysiagrass cultivars, it has a moderate rate of establishment. Empire Zoysia® has performed well in sandy and clay soil types with aggressive growth from its stolons and rhizomes, but it can be mowed with a standard rotary mower due to its broader leaf and open growth habit. It does not do as well in shade as other zoysiagrass cultivars. Empire Zoysia® is being planted in numerous communities in

Florida and seems to do well in many areas throughout the state; however, it is susceptible to large (brown) patch disease.

JaMur. JaMur is a medium coarse-textured cultivar that has performed well in many areas and is now produced in limited quantities in Florida. It has a very attractive color and does well in moderate shade. JaMur has an excellent rate of establishment, performs well at normal home lawn-mowing heights, and can easily be mown with a rotary mower. It is susceptible to large (brown) patch disease.

Meyer. Meyer (Z-52, Amazoy®) has been in use since the 1950s and is often seen in ads as the "miracle grass." It is very slow to establish, and hunting billbugs and nematodes pose serious problems with Meyer, limiting its use in Florida. Meyer zoysiagrass performed very poorly at the Florida locations of the NTEP trial conducted from 1997 -2000, and its use in Florida is discouraged.

Toccoa Green™. Toccoa Green™ brand *Zoysia matrella* cultivar BA-305 was released by the University of Florida. (BA-305 was formerly marketed under the brand **PristineFlora™**). It is recommended for use in high-maintenance situations, including high-end home lawns. This variety is fine textured, extremely dense, and has a dark green color. Toccoa Green™ does not produce seed heads as prolifically as other fine-textured cultivars, such as Emerald or Diamond. Toccoa Green™ is similar in appearance and maintenance to Diamond; however, it has a much faster rate of growth and recovers more quickly from scalp damage.

BA-189. BA-189 is a *Zoysia japonica* cultivar developed by the University of Florida ('BA-189' was formerly marketed under the brand **UltimateFlora™**). It has a similar leaf texture and upright growth habit to Meyer, but it has a faster rate of spread and better adaptability for use in Florida. This cultivar is used for home lawns and was selected for the lawn at the Birmingham Home & Garden Inspiration Home in Vestavia Hills, Alabama, and at the 2006 New Southern Home in St. Cloud, Florida.

Zeon. Zeon is a fine-textured *Zoysia matrella* that has performed well in Florida, though its availability is limited in the state.

Zenith. Zenith zoysiagrass is one of the few commercially available seeded varieties. Generally, the seeded cultivars do not perform as well as the vegetative cultivars. Zenith zoysiagrass is dark green and medium textured.

Zorro. Zorro is a fine-textured *Zoysia matrella* released by Texas A&M University. Zorro establishes well, has good shade tolerance, and is easier to mow than some fine-textured cultivars. This turf performed moderately well in Florida in the 1997 to 2000 NTEP trial.

Preparing to Plant a Lawn

Proper soil preparation before grass planting is critical to ensure the establishment of quality turf. Preparation determines how quickly the lawn becomes established and its long-term maintenance requirements. The general guidelines for preparing to plant a lawn are as follows:

- Call 811 before you dig (or 800-432-4770 or **www.callsunshine.com**) before installing any and/or all plant material.
- Clean and rough grade—remove debris and level the area to make it suitable for mowing.
- Install irrigation—if you are including an irrigation system, install it prior to planting.
- Soil analysis—determine soil pH and phosphorus and potassium concentrations. Contact your county's UF/IFAS Extension office for information on how to do this.
- Soil amendments—add these prior to planting if you need to improve the soil's physical and chemical properties.
- Deep tillage—this loosens compacted soil and improves the establishment of turf. Tilling sand is unnecessary.
- Weed control—use a nonselective herbicide such as glyphosate to aid in weed control before planting. Several applications may be necessary.
- Final grading—a final leveling makes mowing easier and safer.

For more information, see *Preparing To Plant a Florida Lawn*, IFAS Publication ENH-02, at **http://edis.ifas.ufl.edu/LH012**.

Environmental Stresses on Lawns

Florida lawn grasses are subjected to many environmental stresses as a result of prolonged exposure to shade, drought, nutrient deficiency, the effects of vehicle and foot traffic, salinity, and occasional cold temperatures. Biotic stresses result from living organisms such as insects, diseases, or nematodes.

Environmental stresses can be managed in two ways: 1) choosing the most stress-tolerant species or cultivar for a particular area, and 2) using proper cultural and management practices to alleviate the effects of the stress. Practices that reduce environmental stresses include the following:

- **Moderating nitrogen fertility.** Nitrogen encourages the plant to form new tissue and grow. When nitrogen is applied in excess, more energy reserves are used to form new tissue than can be replaced by photosynthesis, and the grass becomes more vulnerable to stresses. Less reserves are then available for recovery from, or avoidance of other problems.
- **Mowing at proper heights.** Mowing below recommended heights removes a large portion of the shoot tissue available for photosynthesis. This leaves the grass less able to support itself or recover from injury.
- **Irrigating when the grass needs water.** Over irrigating leads to the failure of many lawns by increasing fungal problems and limiting the root system to the top few inches of soil.

Many environmental stresses lead to increased disease or insect problems, which are often treated chemically without changing the cultural practices that initially caused the problem. Chemical treatment in these cases will not take care of the problem until the cultural factors are handled correctly.

Shade Considerations for Turf

Most landscapes include shaded areas, with shade coming from either trees or buildings. This shade can drastically affect turfgrass growth, depending on the degree and duration of shade. In many landscape settings, grass receives a minimum amount of light for enough of the day to maintain adequate growth, even if an area is shaded for other portions of the day. In some situations, however, a grassed area may be shaded for most or all of the day, making it difficult for the grass to obtain either an adequate intensity or duration of light for growth.

Under shaded conditions, turfgrasses have elongated leaf blades and stems as they attempt to obtain sunlight by outgrowing their neighbors. This reduces their overall health and vigor. Coverage is also reduced, and the bare ground that results is conducive to weed growth. It is generally not advisable to grow turfgrass in heavy shade. Other ground covers or mulch should be used in these sites. For areas receiving moderate amounts of shade, however, certain species and cultivars are able to maintain suitable growth. Specific management practices also encourage better turfgrass health under shaded conditions.

Some species are particularly well suited for use in shaded areas. Within these species, certain cultivars sometimes maintain considerable advantages when grown in a shaded environment. These species and cultivars include the following:

- **St. Augustinegrass** is somewhat better than others for growth in partial shade, although it also performs well in full sunlight. Cultivars that exhibit the most shade tolerance include 'Seville' and 'Delmar.' 'Floratam,' 'Floratine,' and 'Floralawn' exhibit somewhat less shade tolerance.
- **Zoysiagrass** is another good choice for partially shaded areas. Like St. Augustinegrass, it also does well in full sunlight. Generally, any cultivar of zoysiagrass performs well in partial shade.
- **Bahiagrass** is not recommended for use in shaded conditions, but centipedegrass tolerates some partial shade.
- **Seashore paspalum** and **bermudagrass** do not do well in shaded situations.

The following management practices produce better turfgrass growth in shaded situations:

- **Increase the mowing height** for grasses growing in the shade. For instance, if you normally cut St. Augustinegrass at a three inch height, increase the cutting height to four inches. This allows for more leaf area to intercept as much available light as possible. In addition, leaf blades are longer and narrower in the shade, and a lower cutting height excessively reduces leaf length, which is not good for the grass. Increased mowing height also promotes deeper rooting, which is one of the key mechanisms of stress tolerance for turfgrasses.

- **Reduce fertilizer applications to turf growing in shade.** The grass grows more slowly in a shaded environment, which reduces fertility needs. Too much nitrogen fertilizer depletes carbohydrates and produces a weaker turf system. If you normally apply 4 pounds of nitrogen per 1,000 square feet yearly, apply 2.5 to 3 pounds to turf growing in the shade. Limit any single fertility application to no more than 0.5 pounds of nitrogen per 1,000 square feet at any one time.

- **Water use is substantially reduced under shaded conditions, so adjust irrigation accordingly.** If the irrigation system covers an area that is partially shaded and partially in sun, consider removing the sprinkler heads from the shaded areas and irrigate by hand when rainfall is inadequate.

- **Avoid the effects of vehicle and foot traffic.** The grass is more easily injured by traffic if growing in shade, and may not be able to recover adequately. Also, traffic in shady areas may damage a tree's roots, resulting in the decline or death of the tree.

- **Monitor for weed pressure.** Weeds are able to outcompete turf in certain situations, and will seek out those opportunities. In a shaded environment, lateral turfgrass growth and ground cover may be sparse, leaving bare ground suitable for certain weeds. Treatment with a pre- or postemergence herbicide may be necessary. Use caution, however, when applying any chemical treatment to a shaded lawn, as there is a greater chance of phytotoxicity (toxicity to plants) when a grass is under stress. Also, many herbicides can damage landscape trees and shrubs.

- **Monitor for disease pressure.** In many shaded environments, there is less air movement and more humidity, which may increase the possibility of disease. Again, use caution if applying pesticides to a turf that is already under environmental stress.

In particularly troublesome areas, consider other ground covers besides turf. Examples include ivies (*Hedera* spp.), liriope (*Liriope* spp.), mondo grass (*Ophiopogon* spp.), and Asiatic jasmine (*Trachelospermum asiaticum*). **Remember, the key to a successful landscape is *"Right Plant, Right Place."***

Test Your Knowledge

Q: What should be the first step in selecting plants for a landscape?
A. Making a trip to the nursery
B. Conducting a site evaluation
C. Installing an irrigation system
D. Adding the correct amounts of fertilizer and lime

A: B

Q: What are the nine principles of Florida-friendly landscaping as defined by Florida law? (Select all that apply)
A. Applying the highest rates of pesticides allowed by the label
B. Planting the right plant in the right place
C. Efficient watering
D. Appropriate fertilization
E. Using seashore paspalum as the turfgrass in the landscape
F. Mulching
G. Attracting wildlife
H. Responsible management of yard pests
I. Baiting with highly toxic pesticides to eradicate nuisance wildlife
J. Recycling yard waste
K. Reduction of stormwater runoff
L. Waterfront protection

A: B, C, D, F, G, H, J, K, L

Q: True or False:
When installing a landscape plant, the root ball should be positioned in the hole shallowly enough so that the finished grade of the soil is lower than the top of the root ball.

A: True

Q: Which turfgrass would be best adapted to acidic soil conditions? (Select all that apply)
A. Bermudagrass
B. Zoysiagrass
C. Bahiagrass
D. Centipedegrass

A: C, D

Q: Which turfgrass has the greatest salt tolerance?
A. Zoysiagrass
B. Seashore paspalum
C. Centipedegrass
D. Bahiagrass

A: B

Q: Which turfgrass has the greatest drought tolerance?
A. Zoysiagrass
B. Seashore paspalum
C. Centipedegrass
D. Bahiagrass

A: D

Q: Which turfgrass would be expected to have the greatest maintenance level?
A. Zoysiagrass
B. Seashore paspalum
C. Centipedegrass
D. Bahiagrass

A: B

Q: What is the most commonly used lawn grass in Florida?
A. Bermudagrass
B. Zoysiagrass
C. St. Augustinegrass
D. Centipedegrass

A: C

Q: Match the following turfgrasses with its cultivars.

1. Centipedegrass	A. Emerald, Empire, Meyer
2. Bermudagrass	B. Common, Argentine, Pensacola
3. Bahiagrass	C. Floratam, Captiva, Raleigh
4. Zoysiagrass	D. Salam, Sea Isle 1, Sea Lawn
5. Seashore paspalum	E. Common, Cheyenne, FloraTex
6. St. Augustinegrass	F. Common, Hammock, TifBlair

A: 1-F, 2-E, 3-B, 4-A, 5-D, 6-C

Q: Which practices reduce environmental stresses to Florida lawn grasses? (Select all that apply)
A. Moderating nitrogen fertility
B. Irrigate each morning and evening
C. Mow at the proper heights
D. Apply herbicides

A: A, C

Q: Which of the following practices would produce better turfgrass growth in shaded situations?
A. Lower the mowing height
B. Increase fertilizer rates
C. Increase frequency of irrigation
D. None of the above

A: D

Chapter 5

Irrigation Best Management Practices

In this Chapter

Learning Objectives

After you complete your study of this chapter, you should be able to:

- Know the agencies involved that have jurisdiction over an irrigation project before, during, and after construction.
- Name the device that Florida Law requires installed on all automatically controlled irrigation systems.
- Describe the considerations to take into account when using reclaimed water for irrigation of landscape plants.
- Describe the factors that are involved in determining the design of an irrigation system for a landscaped site.
- Name and describe the three main components of any landscape irrigation system.
- Define evapotranspiration (ET).
- Described the amount of water required for plant growth under ideal conditions.
- Know the plant growth stages and time of year when more or less water is required for optimum growth.
- Name several common visual indicators that can be used as guidelines to determine the need for irrigation.
- Name several common methods to determine irrigation quantities.
- Be able to recognize common irrigation efficiency problems.
- Describe a method to determine an irrigation system's distribution uniformity.

Terms to Know

BMPs: Best management practices. Procedures to reduce nonpoint source pollution and promote the efficient use of water.

Chemigation: Usually a specially configured irrigation system to apply pesticide to a target site.

Effective rainfall: Rainfall stored in a plant's root zone for plant use.

Evapotranspiration (ET): Water loss from plants and soil.

Field capacity: The amount of soil moisture or water content held in the soil after excess water has drained away and the rate of downward movement has decreased.

FYN: Florida Yards and Neighborhoods. A statewide public education and outreach program for homeowners offered through most UF/IFAS Extension offices.

Hydrozone: An area of an irrigation system where all the factors that influence the watering schedule are similar.

Irrigation: The application of supplemental water to the soil for plant growth.

Introduction

Green Industry workers need to be aware of the different irrigation processes and system components because irrigation is a major factor in the success of their industry. By understanding the irrigation system, they can save the company and the client money and help protect ground water supplies and water quality.

This section of the document includes background information and irrigation BMPs for the Green Industry. Some of the BMPs mentioned are not usually considered the responsibility of mowing and trimming services or route-based service businesses. However, many Green Industry workers, who may be directly employed by property owners, associations or municipalities, are often responsible for operation and maintenance of an irrigation system. For complete BMPs specific to irrigation, please refer to:

- Florida Irrigation Society (**www.fisstate.org**)
- Irrigation Association (**www.irrigation.org**)
- The University of Florida's Institute of Food and Agricultural Sciences (UF/IFAS) (**http://edis.ifas.ufl.edu/**)

Irrigation is an age-old art and is defined as the application of supplemental water to a soil for plant growth (Figure 5.1). It also provides a mechanism for nutrients to move from the soil into a plant. Other uses include salt leaching, chemigation, system flushing, seed germination, and climate modification.

Figure 5.1: Irrigation is an age-old art. Credit: UF/IFAS Image Database.

On average, Florida receives more than 50 inches of rain per year. However, the distribution and amounts of this rainfall are not always adequate to meet a plant's water demands. Providing the amount of water that a plant needs at the correct time is the key to resource conservation, reduced pollutant loading, and optimum plant growth.

This chapter describes irrigation concepts to help explain the fundamentals of good irrigation. In addition, this chapter identifies specific irrigation BMPs for the Green Industry. Throughout the chapter, the term "plant" refers to both turf and landscape plants, including trees.

Permitting and Regulations

Many agencies have jurisdiction over an irrigation project before, during, and after construction. For example, Florida's five water management districts, Florida Department of Health, Florida Department of Environmental Protection, or local governments may require well permits. Typically, for large projects the water management districts issue water use permits, which are usually calculated for drought conditions rather than for normal irrigation. To prevent potential fines, it is important to identify and abide by all regulatory requirements.

Besides water use permits, some water management districts have special year-round water conservation measures and drought/water shortage restrictions that govern the amount and timing of irrigation. It is important to know the restrictions for a site and to set timers/controllers to those conditions. Since water shortage restrictions change with the severity of a drought, it is important to be aware of and to abide by current restrictions. If a site's irrigation system cannot be adjusted to meet the restrictions, the system should be upgraded as soon as possible, but in the interim, there are methods to obtain variances. These variances need to be obtained in writing, before irrigating.

Florida law requires an operating moisture cutoff device on all automatically controlled irrigation systems. In 2009 this was revised and mandates owners and contractors to maintain these systems. Any person who purchases and installs an automatic landscape irrigation system must properly install, maintain, and operate technology that inhibits or interrupts operation of the system during periods of sufficient moisture. A licensed contractor who installs or performs work on an automatic landscape irrigation system must test for the correct operation of each inhibiting or interrupting device or switch on that system. If the devices or switches are not installed in the system or are not in proper operating condition, the contractor must install new ones or repair the existing ones and confirm that each device or switch is in proper operating condition before completing other work on the system.

The following permitting and regulatory guidelines should be followed for all irrigation projects:

- Contact local and state regulatory agencies (such as the county, city, Florida Department of Environmental Protection, water management districts, and health department) to determine current irrigation regulations and criteria.
- Obtain all permits before construction.
- Abide by all permit conditions and current water restrictions when operating the irrigation system.
- Obtain any desired regulatory variances before irrigating.

Reclaimed Water Use

Many urban areas use reclaimed wastewater for their irrigation water source. While this offers many benefits, it also can lead to landscaping and pollution problems if not properly managed. Nutrient levels in reclaimed water may vary by a factor of 10 or more, depending on the treatment plant supplying the water. Contact the supplier to get information on nutrient content. When applying fertilizers to a site that irrigates with reclaimed water, consider the amount of nutrients in the water, and reduce fertilization appropriately. Reclaimed water may contain high levels of chloride, leading to salt accumulation in the soil. Additional considerations, such as water for flushing salts, may be needed.

Nutrient pollution may occur if the user over-irrigates, because both reclaimed water that runs off on the surface, and the water and nutrients that move below the root zone, are lost. Maintenance of a high level of distribution uniformity is critical to prevent leaching of these nutrients. Irrigation managers should also pay close attention to all cross-connection controls and backflow prevention devices. All reclaimed water piping, heads, valves, fixtures, etc. are required by law to be color-coded purple, and labeled "Do not drink this water" (Figure 5.2). As long as field capacity is not exceeded when irrigating, reclaimed water is a safe and reliable irrigation source.

Figure 5.2: Site using reclaimed water for irrigation. Credit: UF/IFAS Image Database.

Irrigation System Design

Irrigation system design is a complex issue and should be performed by trained professionals (Figure 5.3). These professionals should use existing standards and criteria, as well as the manufacturer's recommendations, to design the most appropriate system for a location. In addition to the FDEP publication, Landscape Irrigation and *Florida-Friendly Design Standards*, a list of sources for current standards and criteria can be found at the end of this chapter. Many communities require construction and design documents and permits that require the signature and seal of a registered design professional. Members of the Green Industry should be able to visually identify system design problems to help their clients irrigate more efficiently, save water, reduce the need to add fertilizers or other chemical treatments, and improve plant health and water quality.

Figure 5.3: Irrigation system design is complex. Credit: UF/IFAS Image Database.

The irrigation design for a site depends on a number of factors, including location, soils, landscape vegetation, water supply, and water quality. An irrigation system needs to be designed to meet a site's peak water requirements. In addition, to prevent irrigation runoff, a system's application rate must not exceed the ability of the soil to absorb and retain the water applied during any one application. The irrigation system should also have enough flexibility to adapt to various water demands and local restrictions.

Design operating pressure must not exceed the source pressure. The design operating pressure should account for low pressure during periods of high use (i.e., mornings) and for project buildout when all of a development's landscaping is in place. Plants should be grouped in irrigation zones based on similar water use requirements. Irrigation systems designed to service both turf and landscape areas should have enough zones to meet each area's individual water needs. In some regions, the irrigation design should account for the extra water required to periodically leach salt buildups that may accumulate due to high chloride levels in some sources of irrigation water.

An irrigation system consists of three main components: water supply (water source, pump, filters, and valves), water conveyance (mainline, manifold, lateral, and spaghetti tubes) and a distribution device (such as an impact sprinkler, oscillating sprinkler, rotary sprinkler, spray, or drip emitter). The proper design and installation of these components optimizes their use and decreases any off-site impacts. Irrigation design must also account for different site characteristics, such as soils and topography.

Hand-moved irrigation systems should have enough flexibility to provide sufficient coverage (see the manufacturer's recommendations) after each move. Microirrigation systems for shrubs and other landscape plants should be designed to cover at least 50 percent of the root systems. Microirrigation is rarely used for turf in Florida, and is prohibited in some places, but if used should be designed to cover 100 percent of the grass's root system.

To provide for peak water demands and have enough flexibility to reduce supply for different demand requirements, irrigation systems need to be designed with various control devices, rain shut-off devices, and backflow prevention. Water conveyance systems should be designed with devices to protect against blowouts. The water conveyance pipelines should provide the system with the appropriate pressure required for maximum irrigation efficiency, uniformity, and the distribution devices should be designed for optimum uniform coverage.

In addition, the distribution system should not include the irrigation of non-planted areas (such as driveways, parking lots, roads, sidewalks, underneath roof overhangs, and natural buffer zones).

To ensure optimum uniformity, permanent irrigation sprinklers, spray jets, and other distribution devices should be spaced according to the manufacturers' recommendations. Typically, this spacing is based on average wind conditions and operating pressures during irrigation. If site-specific wind conditions are different than published averages, check with the local UF/IFAS Extension office, USDA NRCS, or the Florida Irrigation Society for their recommendations. Table 5.1 is provided as a general guideline. Spacing should not exceed the percentages provided in the table. After the system is constructed and operating, periodic "catch can" uniformity tests should be performed (see the section on Irrigation Maintenance later in this chapter) to ensure that the system is continuing to function as designed.

Table 5.1. Irrigation spacing.

Wind (miles per hour)	Square coverage	Triangular coverage
	Percentage of diameter of coverage	
0-5#	55%	60%
5-10	50%	55%
10+	45%	50%

#For many locations, the 0-5 mph wind condition occurs very infrequently and this spacing recommendation should only be used after careful consideration and site investigation.

Microirrigation for Landscape Plants

When designed and operated correctly, microirrigation, also known as drip or low-volume irrigation, is one of the most efficient methods of irrigation (Figure 5.4). It is highly manageable and provides small quantities of water directly to the plant's root zone. Low-pressure sprinklers, sprayers or drippers are also known as emitters, and they slowly release water into the soil around a plant. This saves water because only the main feeder roots receive water, and less water evaporates from the surface of the soil.

Typically, with drip irrigation in a sandy soil, water moves laterally only 10 to 12 inches. Drip irrigation is ideal when such precision is desirable or for narrow strip plantings, such as hedgerows. Because of the nature and location of drip

Figure 5.4: Microirrigation is very efficient. Credit: UF/IFAS Image Database.

irrigation it is difficult to determine if the emitters are providing enough water. Visual inspection of the landscape may identify clogging (dry spots, dead plants, and wilted plants) or excessive watering (soggy soil, weeds, excessive plant growth) problems from a drip irrigation system.

Figure 5.5: Spray-jets cover larger areas and fewer clogging problems. Credit: UF/IFAS Image Database.

Overall, spray-jets (either microsprayers or microsprinklers) are more desirable than drip emitters for most landscape applications. This is because they cover larger areas and have fewer clogging problems (Figure 5.5). Clogging and excess water problems can be seen either by careful examination of the irrigation system or by looking at the landscape. Spray jets should not be designed or operated to irrigate non-planted areas.

Regardless of the type of microirrigation system, clogging can be a problem if the water supply is not filtered before entering the irrigation system or if the filtration system is not cleaned. The safest and easiest way to maintain the emitters in a microirrigation system is to keep a small supply of clean backups on hand. Clogged devices can be easily replaced with clean units, then placed in a small container of the cleaning fluid appropriate for the clogging material. Replacement emitters should always have the same operating characteristics--that is, operating pressure and discharge rate--as the original emitters.

For more information, see the following: *Turf and Landscape Irrigation Best Management Practices*, April 2005. The Irrigation Association, at **http://www.irrigation.org**.

Irrigation System Installation

Only professionals who are trained, certified, appropriately licensed for irrigation installation by the appropriate agency, bonded, and insured should handle irrigation installation (Figure 5.6). These individuals must follow the designer's plans and use recognized standards and criteria such as those promulgated by the American Society of Agricultural and Biological Engineers (ASABE), Florida Irrigation Society (FIS), Irrigation Association (IA), U.S. Department of Agriculture Natural Resources Conservation Service (NRCS), or the manufacturer's recommendations. The designer must approve any changes to the design.

Figure 5.6: Irrigation systems should be installed by a trained professional. Credit: UF/IFAS Image Database.

To prevent system failures, waste, and property damage, construction materials must meet appropriate standards, such as those from ASABE, the American Society of Civil Engineers (ASCE), or the American Society of Testing Materials (ASTM). Plan all construction practices according to standard safety practices. Before construction, the contractor should identify and flag all underground pipes, cables, and other elements. **Call before you dig.** Call 811 (or 800-432-4770 or **www.callsunshine.com**) for free Sunshine State One Call locator service. The contractor should clean the site of any construction materials before the job is complete and at the end of construction, provide the owner with a copy of the as-built plans, operating manuals, recommended operating schedules for both plant establishment and supplemental irrigation of mature plants, and warranties. For new construction, the job should include a follow-up site visit to reset the controller, a rain shut off device, and a soil moisture sensor (if installed) after the landscape is established.

Irrigation Management

Irrigation management (knowing when and how much to irrigate) is the cornerstone of water conservation and reducing nonpoint source pollution. It encompasses the amount of water applied and the frequency of application. To prevent excess water use that could lead to chemical leaching, runoff, and plant disease, irrigation scheduling should take into account plant water requirements, recent rainfall, recent temperature extremes, and soil characteristics. In addition, the irrigation system must be properly designed and maintained, so that all of the plants in a given zone receive the same amount of water. See the Irrigation Maintenance section of this chapter for information about measuring distribution uniformity.

Under ideal conditions, the water required for a plant is equal to the water used during plant growth. This water goes to soil evaporation and plant transpiration. Typically, both processes are combined and called evapotranspiration (ET).

A plant's water requirements vary with its growth cycle and climatic conditions. The limiting ET factors are the amount of soil moisture to be transpired by the plant, solar energy reaching the plant (affected by latitude, season, cloud cover, and shade), the temperature and relative humidity of the air, and wind speed. If a soil is at field capacity, 100 pecent canopy coverage is present to absorb radiation, and other factors are equal, the amount of water transpired varies little between plant types. Plant irrigation requirements will differ based on a plant's ability to extract soil moisture (i.e., root zone depth) and its physiological ability to deal with reduced availability of moisture.

Plants require more water during seed, flower, and fruit production, but will not require very much when they are dormant. During the colder months, or those with shorter periods of daylight, most turfgrasses and landscape plants are not actively growing, thus they use less soil moisture and may not require irrigation.

Many established, drought-tolerant landscape trees and shrubs require little or no irrigation, provided the soils do not obstruct root development. Plants such as azaleas, copperleaf, impatiens, or other bedding plants that lack drought tolerance may require irrigation during extended drought periods.

In humid regions such as Florida, irrigation is considered supplemental because it supplements natural rainfall. Proper irrigation management must account for rainfall. Since rainfall varies from location to location, the proper use of rain gauges, rain shut-off devices, flow meters, soil moisture sensors, and/or other irrigation management devices should be incorporated into the site's irrigation schedule (Figure 5.7).

Using an irrigation schedule can help prevent wasteful over-irrigation, the leaching of fertilizers/pesticides, and promote root development for drought conditions (Figure 5.8). No more than 1/2 to 3/4 inch of water should be applied for a single irrigation event. The exact amount of irrigation needed for each event will depend on a plant's needs for growth, fruiting, dormancy for that time of year, and soil characteristics (soil moisture, infiltration rates, soil root zone depth, and water-holding capacities). In addition, water management districts and local requirements should be considered before irrigating. A properly working, installed and calibrated rain shutoff device prevents the irrigation system from turning on if adequate

Figure 5.7: Irrigation management devices should be incorporated into irrigation scheduling. Credit: UF/IFAS Image Database.

Figure 5.8: The control box for irrigation scheduling and amount of water to apply.

Figures 5.9 and 5.10: Shut-off devices and rain gauges should be placed in open areas.

rainfall has occurred. Rain shutoff devices are required by law on all automatic irrigation systems.

Irrigation management and control devices need to be installed correctly for proper irrigation management. Rain shut-off devices and rain gauges should be placed in open areas to prevent erroneous readings (Figures 5.9 – 5.10). Flow meters should have a straight enough run of pipe both downstream and upstream to prevent turbulence and bad readings. Soil moisture sensors and other irrigation management tools should be installed in representative locations and be maintained to help make good irrigation management decisions. When mechanical/electronic devices are not available for irrigation management, the following visual indicators should be used as guidelines to determine the need for irrigation:

- The grass has a dull, bluish-gray coloring
- Foot tracks remain in the grass
- Leaf blades are folded in half on at least one-third of the site
- Soil samples from the root zone are dry and crumbly
- Indicator landscape plants, such as impatiens and azaleas, have drooping leaves

There are several ways to prevent excess irrigation. Visual observations of runoff or puddles are simple indications (Figure 5.11). A system's timer/clock/controller can be adjusted to meet a plant's seasonal water requirements. Flow meters can be used to determine how much water is applied and when to turn off the irrigation system. Rain gauges, cans, or other containers can be used to measure how much water has been applied.

Rain shutoff devices, already required by law on all automatic systems installed since 1991, can save up to 30 pecent or more over a timer-only system. However, many systems that should have sensors do not, either because they were not installed as required or because they have failed or been removed. Those who are responsible for overseeing an irrigation system should check the operation of the rain shutoff device at least once per year, and replace the unit if it is not operating correctly. Other workers who may notice a system irrigating shortly after a good rain event should attempt to notify their client of a possible problem with the rain shut off device so they can have it repaired.

One of the most effective and efficient methods of irrigation control is the use of properly installed and maintained soil moisture sensors with a specialized controller. There are two basic types of systems: direct control, where soil moisture sensors actually call for irrigation; and bypass control, where regularly scheduled irrigations are bypassed if sufficient

Figure 5.11: Visual puddling is a simple indication to prevent excess irrigation.

moisture is present. Direct control systems are more expensive and require considerable management expertise, such as may be present at a golf course. Bypass systems are much less expensive and easier to install. Most bypass systems work with the existing controller.

Although soil moisture levels are the preferred method to determine irrigation quantities, in the absence of soil data, calculated ET methods may be used. Current weekly calculated ET rates are available at **http://fawn.ifas.ufl.edu** for more than 40 locations throughout Florida. This site also includes a landscape irrigation scheduling tool and rainfall data. Rainfall can make up some or all of the ET, especially during the cooler months. Total rainfall is not the same as effective rainfall. Florida soils generally have low water holding capacity, so a two-inch rain may have little more effect on reducing landscape irrigation than a typical irrigation event in any given month.

An alternative irrigation scheduling method often used by homeowners and on some commercial landscapes is to assume that on average one inch of water wets the top 12 inches of a sandy soil. Typically most roots grow in the top 6-12 inches of soil, and 1/2 to 3/4 inch is needed for replenishment of moisture every 2 to three days during warm periods of active growth, and every 10 to 14 days during less active growth periods. This water can come from rainfall or be provided by the irrigation system. Again, soil characteristics, including infiltration rates and water holding capacities, water management districts and local requirements should be considered before irrigating.

Although irrigation management is a complex process, it can be boiled down to a simple "checkbook", or water balance, process, where the irrigation amount consists of the difference between a plant's need for water and the effective rainfall (rainfall stored in a plant's root zone for plant use). When possible, the timing of an irrigation event should be planned to increase irrigation efficiency, by reducing evaporative losses due to climatic conditions (for example, high temperature, low humidity, windy conditions) and by maintaining high irrigation uniformity.

Several irrigation management techniques help to improve a plant's health and reduce water use. Delayed irrigation and deficit irrigation promote root development and provide a level of drought tolerance. Delayed irrigation promotes deeper root development by postponing irrigation until wilt is observed. Deficit irrigation calls for managing irrigation quantities so that there is always soil storage to take advantage of any possible rainfall.

When leaching salts, which is necessary in some soils due to poor water quality, always wait until the nutrient level in the soil is depleted to avoid leaching of fertilizer nutrients with the salt.

Irrigation System Maintenance

Proper maintenance extends the life of an irrigation system and helps it to perform optimally. Maintenance begins with a visual observation of the system and the plants. Check for proper functioning of rain sensors and controllers, leaks, broken/cracked lines, proper rotation, and damaged sprinkler heads. Also, check for obstacles that may interfere with irrigation uniformity. Brown spots, unnaturally green grass, certain types of weeds, and soggy spots are indicators of problems. Many types of businesses do not have control over the irrigation system, nor the expertise or contractual duty to address irrigation issues, but every effort should be made to inform the client when problems are noted and to explain the importance of proper operation and prompt repairs.

Damaged or defective systems should be repaired as soon as possible. Replacement parts should always have the same characteristics (that is, discharge-pressure relationship, jet size/colors) as the original components. Otherwise, the replacement might cause more harm than the bad component. Florida law requires licensed irrigation contractors to repair defective sensors, and there may be fines and penalties for failing to report a client that refuses repairs.

Evaluating a system's uniformity and efficiency---an irrigation audit--reduces water use and fertilizer/pesticide leaching. There are many procedures (such as NRCS, IFAS, ASABE, IA, and FIS) for irrigation system evaluation, all of which can be traced to a process published by Miriam and Keller. By following any of these methods, you can ensure that a system is operating at optimum levels.

Common irrigation efficiency problems include leaks, sprinkler head plugging, poor irrigation uniformity caused by nozzle wear, and poor system pressure. Some problems, such as repairing leaks and replacing nozzles, can be repaired at a minimal cost, while others, such as poor system design, might

Figure 5.12: Some irrigation repairs are simple adjustments. Credit: UF/IFAS Image Database.

at first glance be very costly, but will pay off in the end (Figure 5.12). Problems need to be corrected as soon as possible to prevent wasted water and the leaching of fertilizers and other chemicals. In the long term, the investment made to improve the irrigation system pays off in reduced fertilizer, chemical, and water bills.

Distribution uniformity is a measurement of how evenly water is distributed over a given area, and should be considered when managing irrigation. This measurement is an indication of the system's hydraulic performance and can be used to identify deep percolation. Distribution uniformity can be determined by a "catch can" test. Baby-food jars, tuna cans, or other straight-sided containers are evenly placed around sprinklers. The system is turned on one zone at a time for a fixed amount of time, and the water collected in each container is measured with a ruler and recorded. The distribution uniformity is calculated by adding the depths of water collected in each container and dividing by the total number of containers. For example, if you collect an average of ¼ inch in 15 minutes, and your target application rate is ½ inch, you will need to run the irrigation system for 30 minutes.

Higher uniformities occur when spacing is adequate and sprinkler nozzles are matched. Poor application uniformity leads to localized over-irrigation or under-irrigation, brown spots in the grass, fertilizer or pesticide leaching or runoff, and the waste of irrigation water. Many of these problems can be solved and the site's owner can reduce water costs. Distribution uniformity is not a measurement of irrigation efficiency. For more information, see UF/IFAS Publication AE 144, *Turf Irrigation for the Home*, at **http://edis.ifas.ufl.edu/AE144**.

For microirrigation systems, emission uniformity is used instead of distribution uniformity. Emission uniformity is calculated by comparing the volume of water from the emitters to the statistical differences in the total volume. An emission uniformity of 90 pecent or higher is considered excellent. For more information, see UF/IFAS Publication AE094, *Field Evaluation of Microirrigation Water Application Uniformity*, at **http://edis.ifas.ufl.edu/AE094**.

Water application efficiency is a component of irrigation system efficiency and indicates how well a system is providing water to the plant's root system (Figure 5.13). Irrigation application efficiency is another form of irrigation system efficiency and it compares the amount of water delivered to an area by the amount of water beneficially used.

To help with irrigation efficiency, water management districts or other local agencies may provide mobile irrigation lab (MIL) services. MIL staff will evaluate an irrigation system and make recommendations to improve system efficiency and help with irrigation scheduling.

Figure 5.13: Watering the pavement is not an efficient use of water.

Contact your local water management district for more information about these services in your area. Irrigation requirements represent the amount of water an irrigation system needs to apply to meet a plant's water needs. This quantity is a function of the plant's water requirements, soil moisture, and the system's efficiency.

Summary

To summarize, the principal BMPs for all of the Green Industry include the following recommendations regarding irrigation:

- Call before you dig. Call 811 for free Sunshine State One Call locator service.
- When possible, the application of fertilizers, herbicides, or other chemicals that need to be watered, should coincide with an irrigation event.
- Proper cultural practices, such as mowing, to promote healthy, deep root development and reduce irrigation requirements.
- Account for the nutrients in reclaimed water when making fertilizer calculations. Knowing the nitrate levels in reclaimed water can reduce your fertilizer purchases. The application of one inch of reclaimed water containing 20 ppm nitrate-Nitrogen adds about 4.5 pounds of nitrogen per acre (lb N/acre) to the soil. If you irrigate 40 inches per year, that works out to a little over 4 lb per 1,000 ft^2.
- Repair any irrigation devices broken while servicing a site. Replacement parts should have the same characteristics as the original components.
- Visually observe site problems associated with irrigation (wet, dry spots, excessive weeds) or system components (leaks, broken equipment) and report problems to the client.
- When leaching salts, which is necessary in some soils due to poor water quality, always wait until the nutrient level in the soil is depleted to avoid leaching of fertilizer nutrients with the salt.

Additional BMPs for those with ownership/management responsibility:

- Group plants by similar water requirements; that is, by hydrozones.
- Irrigation controllers/timers should be reset seasonally to account for plant growth requirements and local climatic conditions.
- Properly calibrated flow meters, soil moisture sensors, rain shut-off devices, and/or other automated methods should be used to manage irrigation.
- Irrigation rates should not exceed the maximum ability of the soil to absorb and hold the water applied in any one application.
- Implement a preventive maintenance program to replace worn components before they cause water, fertilizer and chemical waste.
- Perform weekly (or at each site visit) visual inspections to identify leaks, broken rain sensors or sprinkler heads, and other system malfunctions.
- Replace or repair all broken or worn components before the next scheduled irrigation.
- Distribution uniformity should be checked annually.

Sources for Irrigation Standards

The following publications contain current irrigation standards:

- *Landscape Irrigation and Florida-Friendly Design Standards*, December 2006, Florida Department of Environmental Protection. **http://www.dep.state.fl.us/water/waterpolicy/docs/LandscapeIrrigationFloridaFriendlyDesign.pdf**
- *National Engineering Handbook Series 210-VI*. November 1997. U.S. Department of Agriculture, Natural Resources Conservation Service, Washington D.C., 20013. **http://directives.sc.egov.usda.gov/**.
- *Turf and Landscape Irrigation Best Management Practices*, April 2005. The Irrigation Association. (703) 536-7080, 6540 Arlington Blvd., Falls Church, VA 22042-6638 **http://www.irrigation.org**.

Test Your Knowledge

Q: Who would be most appropriate to contact for information regarding water conservation measures in your vicinity?
A. Florida Department of Agriculture and Consumer Services
B. Your local water management district office
C. Florida Department of Health
D. Florida Department of Natural Resources
A: B

Q: What does Florida Law require on all automatically controlled irrigation systems?
A. An operating moisture cutoff device
B. Powered by a natural conservative energy source, such as solar or wind
C. Plumbing constructed of galvanized steel
D. The use of reclaimed wastewater for the water source
A: A

Q: Which of the following statements is ***false*** regarding the use of reclaimed wastewater for irrigation?
A. Reclaimed water may contain high levels of chloride
B. The amount of nutrients in the water should be considered to reduce fertilization appropriately
C. All reclaimed water piping, heads, valves, fixtures, etc. are required by law to be color-coded purple
D. Nutrient levels in reclaimed water are fairly consistent among treatment plants supplying the water
A: D

Q: True or False:
An irrigation system consists of three main components: water supply, water conveyance, and a distribution device.
A: True

Q: Evapotranspiration refers to __________.
A. Water loss from plants and soil
B. Water loss from surface water sources
C. Water loss from plants
D. Water loss from soil
A: A

Q: As a general rule, no more than _____ of water should be applied for a single irrigation event.
A. 1/8 to ¼ inch
B. ¼ to ½ inch
C. ½ to ¾ inch
D. 1 to 1 ½ inch
A: C

Q: Match the following water use requirements with their plant growth stages:

1. Require more water	A. Dormant stage
2. Don't require much water	B. during seed, flower, and fruit production

A: 1-B, 2-A

Q: Under ideal conditions, how much water is required for plant growth?
A. The amount is equal to the water used during plant growth
B. The amount necessary to cause visual ponding on the soil surface
C. The amount that is supplied by daily operation of the irrigation system
D. The amount that is the maximum legally allowed by local regulations
A: A

Q: Who would be most appropriate to consult in the design of a landscape irrigation system?
A. A systems engineer with your local water management district
B. A trained irrigation system design specialist
C. A person who specializes in regulations
D. A person who offers the most reasonable cost
A: B

Chapter 6

Mulching, Mowing, and Pruning

In this Chapter

Learning Objectives

After you complete your study of this chapter, you should be able to:

- Describe the basic purpose of mulch.
- Describe the common types of mulches available for landscape use.
- Describe the benefits of mulch in the landscape.
- State three mulch BMPs.
- Describe the benefits of mowing a lawn at the correct height.
- Know the correct mowing heights for the turfgrass species commonly grown in Florida.
- State ten mowing BMPs.
- State three objectives of pruning trees.
- Describe the basic provisions of the 1996 Mangrove Trimming and Preservation Act.
- Describe the consequences of improper disposal of landscape wastes.

Terms to Know

BMPs: Best management practices. Procedures to reduce nonpoint source pollution and promote the efficient use of water.

Capillary action: The ability of a liquid to flow in narrow spaces without the assistance of, or even in opposition to, external forces like gravity.

Mulch: Any material applied to the soil surface to protect or improve the area covered.

Photosynthesis: The process by which plants convert sunlight into energy.

Pneumatophores: Numerous fingerlike projections that protrude from the soil around black mangroves' trunks.

Landscape Mulches

Mulch is any material applied to the soil surface to protect or improve the area covered. Mulches are frequently applied around plants to modify the soil environment and enhance plant growth. They may consist of organic material such as bark, wood chips, leaves, pine needles, or grass clippings; or they can be inorganic material such as gravel, pebbles, polyethylene film, or woven ground cloth (Figure 6.1). Mulch can be applied to the soil surface, but should not rest against the stems of landscape plants.

Figure 6.1: This landscape uses a combination of organic and inorganic mulch materials.

Benefits of Mulching

Mulching has the following beneficial effects on the soil and plants:

- Mulches can prevent the loss of water from the soil by evaporation. Moisture moves by capillary action to the surface and evaporates if the soil is not covered by a mulch.

- Mulches suppress weeds when the mulch material itself is weed-free and applied deeply enough (two to thee inches after settling) to prevent weed germination or to smother existing small weeds.

- A more uniform soil temperature can be maintained by mulching. The mulch acts as an insulator that keeps the soil cool under intense sunlight and warm during cold weather.

- Most mulches prevent crusting of the soil surface, thus improving absorption and percolation of water into the soil and at the same time reducing erosion.

- Organic materials used as a mulch can improve soil structure and tilth. As mulch decays, the material becomes topsoil. Decaying mulch may also add nutrients to the soil.

- Mulches add to the beauty of the landscape by providing a cover of uniform color and an interesting surface texture (Figure 6.2).

- Mulched plants produce roots in and directly under the mulch that surrounds them. The plants produce these roots in addition to the roots in the soil. As a result, mulched plants have more roots than plants that are not mulched.

Figure 6.2: Mulches add to the beauty of the landscape.

Mulching BMPs

- When feasible, use mulches made from environmentally friendly sources or recycled materials.

- Do not pile mulch against a tree or around the bases of shrubs. Burying the crowns can lead to crown and root rot (Figure 6.3). Leave a clear space for air to reach the trunk.

- Maintain a two to three inches depth of mulch after settling.

Figure 6.3: Don't build a mulch volcano—it can lead to crown and root rot.

Mowing the Florida Lawn

Mowing is an important maintenance operation. Mowing at the correct height increases turf density and root health and suppresses weeds. A dense turf impedes stormwater runoff. A healthy root system ensures that water and nutrients are absorbed and not wasted. Fewer weeds mean less need for herbicides.

Clippings contain nutrients and should be recycled on the lawn. The nutrients in clippings are pollutants when they end up in stormwater systems and waterbodies.

Growth rates and mowing height have the most influence on mowing frequency. As a rule of thumb, mowing should be done often enough so that no more than one-third of the leaf blade is removed at any one mowing. For example, if a St. Augustinegrass lawn is mowed at a height of four inches, it should be mowed when it grows to a height of 5.5 to 6 inches. Following this practice minimizes the effect of mowing on photosynthesis and helps to maintain the high percentage of leaf surface necessary for healthy root development. Research shows that returning grass clippings to the surface, sometimes referred to as grass recycling, does not increase thatch buildup on turf. Clippings have significant nutrient value and decompose rapidly, returning some fertilizer and organic matter to the soil.

Mowing equipment and string trimmers can damage trees. Tree trunks that are bumped by mowers, or trees that are used as pivot points for turns, are injured via contact. Mechanical damage to trees can cause progressively bigger wounds, since the trees are hit in the same general area repeatedly over time. The damage eventually progresses through the phloem, cambium, and xylem of the tree. In a worst-case scenario, the tree is girdled and dies. Those trees not killed are stressed and the wounds end up as an entry point for disease and insect infestation. The whipping action of the nylon string on a trimmer can debark a young tree quickly, causing its demise.

The careful use of string trimmers and mowers in the landscape is imperative, and there is no reason to use them around trees. Replacing the grass around the base of trees with mulch provides a buffer zone. The larger the mulched area, the less the turf near the tree is stressed by shade, the more room the lawn mower has to maneuver with ease, and the less the string trimmer needs to be used. Mulch also confers other benefits, such as reduced competition from weeds and water conservation.

The growth habit and leaf width of a turfgrass species determines the optimum cutting height, frequency, and preferred mower type (Table 6.1). A grass that spreads horizontally can usually be mowed shorter than an upright-growing, bunching grass. Grasses with narrow blades can generally be mowed closer than grasses with wide blades. Bermudagrass is mowed at very low heights because of its numerous narrow leaf blades and low growth habit (Figure 6.4). On the other hand, bahiagrass needs to be mowed higher because of its open, upright growth habit.

Figure 6.4: Bermudagrass can be mowed at very low heights. Credit: UF/IFAS Image Database.

Turfgrass undergoes physiological stress with each mowing, particularly if too much leaf tissue is removed. The effects of this "scalping" can produce long-term damage to the turf and leave it susceptible to numerous other stresses, such as insects, disease, drought, and sunscald. It is always important to leave as much leaf surface as possible for photosynthesis to provide food for regrowth.

For mowing safety, be sure to follow these tips:

- Pick up all stones, sticks, and other debris before mowing to avoid damaging the mower or injuring someone with flying objects.
- Never fill a hot mower with gasoline.
- Always wear heavy leather shoes when mowing the lawn.
- Check your mower every time it is used. Follow the manufacturer's recommendations for service and adjustments.

Table 6.1. Suggested mowing heights and mower types for Florida lawns.

Turfgrass species	Optimal mowing height (inches)	Mowing frequency (days)	Preferred mower type
Bahiagrass	3.0 - 4.0	7 - 14	Rotary/flail
Bermudagrass	0.75 - 1.5	5 – 7	Reel
Centipedegrass	1.5 – 2.5	7 – 14	Rotary
Seashore paspalum	1.0 – 2.0	5 – 10	Rotary/reel
St. Augustinegrass	3.5 – 4.0	5 – 7	Rotary
[1]St. Augustinegrass Dwarfs	2.0 – 2.5	5 – 7	Rotary
Zoysiagrass	1.5 – 2.5	5 – 7	Reel
[1]Dwarf varieties of St. Augustinegrass (Seville, Jade, Palmetto, Delmar) are the only cultivars of this species that should be mowed at less than three inches.			

Mowing BMPs

- Adjust the cutting height by setting the mower on a driveway or sidewalk and using a ruler to measure the distance between the ground and the blade.
- Do not mow wet turf because it can promote disease and fungus, and clippings can clog the machine. Mow only when the turf is dry.
- Sharpen the mower blade frequently enough to prevent a ragged appearance to the turf.
- Mow in a different direction every time the lawn is cut. This prevents wear patterns, reduces the grain (grass laying over in the same direction), and reduces the possibility of scalping.
- Use the highest acceptable mowing height for the grasses being grown.
- Do not remove more than one-third of the foliage at one time.
- Do not direct clippings into bodies of water or onto impervious surfaces. Remove any clippings that are blown onto sidewalks, driveways, and other impervious areas.
- Do not remove clippings. If clumping occurs, distribute the clippings by re-mowing or by lightly raking. You can also use a leaf blower to distribute clippings.
- Clean the mower after use to reduce rusting and weed seed movement.
- Practice grass recycling and return nutrients to the soil.
- If you must collect clippings, compost them. Use the compost as a soil modifier or mulch.
- Avoid mechanical damage to trees and shrubs from string trimmers, mowers, and other equipment.

Pruning of Landscape Plants

Pruning is another important landscape maintenance task. Through the selective removal of shoots and branches, pruning a plant can improve its health, reduce the risk of failure, control growth, and enhance fruiting, flowering or appearance.

Pruning should be a part of routine maintenance and should not be delayed until the landscape is overgrown. However, close attention should be paid to proper timing, depending on the needs of various plants. Proper plant selection can eliminate many pruning requirements, especially for shrubs.

Trees should not be pruned without a clearly defined objective. Objectives can include 1) reducing the risk of failure by improving structure and removing dead branches, 2) raising or reducing the crown to provide clearance, and 3) thinning the crown to increase air and light penetration. Removing the correct stems and branches to accomplish the specified objectives is as important as making the correct pruning cuts. If the wrong branches, or too many branches, are removed even with proper pruning cuts, nothing of merit has been accomplished.

For more information, see the following: *Pruning Shade Trees in the Landscape*, at **http://hort.ifas.ufl.edu/woody/pruning/**.

Mangroves

Three species of mangroves are native to Florida: red mangrove, black mangrove, and white mangrove.

Red mangroves are easily identified by their "prop roots," which are tangled, reddish, aerial roots that originate from the trunk and branches (Figure 6.5). Their leaves are one to five inches long, broad and blunt on the tip, shiny deep green on top, and paler on the underside.

Black mangroves can be identified by numerous fingerlike projections, called pneumatophores, that protrude from the soil around the tree's trunk. Black mangrove leaves are oblong, shiny green on top, and very pale on the underside. Black mangroves are usually found at slightly higher elevations, upland from red mangroves.

White mangroves have no visible aerial root system, as do red and black mangroves. The easiest way to identify white mangroves is by their leaves. These are up to three inches long, elliptical (rounded at both ends, often with a notch at the tip), and yellowish in color, with two distinguishing glands at the base of each leaf blade where the stem begins. White mangroves are usually found at higher elevations and farther upland than either red or black mangroves.

Figure 6.5: Red mangroves' reddish aerial "prop roots." Credit: UF/IFAS Image Database.

The 1996 Mangrove Trimming and Preservation Act, Sections 403.9321-403.9333, Florida Statutes, governs the trimming and alteration of mangroves. The Florida Department of Environmental Protection (FDEP) and several delegated local governments implement the mangrove program. Mangrove trimming and alteration may be done by property owners under certain exemptions, as specified in Section 403.9326, Florida Statutes. Other trimming requires the services of a professional mangrove trimmer and may require an FDEP permit. Section 403.9329, Florida Statutes, governs who may be considered a professional mangrove trimmer.

The mangrove preservation act's major provisions include the following:

- The difference between "trimming" and "alteration" of mangroves is defined.
- Mangroves may not be reduced to a height below six feet from the substrate and often may not be legally trimmed down to six feet.
- Mangrove roots, including aerial and prop roots (red mangroves) and pneumatophores (black mangroves), may not be trimmed.
- Under certain conditions, a professional mangrove trimmer must conduct or supervise the trimming.
- **Dead mangrove trees are covered by the same regulations as living mangrove trees;** contact the closest Florida Department of Environmental Protection office for specific information on dealing with dead mangrove trees on your client's property.

It is especially important that green industry professionals understand that, under the act, **homeowners and the individuals they hire to trim their mangroves are jointly and severally responsible for the appropriate trimming of mangroves.**

All trimming should be done in a manner that does not result in the removal, defoliation, or death of the mangroves. Red mangroves are particularly sensitive to inappropriate trimming. In general, the canopy of red mangroves should not be trimmed, and no more than 25 percent of the canopy of black and white mangroves should be removed. Preferably, views should be obtained by thinning the canopy, creating "windows," and "uplifting," compared with hedging (which can be particularly damaging to red mangroves).

The booklet *Mangrove Trimming Guidelines for Homeowners* is available at FDEP's district offices throughout the state. You may wish to obtain several copies to give your clients. Before trimming mangroves, homeowners and landscapers should read the publications cited in this section, or call the Environmental Resource Permitting staff at FDEP's district offices to avoid violating the mangrove preservation act. For more information about the mangrove program, call (850) 245-8482 or go to **http://www.dep.state.fl.us/water/wetlands/mangroves/**.

Disposing of Landscape Material

Never sweep grass clippings, leaves, or other debris into a storm sewer. This pollutes our waterbodies, and in some cases it may clog the system and contribute to flooding.

Be careful with yard waste! Careless disposal may spread invasive non-native plants to areas where they don't belong. Lawn and landscape maintenance involves the removal of leaves, clippings, whole landscape plants, and even unwanted houseplants. Given contact with soil and sufficient water, these materials may become established at the disposal site. Dispose of them carefully, so plants that are unwanted in one location don't unintentionally become established elsewhere. Contact your county waste management utility or local UF/IFAS Extension office for information about local disposal sites in your area that are designated f or plant waste. Educate your customers about proper plant disposal and how it enhances the protection of natural areas.

Sometimes landscape waste materials are disposed of in accessible locations on someone else's property, either public or private. Illegal dumping has allowed several species to become established in natural areas. Wax begonia, pothos, heavenly bamboo, ardisia, golden bamboo, and arrowhead vine are among the species that have moved into wild areas through this mechanism (Figure 6.6). This spread of non-native species into protected sites is threatening the plant and animal species those sites were purchased to conserve.

Awareness of how a species is likely to become established is important. A plant's relative ease of propagation may provide

Figure 6.6: Dense stand of coral ardisia in a natural area. Credit: UF/IFAS CAIP.

valuable insight into its potential to spread. Pruned material from a species that is quickly propagated from cuttings, such as wedelia or lantana, may take root without appropriate precautions. The timing of maintenance activities can reduce the potential for discarded plants to become established where they shouldn't.

Depending on the situation and local ordinances, several options are available to dispose of plant material. Living plant tissue can be destroyed on-site through burning, composting in bins, or putting it in or under heavy plastic. Material may also be dumped in designated disposal areas.

The following tips can reduce the accidental propagation of non-native species:

- Plants can be pruned before the fruit is mature, and leaf raking can be done before the seeds of surrounding plants have dropped.

- Whenever practical, and if the homeowner is amenable, yard wastes should be composted on-site and retained for use as mulch. This also avoids transportation and disposal costs and reduces the need for purchased materials.

Test Your Knowledge

Q: Match the type of mulch with their examples.

1. Inorganic 2. Organic

A. Bark, wood chips, leaves, pine needles, grass clippings
B. Gravel, pebbles, polyethylene film, woven ground cloth

A: 1-B, 2-A

Q: Which statement is ***false*** regarding the benefits of mulches?
A. Organic materials used as a mulch can improve soil structure and tilth
B. Mulches can suppress weeds
C. Most mulches cause crusting of the soil surface
D. A more uniform soil temperature can be maintained by mulching

A: C

Q: True or False:
Mowing at the correct height increases turf density and root health and suppresses weeds.

A: True

Q: Match the turfgrass species with its proper mowing height.

1. Bermudagrass	A. 3.5" - 4.0"
2. Centipedegrass	B. 0.75" - 1.5"
3. St. Augustinegrass	C. 1.5" - 2.5"

A: 1-B, 2-C, 3-A

Q: True or False:
When mowing, do not remove more than one-third of the foliage at one time.

A: A: True

Q: What are the 3 main objectives for pruning trees? (Select all that apply)
A. Improving structure and removing dead branches
B. To obtain firewood
C. Raising or reducing the crown to provide clearance
D. Control of nuisance wildlife by habitat destruction
E. Thinning the crown to increase air and light penetration

A: A, C, E

Q: Which native Florida mangrove species is particularly sensitive to trimming?
A. Red
B. Variegated
C. White
D. Black

A: A

Q: True or False:
Dead mangrove trees aren't covered by the 1996 Mangrove Trimming and Preservation Act.

A: False

Q: What is a major consequence of improperly disposing of landscape material?
A. It can pollute waterbodies
B. It can spread non-native species into protected sites
C. It can instigate serious penalties imposed by the EPA
D. Both A and B are correct

A: D

Chapter 7

Fertilization

In this Chapter

Learning Objectives

After you complete your study of this chapter, you should be able to:

- Describe the consequences of fertilizing when a heavy rainfall is expected, especially tropical or frontal weather systems.
- Know that all fertilizers, even slow release products, contain nutrients and can cause pollution if allowed to escape the root zone.
- Be aware of the effects soil pH, shade, overwatering, or other stresses may have on plants and know that fertilizer may not be the correct response to the problem.
- Describe the effects of the turfgrass species, season of the year, level of maintenance desired, source of nitrogen (N) applied, and location in the state on the rate and timing of N fertilization.
- State the maximum recommended amount of water-soluble (quick release) N to apply per 1,000 ft^2.
- State the total amount of N to apply per 1,000 ft^2 per the Urban Turf Rule.
- Describe the basis for phosphorous (P) application.
- Describe the timing and number of applications of N and P fertilizer recommended at the time of turfgrass establishment.
- Describe the concept of "Ring of Responsibility" and how it can be achieved near water bodies or impervious surfaces.
- Know what to do with any fertilizer left on impervious areas.
- Become proficient in reading and understanding the fertilizer label.
- Become knowledgeable in soil sampling procedures and soil test interpretation.
- State the amount of irrigation necessary following fertilization to avoid loss of N and increase uptake efficiency.
- Name the micronutrients to apply instead of N to enhance turfgrass color on soils having a pH greater than 7.0.
- Know that the proper application of fertilizer is more important than the type of product in terms of BMPs for environmental protection.

Terms to Know

Activity index: The slow release portion of a fertilizer that is available over the course of several months.

Apatite: A group of phosphate minerals.

BMPs: Best management practices. Procedures to reduce nonpoint source pollution and promote the efficient use of water.

Electroconductivity: The ability of a material to conduct (transmit) an electrical current.

Eutrophication: The ecosystem's response to the addition of artificial or natural nutrients, mainly phosphates, to an aquatic system.

Fertilizer: Any substance that contains one or more recognized plant nutrients and promotes plant growth, or controls soil acidity or alkalinity, or provides other soil enrichment, or provides other corrective measures to the soil.

Fertilizer grade or analysis: The percent nitrogen, phosphorus, and potassium guaranteed by the manufacturer to be in the fertilizer. For historical reasons, nitrogen is expressed as total N, available phosphate as P_2O_5, and soluble potash as K_2O. The percent sign is not used, but instead the numbers are separated by dashes, and the order is always N, P_2O_5, and K_2O (for example, 15-0-15).

Leaching: The downward movement of a substance through the soil.

Mehlich-1: A soil nutrient extractant process that extracts all the essential plant nutrients from a soil sample, and is especially suited for the acidic, low organic matter, mineral soils of the southeastern United States.

Nitrification: The process by which bacteria in soil oxidize ammonia and form nitrates and nitrites.

Nonionic: Compound without a net positive or negative charge.

Oligomer: A polymer whose molecules consist of relatively few repeating units.

Urease: A naturally occurring enzyme that hydrolyzes urea into ammonia and carbon dioxide.

Volatilization: Conversion to a vapor or gas.

Fertilizer Analysis

The Florida fertilizer label is detailed and intended to be highly informative. By law, the product's label is required to provide the following basic information: the brand and grade, manufacturer's name and address, guaranteed analysis (Figure 7.1), sources from which the guaranteed primary and secondary nutrients are derived, and net weight. In addition to the grade of the fertilizer, the label also identifies the breakdown of total N as either nitrate-N, ammoniacal-N, water soluble or urea-N, and water insoluble-N. This N breakdown supplies information on the immediate availability and/or leachability of the N in the bag. Slow- or controlled-release fertilizer is defined by the Association of American Plant Food Control Officials (AAPFCO) as a fertilizer containing a plant nutrient in a form that delays its availability for plant uptake and use after application, or that extends its availability to the plant significantly longer than a reference "rapidly available nutrient fertilizer" such as ammonium nitrate or urea, ammonium phosphate, or potassium chloride. Many fertilizer terms used throughout this chapter are officially defined by the Association of American Plant Food Control Officials (AAPFCO), **http://www.aapfco.org/**.

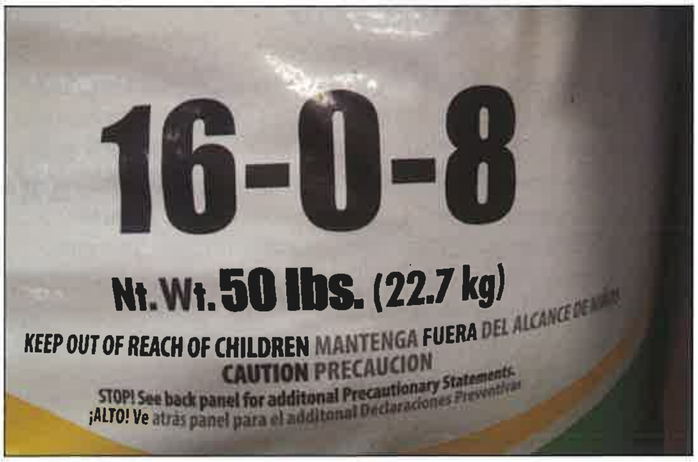


Figure 7.1: Fertilizer analysis: 16% N, 0% P_2O_5, and 8% K_2O.

Such delay of initial availability or extended time of continued availability may occur by a variety of mechanisms. These include the controlled water solubility of the material (by semipermeable coatings, occlusion, or the inherent water insolubility of polymers, natural nitrogenous organics, protein materials, or other chemical forms); by the slow hydrolysis of water-soluble, low molecular weight compounds; or by other unknown means.

In most cases, the higher the water insoluble-N percentage in the mix, the longer lasting the fertilizer. This is the portion where most of the N from natural organic and slow-release N sources appears. A fertilizer that contains all of its N as nitrate-N, ammoniacal-N, and/or water soluble N is referred to as a soluble N fertilizer, which has a high potential for leaching and should not be applied at rates greater than 0.5 lbs N/1,000 ft^2. A fertilizer label also contains a "derived from" section that identifies the materials from which the fertilizer was formulated.

Secondary and micronutrients are identified in the lower portion of the label and are expressed in the elemental form. Sulfur (S) is expressed as "combined" (usually expressed as SO_4) and as "free" (elemental S form). The reason for this distinction is that "free" S is very acidifying when placed in the soil. Magnesium (Mg), Iron (Fe), Copper (Cu), Manganese (Mn), and Zinc (Zn) must be expressed as total and/or soluble or water soluble depending on the source materials formulated in the fertilizer. Chelated elements are guaranteed separately when a chelating agent is denoted in the derivation statement below the guaranteed analysis. For additional information, see UF/IFAS publication SL 3, *The Florida Fertilizer Label*, at **http://edis.ifas.ufl.edu/SS170**.

Fertilizer Applicator Licensing

Effective in 2014, Florida Statute 482.1562 was passed requiring all commercial urban landscape fertilizer applicators to obtain and maintain a Limited Commercial Fertilizer Applicator Certificate (LCFAC) from the Florida Department of Agriculture and Consumer Services.

One requirement of obtaining this certificate is to complete an approved training program. Training is available throughout the state at UF/IFAS County Extension offices, online through UF/IFAS Extension, and from industry associations and other trainers. See **http://fyn.ifas.ufl.edu** or **http://www.flaes.org/aes-ent/index.html**.

Urban Turf Fertilizer Rule

In 2007, the Florida Department of Agriculture and Consumer Services adopted rule 5E-1.003 (revised 2015), labeling requirements for urban turf fertilizers. The complete rule, as first adopted in 2007, is presented in Appendix C. The rule limits the amount of nitrogen and phosphorus that the manufacturer may recommend for application on urban turf and lawns in Florida. It also directs the manufacturer to recommend the use of BMPs for professional applicators and golf course or athletic field managers.

While this rule only applies to the manufacturer's label for fertilizer, many local government ordinances, and future state requirements, may require that applicators abide by the recommendations on the label. In addition, weed and feed products are legally pesticides (Figure 7.2). For pesticide/fertilizer combination products, the label recommendation carries the full force of state and federal law.

Figure 7.2: Weed and feed products are legally pesticides.

Turf Fertilization Management

One of the first steps in developing a turfgrass fertilization management program involves a basic knowledge of the soils on which the turfgrasses are being grown. This knowledge can be acquired by observing and evaluating the soil's physical and chemical properties. Most Florida soils are sands and therefore retain limited quantities of water and nutrients. Individuals with only limited training in soils can discern whether a soil is mostly sand or predominately clay, and whether the soil contains flakes of free calcium carbonate or shell. These properties may significantly affect a turfgrass fertilization management program.

Chemical properties such as soil pH, lime requirement, extractable levels of P, K, Ca, Mg, and selected micronutrients such as Mn, Cu, and Zn can be determined through soil testing. Florida soils are not analyzed for N because it is highly mobile in sandy soils. Since reliable correlations between turfgrass growth and soil test N have not been developed, turfgrass N fertilization is based on the requirements of the individual turfgrass being grown.

Additional information on soil testing for turfgrasses can be found later in this chapter or in UF/IFAS publication SL 181, *Soil Testing and Interpretation for Florida Turfgrasses*, at **http://edis.ifas.ufl.edu/SS317**.

Nitrogen Management

Fertilizer sources. Matching the fertilizer source and rate with the growth phase of the turfgrass is one of the keys to nutrient management. For example, you may shift from 1 lb total N of 15-0-15 slow release to a ½ lb N of 5-0-20 for a fall fertilization as dormancy approaches. Leaching losses of nitrogen can be minimized by using controlled-release nitrogen sources, making frequent, low-rate applications of soluble fertilizers, or applying a combination of the two fertilizer materials. Low-rate applications are usually made using soluble fertilizers, whether applied as a liquid or granular product.

Quick release sources. One of the most common nitrogen fertilizers is urea (46% N), which is a water-soluble, synthetic organic nitrogen fertilizer with quick N-release characteristics. Urea can be applied as either liquid or granules, and is subject to volatilization, or loss of nitrogen to the atmosphere. If urea is applied to a turfgrass surface and not incorporated through proper irrigation, significant quantities of N can be lost through volatilization. Therefore, it is imperative that the proper quantity of water be applied following the application of urea fertilizer, unless rainfall is anticipated within 8 to 12 hours. Recall that one inch of applied water wets the top 12 inches of a Florida sandy soil; therefore, do not apply excessive irrigation. Application of ¼ inch of water should be sufficient to solubilize most of the urea and move it into the turfgrass root zone.

If urea is applied and followed by rainfall of an inch or greater within 8 to 12 hours after application, urea-N may move below the turfgrass root zone because of its nonionic nature and be lost through leaching. Although urea does not leach as rapidly or uniformly as nitrate-N, significant loss of N can occur if excessive irrigation or rainfall occurs shortly after application. Once the urea has been exposed to soil or turfgrass thatch layer for a short time, it is converted by the enzyme urease to the ammonium-N form, which is more likely to be retained by the soil. This conversion of urea is usually complete within the first 24 hours after application. Thus, a heavy rainfall two to three days after an application of urea should not be as influential on N movement.

Recently some new types of stabilized N fertilizer materials have been commercialized. These products contain urease inhibitors, which slow the conversion of urea to ammonium and reduce the volatilization loss of N. Therefore, these products can be left on the surface longer without significant loss of N through volatilization. This delay in urea conversion is usually three to five days, which means that the N remains in the urea form for a longer period of time and subjects the urea to leaching losses if heavy rainfall occurs during this period. In most cases, these stabilized N materials also contain nitrification inhibitors, which slow the nitrification process as well. Recent research suggests that these stabilized N materials extend the N availability to turfgrass for 10 to 14 days over that of quick release products.

Recent research has shown that some slow-release N materials may leach more urea than applications of quick release urea. This is thought to be due to the slow-release urea product leaching through the soil without being degraded by urease. Small quantities of urea (less than 10% of the total released N) have been detected in the leachate from some slow-release N sources during the first 7 to 10 days after application. However, by 14 days after application no urea was detected in the leachate regardless of the N source applied; only nitrate N remained after this period.

Ammonium nitrate (AN) and ammonium sulfate (AS) are two other soluble, quick-release N sources commonly used by professional lawn-care services. These two materials are not as high in N as urea. AN (33.5% N) and AS (21% N), however, have a higher salt index and burn potential than urea on a per-pound-of-N basis. AS is also a very acidifying N source. For each pound of N applied as AS, 5.35 pounds of acidity are produced due to the ammonium-ion content. AS is often the preferred N source on high pH soils due to its acidifying properties.

Urea and AN are often formulated as liquid N sources for application in solution form through the irrigation system (fertigation) or direct application. Lawn-care professionals often use solution fertilizers because of application uniformity and efficiency. Solution fertilizers do not leach more readily than similar granular fertilizers once they have reacted with the soil components.

Slow Release Sources. A slow or controlled release fertilizer is a fertilizer containing a plant nutrient in a form which delays its availability for plant uptake and use after application, or which extends its availability to the plant significantly longer than a reference "rapidly available nutrient fertilizer" such as ammonium nitrate or urea, ammonium phosphate, or potassium chloride (Figure 7.3). Such delay of initial availability or extended time of continued availability may occur by a variety of mechanisms. These include controlled water solubility of the material (by semi-permeable coatings, occlusion, or by inherent water insolubility of polymers, natural nitrogenous organics, protein materials, or other chemical forms), by slow hydrolysis of water soluble low molecular weight compounds, or by other unknown means.

Figure 7.3: Fertilizer bag indicating 50% slow release N contents.

Enhanced Efficiency is a term describing fertilizer products with characteristics that allow increased plant uptake and reduce the potential of nutrient losses to the environment such as gaseous losses, leaching or runoff, as compared to an appropriate reference product.

Ureaform Fertilizer Materials (sparingly soluble) are reaction products of urea and formaldehyde which contain at least 35% N, largely in insoluble but slowly-available form. The water insoluble content is required to be at least 60% of the total N. The water-insoluble N in these products must have an activity index of not less than 40% when determined by the appropriate Association of Official Agricultural Chemists (AOAC) International method.

Urea-Formaldehyde Products (sparingly soluble) are reaction products of urea and formaldehyde which contain less than 35% N, largely in insoluble but slowly available form. They are required to have the percentage of total nitrogen as part of the product name; for example: 20% N urea-formaldehyde. The water insoluble nitrogen must be at least 60% of the total N. The activity index of the water-insoluble N is either 1) not less than 40% by the AOAC International method for urea-formaldehyde, or 2) not less than 50% by the AOAC international alkaline permanganate method or 80% by the neutral permanganate method.

Isobutylidene Diurea (IBDU) is a condensation product of isobutyraldehyde and urea having a minimum total N content of 30%. It is a source of slowly available nitrogen by virtue of particle size, solubility decreasing with increase in particle size. Material conforming to the description of a "granular fertilizer" will have 90% of its N content in the water-insoluble form prior to grinding as tested by AOAC.

Sulfur Coated Urea (SCU) is a slow-release fertilizer consisting of urea particles coated with sulfur. The product is usually further coated with a sealant (2% to 3% of total weight) and a conditioner (2% to 3% of total weight). It typically contains about 30% to 40% N and about 10% to 30% S.

Urea-Formaldehyde Products (water soluble) are reaction products of urea and formaldehyde that contain at least 30% N, largely in water-soluble form. Some slowly-available nitrogen products are present. Stable aqueous solutions may be prepared from these materials. The reaction products are required to contain a maximum of 55% free urea, with the remainder of the urea being chemically combined as methylolureas, methylolurea ethers, and/or methylenediurea (MDU) and dimethylenetriurea (DMTU).

Methylenediurea (MDU) is a water-soluble condensation product resulting from the reaction of one molecule of formaldehyde with two molecules of urea, with the elimination of one molecule of water. It has a minimum total N content of 42% and is a source of slowly-available N.

Dimethylenetriurea (DMTU) is a water-soluble condensation product resulting from the reaction of two molecules of formaldehyde with three molecules of urea, with the elimination of two molecules of water, and having a minimum total N content of 41%. It is a source of slowly- available N.

Dicyandiamide (cyanoguanidine) is a water-soluble organic compound of formula $C_2H_4N_4$ that contains at least 65% N. It is a source of slowly-available N. It is a nitrification inhibitor.

Polymer Coated Urea (PCU) is a coated slow release fertilizer consisting of urea particles coated with a polymer (plastic) resin. It typically contains about 40% N. It is a source of slowly-available N.

Triazone is a water soluble compound of formula $C_5H_{11}N_5O_2$ [5-(N-methyl)-urea-1,3,5-triazin-2-one or 5-methyleneureido-2-oxohexahydro-s-triazine] that contains at least 40% total N.

Urea-Triazone Solution is a stable solution resulting from controlled reaction in aqueous medium of urea, formaldehyde, and ammonia that contains at least 25% total N. The solution contains no more than 40% nor less than 5% of total N from unreacted urea and not less than 40% from triazone. All other N is derived from water-soluble, dissolved-reaction products of the above reactants. It is a source of slowly-available N.

Methylene Urea(s) (MU, polymethylene urea(s)) is a product obtained by the reaction of urea with formaldehyde and contains oligomers of urea bonded together by methylene ($-CH_2-$) linkages. It is chiefly composed of cold-water-soluble fractions from methylenediurea (MDU) and dimethylenetriurea (DMTU), hot-water-soluble fractions from trimethylenetetraurea (TMTU) and tetramethylenepentaurea (TMPU), and hot-water-insoluble fractions from longer chain oligomers. It is generally free of methylolureas and methyol ethers. It is a source of slowly- available N.

Urea is often formulated using a chemical reaction or coating to produce fertilizers with slow-release characteristics, such as ureaformaldehyde (UF or nitroform), isobutylidene diurea (IBDU), and sulfur- or polymer-coated urea. These fertilizers depend on microbial action, soil moisture, and/or a chemical reaction for the release of N for use by turfgrass. It is important to know when to use a given slow-release N source in order to obtain maximum effectiveness from the material. This is due to environmental influences on the N-release mechanisms of slow-release N sources.

The N-release mechanism for methylene urea-type products (Urea-formaldehyde, UF, Nitroform, Nutralene, Methex, or CoRon) is microbial. Because temperature influences the activity of the soil microbial population, these materials release N more slowly and are less effective during the cool season.

Particle size and rate of hydrolysis control the N release from IBDU; thus, this product should not be used during periods of heavy rainfall. However, it is one of the more effective materials in the cool season when precipitation levels decrease.

N release from sulfur-coated urea (SCU) products is controlled by the coating thickness and the degree of imperfection in the coating. SCU products typically induce a somewhat mottled appearance when used during the cool season, but are generally very effective during the high rainfall, warm-season growth period. Because of the fragile nature of the sulfur coating on most SCU materials, they should not be applied using a drop-type spreader.

Other products include polymer-coated, controlled-release fertilizers that use a polymer coating to encapsulate nutrient granules. A polymer membrane is chemically bonded to the substrate resulting in a fertilizer with release governed largely by soil temperature, provided adequate moisture is present. The release mechanism is osmotic diffusion. Some systems consist of multiple layers of polymer, and may include other intermediate coatings. Product longevity may be controlled by coating thickness and blending ratios.

Organic fertilizers are another source of nitrogen that is slowly made available through microbial degradation. In this case, the release rates depend on nature of the product and the prior treatment that it has received as well as temperature and moisture. Organic fertilizers, including biosolids from wastewater treatment plants, generally have low N:P_2O_5 ratios, which means that it is difficult or impossible to meet the nitrogen needs of the turf without exceeding the annual maximum allowable P_2O_5, unless other nitrogen sources are added. Some manufacturers do blend in other N sources to overcome this and provide a more balanced product that preserves the benefits of nutrient recycling.

In conclusion, a wide variety of slow-release materials is available. Under typical Florida conditions, slow-release N sources are likely to leach less than an equal amount of soluble N sources. However, leaching can still take place and some slow-release products may be subject to runoff of the nutrient-containing slow release particles. Judicious use of professional judgment and a mixture of soluble and slow-release N sources are recommended.

For more information on N sources for lawn fertilization, see UF/IFAS publication SP 141, *Florida Lawn Handbook: An Environmental Approach to Care and Maintenance of Your Lawn*, Third Edition, available from the UF/IFAS Extension Bookstore at **https://ifasbooks.ifas.ufl.edu/**.

Nitrogen Rate and Frequency. The rate of nutrient application, particularly N, depends on a number of factors: turfgrass species, turfgrass maintenance level goals, the location in the state where the turfgrass is being grown, time of year, and type of fertilizer source being used (soluble or slow release). Thus, a single rate of application cannot be recommended. The frequency of fertilization also depends on all the factors listed above for N rate. To limit the environmental impact of your fertilization program, **it is recommended that no more than 0.5 pounds of water-soluble N per 1,000 square feet be applied in a normal application**. Total N should be limited to 1 lb/1000 ft^2, per the Urban Turf Rule. Table 7.1 is from the Florida Fertilizer Rule, 5E-1.003(revised 2015) and provides nitrogen fertilizer guidelines. In areas irrigated with reclaimed water, check with the reclaimed water supplier for estimates of the N applied per year in the reclaimed water, and recommendations to adjust the fertilization. A study for the Tampa Bay Estuary program (April 2008) estimated 0.6 to 5.3 lb N/1000ft^2 was applied annually to lawns from several different wastewater treatment systems.

For a detailed fertilization guide for Florida turfgrasses, see UF/IFAS publication SL 21, *General Recommendations for Fertilization of Turfgrasses on Florida Soils*, at **http://edis.ifas.ufl.edu/LH014**.

Table 7.1. Fertilization guidelines for established turfgrass lawns in three regions of Florida.

Nitrogen recommendations (lbs N / 1,000 ft^2 / year)[1]			
Species	**North**	**Central**	**South**
Bahia	2 - 3	2 - 4	2 - 4
Bermuda	3 - 5	4 - 6	5 - 7
Centipede	1 - 2	2 - 3	2 - 3
St. Augustine	2 - 4	2 - 5	4 - 6
Zoysia	3 - 5	3 - 6	4 - 6

[1]North Florida is north of Ocala. Central Florida is defined as south of Ocala to a line extending from Vero Beach to Tampa. South Florida includes the remaining southern portion of the state.

The timing of fertilization is tied to the turfgrass species, maintenance level goal, season of the year, the location in the state where the turfgrass is being grown, and the fertilizer source being used. One of the most important principles of fertilization timing is avoiding fertilizer application to dormant or non-growing turfgrass. During dormancy, turfgrasses take up very small quantities of nutrients, and applied nutrients are more likely to leach or run off site in the next thunderstorm. Slow-release sources also influence the timing of fertilization, in that fertilization is required less frequently.

Rainfall that exceeds the ability of the soil to retain moisture in the root zone may lead to runoff into surface waters or leaching through the soil to ground water. **Do not apply fertilizer when the National Weather Service has issued a flood, tropical storm, or hurricane watch or warning, or if heavy rains are likely.** The World Meteorological Organization defines heavy rain as rainfall greater than or equal to two inches in a 24-hour period. According to data, only about three to five pecent of Florida rain events exceed two inches; however, caution should always be used to avoid runoff or leaching from saturated or compacted soils or in other high-risk situations.

Additional information on storms and weather may be found at **http://severe.worldweather.org/rain/**, **http://bit.ly/noaa_terms**, and **http://bit.ly/FL_stormwater**.

Location in the State. Based on seasonal differences, changes in soil types, and the predominant turfgrass species used on lawns, the state is divided into three regions: south, central, and north. The dividing line between north and central Florida is a straight east-west line from coast to coast through Ocala, and the dividing line between central Florida and south Florida is a line from coast to coast through Tampa and Vero Beach.

For tables providing fertilization guidelines for the various turfgrass species by maintenance level in a given region of the state, see UF/IFAS publication SL 21, *General Recommendations for Fertilization of Turfgrasses on Florida Soils*, at **http://edis.ifas.ufl.edu/LH014**.

Soil Types and Turfgrass Species. Ninety-six percent of soils in Florida are classified as sands, but within these soil types the chemical properties of the soils vary according to the region of the state in which they occur. Soils in south Florida tend to contain higher levels of free calcium carbonate (lime or shell) and have a higher pH than the rest of the state. Generally speaking, St. Augustinegrass grows better on high pH soils than do bahiagrass or centipedegrass; thus, one finds more lawns with St. Augustinegrass in south Florida. In fact, approximately 85 pecent of the residential and commercial lawns in Florida use one of the several cultivars of St. Augustinegrass. For the recommended soil pH for the various turfgrasses used in Florida, see UF/IFAS publication SL 181, *Soil and Tissue Testing and Interpretation for Florida Turfgrasses*, at **http://edis.ifas.ufl.edu/SS317**.

Due to the potential for ammonia volatilization, **the surface application of ammonium-N and/or urea-containing fertilizers to these high pH soils without watering in (with 0.25 inch of irrigation) is not recommended.** Central Florida soils contain less calcium carbonate and tend to be more acidic, with a pH of between 5.5 and 7.5. Except for areas where limestone outcroppings occur, most of the turfgrass species can be grown. Since bahiagrass and centipedegrass do not grow well on high pH soils, their establishment on soils with a pH of greater than 7.0 should be avoided. Soils in north Florida tend to contain higher quantities of clay and to be more acidic than soils in the rest of the state. Therefore, bahiagrass and centipedegrass are used more commonly for lawns in this part of the state.

Zoysiagrass is not used extensively as a lawn grass in Florida, but when used it grows best under the same soil and fertilization conditions as St. Augustinegrass. Bermudagrasses require high maintenance and specialized equipment, but can be grown under a broad array of soil conditions. They are typically grown under intensively managed golf course conditions. Bermudagrass maintenance is not covered in this manual but is included in *Best Management Practices for Enhancement of Environmental Quality on Florida Golf Courses*, published by FDEP in 2007. Available: **http://www.dep.state.fl.us/water/nonpoint/docs/nonpoint/glfbmp07.pdf**. Seashore paspalum produces a high quality turfgrass with minimal fertility requirements and a high tolerance for salinity. This is a relatively new grass in Florida and may be very sensitive to cultural practices. For up-to-date information, contact your UF/IFAS Extension office.

Phosphorous Fertilization

Because P has been implicated as a cause of increased algae growth in surface water impoundments, proper P fertilization management is imperative. Therefore, the goal in P management should be to apply the correct amount based on soil test recommendations (Figure 7.4). In addition to the nitrogen restrictions discussed earlier, the Urban Turf Fertilizer Rule has phosphorus application limits. The rule limits phosphate application to no more than 0.25 lb P_2O_5 /1,000 ft^2 per application, not to exceed 0.5 lb P_2O_5 /1,000 ft^2 per year, without a soil test. A one-time only application of up to 1.0 lb P_2O_5 /1,000 ft^2 is permitted for establishment of new turf. Soil testing is strongly recommended before any initial P_2O_5 application and annually if applications are being made based on previous testing. Where subdivisions have been determined to have relatively similar soils, this may be reduced to testing ½ to ⅓ of the customers each year, rotating the testing so all are tested every two or three years. For more information, see UF/IFAS publication SL 181, *Soil and Tissue Testing and Interpretation for Florida Turfgrasses*, at **http://edis.ifas.ufl.edu/SS317**.

Figure 7.4: UF/IFAS provides soil testing services.

Turfgrasses use significantly less P than N and/or K. Some Florida soils are high in native P, and turfgrasses grown on these soils require only limited P fertilization or none at all. Soil or tissue testing should always be used in these situations. Responses to P fertilization are most typically observed for rooting enhancement during establishment and where soils have a P deficiency.

The off-site transport of P is often associated with soil erosion from unvegetated and thin turfgrass areas. Research shows that runoff from a healthy turfgrass area is minimal, but thin and/or poor quality turfgrass has much a higher erosion and runoff potential. Because P can be a significant contributor to eutrophication, the proper management of P on turfgrass is just as important to the environment as N management.

Another source of P is in reclaimed water. Turf irrigated with reclaimed water may receive an excess of P, compared to the maximum amounts recommended in the Urban Turf Rule. Do not add phosphorus to a site irrigated with reclaimed water without a soil test recommendation to do so.

By using the following simple measures, you can properly manage the P fertilization of your turfgrasses:

- P fertilization should always be based on reliable soil or tissue test recommendations. Many Florida soils are high in extractable P and may never require P fertilization for optimum turfgrass growth. Never exceed the amounts allowed by the Florida Fertilizer Label without a soil or tissue test recommendation.

- Since unvegetated slopes or thin, low-quality turfgrass areas are more likely to produce runoff and off-site P contamination than healthy, well-maintained turfgrass areas, it is important to properly maintain your turfgrass.

Potassium Fertilization

Of the three primary nutrients (N, P, and K), K is second only to N in utilization by turfgrasses. Large responses in turfgrass growth are not typically observed in response to K fertilization, but K has been linked to reduced disease incidence, drought and cold tolerance, and enhanced root growth. The K fertilization rate is often tied to the N fertilization level, generally in a 3:1, 2:1, or 1:1 ratio. Recent research on Bermudagrasses suggests that optimum growth and tissue K levels can be attained at a 3:1 or 2:1 ratio.

Ideally, turfgrass K fertilization should be based on soil test recommendations. Because of high mobility in sandy soils, K fertilization should be made as soon after soil testing as possible. However, K is often applied without a prior soil test, based on the requirements of the turfgrass. Fortunately, K is not considered a pollutant, but prudence in K fertilization is essential for economic and resource conservation reasons. Excessive K fertilization can contribute to high soil electroconductivity (EC) levels that may limit root growth and turfgrass tolerance to drought.

Secondary Nutrient Fertilization

Calcium (Ca), magnesium (Mg), and sulfur (S) are referred to as secondary plant nutrients, not because they are of secondary importance, but because they are typically used in smaller quantities than the primary nutrients. Of these three, the Extension Soil Testing Laboratory (ESTL) makes recommendations only for Mg. Mehlich-1 extractable Mg levels are typically low, and responses have been observed when the soil Mg status drops below 40 pounds per acre. For more information, see UF/IFAS publication SL 181, *Soil and Tissue Testing and Interpretation for Florida Turfgrasses*, at **http://edis.ifas.ufl.edu/SS317**.

Due to the presence of apatite and/or residuals from previous P fertilizations, the Mehlich-1 extractant may dissolve higher levels of Ca than are plant-available; therefore, no interpretation is made for the extracted soil Ca. Generally, plant-available Ca levels of Florida soils are high and no responses to applied Ca have been observed. You may increase Ca levels by applying irrigation water containing high levels of Ca.

Consistent and reliable correlation data do not exist for soil test S levels and turfgrass growth; thus, the ESTL does not analyze or make recommendations for S. Fortunately, S is often an accompanying anion in N, K, Mg, and micronutrient sources and is not often deficient for turfgrass growth.

Micronutrients

The ESTL analyzes and makes recommendations for copper (Cu), manganese (Mn), and zinc (Zn). Of these three micronutrients, turfgrass responses have only been observed for Mn. In most Florida soils, extractable Cu and Zn levels are adequate for optimum turfgrass growth, except for Cu on organic soils under sod production. No analysis or recommendation is made for Fe in Florida soils due to limited information on the correlation between soil and tissue levels, and turfgrass growth response. A greening in response to the application of Fe and/or Mn will most likely be obtained on turfgrasses grown on soils having a pH of 7.0 or greater or irrigated with alkaline water. The application of 2 ounces of iron sulfate per 1,000 ft^2 as a foliar spray usually produces the desired response. This response is generally short-lived, however, and reapplication may be required. For additional information, see UF/IFAS publication SL 181, *Soil and Tissue Testing and Interpretation for Florida Turfgrasses*, at **http://edis.ifas.ufl.edu/SS317**.

Fertilizing Grass for Establishment or Recovery

Establishment and recovery are special situations. The goal is to get the environmental benefits of a solid cover of turfgrass as quickly as possible, and this may require fertilization above what established turf requires. N and K are used to promote a thick, vigorous stand of turf. Use P only when a soil test indicates there is a need. The BMP for retaining nutrients on the lawn is a dense stand of turf.

The following measures can be used to fertilize grass for establishment or recovery:

- New sod should not be fertilized with nitrogen for the first 30 days, until it has firmly rooted into soil. Plugs can be fertilized at the time of installation to encourage the runners to spread. A quick, complete ground cover is the ultimate goal.
- Newly seeded areas should not receive nitrogen fertilization until a cover has been established and roots have pegged down, usually about 30 days.
- For new turf establishment only, soil test results may indicate a one-time application of up to 1 lb P_2O_5 /1,000 ft^2 is needed to encourage root growth. This should not be applied until 30 days after planting.
- Newly established turf often requires a different fertility schedule to grow and develop a dense stand. Both rates and timing may be different.
- Weakened turf may be stimulated back to health by N fertilization.
- N rates should be adjusted to meet the needs of the turf.
- Soluble fertilizer may be necessary to provide a rapid response on weakened turf.
- Lower total rates of soluble fertilizer can produce desired turf improvement when applied frequently.
- Fe and Mn may be useful to improve color, especially in neutral or alkaline soils. Micronutrients may provide an initial color response, while N thickens the turf and improves root development.
- Slow-release fertilizer may be an advantage when nutrients cannot be applied as frequently.

There is no significant difference between liquid or dry applications. Turfgrasses take up N in the form of nitrate and ammonium, and all dry fertilizers have to be dissolved by water before they benefit the turf. In terms of BMPs for environmental protection, the proper application of fertilizer is more important than the type of product.

Untreated Buffers near Bodies of Water

Except when adjacent to a protective seawall, always leave a "Ring of Responsibility" around or along the shoreline of canals, lakes, or waterways, so that you do not get fertilizer into a body of water. When fertilizing, it is important to ensure that fertilizers and other lawn chemicals do not come into direct contact with the water or with any structure bordering the water or a storm drain such as a sidewalk, brick border, driveway, or street. If any materials do get onto these impervious surfaces, sweep them into the vegetated landscape or otherwise clean them up. This untreated buffer protects the water quality of the waterway by ensuring no prills or droplets enter the water. When applying liquid fertilizers, the Ring of Responsibility should be at least 3 feet from the edge of the water.

The same is true for applying granular fertilizers with a broadcast fertilizer spreader that features a deflector shield (Figure 7.5). A deflector shield only allows fertilizer to be distributed on one side. This half-circle application (instead of the typical full-circle application of most fertilizer spreaders) allows for a more accurate fertilizer application.

If you are broadcasting fertilizer without a deflector shield, the Ring of Responsibility should extend at least 10 feet from the edge of the water, since the prills may be thrown up to seven feet.

The Ring of Responsibility is a preventative buffer that protects against accidental direct contamination when fertilizing, and is the responsibility of the applicator. Some communities may require larger treatment buffers, which are intended to absorb pollutants from stormwater flowing across the land. Land development codes in these communities require developers and builders to leave native vegetation or other riparian buffers or filter strips to protect the water from the broader effects of upland development. These areas usually do not require fertilization, or need it only during an initial establishment period. The applicator should understand and respect the nature of these areas.

Impervious Surfaces

Most urban landscapes are surrounded by impervious surfaces such as sidewalks, driveway and streets. An impervious surface that drains to a water body or the stormwater system is called a Directly Connected Impervious Area (DCIA). Fertilizer inadvertently applied on these surfaces has ready access to

Figure 7.5: Arrow indicating a deflector shield on a rotary spreader.

our water resources through storm drains. This is why it is so important to keep fertilizer off impervious surfaces and to remove any that is spilled on them and deposit it back into the landscape.

If using a broadcast spreader, deflector shields should always be used when applying fertilizer adjacent to these surfaces.

Fertigation

Fertigation is the application of liquid fertilizer thorough irrigation systems. While fertigation is not widely practiced in residential or commercial lawn and landscape care, some systems are available. For effective nutrient management to be achieved, a fertigation system should be designed, installed, and maintained by a qualified irrigation specialist. Proper and legal backflow prevention devices must be used so that fertilizer does not back-siphon into the water supply. Apply minimum quantities of fertilizer. Due to the hazards of direct deposition on streets, driveways, and sidewalks; and potential over-application by misadjusted irrigation systems; FDEP does not recommend use of fertigation for residential use unless the entire system is under an operation and maintenance contract with a reputable contractor who is fully responsible for any pollution due to improper operation of the fertigation equipment or the associated irrigation system.

Fertilizing Landscape Plants

Why Fertilize?

Clearly, plants grow in the wild without any help from humans. However, our modern urban landscape is not the same as the one where our native plants evolved. Subdivisions filled with subsoils, forests cut down, and drainage modifications all combine to make an urban landscape a very different environment. In addition, we have learned that some plants respond to fertilizers in ways that we may consider desirable, such as faster growth or improved appearance. The value of these outcomes is subjective. For example, faster growth may be desired in one circumstance but may lead to unwanted pruning in another. Improved appearance is important to some and unimportant to others.

Thus, the reason for fertilizing plants should be to supply nutrients to achieve a clearly defined objective, such as the following:

- Increasing shoot growth, root growth, flowering, or fruiting;
- Establishing newly planted trees and shrubs;
- Enhancing foliage color and plant appearance;
- Correcting or preventing nutrient deficiencies.

Recommendations and Basic Principles for Fertilizing Landscape Plants

The recommendations in this section do not pertain to products containing insecticides, herbicides, or other pesticides. By law, such products are considered pesticides. For-hire applicators must be licensed and the label instructions must be followed.

Important recommendations and principles for fertilizing landscape plants are as follows:

- Prior to fertilizing, a soil and/or foliar nutrient analysis should be used to determine whether any need exists for phosphorus fertilizer.
- Before fertilizing, pests may need to be controlled and/or soil modified to improve nutrient uptake or plant responses to fertilizer. Plants with pests or other problems that could increase to damaging levels with fertilization should be fertilized only in conjunction with a treatment program. Without a treatment program, fertilizer may increase the severity of the damage.
- Soil pH should be considered when selecting a fertilizer.
- The amount of fertilizer applied should be the minimal amount needed to achieve the defined objective.
- Read and follow **all** label instructions and safety precautions.
- The types and rates of fertilizer should be specified, as well as the timing, method, and location of application. Slow-release fertilizers are often preferred. High levels of nitrogen fertilizer may reduce flowering in some plants.

When to Fertilize

Fertilization MAY be justified in the following situations:

- If trees and shrubs are newly planted (thus justifying fertilization until established);
- If homeowners or clients desire more or faster growth;
- If landscape beds have been leached of nutrients by flooding or over-irrigation;
- If trees and shrubs are NOT near fertilized turfgrass;
- If established plants are lacking in foliage color or density for the homeowners' or clients' purposes;
- If plants exhibiting nutrient deficiencies are in situations where they cannot be replaced with better-adapted species.

Fertilization may NOT be required in the following situations:

- If homeowners or clients are pleased with the appearance of their landscape plants;
- If plants are established;
- If plants are flowering or fruiting, since exposure to high nitrogen at this stage may impede development;
- For trees, unless nutrient deficiencies exist.

If landscape plants exhibit nutrient deficiency symptoms, they may not be suited to the site due to soil pH, soil drainage, soil salts, limited soil volume, irrigation water quality, or mineral content of the soil. Consider replacing such plants with others adapted to the site's conditions.

General Recommendations. When it has been determined that fertilization is necessary, most established landscape plants should be fertilized at rates within the ranges shown in Table 7.2.

Table 7.2. Landscape plant nitrogen fertilization rates.

Level of maintenance	Amount of nitrogen fertilizer		
	lbs N / 1,000 ft^2/year	per 3 ft diameter plant/year[1]	
		Oz[2]	Tablespoons
Basic	0 - 2	0 - 3	0 - 6
Moderate	2 - 4	3 - 6	6 - 12
High	4 - 6	6 - 9	12 - 18

[1]Typical, assumes 15% N 50% slow release, approximately 7 ft^2 root zone.
[2]1 lb N rate is about 1.5 oz or 3 Tablespoons per 10 ft^2 per application.

The P content of the fertilizer should be zero unless a soil or tissue test indicates a need for additional phosphorus. Historically, the ratio of N to K for landscape plants has been in the range of 1:1 to 2:1. Since magnesium (Mg) deficiency occurs in certain landscape plants in many parts of the state, up to 2.5 pounds Mg/1,000 ft^2/year may be applied to address this problem. Micronutrients can be applied at specified rates and timing to achieve fertilization objectives.

In general, slow release fertilizers are horticulturally and environmentally preferable for landscape plantings. Water-soluble fertilizers should be applied at a rate of no more than 0.5 pounds N/1,000 ft^2 per application. The maximum application rates for controlled-release fertilizers depend on the percent that is water soluble and the release rates of the product. Never broadcast fertilizers on newly bedded plants. Apply the appropriate amounts to the individual plant within the area under the plant canopy, which usually indicates the major root area.

Palms. Palms have different nutritional requirements than most other landscape plants. In Florida's rock, muck, and sandy soils, palms may be especially prone to K, Mg, Mn, Fe, and B deficiencies. If you suspect deficiencies in a palm tree, take a leaf to your UF/IFAS Extension agent for assistance. In general, fertilizers or supplements should be applied to supply N, P, K, and Mg at about an 8:2:12:4 ratio. The N, K and Mg should be in a slow-release form. In addition, one to two percent Fe and Mn, and trace amounts of Zn, Cu, and B, may be needed.

For more information on palms and palm deficiencies, see UF/IFAS publications ENH 1009 *Fertilization of Field-grown and Landscape Palms in Florida,* **http://edis.ifas.ufl.edu/EP261** or ENH 1018 *Nutrient Deficiencies of Landscape and Field-grown Palms in Florida,* **http://edis.ifas.ufl.edu/EP273**.

Where and How to Fertilize

Fertilizer should be broadcast uniformly over the desired areas of the landscape. Root location, fertilization objectives, and plant species should be considered. Areas where tree or shrub fertilization zones overlap with lawn fertilization zones should receive one, not two, fertilizations. Start with the lowest recommended rate and slowly increase the amount up to the maximum recommendation only if the plant requires it. Foliar applications, injections, or implants should only be used when the soil application of fertilizer is impractical or ineffective in achieving fertilization objectives. When applying foliar fertilizer, the fertilizer solution should be thoroughly sprayed to cover the affected foliage at the proper stage of growth to achieve objectives.

Make sure your fertilizer spreader is properly calibrated and on the correct setting to deliver the desired amount of fertilizer for the area being treated (Figure 7.6). This is discussed in more detail in the section on calibrating pesticide spreaders.

Figure 7.6: Make sure the spreader is set correctly.

Fertilizer Storage and Loading

If not handled properly, fertilizers can alter or degrade the environment. Nutrients such as N and P in fertilizers can lead to the excessive growth of algae and noxious plants in estuaries, lakes, and streams.

Mishandling of fertilizers containing nitrates may result in excessively high levels of nitrate in drinking-water supplies (greater than 10 parts per million [ppm] of NO_3-N). This has been linked to health problems such as "blue baby" syndrome (methemoglobinemia) in infants. Because the state's aquifers and surface waters are extensively interconnected, Florida requires all potentially potable ground water to meet drinking-water standards. For nitrate, federal and state regulations set the drinking-water standard at 10 ppm NO_3-N. Shallow wells (less than 50 feet in depth) and old wells with faulty casings are at the highest risk for nitrate contamination.

Storage

Always store nitrate-based fertilizers separately from solvents, fuels, and pesticides, since nitrate fertilizers are oxidants and can accelerate a fire. Ideally, fertilizer should be stored in a concrete building with a metal or other flame-resistant roof.

Take care when storing fertilizer to prevent the contamination of nearby ground water and surface water. Always store fertilizer in an area that is protected from rainfall (Figure 7.7). Storing dry bulk materials on a concrete or asphalt pad may be acceptable if the pad is adequately protected from rainfall and from water flowing across the pad. The secondary containment of stationary liquid fertilizer tanks is addressed in Florida Department of Environmental Protection Rules 62-761 and 62-762, Florida Administrative Code (F.A.C.). Even where not required, the use of secondary containment is sound practice.

Figure 7.7: Fertilizer should be stored in a dry place protected from rainfall.

Loading

Load fertilizer into application equipment away from wells or surface waterbodies. A concrete or asphalt pad with rainfall protection is ideal, as it permits the easy recovery of spilled material. If this is not feasible, loading at random locations in the field can prevent a buildup of nutrients in one location. Fertilizers contaminated with pesticides may damage plants or generate hazardous wastes.

Clean up spilled fertilizer materials immediately. Collected material may be applied as a fertilizer. At fixed sites, the area can be cleaned by sweeping or vacuuming (or with a shovel or loader, if a large spill), or by washing down the loading area to a containment basin specifically designed to permit the recovery and reuse of the wash water. Wash water generated should be collected and applied to the target crop. Discharging this wash water to waterbodies, wetlands, storm drains, or septic systems is illegal.

For more information, see *Best Management Practices for Agrichemical Handling and Farm Equipment Maintenance*, published by the Florida Department of Agriculture and Consumer Services and the Florida Department of Environmental Protection, at **http://dep.state.fl.us/water/nonpoint/docs/nonpoint/agbmp3p.pdf**.

Soil Testing

Although it may not be an essential practice for the everyday maintenance of a healthy landscape, testing to determine the soil's chemical properties before installing turfgrass or landscape plants is a recommended practice. Through soil testing, the initial soil pH and P level can be determined. Soil pH is important in determining which turfgrass is most adapted to initial soil conditions (bahiagrass and centipedegrass are not well adapted to soil with a pH greater than 7.0). Since it is not easy to reduce the pH of soil on a long-term basis, you should use St. Augustinegrass or bermudagrass on high-pH soils.

After initial soil testing, additional testing may only be required when fertility problems arise and the responses to fertilization are poor.

Soil testing is an applied science and can be used as one of the tools in the maintenance of healthy turfgrass and landscapes (Figure 7.8). For the effective management of nutrients, soil testing should be used in conjunction with tissue testing. Soil test recommendations are based on a correlation between the level of a given nutrient extracted from the soil and the anticipated plant response. The amount of nutrients extracted by a particular extractant is only an index relative to crop response. It is not a direct measure of actual plant nutrient availability.

The levels of extracted P, K, and Mg are divided into five categories: very low, low, medium, high, and very high.

For more information, see your UF/IFAS Extension agent or UF/IFAS publication SL 181, *Soil and Tissue Testing and Interpretation for Florida Turfgrasses*, at **http://edis.ifas.ufl.edu/SS317**.

Figure 7.8: Taking a soil sample.

Soil Sampling Methodology

The soil test and resulting recommendations are only as representative as the sample itself. Therefore, it is imperative that the soil sample be taken and handled properly. The sample should be obtained by taking 15 to 20 small plugs at random over the entire area where information is desired (Figure 7.9). Avoid any unusual areas or areas with a specific identifying appearance. Areas with identifying characteristics should be sampled separately. For turfgrass, since most of the roots are in the top four inches of soil, limit the sampling depth to four inches. For landscape plants, the sampling depth should be no more than six inches.

Place the plugs that have been collected into a plastic container, mix them thoroughly, and send approximately one pint of the mixed sample to the Extension Soil Testing Laboratory (ESTL) for chemical analysis. Several commercial laboratories also offer the same service in Florida. You should use the same laboratory on a continued basis to establish a historical log of your soil properties. Laboratories across the state do not use the same extractant, so if you change labs often you may be comparing results obtained by different methods.

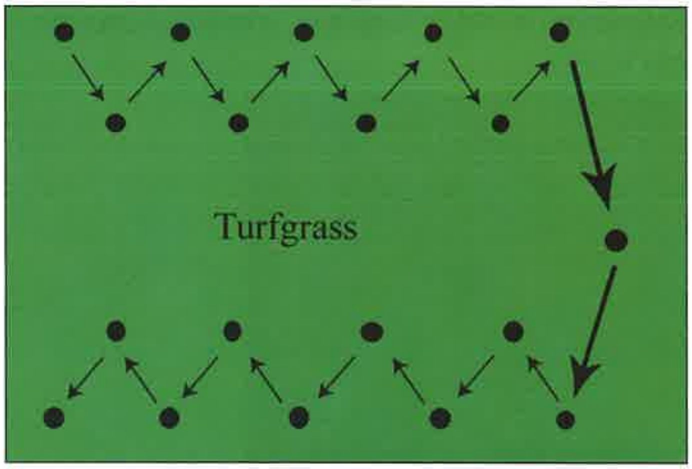


Figure 7.9: Pattern for taking a soil sample.

Soil Test Interpretation

A soil analysis supplies a wealth of information on the nutritional status of a soil and can detect potential problems that limit plant growth. A routine soil analysis supplies information on soil pH and the extractable P, K, Ca, and Mg status of the soil. The ESTL currently uses Mehlich-1 as an extractant on all the acidic mineral soils in the state and AB-DTPA (Ammonium Bicarbonate-DTPA) extractant on soils with pH above 7.3 (calcareous soils).

The UF/IFAS Everglades Extension Soils Laboratory currently uses acetic acid to extract nutrients from all organic soils. Therefore, the extractants are calibrated to different soil types. These extraction procedures must be ascertained when approaching any laboratory for a soil analysis. The routine analysis includes a lime requirement determination if the soil pH is below 6.0. N is not determined, because in most soils it is highly mobile and its soil status varies greatly with rainfall and irrigation events.

Table 7.3 presents interpretation ranges for soil test levels of P, K, Mg, Mn, Zn, and Cu. For detailed explanations of soil tests and interpretation, see UF/IFAS publication SL 181, *Soil and Tissue Testing and Interpretation for Florida Turfgrasses*, at **http://edis.ifas.ufl.edu/SS317**.

Note that there is no interpretation made for soil test Ca or Fe. No interpretation is made for Mehlich-1 extractable Ca levels because the extractant dissolves Ca compounds, which may not be readily plant available. Thus, the amount of plant-available Ca can be erroneously interpreted. In most cases, Ca levels are adequate for turfgrass growth because Florida soils are inherently high in Ca, have a history of Ca fertilization, or receive Ca regularly through irrigation with high-Ca water. The soil test level for Mehlich-1 extractable Ca is used only to determine the type of limestone needed when lime is recommended. For most soils and turfgrasses, liming to ensure an adequate soil pH ensures more-than-adequate Ca. Research has shown no turfgrass response to added Ca, from either liming materials or gypsum, when the Mehlich-1 extractable Ca level is above 250 ppm.

The ESTL does not analyze for extractable Fe because definitive interpretation data are lacking. Significant correlation of soil test Fe levels with plant tissue levels is also lacking. The testing procedures tend to produce highly variable results. Most soils, except those having a pH greater than 7.0, generally contain adequate levels of Fe for optimum growth. Turfgrasses grown on soils with pH greater than 6.5 exhibit a greening response to Fe applied as a foliar spray. Unfortunately, reapplication may be required on a frequent basis to sustain the desired color.

Table 7.3. Suggested ranges for Mehlich-1 extractable soil nutrient levels for Florida turfgrasses.

Macronutrients[1]			Micronutrients[2]		
P	K	Mg	Mn	Zn	Cu
Parts per million (ppm)					
16 - 30	36 - 60	20 - 30	3 - 9	0.5 - 3	0.1 - 0.5

[1]Medium ranges of Mehlich-1 extractable P, K, and Mg when in 25% of the cases a response to applied fertilization would be expected.

[2]Soils testing below these levels of micronutrients are expected to respond to applied micronutrients. The interpretation of soil test micronutrient levels is based on soil pH. The smaller number is for soils with a pH of less than 6.0 and the larger number is for soils with a pH of 7.0 or greater. Mehlich-1 extractable micronutrient levels are only determined when requested and require an additional charge.

Tissue Testing

Because of the mobility of most essential nutrients for landscape plant and turfgrass growth in Florida soils, one of the best indicators of appropriate fertilization and plant health is tissue analysis. Since turfgrass is a perennial crop, historical logs of tissue composition can be used to fine-tune a turfgrass fertilization program for optimum plant growth and minimum environmental impact. Leaf analysis, along with appearance and soil analysis, can be used to diagnose the problems and the effectiveness of a fertilization program, especially for micronutrient deficiencies. Because it is a snapshot of what is present at the time of sampling, soil analysis for some nutrients does not always indicate their availability to plants. Potential nutrient deficiencies can be detected with leaf analysis before visual symptoms appear. Leaf analysis may provide information on induced deficiencies and inferences on plant uptake.

Tissue Sampling Methodology

Clippings can be collected during regular mowing practices for tissue analysis. It is essential that the clippings are free of sand and fertilizer contamination. Do not harvest clippings immediately after fertilization, top-dressing, or any other cultural practice that results in significant mower pickup. Place approximately a handful of well-mixed clippings in a paper bag. Do not place the clippings in a plastic bag because the clippings may begin fermenting prior to drying.

If facilities exist at your location, dry the collected clippings at approximately 158°F for 24 hours and then mail them to your favorite analytical laboratory for analysis. If you do not have drying facilities, ship them, preferably overnight, to the analytical laboratory. Even if placed in a paper bag, if the sample is allowed to sit for more than a couple of days the tissue will begin to ferment and the value of the sample for analytical purposes will be lost.

Sample Contamination

Turfgrass clippings that have been recently sprayed with micronutrients for fungicidal or nutritional purposes should not be used for micronutrient analysis. Washing recently unsprayed clippings to remove soil and dust particles is recommended prior to sending the samples to the lab for analysis. If you wash one collection of clippings and not all, the nutritional analyses may not be comparable because the concentration of some nutrients in tissue, such as K, is highly mobile and a portion of the K may be removed during washing. Unwashed samples may appear to have a much higher concentration than the washed samples, and you may suspect a deficiency in the washed samples when in fact an adequate supply of K exists.

Interpretation of Results

Sufficiency levels of essential nutrients in the various turfgrass species do not vary much among the various species, except for N. The sufficiency tissue N concentration can vary from a low of 1.5% for centipedegrass or bahiagrass to a high of 3.5% in cool-season, overseeded ryegrass. Table 7.4 lists the sufficiency ranges for tissue N concentration for the various turfgrasses used in lawns. In most cases, tissue N concentrations below the minimum of the range would be deficient and above the range would be excessive.

The concentration of other macro and micronutrients in the tissue does not vary greatly among the various species of turfgrasses. The sufficiency ranges in Table 7.5 are applicable to most of Florida's turfgrass species. All of these values are on a dry weight basis.

Table 7.4. Sufficiency ranges of tissue N concentration for selected lawn turfgrasses.

N (%)					
St. Augustine	Zoysia	Bermuda	Centipede	Bahia	Rye
2.0 - 3.0	2.0 - 3.0	2.5 - 3.5	1.5 - 2.5	1.5 - 2.5	3.5 - 5.5

Table 7.5. Sufficiency concentration ranges for selected macro and micronutrients in turfgrass tissue.

P	K	Ca	Mg	Fe	Cu	Mn	Zn	B
Percent (%)				ppm				
0.15 - 0.50	1.00 - 3.00	0.5 - 1.0	0.20 - 0.50	50 - 250	5 - 30	25 - 100	20 - 250	5 - 20

These values represent the range over which a particular nutrient might vary across the various species of turfgrasses. They represent sufficiency ranges, which suggest that levels below the range may indicate a deficiency or above the range may represent excessive fertilization or toxicity.

The sufficiency ranges in the tables show the most current interpretation for nutrient concentrations in turfgrass tissue. If analytical test results are in the deficiency range or below the sufficiency range, an increase in fertilization for that nutrient is recommended. Alternatively, if test results fall above the sufficiency range, the fertilization program should be adjusted downward. If a change in fertilization is indicated, the adjustment should be reasonable. The intent is to find the correct nutrient management level that maintains turfgrass tissue nutrient concentration within the optimum range, but does not lead to over-fertilization and possible adverse environmental and economic results.

Figure 7.10: Fertilization is a key turfgrass management practice.

Summary

Fertilization is one of the key management practices in establishing and maintaining healthy, actively growing turfgrass (Figure 7.10). The desires of the individual lawn owner or turfgrass manager often dictate the level of fertility management. Due to environmental concerns, some think that less fertilization is always best, but research shows that fewer nutrients are lost from the surface or leached through a healthy, well-maintained turfgrass than an unhealthy, sparsely established turfgrass.

The importance of proper irrigation during fertilization cannot be overemphasized. Excessive irrigation after fertilization may cause leaching or runoff, and a lack of irrigation may result in volatilization and inefficient use of fertilizer.

Due to the prevalence of streets, driveways, and other impervious areas, it is very important to ensure no fertilizers are left where they can run off into stormwater systems or water bodies. Deflector shields should always be used near boundaries with water or impervious areas.

The following bullet points best summarize the key BMPs emphasized in this chapter:

- Do not fertilize if a heavy rainfall is expected, especially tropical or frontal weather systems.
- Avoid both leaching and surface runoff. Match the product to the situation. Remember that all fertilizers, even slow release products, contain nutrients and can cause pollution if allowed to escape the root zone.
- Correct other deficiencies first. Be aware of the effects soil pH, shade, overwatering, or other stresses may have on the plants. Be sure fertilizer is the correct response to the problem.
- Remember that rate and timing of N fertilization depends on the turfgrass species, season of the year, level of maintenance desired, source of N applied, and location in the state.
- Limit water-soluble (quick release) nitrogen applications to 0.5 lb/1,000 ft^2. This includes the water soluble part of slow-release blends. Limit total N to 1 lb/1,000ft^2 per the Urban Turf Rule.
- P application should be limited to soils that require additional P based on soil or tissue testing.
- Limit N and P fertilization at establishment to one time 30 days after seeding/sodding. Do not add N or P before installation, but amend the soil as needed with lime or organic matter.

- Always leave a Ring of Responsibility near water bodies or impervious surfaces. Always use deflector shields on broadcast or rotary spreaders when applying fertilizer near water or sidewalks, driveways and streets.
- Sweep any fertilizer left on impervious areas back into the vegetated area.
- Become proficient in reading and understanding the fertilizer label.
- Know the exact square footage of the area where fertilizer is being applied and make sure the spreader/application equipment is properly calibrated and set to deliver the correct amount of fertilizer to that area.
- Become knowledgeable in soil sampling procedures and soil test interpretation.
- When fertilizing (other than when watering restrictions apply), irrigate with ¼ inch of water following fertilization to avoid the loss of nitrogen and increase uptake efficiency. If water restrictions apply, you may irrigate as you are allowed, but more than ½ inch may cause some nitrogen to be leached past the root zone.
- Use Fe and/or Mn instead of N to enhance turfgrass color on soils having a pH greater than 7.0, especially during times of enhanced rainfall.
- Maintain a healthy, actively growing turfgrass to minimize the environmental impact of fertilizer and pesticide application, erosion, and stormwater runoff.
- There is no significant difference between liquid or dry applications of similar products. In terms of BMPs for environmental protection, *the proper application of fertilizer is more important than the type of product.*

Test Your Knowledge

Q: What does a fertilizer grade (analysis) of 24-6-12 indicate?
A. The fertilizer contains 24% P_2O_5, 6% N, and 12% K_2O
B. The fertilizer contains 24% K_2O, 6% P_2O_5, and 12% N
C. The fertilizer contains 24% N, 6% K_2O, and 12% P_2O_5
D. The fertilizer contains 24% N, 6% P_2O_5, and 12% K_2O
A: D

Q: What is the overall purpose of Florida's Urban Turf Fertilizer Rule?
A. It limits the amount of N and P that manufacturers may recommend for application on urban turf and lawns
B. It requires that soil and tissue testing be conducted prior to any fertilizer application on urban turf and lawns
C. It requires that the maximum amount of irrigation applied to any urban turf or lawn not to exceed ¼ inch of water per application
D. It does not allow the application of any pesticides to urban turf and lawns during the months of October through February
A: A

Q: Why doesn't soil sampling provide an analysis for N?
A. Because N is a secondary nutrient and is needed in relatively small quantities
B. Because N is highly mobile in Florida's sandy soils
C. Because a standard rate of 5.0 lbs/1,000 ft^2 is recommended regardless of other factors
D. Because current laboratory procedures are not capable of detecting it
A: B

Q: What is a practical means to minimize volatilization loss from a N source such as urea?
A. Conduct core aeration to the turfgrass, then apply the urea
B. Do not apply liquid formulations of urea on windy days
C. Following urea application, irrigate with ¼ inch water
D. Apply the urea during the night to prevent photodegradation
A: C

Q: Match the N source with its release characteristics:

1. Ammonium nitrate, ammonium sulfate, urea
2. Isobutylidene diurea, sulfur coated urea, Methylenediurea

A. Slow release B. Quick release

A: 1-B, 2-A

Q: True or False:
The proper application of fertilizer is more important than the type of product.
A: True

Q: True or False:
Slow-release N sources are likely to leach more than equal amounts of soluble N sources.
A: False

Q: What is the recommended maximum amount of water-soluble N per 1,000 ft^2 per application?
A. ¼ lb
B. ½ lb
C. ¾ lb
D. 1 lb
A: B

Q: Regardless of region in Florida, which lawn turfgrass species has the lowest N fertilizer requirement?
A. Bermudagrass
B. St. Augustinegrass
C. Bahiagrass
D. Centipedegrass
A: D

Q: Match the nutrients with their type:

1. N, P, K	A. Micro
2. Ca, Mg, S	B. Secondary
3. Fe, Mn, Cu	C. Primary

A: 1-C, 2-B, 3-A

Q: Which of the following statements is ***false*** regarding P fertilization?
A. P has been implicated as a cause of increased algae growth in surface water impoundments
B. The goal in P management is to apply the correct amount based on soil test recommendations
C. The Urban Turf Fertilizer Rule does not pertain to P, but only N
D. The proper management of P on turfgrass is just as important to the environment as N management
A: C

Q: Which of the following statements is ***false*** regarding K fertilization?
A. Large responses in turfgrass growth are not typically observed in response to K fertilization
B. K has been linked to reduced disease incidence, drought and cold tolerance
C. The K fertilization rate is often tied to the N fertilization level, generally in a 3:1, 2:1, or 1:1 ratio.
D. K is relatively immobile in soil compared with N
A: D

Q: What is the meaning of the concept, "Ring of Responsibility?"
A. To use pest management methods which exclude the use of pesticides
B. To maintain a buffer in order not to get fertilizer into a body of water
C. To maintain relatively higher soil pH values around a 3-foot zone of landscape tree trunks
D. To make fertigation a more common practice around clients' landscapes
A: B

Q: What is a practical means to apply fertilizer around bodies of water and impervious surfaces in order to abide by the "Ring of Responsibility"?
A. Use a Scott's electric-powered fertilizer spreader
B. Install a deflector shield on the fertilizer spreader
C. Apply fertilizer sources containing only water soluble N
D. Apply fertilizer only when rain is forecasted in order to move it into the root zone
A: B

Q: Which of the following statements is ***false*** regarding the fertilization of landscape plants?

A. High levels of nitrogen fertilizer can induce flowering in plants
B. Prior to fertilizing, a soil and/or foliar nutrient analysis should be used
C. Fertilization may be justified if trees and shrubs are newly planted
D. Magnesium (Mg) deficiency occurs in certain landscape plants in many parts of the state

A: A

Q: True or False:
Palms have different nutritional requirements than most other landscape plants.

A: True

Q: Which of the following statements is ***false*** regarding soil testing?

A. Testing is recommended before installing turfgrass or landscape plants
B. It is important in determining which turfgrass is most adapted to initial soil pH conditions
C. Recommendations are based on a correlation between the level of a given nutrient extracted from the soil and the anticipated plant response
D. Soil testing should be conducted separately from tissue testing

A: D

Q: What is an advantage of tissue testing for maintaining healthy fertility levels? (Select all that apply)

A. It is a good indicator because of the mobility of most essential nutrients for landscape plant and turfgrass growth
B. Historical logs of tissue composition can be used to fine-tune a turfgrass fertilization program
C. It is especially effective for diagnosing micronutrient deficiencies
D. It is a snapshot of what is present at the time of sampling, as soil sampling does not always indicate nutrient availability to plants
E. Potential nutrient deficiencies can be detected with leaf analysis before visual symptoms appear

A: A, B, C, D, E

Chapter 8

Integrated Pest Management

In this Chapter

Learning Objectives

After you complete your study of this chapter, you should be able to:

- Define IPM.
- Name five practices that are common to all IPM programs.
- Describe the following concepts:
  - Aesthetic injury level
  - Economic threshold
- Describe several methods to prevent pest problems from occurring.
- Describe the following IPM practices:
  - Cultural control
  - Biological control
  - Mechanical and physical controls
  - Genetic control
  - Chemical control
- Be able to identify beneficial arthropods that commonly occur in the landscape.

Terms to Know

Aesthetic injury level (AIL): A level of pest damage or number of pests the general public or a customer will tolerate on a plant or landscape.

Biological control: The release and/or conservation of natural enemies (such as parasites, predators, and pathogens) and other beneficial organisms (such as pollinators).

BMPs: Best management practices. Procedures to reduce nonpoint source pollution and promote the efficient use of water.

Cultural control: The proper selection, establishment, and maintenance (such as mowing/pruning, fertilization, and irrigation) of turf and landscape plants.

Economic threshold: The density of a pest at which a management intervention is economically justified.

Integrated pest management (IPM): the selection, integration, and implementation of multiple pest control techniques based on predictable economic, ecological, and sociological consequences, making maximum use of naturally occurring pest controls, such as weather, disease agents, and parasitoids; using various biological, physical, chemical, and habitat modification methods of control; and using artificial controls only as required to keep particular pests from surpassing intolerable population levels predetermined from an accurate assessment of the pest damage potential and the ecological, sociological, and economic costs of other control measures.

Mechanical or physical control: The use of tools, machines, or hands to reduce pests.

Oviposition: To deposit or lay eggs.

Saprophytes: An organism that lives on dead or decaying organic matter.

What is Integrated Pest Management (IPM)?

The philosophy of IPM was developed in the 1950s because of concerns over increased pesticide use, environmental contamination, and the development of pesticide resistance. The objectives of IPM include reducing pest management expenses, conserving energy, and reducing the risk of exposure to people, animals, and the environment. Emphasis should be placed on preventative practices such as sanitation (e.g., weed control, removal of plant debris), proper fertilization, irrigation, pruning, etc. Examples of management activities that affect pests and diseases include selection of resistant plant species, regulation of irrigation timing and frequency, use of least-toxic pesticides as needed to preserve beneficial organisms and reduce environmental contamination, or application of biological control agents. Its main goal, however, is to reduce pesticide use by using a combination of tactics to control pests, including cultural, biological, genetic, mechanical, and physical, as well as chemical controls.

The following five practices are common to all IPM programs:

1. Identify pests correctly
2. Monitor and scout pests
3. Follow control-action guidelines
4. Prevent pest problems
5. Use different IPM practices together (integrate)

IPM is commonly used in agricultural crop production, where the economic thresholds for key pests have been determined. Using IPM in the urban environment, however, has been more challenging. The Green Industry is sensitive to aesthetic damage, and customers are often intolerant of anything that could affect the appearance of ornamental plants. Increased education of growers, consumers, and maintenance personnel could raise the aesthetic threshold and allow for minor damage without compromising plant health and beauty.

Identify Pests Correctly

Determine the identification of the pests (Figure 8.1). Most pest management practices, including pesticide use, are effective only against certain species of pests. Because of this, you must know which pests are causing the problem before you choose a management practice. You need to:

- Identify pests correctly to determine the pests present.
- Determine the pest's life cycle, and know which life stage to target (e.g., for an insect pest, whether it is an egg, larva/nymph, pupa, or adult).
- Determine potential damage they may cause.

Monitor and Scout Pests

Scouting or monitoring is one of the most important tools of any IPM program. The timely detection of pests and accurate assessment of population densities of the pests and their natural enemies are fundamental to IPM decision-making. Early detection of pests enables the manager to reduce plant damage, improve plant quality, reduce production costs, avoid production delays and increase profits. Continuous pest

Figure 8.1: Pests identification is the first step in IPM.

monitoring and accurate record-keeping help predict when pests most frequently occur and will increase the ability to anticipate and schedule activities related to pest management. Detection should be followed closely with appropriate controls when necessary to prevent pest outbreaks. Scouting provides the overview and the raw data by which preventative and pest management options are chosen.

Pest management systems cannot be implemented if a manager does not know which pests exist and whether populations are significant. Therefore, a scouting plan must be devised for each site. To be successful, scouting must be performed routinely and consistently. Knowledge of the plant and its pests forms the background for successful monitoring. Several prerequisites must be satisfied to implement a successful monitoring program. The scout must do the following:

- Divide the site into logical units and make maps of these units so that all areas can be efficiently monitored on a routine basis. Communicate pest and plant species information clearly and consistently to those responsible for acting on that information.
- Define key plants/pests, such as azalea and azalea lace bugs (Figure 8.2 and 8.3) with your clients. Both the client and the manager must agree on those plants that are key plants for purposes of routine scouting.

Figure 8.2: Damage caused by azalea lace bug. Credit: J.L. Castner, UF/IFAS Entomology and Nematology.

Figure 8.3: Azalea lace bugs. Credit: L.J. Buss, UF/IFAS Entomology and Nematology.

The frequency of monitoring is determined by pest trends, desired level of aesthetics and the cost of pest control. During periods when turfgrass and landscape plants are actively growing or pests are active, you may have to monitor more often. When lawns and other plants are dormant or growth is slow, scouting may be less frequent.

Look for abnormal plant symptoms, direct evidence of insects, mites or pathogen signs, and situational problems such as malfunctioning sprinkler heads. Walk at random through the landscape area in a zigzag pattern.

Make an effort to select those plants that appear less healthy for visual inspection. In other words, conduct biased sampling. Examine foliage for signs of trouble, checking both new and old growth, but predominately the new growth. Examine both leaf surfaces, especially the undersides, and also the leaf axils for large insects and symptoms of foliar nematodes and diseases. Use a hand lens to facilitate observation of the smaller pests such as mites and thrips, or the reproductive signs of fungal pathogens. During individual plant inspection, strike the foliage over a white sheet of paper or a paper plate to dislodge small pests, primarily mites and thrips, for easier viewing (Figure 8.4). When problem spots are identified, increase the number of plants inspected in those areas.

Yellow sticky traps (cups, plates, or cards) that attract and capture whiteflies, aphids, thrips, and leafminer flies are valuable aids in monitoring for early invasions and serve as an index of activity for these pests. Place just above the plant canopy. Determine a rough count of plants with symptoms of disease or insect injury. It is also important to look closely at certain problem areas such as weedy spots.

Figure 8.4: Strike the foliage over a white sheet of paper or a paper plate to dislodge small pests, such as mites. Credit: L.J. Buss, UF/IFAS Entomology and Nematology.

This information can be combined with historical records, sticky trap data, random plant counts, and indicator plant records so that predictions and decisions can be made concerning pesticide applications. Record an estimate of the percent of the pest populations in each life stage in relation to the sample unit. These data will help assess the risk of further damage and the pest population status. Immediate application of control measures is usually only cost-effective for populations that are increasing. Much money is wasted by treating infestations that are declining. This error is compounded by the detrimental impact of chemical controls on beneficials, which are often most abundant at the termination of a pest infestation.

Follow Control-Action Guidelines

Control-action guidelines will help you decide how to avoid possible losses from pest damage. How many pests and how much damage are acceptable or tolerable? Control-action guidelines include:

- Aesthetic injury levels
- Treatment thresholds
- Timing

Aesthetic injury levels. An aesthetic injury level (AIL) can help you decide when pests need control. "Aesthetic" means how good or nice something appears. The AIL is a level of pest damage or number of pests the general public or a customer will tolerate on a plant or landscape. Aesthetic tolerances depend on the person and where the damage is on the plant or turfgrass and where it is in the landscape.

Examples: People may tolerate some pest damage to plants in the background of a landscape. They may be less tolerant of pest damage to plants in places easily seen. Some people do not want to see any insects or weeds or damage. This may not bother others at all. Educating customers can help them become more tolerant of pests and their damage.

Treatment thresholds. You may use treatment thresholds to decide when to control a pest. The treatment threshold refers to the number of pests on the plants or certain plant parts. If pests reach this number, begin control measures to prevent reaching the AIL.

Sometimes, though, you may have to treat certain pests well before the damage appears. You may need to control pathogens that cause disease before they begin developing. If you do not, they will develop and spread rapidly if the environment is favorable.

Highly maintained landscapes have a lower aesthetic threshold (Figure 8.5). Nothing can be out of place. Because of this, action may be necessary sooner and more often. Landscapes kept at much lower maintenance levels have higher aesthetic thresholds (Figure 8.6). These areas do not need treatment as often, if any at all.

Figure 8.5: Landscape with low aesthetic threshold.

Figure 8.6: Landscape with high aesthetic threshold.

How quickly you need to act to reduce pests will also assist your decision-making. Pesticides generally kill more pests faster than natural enemies. But natural enemies will suppress pests for the long term better than pesticides.

Timing. Thresholds do not always indicate when the treatments are most effective. For example, a fungicide must cover the plant surface to protect the plant prior to fungal infection. Leaves that appear after treatment may not be protected from fungi. More fungicide applications may be necessary to protect the new growth.

Certain stages of a pest's life cycle influence the effectiveness of pesticides. It is important that you use pesticides and other management practices at the time when they are most effective against pests. To determine the proper times to use pesticides, become knowledgeable of the most susceptible stages of the pest's life cycle. Examples:

- Scale insects are often noticed after plant damage appears, such as leaf yellowing or dieback (Figure 8.7). An insecticide applied after damage appears is often ineffective. The most effective treatment timing for many scale species is when the young nymphs are active. The wax on their bodies protects older nymphs and adults from insecticides that contact them. Horticultural oil can control scales at any stage by suffocating them. The most effective time to apply this oil is when plants are dormant or when temperatures are below 90°F.

- For turfgrass, mole crickets are more susceptible to chemical control when they are immature (Figure 8.8). Chemicals applied at other times are not as effective. In general, insecticides are most effective on young, immature insect pests.

Figure 8.7: Armored scale infestation. Credit: L.J. Buss, UF/IFAS Entomology and Nematology.

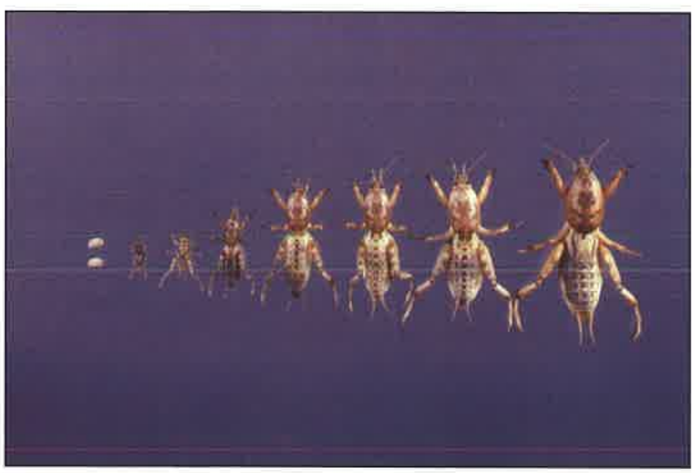


Figure 8.8: Mole cricket life stages. Credit: J.L. Castner, former UF/ IFAS Entomology and Nematology.

Prevent Pest Problems

To prevent pest problems, you can plant pest-resistant plants and grass or change the landscape.

Pest-resistant plants. One of the most dependable methods to prevent problems is to plant pest-resistant turfgrass cultivars. Pest-resistant plants and turfgrass are very effective cultural controls. This method is very useful in the management of plant pathogens, nematodes and some insects. Examples:

- Some rose cultivars resist powdery mildew and black spot (Figure 8.9).

- The dwarf yedda cultivar of Indian hawthorn resists Entomosporium leaf spot disease.

- Some crape myrtles resist powdery mildew disease.

Pest resistance is also somewhat useful with insect pests. Pest resistance is long-term, is cost effective and does not require special equipment.

Change the landscape. Make alterations to the landscape so that it does not attract pests. Examples:

- Reduce food, water and shelter that attract pests.

- Install plants in the landscape that attract the natural enemies of pests.

- Pest-resistant plants also can be part of a habitat change.

Use Different IPM Practices Together (Integrate)

Biological, cultural, genetic, physical or mechanical and chemical controls are all IPM practices. Use them as necessary to help prevent problems and keep pest numbers down.

Cultural Control

The cultural component consists of the proper selection, establishment, and maintenance (such as mowing/pruning, fertilization, and irrigation) of turf and landscape plants. Keeping lawns and landscapes healthy reduces their

Figure 8.9: Black spot of rose, a common fungal disease of roses. Credit: J. Mangandi, UF/IFAS Gulf Coast Research and Education Center.

susceptibility to diseases, nematodes, and insects, thereby reducing the need for chemical treatment. In the service industry, unfortunately, many of the cultural components of IPM are not under the control of the pesticide application professional. It is essential that customers be made aware of their responsibility for cultural factors, whether in doing their own work or in selecting qualified professionals for third-party activities such as irrigation and mowing.

Put the right plant in the right place. Plants growing in adverse conditions very likely will have disease or insect problems. No amount of pesticides eliminates pests as long as the area is not conducive for a specific plant. Examples:

- Planting turfgrass in dense shade or most azalea cultivars in full sun are not the optimal sites for these plants. Plants and groundcovers native to the area are a good choice if the location and growing conditions are favorable.

- Native plants (Figure 8.10) are a good choice if an owner does not mind a less formal landscape. However, native plants placed where they cannot grow properly can have also have problems.

Know your USDA plant hardiness zone. The USDA plant hardiness zone map is the standard by which gardeners and

Figure 8.10: American beautyberry is a native plant of Florida. Credit: St. Johns River Water Management District, Palatka, FL.

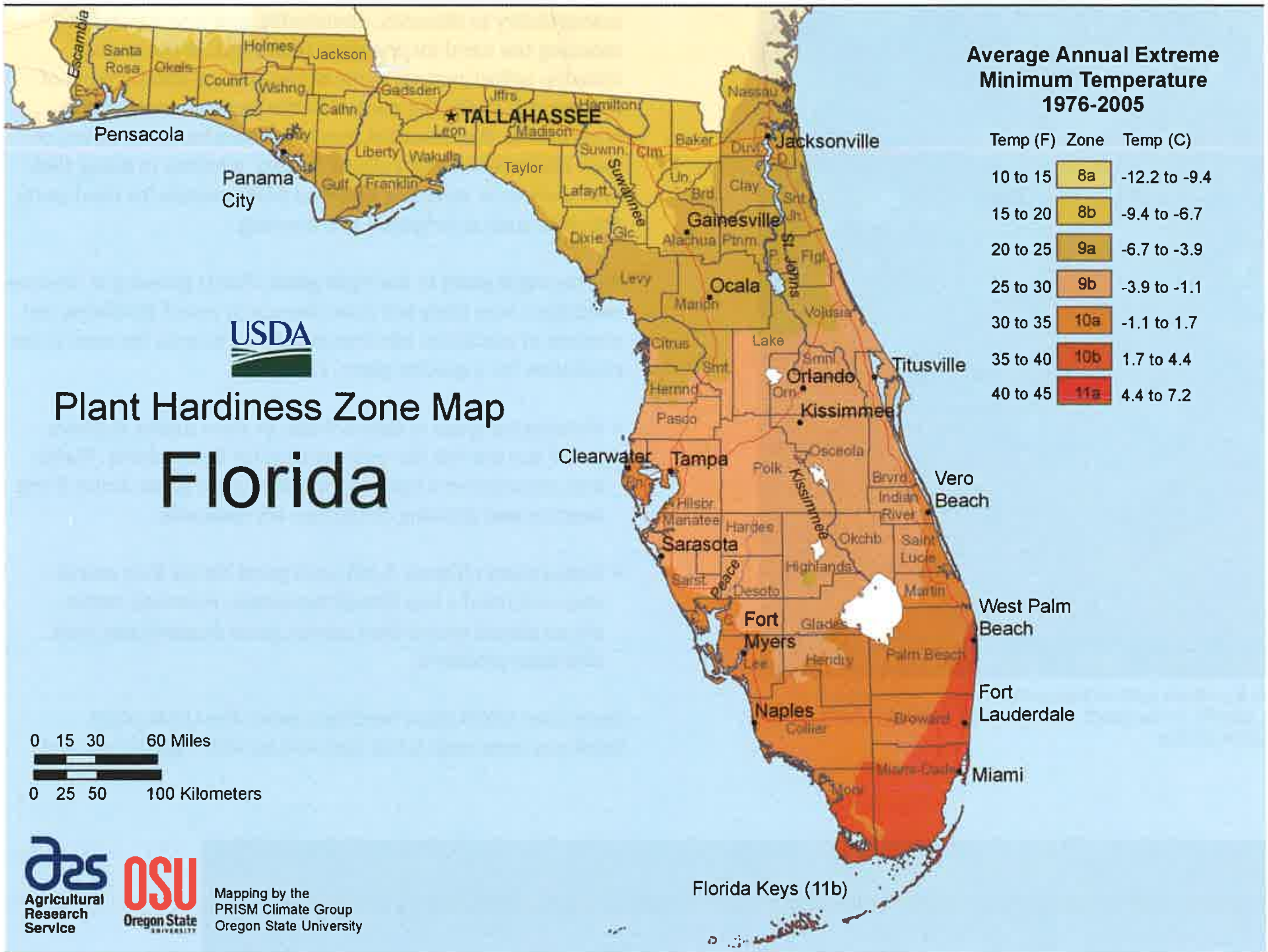


Figure 8.11: USDA plant hardiness zone map of Florida. Credit: USDA.

growers can determine which plants are most likely to thrive at a location (Figure 8.11). The map is based on the average annual minimum winter temperature, divided into 10°F zones. Hardiness zone maps are a good shorthand method for approximating where plants will grow, but they need to be taken with a grain of salt. For the most part, the simple and easy-to-use USDA map does a good job of identifying both the northern and southern limits of where a plant will grow.

Use materials that are pest free. Check seeds, plants, plugs and sod for pests before you buy them. For turfgrass, Florida has a certification program to provide pest-free plant material. Each bag of grass seed must provide information on purity and germination percentages, and a list of weed seeds. Some weeds are determined to be harmful to the environment and classified as noxious. Other weeds crowd desirable plants. Bags of certified seed have few, if any, of these weeds (Figure 8.12).

Prepare the planting site. Proper preparation of the planting site helps new plants become established and continue to grow well. Check areas that have irrigation and drainage systems that manage water. If the soil stays wet for extended periods, diseases and soil compaction may become problematic.

Observe planting dates. Flowering annuals have a particular season. If these plants are grown at the improper times of the year, they will not do well. Example: Do not plant petunias in the fall because they are a summer annual.

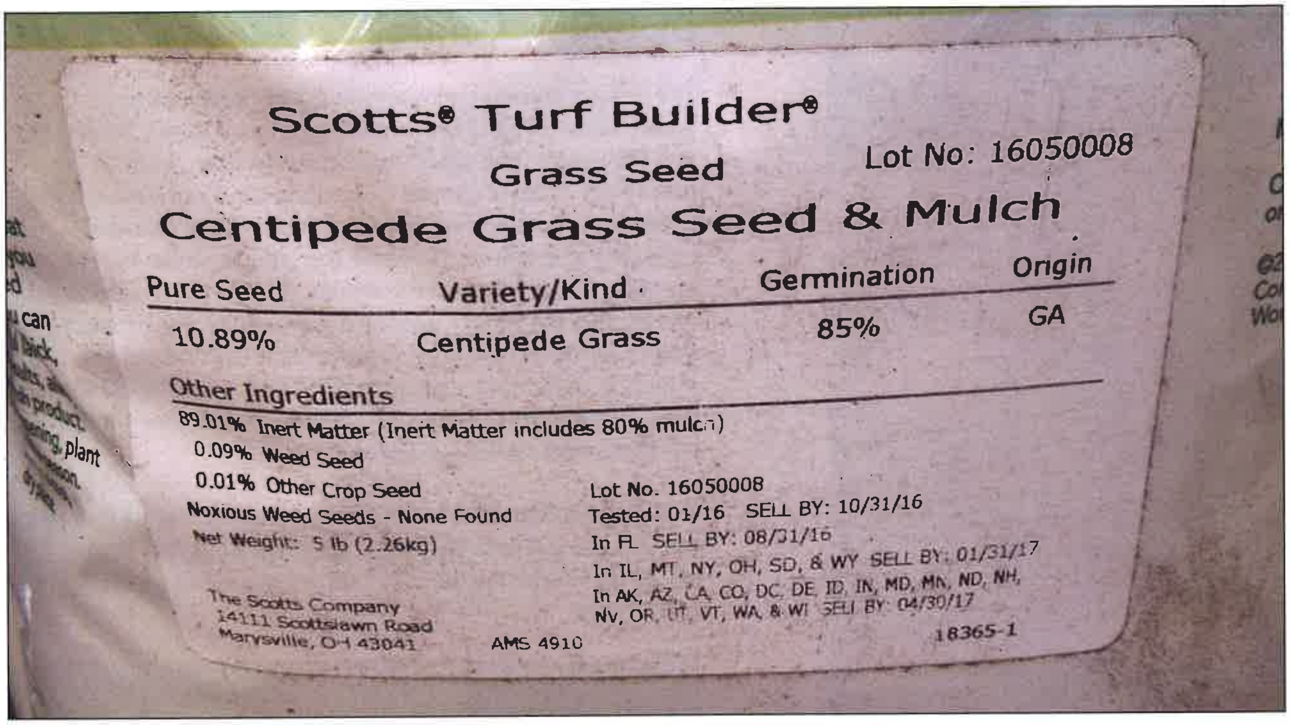


Figure 8.12: Certified seed is labeled with purity and germination guarantee.

Keep plants and turfgrass healthy. Remember many stressed and weak plants are favorable to pests. All plants are more likely to be healthy if they receive proper care. Dense, healthy grass is probably the best defense against pests in turfgrass. When turf does not receive proper care, too much thatch (Figure 8.13) can develop. Thatch is an area of dead and living shoots, stems and roots. It is between the green grass blades and soil. Thatch shelters many insects and disease pathogens. It can also prevent pesticides and fertilizers from reaching the soil.

Figure 8.13: Thatch layer between the grass and soil. Credit: L.B. McCarty, former UF/IFAS Environmental Horticulture.

Fertilize and water correctly. The proper rates of fertilizer and water will keep ornamentals and turfgrass healthy.

Succulent, fast-growing plants and turfgrass often favor pest development. Too much or too little water puts plants under stress. Plants under stress are also conducive to insect pests.

Use mulch. Mulch is any material you put on top of the soil to protect or improve an area. Mulch that breaks down is organic. Examples: bark, wood chips, leaves and pine needles. Mulch that does not break down is inorganic. Examples: gravel, woven ground cloth, ground-up rubber tires, plastic film and pebbles.

Mulch helps preserve moisture in the soil. It does this by reducing the rate of evaporation from the soil. Three to four inches of mulch in plant beds is optimal. Never pile mulch against the trunk of a shrub or tree. Leave three to four inches between the mulch and the trunk.

Mulch helps keep areas free from weeds (Figure 8.14). It also protects trees from damage by lawn mowers and weed eaters. Mulch from hardwoods, such as eucalyptus and melaleuca, lasts longer than mulch made from softwood (pine).

Figure 8.14: Mulched landscape.

Keep landscapes clean. Prune out diseased wood that has fungal or bacterial cankers in it. When you prune diseased material, dip or swab your pruning tools in 70% alcohol (grain, rubbing, or wood alcohol). Alcohol kills insects, nematodes, bacteria, and fungi. Do this between cuts to avoid spreading disease in the same plant.

You can also dip, spray, or brush tools, equipment, and containers with bleach (hypochlorite) 10% solution. Keep the items wet for 10 minutes. This also kills insects, nematodes, bacteria, and fungi.

Tolerate a few pests and a little damage. Maintaining a pest-free landscape is not practical. It is also a waste of time and money. Eradicating all pests eliminates the food source of beneficial organisms, too.

Biological Control

The biological component involves the release and/or conservation of natural enemies, such as parasites, predators, and pathogens, and other beneficial organisms, such as pollinators. Natural enemies, including ladybird beetles, green lacewings, and mantids, may be purchased and released near pest infestations. However, the landscape can also be modified to attract natural enemies, provide habitat for them, and protect them from pesticide applications. For example, flowering plants may provide parasitoids with nectar, or insects with piercing-sucking mouthparts, including aphids, mealybugs, or soft scales, may provide a honeydew source when growing on less-valuable plants.

Beneficial arthropods. Learn to recognize the insects that help manage pests. These beneficial insects include lady beetle adults and larvae (Figure 8.15), lacewings, earwigs, spiders and many more.

Figure 8.15: Ladybug larva attacking an aphid. Credit: L.J. Buss, UF/IFAS Entomology and Nematology.

Lady beetles. Adult lady beetles (Figure 8.16) are among the most recognizable insects, but only when they are the "typical" beetles—orange with black spots. Most people do not realize that these beetles come in many colors including red, brown, or black, and often lack spots. The hemispherical shape of the adult is a helpful characteristic, and the frantic searching behavior—they are always looking for a quick bite to eat—helps to identify lady beetles. Larvae are more difficult to recognize, and many gardeners have killed the beneficial immature stage due to inability to identify this stage. The larval stage is elongate and flattened, and usually blackish or bluish with orangish spots.

Figure 8.16: Adult ladybug. Credit: L.J. Buss, UF/IFAS Entomology and Nematology.

In Florida, one common lady beetle species has larvae with white, waxy exudate on its back. If you see a white insect crawling amongst aphids, it very likely is this lady beetle. The pupal stage is similar to the larva in color, though not capable of moving or feeding. The eggs are yellow and deposited on end in clusters. Lady beetles feed on numerous small insects, and will attack any stage of prey that is small enough to be killed. They are most frequently found feeding among aphid colonies, but many also consume mites, scales, mealybugs, whiteflies, small caterpillars and beetle grubs, and all types of insect eggs.

Lacewings. Both green and brown lacewings occur in Florida, and the pretty, lacy-looking adults are quite recognizable (Figure 8.17). Like lady beetles, lacewings are often found associated with aphid colonies. However, unlike lady beetles, the adults sometimes do not feed on insects, with the larva being the beneficial stage. The large sickle-shaped mouthparts apparent in the larval stage are very effective for clamping onto prey and draining their body contents. The eggs of lacewings are placed on long thin stalks, and placed in clusters. Lacewings feed on insect eggs, scales, mealybugs, and mites as well as aphids.

Figure 8.17: Adult green lacewing. Credit: L.J. Buss, UF/IFAS Entomology and Nematology.

Flower flies. Flower flies (Figure 8.18) are black and yellow insects that resemble honey bees. As the name suggests, they often are found hovering about, or feeding on, flowers. The larvae, however, are voracious predators, and especially fond of aphids. The larvae are maggot-like in appearance, with a thick body that tapers to a pointed head. They are yellowish, reddish, or greenish in color.

Figure 8.18: Adult flower fly. Credit: L.J. Buss, UF/IFAS Entomology and Nematology.

Predatory gall midges. Larvae of predatory gall midges resemble flower flies, and often are overlooked because they are so small. Most people, if they do notice these larvae, think they are very young flower flies. They commonly are found within aphid colonies, but also feed on whiteflies, scales, thrips and mites. However, the adult is strikingly different (Figure 8.19). The adult gall midge, which is rarely observed because it is active at night, is small, pale, and bears long thin legs. It cannot be confused with adult flower flies.

Figure 8.19: Adult gall midge. Credit: L.J. Buss, UF/IFAS Entomology and Nematology.

Bigeyed bugs. This common predator (Figure 8.20) is frequently found in agricultural systems. Both the adult and immature stages are marked by oversized eyes, but they are otherwise fairly nondescript, small, grayish insects. The piercing-sucking mouthparts are used to drain the fluids from moth eggs, caterpillars, thrips, and mites.

Figure 8.20: Adult bigeyed bug. Credit: L.J. Buss, UF/IFAS Entomology and Nematology.

Minute pirate bugs. These very small insects are easily overlooked, but their importance as beneficial insects cannot be overestimated. Like bigeyed bugs, they feed greedily on many small organisms such as psocids, leafhoppers, aphids, thrips, and mites by draining body fluids with their piercing-sucking mouthparts. Adults (Figure 8.21) are silvery-white and black in color. They occur everywhere, including within crops.

Figure 8.21: Minute pirate bug feeding on thrips larva. Credit: L.J. Buss, UF/IFAS Entomology and Nematology.

Soldier bugs or stink bugs. Soldier bugs, also known as stink bugs (Figure 8.22), are known as serious pests as well as useful predators because different species vary in their eating habits. The most common stink bug in Florida, the southern green stink bug, attacks blossoms and fruit, causing deformity and fruit drop. How can you distinguish between good and bad stink bugs? All stink bugs have long, thin, tubular piercing-sucking mouthparts. The good bugs use their mouthparts to extract fluid from other insects, particularly caterpillars and beetle grubs. The bad bugs use their mouthparts to extract plant sap. The mouthparts of good soldier bugs are relatively sturdy, whereas the mouthparts of pest species are relatively thin and frail. If in doubt, you might observe the bug's behavior before deciding whether it is good or bad.

Figure 8.22: Predatory stink bug feeding on a caterpillar. Credit: J.L. Castner, former UF/IFAS Entomology and Nematology.

Ants. People are often surprised to hear that some ants are important predators. Even fire ants (Figure 8.23) can be helpful in reducing numbers of pest insects. Farmers who have fire ant problems rarely have problems with caterpillars and other soft-bodied pests. Ants are not entirely beneficial, however, and in addition to their tendency to bite or sting, ants sometimes protect honeydew-producing insects such as aphids and scales from predation and parasitism. So ants are a mixed blessing, depending on the type of plants and pests present.

Figure 8.23: Red imported fire ants. Credit: L.J. Buss, UF/IFAS Entomology and Nematology.

Parasitic wasps. Most parasitic wasps (Figure 8.24) are small and inconspicuous, but wasps that parasitize insect eggs are even smaller, almost microscopic in size. Gardeners are therefore often unaware that parasitoids are helping control their insect pests. Sometimes these wasps can be seen walking quickly over a leaf and tapping its surface with their antennae in search of the "scent" of the host. Parasitic wasps deposit their egg with the host insect, usually the host egg or larval stage. The young parasite develops within or on the host insect, eventually killing the host. The most common evidence of parasitism is often a sickly caterpillar from which parasitoid larvae are emerging, or a dead caterpillar on which a cocoon is hanging. Parasitic wasps are important natural enemies of caterpillars, grubs, whiteflies, and aphids.

Figure 8.24: Braconid wasp parasitizing a fall armyworm larva. Credit: L.J. Buss, UF/IFAS Entomology and Nematology.

The larra wasp was introduced from South America into south Florida in 1981, and again into north Florida in 1988, to control pest mole crickets. It parasitizes only mole crickets and does not sting people, so it was safe to release. The adult wasp is black with a red abdomen (Figure 8.25), and its wings are clear to smoky blue. A female usually lays one egg on each mole cricket it finds. The egg hatches in six to seven days, the larva feeds on the mole cricket for 10 to 11 days and kills it, then pupates in a cocoon in the soil. A new adult emerges roughly six weeks later during the warmer months, but those that pupate in the fall may become adults by the following April. Larra wasps lay eggs only on mole cricket adults and medium to large nymphs.

Figure 8.25: Larra wasp attacking a tawny mole cricket. Credit: L.J. Buss, UF/IFAS Entomology and Nematology.

Parasitic flies. Several types of parasitic flies attack pests. Many deposit their eggs on the surface of the pest (Figure 8.26). Upon hatching the larva burrows in and eventually kills the host insect. Others deposit their larvae into host, with the same result. However, flies lack the long egg-depositing structure found in most wasps.

Figure 8.26: Tachinid fly eggs on a fall armyworm larva. Credit: J.L. Castner, former UF/IFAS Entomology and Nematology.

Predatory mites. Although some mites, particularly spider mites, are known as serious plant pests, many mites are beneficial. Among beneficial mites, phytoseiid mites are especially important because they are predators of plant-feeding mites and other small organisms such as thrips or insect eggs (Figure 8.27). Predatory mites tend to be larger than other mites, long-legged, and move actively in their search for prey.

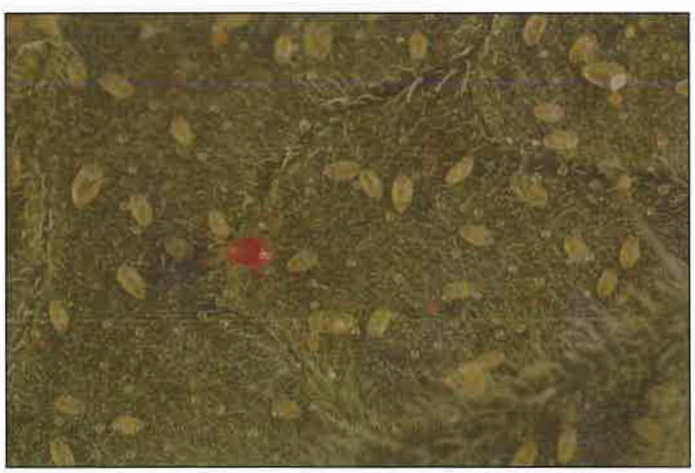


Figure 8.27: Predatory mite attacking white fly eggs. Credit: L.J. Buss, UF/IFAS Entomology and Nematology.

Protect beneficial insects. Do not blanket the landscape with pesticides. This will kill both beneficial insects and insect pests. Spot-treat only the infested areas, if possible. Avoid using broad-spectrum pesticides because they kill all organisms. Keep in mind that biological control agents:

- Require extra knowledge to use
- Do not kill all pests
- Are most effective on small numbers of pests
- Are not always predictable

Mechanical and Physical Controls

Use tools, machines or your hands to reduce pests.

Remove plants or plant parts. Reduce or eliminate many diseases and insects by hand-picking or pruning off leaves or other plant parts. The heel of your shoe can be an effective form of pest control!

Remove and destroy badly diseased plants. Get rid of them by commercial garbage disposal. Remove fallen leaves from around diseased plants. Example: The fungus that causes black

Figure 8.28: Mow grass to the proper height.

Figure 8.29: Marigolds are a good choice where root-knot nematodes are problematic.

spot on roses can survive in dead leaves on the ground in winter. Removing the leaves greatly helps to prevent disease the next season.

Mow and trim (prune) properly. If you overly prune branches from shrubs they will be more susceptible to pest problems. Many pests attack weak or stressed plants. Learn how to properly prune trees and shrubs. Mow grass to the proper height according to grass species and use (Figure 8.28).

Genetic Control

The genetic component relies on the breeding or genetic engineering of turfgrasses and landscape plants that are resistant to key pests. Such resistance could increase a plant's tolerance to damage and weaken or kill the pests. Pests may also develop more slowly on partially resistant plants, thereby increasing their susceptibility to natural enemies or "softer" pesticides. Selecting resistant cultivars or plant species when designing a landscape is a very important part of IPM. Although turfgrass and landscape managers often work with established plant material, they can still recommend changes. Every opportunity should be taken to educate builders, developers, landscape architects, sod producers, and others on which plants are best suited to their areas.

Example: Root-knot nematodes can cause serious problems on flowers and bedding plants. Root-knot, which is characterized by swelling of the root, is caused by the feeding activities of root-knot nematodes. Different species of root-knot nematodes may be present in the soil, and different races may occur within these species. These root-knot nematode races may differ in their ability to infect some plant species and cultivars. Different species or cultivars of flowers may have different susceptibilities to these species and/or races. Selecting the right flower or bedding plant for a site may help to prevent losses due to root-knot nematodes. A wide range in susceptibility is seen among flower species and cultivars. Snapdragon is consistently one of the most susceptible flower crops. Marigolds (Figure 8.29) generally show good levels of resistance. The use of resistant marigolds against root-knot nematodes is well known.

Chemical Control

Chemical controls include a wide assortment of conventional, broad-spectrum pesticides and more selective, newer chemicals, such as microbial insecticides and insect growth regulators. IPM is not antipesticide, but it does promote the use of the least-toxic and most selective alternatives when chemicals are necessary. Pesticides are only one weapon against pests and should be used responsibly and in combination with other, less-toxic control tactics. Chapter 9 of this manual addresses pesticide use.

To determine which pesticides are most appropriate for use, and when and how to use them, consult the appropriate pesticide selection guides produced by UF/IFAS. Whenever practical, limit treatment to infected areas. Spot spraying lessens pesticide use, saving the application service money and lowering risk to beneficial organisms, pets, homeowners, and the environment. Consult with county UF/IFAS Extension Service agents, chemical distributors, product manufacturers, or independent turf or landscape maintenance consultants.

Test Your Knowledge

Q: Which of the following statements is ***false*** regarding IPM?
A. IPM was developed in the 1950s because of concerns over increased pesticide use, environmental contamination, and the development of pesticide resistance.
B. The objectives of IPM include reducing pest management expenses, conserving energy, and reducing the risk of exposure to people, animals, and the environment.
C. Emphasis should be placed on preventative practices such as sanitation (e.g., weed control, removal of plant debris), proper fertilization, irrigation, pruning, etc.
D. Chemical control using pesticides is not in the philosophy of IPM.

A: D

Q: What are the practices common to all IPM programs? (Select all that apply)
A. A. Identify pests correctly
B. Monitor and scout pests
C. Apply pesticides when a rainfall event is predicted
D. Follow control-action guidelines
E. Prevent pest problems
F. Use different IPM practices together (integrate)

A: A, B, D, E, F

Q: Match the following terms with its definition.
1. Aesthetic injury level
2. Economic threshold

A. The density of a pest at which a management intervention is economically justified.
B. A level of pest damage or number of pests the general public or a customer will tolerate on a plant or landscape.

A: 1-B, 2-A

Q: Proper watering and fertilization practices are a form of _______ control.
A. Cultural
B. Genetic
C. Mechanical
D. Chemical

A: A

Q: The use of resistant cultivars in the landscape is a form of _______ control.
A. Cultural
B. Genetic
C. Mechanical
D. Chemical

A: B

Q: This beneficial insect is a _______.
A. Bigeyed bug
B. Minute pirate bug
C. Stink bug
D. Green lacewing

A: D

Q: This beneficial insect is a _______.
A. Bigeyed bug
B. Minute pirate bug
C. Stink bug
D. Green lacewing

A: C

Q: This beneficial insect is a _______.
A. Bigeyed bug
B. Minute pirate bug
C. Stink bug
D. Green lacewing

A: B

Q: This beneficial insect is a _______.
A. Bigeyed bug
B. Minute pirate bug
C. Stink bug
D. Green lacewing

A: A

Chapter 9

Pesticide Use

In this Chapter

Learning Objectives

After you complete your study of this chapter, you should be able to:

- For the three major classes of pesticides—fungicides, herbicides, and insecticides:
  - Know their primary target pests;
  - Describe their general modes of action; and,
  - Name the pest life stages where they are most effective.
- Describe reasons why a pesticide may be ineffective in controlling a target pest.
- Describe the difference between "pesticide tolerance" and "pesticide resistance."
- Describe the concepts, "mode of action" and "mechanism of action."
- State the primary reason for the development of pesticide resistance to occur in a pest population.
- Describe the most effective method for preventing or delaying the onset of pesticide resistance to develop in a pest population.
- Describe the best way to prevent problems from occurring while storing pesticides.
- Describe the features of a good pesticide storage facility.
- Describe why you should never submerge the end of a water supply hose in a tank.
- Describe procedures to prevent problems while mixing and loading pesticides.
- Name and describe the steps in cleaning up a pesticide spill.
- Know when it is applicable to report any accidental release of a spill involving hazardous substances, including pesticides and fuels.
- Describe the proper options for managing wash water from application equipment.
- Define the term "drift," and describe the potential consequences that may occur because of it.
- Describe the importance of pollinators' role in the ecosystem and the need for their protection.
- Describe five specific risk-reduction approaches for professional applicators for reducing the impact of pesticide use on pollinator health.
- Name several low impact pesticides that are available to professional applicators for reducing the risk of bee and pollinator mortality and describe their properties.

Terms to Know

Adjuvant: Substance used to modify the physical characteristic(s) of a liquid spray application to improve its performance.

Amino acids: Important organic compounds that combine to form proteins. Amino acids and proteins are the building blocks of life.

Biotype: A group of genetically identical organisms within a species.

BMPs: Best management practices. Procedures to reduce nonpoint source pollution and promote the efficient use of water.

Drift: The unintentional airborne movement of pesticides to nontarget areas.

EPA Reduced Risk product: A conventional pesticide that poses less risk to human health and the environment than existing conventional alternatives.

Eradicant (curative) fungicide: Fungicide that destroys disease that has already begun to damage plant tissue.

Fatty acids: Molecules that are an important component in cell membranes.

Fungicide: Pesticide that is toxic to fungi.

Herbicide: Pesticide that is toxic to weeds.

Host plant defense induction: A stimulation of the plant to produce salicylic acid, a natural plant constituent that combats potentially injurious plant pathogens.

Insecticide: Pesticide that is toxic to insects.

Mechanism of action: (Also referred to as the site of action) The exact location of inhibition, such as interfering with the activity of an enzyme within a metabolic pathway.

Mitosis: The usual method of cell division.

Mode of action: The manner in which a pesticide destroys or controls a pest.

Nucleic acids: Groups of long, linear molecules, either DNA or various types of RNA, that carry genetic information directing all cellular functions.

OMRI: Organic Materials Review Institute. OMRI lists input products such as fertilizers, pest controls, and livestock care products that are compliant with organic standards.

Photosynthesis: The process by which plants convert sunlight into energy.

Phytotoxicity: Injury to plants.

Protectant fungicide: Fungicide applied prior to fungal infection to prevent disease development.

Resistance: The acquired ability of a pest to survive and reproduce following exposure to a dose of pesticide normally lethal to the wild type.

Respiration: A metabolic process that generates energy for all other cell functions.

Signal transduction: The binding of molecules to receptors that trigger events inside the cell.

Sterols: A subgroup of the steroids that are an important class of organic molecules occurring naturally in plants, animals, and fungi.

Systemic: Pesticide that is absorbed and translocated within a plant or other organism.

Tolerance: The inherent ability of a species to survive and reproduce after pesticide treatment.

Introduction

Pesticides are designed to kill or alter the behavior of pests. When, where, and how they can be used safely and effectively is a matter of considerable public interest. If they are not used wisely, pesticides may pose risks to pesticide applicators and other exposed people, and may create long-term environmental problems.

The best way to manage pesticide storage and disposal is to reduce the amount of pesticide left over after applications through proper planning and equipment calibration. Faulty or improperly managed storage facilities may result in direct runoff or leaching of pesticides into surface water and ground water. Users may be held liable for damage caused by improperly stored or disposed pesticides.

Pesticide spills can be especially problematic. Even pesticides designed for rapid breakdown in the environment can persist for years if present in high concentrations. The results can include the contamination of drinking water, fish kills and other impacts to nontargeted organisms, and administrative fines and legal remedies. It is important that pesticide users protect themselves from all of these hazards.

The most obvious method to reduce the risk from pesticides is to use them only when necessary. Determine which pesticides are the most useful and least environmentally harmful for a given situation. Apply them properly and effectively to minimize costs and the effects on public health and the environment while maximizing plant response. Give particular attention to the vulnerability of the site to ground water or surface water contamination from leaching or runoff.

A pest-control strategy should be used only when the pest is causing or is expected to cause more damage than what can be reasonably and economically tolerated. A control strategy should be implemented that reduces the pest numbers to an acceptable level while minimizing harm to nontargeted organisms. The strategy of IPM is as follows:

- Prevention—keeping a pest from becoming a problem, and then, if needed,
- Suppression—reducing pest numbers or damage to an acceptable level.

Always follow the directions on the label. These directions have been developed after extensive research and field studies on the chemistry, biological effects, and environmental fate of the pesticide. The label is the single most important document in the use of a pesticide. **State and federal pesticide laws require following label directions!**

The following general BMPs should always be used for pesticides:

- **Develop**—and implement a quality IPM program.
- **Labels**—Observe all directions, restrictions, and precautions on pesticide labels. It is dangerous, wasteful, and illegal to do otherwise.
- **Storage**—Store pesticides behind locked doors in original containers with labels intact, separate from seed and fertilizer.
- **Rate**—Use pesticides at the correct application rate and recommended intervals between applications to avoid injury to plants and animals.
- **Handling**—Never eat, drink, or smoke when handling pesticides, and always wash with soap and water after use.
- **Rinsing**—Triple-rinse containers into the spray tank. Never pour pesticides down a drain or into an area exposed to humans, animals, or water.
- **Disposal**—Dispose of used containers in compliance with label directions so that water contamination and other hazards will not result.
- **Clothing**—Always wear protective clothing when applying pesticides. At a minimum, wear a longsleeved shirt, long-legged pants, rubber gloves, boots (never go barefoot or wear sandals), eye protection, and a wide-brimmed hat. Additional protective gear may be listed on the pesticide label.

Pesticide Selection

Identifying or recognizing pests is essential to proper pesticide application and selection. Once the pest has been identified, the best control method must be chosen. If a pesticide is to be used, the applicator must know the proper application technique and read the label thoroughly. Pesticides should be evaluated on effectiveness against the pest, mode of action, life stage of the pest, personnel hazards, non-target effects, leaching or runoff potential, and cost (Figure 9.1).

Figure 9.1: There are many factors to consider when selecting a pesticide.

Pesticide selection BMPs include:

- Develop and implement a quality IPM program.
- Train employees in proper pest identification and pesticide selection techniques.
- Choose the product most appropriate for the problem or pest.
- Mix only the quantity of pesticide needed in order to avoid disposal problems, protect non-targeted organisms, and save money.
- Spot-treat pests whenever appropriate.
- Read and follow all label directions. The label is a legal document.
- Make note of any groundwater advisories on the label.

Types of Pesticides

Have you ever wondered how pesticides control an insect, pathogen or weed? The manner in which a pesticide destroys or controls a pest is called its "mode of action." A similar term, but with a more specific meaning, is "mechanism of action." This term is used to describe the exact location of inhibition, such as interfering with the activity of an enzyme within a metabolic pathway. It is easier to choose the right pesticide if you understand how it works. Then you can make an informed decision about which pesticide will be most effective in a particular situation. There are many other classes of pesticides; however, the major classes of pesticides that are handled by lawn and ornamental managers are insecticides, fungicides, and herbicides.

Insecticides

Insecticides are toxins that kill insects; they have many different modes of action. General insecticide modes of action include:

- Block signals to the insect's nerves or muscles
- Desiccate the insect
- Change normal growth
- Prevent insect reproduction
- Suffocate the insect
- Destroy the insect's digestive tract (Bt)

Insecticides can prevent damage if applied when insects lay eggs or the eggs hatch. These are preventive insecticides used in areas that have had previous insect infestations. Insecticides applied after damage appears are curative—they control insects that caused the damage.

Herbicides

Herbicides are pesticides that specifically control weeds. The mode of action of an herbicide often governs when and how you use it. Some herbicides prevent seed germination or seedling growth shortly after germination-- these are called "preemergence herbicides." These herbicides must be applied to the soil to control weed seedlings before they emerge.

Apply postemergence herbicides to the leaves and stems or soil surrounding actively growing weeds (Figure 9.2). Some postemergence herbicides kill weeds by contact activity, affecting only those parts of the weed touched by the herbicide. Other postemergence herbicides translocate within the tissues of the plant from leaves and other green parts to the growing points. These herbicides are also referred to as systemic.

Figure 9.2: Dollarweed infestation in turf.

General herbicide modes of action include:

- Inhibition of photosynthesis
- Inhibition of amino acids and protein development
- Inhibition of fatty acid synthesis
- Inhibition of growth
- Inhibition of cell membrane development
- Inhibition of pigment synthesis
- Growth regulation

Fungicides

A fungicide is a specific type of pesticide that controls fungal disease by specifically inhibiting or killing the fungus causing the disease. Not all diseases caused by fungi can be adequately controlled by fungicides. To be effective, most fungicides need to be applied before disease occurs or at the first appearance of symptoms. Fungicides can only protect new uninfected growth from disease, thus are called "protectants." Also, few fungicides are effective against pathogens after they have infected a plant-- these are called "eradicants" or "curatives."

General fungicide modes of action include:

- Inhibition of nucleic acids synthesis

- Inhibition of mitosis and cell division
- Inhibition of respiration
- Inhibition of amino acids and protein development
- Inhibition of signal transduction
- Inhibition of cell membrane development
- Inhibition of sterol biosynthesis
- Inhibition of cell wall biosynthesis
- Host plant defense induction
- Multi-site activity

How Pests React Toward Pesticides

Several factors influence how a pest reacts to a pesticide. Two of these are very important:

1. The life stage of the pest or target organism
2. Pesticide uptake

Examples of Life Stages

- Insecticides usually are most effective on nymphs or larvae, and in some situations, adults (Figure 9.3). Eggs and pupae are often located in protected areas. These life stages do not feed so they do not cause damage.
- Herbicides generally are more effective on young, actively growing plants than on mature weeds.
- Some herbicides will control perennial plants when they are applied just prior to flowering. The same herbicides are not as effective when applied to plants that have not begun to flower or have completed flowering.
- Perennial weeds are difficult to control once their rhizomes and other vegetative reproductive structures are well-developed.

Figure 9.3: The more immature stages of pest insects are usually easier to control. Credit: L.J. Buss, UF/IFAS Entomology and Nematology.

Pesticide Uptake

Most pesticides have certain sites of action within the pest where their toxic effects are imparted. Before the pesticide can exert its effect, it must enter and translocate into the pest's tissues to these sites; this is called "pesticide uptake."

Factors that influence pesticide uptake include:

- Structure of the pest
- Outer tissue or cuticle on the plant or insect that protects it
- Habits of pest
- Formulation of the pesticide
- Environmental conditions

Terms that describe the methods and routes of pesticide uptake include:

- **Contact:** A pesticide with contact activity passes through the pest's cuticle.
- **Stomach poison:** The pest must consume the active ingredient in the pesticide. The toxin is absorbed into the lining of the pest's mouthparts or intestine.
- **Fumigant:** The pesticide passes as a vapor or gas into the pest's tissues. The pest inhales the pesticide or it passes through the pest's skin or cuticle.

Some pesticides enter pests by all of these methods.

Why Pesticides May Not Work

Pesticides are valuable additions to the box of tools available to pest managers. However, they should be considered one part of the total IPM plan rather than the only solution. Pesticide failure can occur for a variety of reasons:

- Improper pest identification (incorrect pesticide selection)
- Incorrect pesticide dosage
- Improper application timing
- Pesticide does not reach target pest
- Unfavorable environmental conditions
- State of poor pesticide condition
- Pesticide resistance

Improper pest identification—incorrect pesticide selection. Accurate pest identification should be the first step. Being able to accurately identify pests requires patience and practice. Subtle differences among pest species may often lead to a false identification. For example, control methods vary for different species of grassy weeds. Although they may have common features, such as parallel veins and round stems, crabgrass and bermudagrass control tactics are not always the same. Crabgrass is an annual, while bermudagrass is a tougher-to-control perennial with vegetative rhizomes and stolons. Although some postemergence herbicides may control both species, preemergence herbicides will only reliably control crabgrass.

Likewise, different species of mites can be difficult to distinguish from one another because of their extremely small bodies. However, the pesticides selected to control different mite species can vary. It can even be challenging to distinguish mites from insects that also possess very small bodies, such as aphids (Figures 9.4 – 9.5). Management and pesticide selection can be very different for controlling mites and insects.

Regardless of the pest class, making an accurate identification is critical. UF/IFAS offers a variety of services to help determine the cause of plant problems and to provide pest identification through the UF/IFAS Plant Diagnostic Center (**http://plantpath.ifas.ufl.edu/extension/plant-diagnostic-center/**).

Figure 9.4 – 9.5: Due to their small size, it can be difficult to distinguish aphids from mites. Credit: J.L. Castner, former UF/IFAS Entomology and Nematology.

Incorrect pesticide dosage. Several reasons may account for this problem. Application equipment should be properly calibrated to deliver a known volume. Underdosing can be expensive because retreatment may be necessary. On the other hand, overdosing is a violation of the product's label wording, can be phytotoxic, and harmful to the environment. Keep in mind that the rate listed on a product label as controlling one specific pest will not necessarily be the amount needed to control other species (Figure 9.6).

APPLICATION ON TURFGRASS		
PESTS	*ARENA* 50 WDG INSECTICIDE[1] APPLICATION RATES	TIMING INSTRUCTIONS
Annual Bluegrass Weevils (larval stages) Billbugs Black Turfgrass Ataenius *Phyllophaga* spp. (May or June Beetles) Spittle Bugs White Grubs Asiatic Garden Beetle European Chafer Green June Beetle Japanese Beetle Northern Masked Chafer Oriental Beetle Southern Masked Chafer	6.4 to 12.8 oz/A (0.2 to 0.4 lb ai/A) 0.14 to 0.29 oz/ 1,000 sq ft 4 to 8.3 grams per 1,000 sq ft	**Preventive Applications:** Make applications through peak egg hatch of target species. Use the upper end of the rate range if application is made 60 days or more prior to peak adult flight and/or egg lay. **Post egg hatch application:** After egg hatch of the target species has occurred or there is obvious turf damage from the current generation use the upper end of the rate range.
Armyworms Chinch Bugs including: Hairy, Southern Crane Fly including: American, European Cutworms Nuisance Ants (excluding Fire, Harvester, Carpenter, Pharaoh) Sod Webworms	9.6 to 12.8 oz/A (0.3 to 0.4 lb ai/A) 0.22 to 0.29 oz/ 1,000 sq ft 6.2 to 8.3 grams/ 1,000 sq ft	**Cranefly:** Apply in the spring, when larvae are mature but prior to pupation or in the fall prior to egg hatch. **Other pests:** Apply when pest first appears.
Mole Crickets (suppression)	12.8 oz/A (0.4 lb ai/A) 0.29 oz/1,000 sq ft 8.3 grams/1,000 sq ft	Time application to peak egg lay or early instars. Suppression can either mean control that is not commercially acceptable or inconsistent, ranging from poor to good.

1 level teaspoon contains 3 grams and one cup (8 fl oz) contains 5 oz of *Arena* 50 WDG Insecticide[1].

RESTRICTIONS

- Regardless of the application method do not apply more than 0.4 lb active ingredient clothianidin per acre per year.
- Do not allow this product to contact plants in bloom if bees are foraging the turf area.
- Do not allow children and pets to enter treatment area until sprays have dried.

Figure 9.6: Rates often vary depending upon target species. Credit: CDMS.

Grass (see **Appendix** for the complete list of grasses contrrolled)	Concentrarion of Segment in Spray Solution (%)
Annual grasses up to 6" height	1.5
Annual grasses up to 12" height	2.25
Perennial grasses	2.25[1]

[1]Use 1.5% for wirestem muhly.

Figure 9.7: Rates often vary depending upon growth stage or size. Credit: CDMS.

Figure 9.8: Bagworm control can be a challenge due to their protective bags.

Improper application timing. Apply the pesticide to the life stage of the pest that is most susceptible to the effects of the pesticide. Generally, herbicides are most effective on small, early stages of weed growth. Many insecticides are effective on insect larvae or nymphs but not on adults. Some pesticide labels will list their rates based upon growth stage or size (Figure 9.7).

Another potential problem involving timing is an application that takes place after the infiltration or departure of a pest. An application of a protectant fungicide will provide little or no control of a plant pathogen that has already invaded its host plant. Many labels will instruct that applications should begin prior to the onset of infection.

Pesticide does not reach target pest. Sometimes pesticide applications aren't effective because the pest is in a location that is difficult to reach. Many insects are located on the underside of leaves, under bark or soil, or within stems and fruits (Figure 9.8). When insects are on leaf undersides, applicator sprays must be directed at those areas to have an effect. After application, some pesticides must be watered, by either rainfall or irrigation, into the soil zone where underground insects are feeding. Read the label for maximum product efficacy.

Unfavorable environmental conditions. Aside from the examples above, most pesticides should not be applied just before or during rainfall. Rain washes pesticides off foliage before they have time to take effect. High temperatures, lack of moisture, and both acid and alkaline soil pH are conducive conditions for weeds to develop thicker cuticle formation on their leaf surfaces. Thick cuticles prevent, or minimize, herbicide uptake; thus, weed control is not maximized. Windy conditions can cause pesticides to drift from their intended sites and can also result in damage to desirable plants (Figure 9.9). Injuries of this sort are subject to legal penalties.

Figure 9.9: Herbicide drift caused damage to this residential tree.

State of poor pesticide condition. Under some conditions, some pesticides can change into a form that is not effective. The age of the pesticide, moisture, and temperature extremes are the primary factors responsible for chemical reactions that alter the formulation's active ingredient, rendering them ineffective. Moisture is generally a problem when dry products are stored in bags or containers that have not been adequately sealed. Statements on the product's label often instruct the user not to store the product in extreme heat. Heat may also volatilize some pesticides if their containers are not adequately sealed. Such statements are found in the "Storage and Disposal" section of the product labels.

Using mix water that is alkaline (pH > 7) is known to degrade some pesticides relatively quickly. There are water sources in Florida that tend to be on the alkaline side of the pH scale. Historically, this has been the case with carbamate and organophosphate insecticides; however, it is not strictly limited to those classes. Likewise, some pesticides lose their effectiveness when mixed with water that contains suspended or dissolved solids. Product labels will carry statements cautioning the applicator of such problems. Labels may also recommend the use of specialty adjuvants to alleviate such problems.

Pesticide resistance. Resistance to pesticides is a serious, and growing, problem. Worldwide, more than 600 species of pests have developed some level of pesticide resistance. If resistance to a particular pesticide or "family" of pesticides evolves, these products can no longer be effectively used, thereby reducing the options available for pest management. With few new pesticide modes of action in the development pipeline, landscape managers must do all they can to extend the useful life of the products currently available.

Landscape managers in Florida have become more aware of pesticide resistance development in key turfgrass and ornamental plant pests. Southern chinch bugs became resistant to chlordane used in St. Augustinegrass in 1953, and have since become resistant to other chlorinated hydrocarbon, and organophosphate, carbamate, and pyrethroid insecticides. The leafminer caused significant damage to annual bedding plants in the 1970s and early 1980s, which resulted in considerable insecticide use on infested plants, and subsequent resistance development to several chemical classes.

How does pesticide resistance develop? Resistance can develop when the same pesticide or similar ones with the same mode of action are used over and over again. It often is thought that pests change or mutate in response to a pesticide to become resistant. However, it is not the individual pest that changes, but the population.

When a pesticide is applied to a site, a tiny proportion of the pest population (for example, one insect or weed in 10 million) may survive exposure to the pesticide due to its genetic makeup. When the pests that survive breed, some of their offspring will inherit the genetic trait that confers resistance to the pesticide. These pests will not be affected the next time a similar pesticide is used. If the same pesticide is applied often, the proportion of less-susceptible individuals in the population will increase (Figure 9.10). This illustration shows a "normal" (susceptible) pest population shaded in red. However, over time, this population becomes dominant with a resistant population (shaded in green). Although the members of the resistant population appear identical to the members of the susceptible population, they are genetically distinct. These individuals are known as a "biotype." A biotype is a group of organisms within a species that has biological traits (such as resistance to a particular herbicide) not common to the population as a whole.

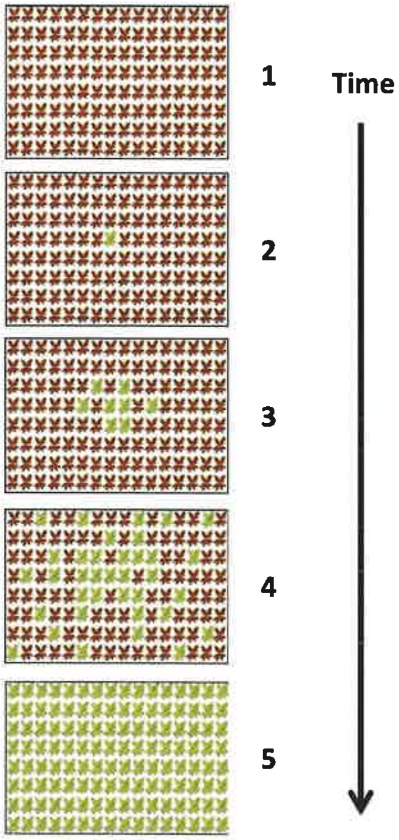


Figure 9.10: Population shift progression from susceptible to resistant individuals.

A similar term, but with an entirely different meaning, is tolerance. The terms are not always clearly distinguished and often are used as synonyms. Tolerance is characterized by survival of the normal population of a pest species following a pesticide dosage lethal to other species. With herbicides, for example, broad-leaved plants are relatively more susceptible than some grass species to herbicides that contain the active ingredient 2,4-D.

How can pesticide resistance be managed, or at least have its development delayed? Rotate pesticides with different mechanisms of action, not just different label names. Avoid consecutive applications of the same pesticide unless it is used in a tank-mix or prepack containing a pesticide with a different mechanism of action, or is used with other pest management options such as mechanical and biological methods. The pesticides and/or alternative methods used must be active against the target pest.

Use pesticides with different mechanisms of action in the same spray tank, in a given season or between seasons. This can be accomplished most efficiently with tank-mixes and pre-packs. Tank-mixes and pre-packs are combinations of two or more pesticides applied as a single mixture. Tank-mixing allows for adjusting of the ratio of pesticides to fit local conditions, while premixes are formulated by the manufacturer. The combinations are designed to broaden the spectrum of pests controlled by an individual pesticide and, if the combination is composed of pesticides with different mechanisms of action active against the same pests, will contribute to resistance management. The different pesticides in the mixture must be active against the target pests, so that biotypes resistant to one mechanism of action are controlled by the pesticide partner with a different mode of action. Theoretically, repeated use of any tank-mix or pre-pack combination may give rise to pesticide resistance if resistance mechanisms to each herbicide in the mix arise together, but the probability is very low.

Knowing the chemical family and mechanism of action group to which a pesticide belongs and knowing which other pesticides have the same mechanism of action are critical for creating a plan to prevent or delay development of pesticide resistance. A pesticide mechanism of action group is composed of pesticides that have the same mechanism of action. The Fungicide, Herbicide, and Insecticide Resistance Action Committees have developed a scheme based on the various groups for those three classes of pesticides. The classification systems are based on numbers assigned to each mechanism of action group to assist managers in rotating pesticides with different mechanisms of action. Encouraged by EPA to use the classification scheme, some manufacturers are using the system by displaying the group number(s) prominently on their labels (Figure 9.11). If there is no group information listed in the product label, refer to the tables listed in the Resistance Action Committees' websites to determine the mechanism of action and group number of the pesticide you are using (Table 9.1). Where feasible, rotate to other pesticides with different group numbers for future applications on the same site. In addition to considering group numbers in the selection of pesticides, review all resistance management recommendations printed on the product label. This may include information on the best management practices for a particular product, target species of most concern, and the maximum number of consecutive applications that should be made before rotating to products containing pesticides with different group numbers.

Figure 9.11: Mechanism of action group number displayed in the upper right corner of a product label. Credit: CDMS.

Table 9.1. Resistance Action Committee websites.

Pesticide class	Website
Fungicide	**http://bit.ly/frac_fungicide**
Herbicide	**http://bit.ly/hracglobal_herbicide**
Insecticide	**http://www.irac-online.org/modes-of-action/**

Always keep in mind that a perceived product failure or poor pesticide performance does not always indicate pest resistance. Poor control may be the result of any of the factors discussed above in this section. Generally, the best approach to resistance management is IPM with utilizing all available control methods, including mechanical and biological controls where feasible along with proper cultural practices.

Pesticide Storage

If you store pesticides for your operation, this storage must be properly constructed and maintained to prevent problems or an expensive cleanup in the event of an accident. **The best way to minimize storage problems is to minimize the amount you store.** Purchasing only small amounts that you can use quickly is the best approach for many turf and landscape management professionals. If you have to store pesticides, follow these guidelines:

- Design and build pesticide storage structures to keep pesticides secure and isolated from the surrounding environment.
- Store pesticides in a roofed concrete or metal structure with a lockable door (Figure 9.12).
- Keep pesticides in a separate facility, or at least in a locked area separate from areas used to store other materials, especially fertilizers, feed, and seed.
- Do not store pesticides near flammable materials, hot work (welding, grinding), or in shop areas.
- Do not allow smoking in pesticide storage areas.

Figure 9.12: Locked metal pesticide storage facility.

- Store personal protective equipment (PPE) where it is easily accessible in an emergency. However, do not store PPE in the pesticide storage area, since that may make it unavailable during an emergency. Check the label and the Safety Data Sheet (SDS) to determine the required safety equipment for each chemical used in the operation. Keep a written pesticide inventory and the SDS file for the chemicals on site. Do not store this information in the pesticide storage room itself. Remember that PPE is specified for normal application and handling activities. Regular PPE may not be protective in emergency situations, such as fires or reactions with other spilled chemicals.
- Depending on the products stored and the quantity, you may need to register the facility with the Florida Department of Community Affairs and your local emergency response agency. Check with your pesticide dealer about community right-to-know laws for the materials that you purchase. An emergency response plan should be in place and familiar to personnel before an emergency occurs, such as a lightning strike, fire, or hurricane. Individuals conducting emergency pesticide cleanups should be properly trained under the requirements of the federal Occupational Safety and Health Administration (OSHA). For reporting chemical spills, see the section on spill reporting requirements later in this chapter.

- Do not store large quantities of pesticides for long periods. Adopt the "first in-first out" principle, using the oldest products first to ensure that the product shelf life does not expire.

- Store pesticides in their original containers (Figure 9.13). Do not put pesticides in containers that might cause children and others to mistake them for food or drink. Keep the containers securely closed and inspect them regularly for splits, tears, breaks, or leaks. All pesticide containers should be labeled. Arrange pesticide containers so that the labels are clearly visible, and make sure that the labels are legible. Refasten all loose labeling using non-water soluble glue or sturdy, transparent packaging tape. Do not refasten labels with rubber bands, which quickly rot and easily break, or nontransparent tapes such as duct tape or masking tape, which may obscure important product caution statements or label directions for product use. If a label is damaged, immediately request a replacement from the pesticide dealer or formulator. As a temporary supplement to disfigured or badly damaged labels, fasten a baggage tag to the container handle. On the tag write the product name, formulation, concentration of active ingredient(s), "signal word," the statement "Keep Out of Reach of Children," and the date of purchase. If there is any question about the contents of the container, set it aside for proper disposal.

Figure 9.13: Store pesticides in original containers

- Dry bags should be raised on pallets to ensure that they do not get wet. Do not store liquid materials above dry materials. Store flammable pesticides separately from nonflammable pesticides. Segregate herbicides, insecticides, and fungicides to prevent cross-contamination and minimize the potential for misapplication (Figure 9.14). Cross-contaminated pesticides often cannot be applied in accordance with the labels of each of the products. This may make it necessary to dispose of the cross-contaminated materials as wastes and could require the services of a consultant and hazardous waste contractor.

Figure 9.14: Segregate pesticides in the storage facility.

- Use shelving made of plastic or reinforced metal. Keep metal shelving painted, unless made of stainless steel, to avoid corrosion. If you use wood shelving, paint it with an enamel or waterproof paint to minimize any absorption of spilled pesticide materials. It is best to replace wood shelving with metal or plastic.

- Construct floors of seamless metal or concrete sealed with a chemical-resistant paint. For concrete, use a water-cement ratio no higher than 0.45:1 by weight, and leave a rough finish to provide adhesion for the sealant. Equip the floor with a continuous curb to retain spilled materials. While a properly sealed sump may be included to help recover spilled materials, do not install a drain, as it can release spilled material into the environment. If you have a drain in a storage area, seal it as soon as possible to prevent uncontrolled releases. Provide sloped ramps at the entrance to allow handcarts to safely move material in and out of the storage area.

- When designing the facility, keep in mind that temperature extremes during storage may reduce safety and affect pesticide efficacy. Provide automatic exhaust fans and an emergency wash area. The emergency wash area should be outside the storage building. Local fire and electrical codes may require explosion-proof lighting and fans. The light/fan switches should be outside the building, and both switches should be turned on before people enter and should remain on until after they have left the building.

The BMPs listed in the next section often address the ideal situation of newly constructed, permanent facilities. However, you are encouraged to apply these principles and ideas to existing facilities.

Plans and specifications for pesticide storage buildings are available from several sources, including the U.S. Department of Agriculture Natural Resources Conservation Service (NRCS), the Midwest Plan Service, and the UF/IFAS Extension Bookstore. These organizations' publications also contain recommended management practices for pesticide storage facilities.

Note that cancelled, suspended, or unusable pesticides must be disposed of properly. Storage for long periods can lead to leaking containers or other costly problems. The Florida Department of Environmental Protection (FDEP) and the Florida Department of Agriculture and Consumer Services (FDACS) operate a program for the free disposal of these materials (Operation Cleansweep, ph. 877-851-5285 toll-free). For more information, go to **www.dep.state.fl.us/waste/categories/cleansweep-pesticides**. If this program is not available, a licensed waste disposal contractor should do the disposal.

A good storage facility should have the following features:

- A secure area where unauthorized persons are restricted from entering.
- Proper labeling on exterior doors, such as signs that state "NO SMOKING" and "WARNING: PESTICIDE STORAGE." No-smoking regulations need to be enforced.
- No opportunity for water to enter.
- Temperature control to avoid excessive cold or heat.
- Nonporous floors.
- Not located close to a body of water, sinkhole, or wellhead.
- Adequate lighting and ventilation.
- The ability to contain runoff from spills.
- A source of clean water with prevention of backflow of chemicals into the water supply.
- Freedom from combustible materials or debris.
- Storage shelves and cabinets of nonporous material that will not absorb pesticides.
- Shelves or other means of keeping chemicals off wet floors.
- A spill kit containing materials and equipment to contain and clean up pesticide spills.
- Clean, readily available personal protective equipment and emergency telephone numbers or other means of securing assistance in an emergency.
- Appropriate fire extinguishers.

The following BMPs should be used for storing and disposing of pesticides:

- Maintain and follow labels on all pesticide containers.
- Store pesticides only in their original containers or make sure the new containers are properly labeled.
- Store similar pesticides together; for example, store herbicides with herbicides, and insecticides with insecticides.
- Store dry pesticides above liquids.
- Keep containers closed tightly.
- Inspect inventory frequently and watch for damaged containers.
- Store separately any pesticides that may be flammable.
- Limit the amount of inventory, and purchase only the amounts needed.
- Triple-rinse, puncture, and crush empty containers. Clean all visible chemical from the container, including the container cap and cap threads. Follow the label directions for container disposal.
- Apply unused chemical mixtures or rinsate to a legal target at or below the label rate, or save it to use as make-up water for later applications of compatible materials.
- For cancelled, suspended, or unusable pesticides, contact FDACS at 877-851-5285 to see if you can enroll in Operation Cleansweep (Figure 9.15). For more information, go to **www.dep.state.fl.us/waste/categories/cleansweep-pesticides**.

Figure 9.15: Operation Cleansweep unused pesticide collection event.

Mixing and Loading Activities

In most cases, the mixing and loading of pesticides into application equipment should be done adjacent to the application site. If chemicals are routinely mixed and loaded at a shop or storage site, spilled material can accumulate and expensive cleanup procedures may be required.

Florida law requires an air gap or back-siphoning device between the water supply and the application equipment to prevent backflow into the water supply. **Never submerge the end of a water supply hose in a tank (Figure 9.16).** This can lead to the costly contamination of a water supply.

Figure 9.16: Never do this; always leave an air gap – it's the law!

Use extreme caution when handling concentrated chemicals (Figure 9.17). Spills could result in an expensive hazardous waste cleanup. It is important to understand how mixing and loading operations can pollute vulnerable ground water and surface water supplies if conducted improperly and at the wrong site. Locate operations well away from ground water wells and areas where runoff may carry spilled pesticides into surface waterbodies. Areas around public water supply wells should receive special consideration and may be designated as wellhead protection areas. Before mixing or loading pesticides in such areas, consult with state and local government officials to determine if special restrictions apply.

Figure 9.17: Use extreme caution when handling concentrates.

To prevent problems when mixing chemicals on-site, use a mixing tray or portable pad to avoid spillage that could be transported to non-targeted areas. Should a chemical spill onto the mixing tray, the material should then be rinsed into the applicator equipment and used according to the product label. For your own safety, always use all personal protective equipment required by the label.

The following BMPs should be used for mixing and loading pesticides:

- Mix the pesticide and load the spreader or sprayer carefully to avoid spills.
- Mix and load pesticides on an impervious mix/load pad with provisions for collecting and reusing spilled or waste material.
- Use excess pesticide mixtures on a site that is specified on the label.
- Consider closed systems for loading and mixing.
- Triple-rinse containers, pour the rinsate into the spray tank, and use the excess according to the product label.

Spill Management

Clean up spills as soon as possible. Unmanaged spills may quickly move into surface waters and injure plants and animals. It is essential to be prepared for major or minor spills (Figure 9.18). The sooner you can contain, absorb, and dispose of a spill, the less chance there is that it will cause harm. Always use the appropriate personal protective equipment as indicated on the SDS and the label for a chemical. In addition, follow the following four steps:

1. **CONTROL actively spilling or leaking materials** by setting the container upright, plugging leak(s), or shutting the valve.
2. **CONTAIN the spilled material** using barriers and absorbent material. For small spills, use kitty litter, vermiculite, shredded newspaper, absorbent pillows, clean sand, or pads. Use dikes to direct large spills away from ditches, storm drains, ponds, sinkholes, or woods. You can also use commercially-available products to absorb spilled materials.
3. **COLLECT spilled material,** absorbents, and leaking containers and place them in a secure, properly labeled container. Some contaminated materials could require disposal as hazardous waste.
4. **STORE the containers of spilled material until they can be applied as a pesticide** or appropriately disposed of.

Table 9.2. Reportable quantities (pounds) for certain landscape and turf pesticides.

Active ingredient	Brand name	[1]CAS number	[2]EHS RQ	[3]CERCLA RQ
Atrazine	Aatrex	1912249	NA	NA
Fenoxycarb	Logic	74490-01-8	NA	NA
Hydramethylnon	Maxforce	67485-29-4	NA	NA
Malathion	Cythion	121-75-5	NA	100
Methiocarb	Mesurol	2032-65-7	10	10
Simazine	Princep	122-34-9	NA	NA
Trifluralin	Treflan	1582098	NA	10
[1]Chemical Abstracts Service; [2]Extremely Hazardous Substance reportable quantity; [3]Comprehensive Environmental Response Compensation and Liability Act reportable quantity.				

Small liquid spills may be cleaned up by using an absorbent such as cat litter, diluting it with soil, and then applying the absorbent to the target site as a pesticide in accordance with the label instructions.

Figure 9.18: Be ready for spills – large or small.

Spill Reporting Requirements

Comply with all applicable federal, state, and local regulations regarding spill response training for employees, spill reporting requirements, spill containment, and cleanup. **Keep spill cleanup equipment available when handling pesticides or their containers.** If a spill occurs for a pesticide covered by certain state and federal laws, you may need to report any accidental release if the spill quantity exceeds the "reportable quantity" of active ingredient specified in the law. See Appendix A for important telephone numbers for reporting pesticide spills. Very few of the pesticides routinely used in landscape and turf management are covered under these requirements. A complete list of hazardous substances, including pesticides, and reportable quantities is available by calling (850) 413-9970 or at **http://bit.ly/2pFskMP**. Table 9.2 provides reportable quantities for some common landscape and turf pesticides, but it is your responsibility to determine if a pesticide you use has a reportable quantity. The list in the table should not be used as a substitute for the list provided at the website above.

Wash Water

Wash water from pesticide application equipment must be managed properly, since it could contain pesticide residues. Ensuring that no pesticide spills occur on the vehicle by mixing all pesticides over mixing trays eliminates potential pesticide hazards. Sweep any granular products that have spilled onto the vehicle or non-targeted areas into labeled bags for later use.

Wash the vehicle in a designated wash area. The water hose should have an on/off valve and a water-reducing nozzle. Use the least amount of water possible to wash the equipment adequately. Motorized spray equipment can be rinsed of pesticides residues over turf areas at the job site where the rinsate will be used according to the product label. These practices prevent unwanted pesticide residues from being washed onto non-targeted areas. **Avoid conducting such washing in the vicinity of wells or surface waterbodies.**

For most turf application equipment, the inside of the application tank should be rinsed. This is done by filling it with water and then applying the rinse water in the same manner and at the same site as the original pesticide. For larger equipment that is loaded at a central facility, the inside of the application equipment should be washed on the mix/load pad. This rinsate may be applied as a pesticide (preferred) or stored for use as make-up water for the next compatible application (Figure 9.19). Otherwise it must be treated as a (potentially hazardous) waste. After washing the equipment and before an incompatible product is handled, the sump should be cleaned of any liquid and sediment.

Figure 9.19: Large facility with separate rinsate tanks designated for different pesticide classes.

Know the Law

Public Law 96-510 and Public Law 92-5000 (CERCLA) require immediate notification of the appropriate U.S. governmental agency when oil or hazardous substances are discharged. The law states, "Any such person who fails to notify immediately such agency of such discharge shall, upon conviction, be fined not more than $10,000 or imprisoned for not more than one year, or both."

Under Chapters 376 and 403, Florida Statutes:

- Any owner or operator of a facility who has knowledge of any release of a hazardous substance from a facility in a quantity equal to or exceeding the reportable quantity (see the SDS sheet) in a 24-hour period shall immediately notify the State Warning Point.

- The owner or operator having a discharge of petroleum products exceeding 25 gallons on a pervious surface (or any amount in a waterbody) must report such discharge to the Florida Department of Environmental Protection or the State Warning Point.

- Report the following information:

  – Name, address, and telephone number of person reporting.

  – Name, address, and telephone number of person responsible for the discharge or release, if known.

  – Date and time of the discharge or release.

  – Type or name of the substance discharged or released.

  – Estimated amount of the discharge or release.

  – Location or address of the discharge or release.

  – Source and cause of the discharge or release.

  – Size and characteristics of the area affected by the discharge or release.

  – Containment and cleanup actions taken to date.

  – Other persons or agencies contacted.

Managing Pesticide Drift

The drift of spray from pesticide applications can expose people, plants and animals, and the environment to pesticide residues that can cause health and environmental effects and property damage. Pesticide use is poorly understood by the public, which causes anxiety and sometimes overreaction to a situation. Even the application of fertilizers or biological pesticides, like Bt or pheromones, can be perceived as a danger to the general public. Drift can lead to litigation, financially damaging court costs, and appeals to restrict or ban the use of pesticides. Urbanization, including residential subdivisions, assisted living facilities, hospitals, and schools are sensitive sites that heighten the need for drift mitigation measures to be taken by applicators of pesticides, particularly in areas where children and the elderly are present.

Drift can be defined simply as the unintentional airborne movement of pesticides to nontarget areas. The goal of all pesticide applications is to reach a specific target and remain there. Scientists recognize that almost every pesticide application produces some amount of drift away from the target area. Not all drift may be harmful or illegal. Because some drift can occur with any application, the laws focus on preventing substantial drift. How much a pesticide may drift and whether it's harmful depends on interrelated factors that can be complex.

Where significant drift does occur, it can damage or contaminate sensitive crops, poison bees and other pollinators, pose health risks to humans and animals, and contaminate soil and water in adjacent areas (Figure 9.20). Applicators are legally responsible for the damages resulting from the off-target movement of pesticides. It is impossible to eliminate drift totally, but it is possible to reduce it to a legal level.

Figure 9.20: Sensitive plant showing injury from herbicide drift.

Applicator Decisions

Ultimately, it is the applicator's job to determine if conditions are conducive for drift to occur and to take precautions against it. To minimize concerns to neighbors and the environment, applicators must recognize sensitive areas around each landscape before beginning an application. By exercising sound judgment regarding both equipment and weather factors relative to each application, applicators can minimize drift potential in nearly every case.

Follow label directions. If there are specific conditions spelled out on a product label in regards to drift, they should be the first concern.

Know the Right Conditions. If winds are blowing towards a sensitive area, do not spray at any wind speed. Ideally, winds should be in the range of three to nine mph. Generally, pesticide should not be sprayed when winds exceed 10 mph. Use caution when winds are light and variable, especially when applications are to be made near susceptible vegetation. Be aware that very calm conditions could indicate the presence of a temperature inversion, especially during the early morning. Inversions favor pesticide drift. Also, use special caution when relative humidity is low and when temperatures are high. Drift is much more likely during the hottest part of the day as those conditions are conducive for drops to evaporate, form smaller droplets, and drift off target.

Keep Application Records. Keep records of air temperature, relative humidity, wind speed, and wind direction. These records, as well as equipment and application information, may be very helpful in dealing with drift-related litigation.

Pesticides and Pollinators

The western honey bee is one of more than 300 bee pollinator species occurring in Florida that play a role in the pollination of agricultural crops and natural and managed landscapes. The western honey bee is conceivably the most important pollinator in Florida and American agricultural landscapes. The honey bee is credited with approximately 85 pecent of the pollinating activity necessary to supply about one-quarter to one-third of the nation's food supply. There are also over 3,000 registered beekeepers in Florida, managing a total of more than 400,000 honey bee colonies and producing between 10 to 20 million pounds of honey annually.

Urban landscape ecosystems are a complex and diverse interaction between people, plants, insects, and the environment. Over 90 pecent of Floridians live among urban

Figure 9.21: Tending bee hives in an urban garden.

landscapes, often in close proximity to commercially managed bee hives, although the hives may be kept outside of city limits (Figure 9.21). However, a growing number of small-scale beekeepers and hobbyists maintain colonies in urban landscapes. Bees can fly two to five miles in any direction to search for pollen and nectar, so colonies located in proximity of managed landscapes can be affected by the pesticides used.

Protecting honey bees and other pollinators from pesticide impacts is important to the sustainability of agriculture and urban landscapes, but can be challenging. A primary challenge is the fact that urban landscapes can be highly disturbed harsh environments with frequent pest outbreaks. Consequently pesticide applicators must determine if there is a clear hazard to managed or wild populations of bees, and other pollinators in these environments when managing pests. Potential exposure of bees to pesticides can vary greatly depending on the type of pesticide, formulation, application method, label restrictions, and other factors. The goal in using a pesticide is to achieve maximum success with minimum negative impact, and these factors should always be considered in pesticide selection.

Native bees, butterflies and other pollinators are wildlife, deserving of protection in the same way birds such as raptors and songbirds are protected. Unfortunately, honey bee health is in decline, and some native bees and butterflies are threatened. Honey bees are well studied because of their economic importance. From April 1, 2014 to April 1, 2015, the U.S. lost 42 percent of its honey bee colonies, and winter losses since 2006 are generally around 30 percent every year. Beekeepers consider annual losses of 15 pecent to be acceptable, and losses greater than this make it difficult or impossible to remain profitable.

Factors That Threaten Pollinator Health

Most researchers agree that a combination of factors is causing declines in bee and pollinator populations, including parasites, pathogens, loss of habitat or flowers that provide pollen and nectar, and pesticide exposure. Each of these has been found to negatively affect bees, but there is also evidence the combination of stresses is especially harmful. Bees and other pollinators depend on flowers for food—nectar provides carbohydrates, while pollen is their source of protein. Flowerless landscapes like mowed lawns with strict weed control, heavily paved areas of cities and fields with no plant diversity contain little food for bees which leads to poor nutrition and compromised immune systems. Nutritionally weakened bees are more susceptible to disease and pesticides.

Many pests and pathogens also affect bees. The *Varroa* mite, a parasite of honey bees, is one of the most destructive factors causing honey bee decline. Other parasites and pathogens may become a more serious problem in hives weakened by *Varroa* mite.

In some cases, the flowers that bees forage on have pesticide residue on the petals or in the nectar and pollen. These chemicals can kill bees directly or cause a variety of sublethal effects such as impairing their ability to find their hive or provide food for their larvae. The toxicity of pesticides for bees ranges from highly toxic to relatively safe, depending on the specific chemical and the exposure, although long-term exposure to low doses has not been investigated for many types of pesticides. In some cases the impacts are worse when pollinators are exposed to combinations of pesticides. Since bees forage through a wide range of landscapes, they may be exposed to a complex mixture of many different chemicals.

One group of insecticides, the neonicotinoids (neonics), has recently been studied intensively by scientists to determine their impact on bees, primarily because of their widespread agricultural use on field crops. However, neonics are also used by professionals and homeowners in landscapes and gardens. Neonics are a class of insecticide that acts on the insect's nervous system. They are more selective, having greater toxicity to insects than mammals, and safer for humans to use than most old classes of insecticides. They are toxic when ingested or through direct contact. The most widely used neonics -- imidacloprid, thiamethoxam, clothianidin and dinotefuran -- are all highly toxic to bees. Products containing these active ingredients have bee-warning boxes on the label with important instructions for limiting bee exposure that must be followed (Figure 9.22). Neonics move upwards in xylem sap internally within plants when applied to the plant's base (to roots via a soil application, or to the stem via injection or a basal spray), where they can later reach nectar and pollen. Pesticides remain primarily in leaf tissue following a foliar spray.

Neonics, like most insecticides, will cause significant harm if pollinators come directly into contact with them. This exposure generally occurs when a neonic is misused and sprayed on a blooming plant or one that will bloom soon.

This does not imply that neonics are the only insecticide class toxic to bees and other pollinators. There are others; check the Environmental Hazards section of product labels for this information. That section will contain statements regarding precautionary measures for minimizing exposure of bees and pollinators.

PROTECTION OF POLLINATORS

APPLICATION RESTRICTIONS EXIST FOR THIS PRODUCT BECAUSE OF RISK TO BEES AND OTHER INSECT POLLINATORS. FOLLOW APPLICATION RESTRICTIONS FOUND IN THE DIRECTIONS FOR USE TO PROTECT POLLINATORS.

Look for the bee hazard icon in the Directions for Use for each application site for specific use restrictions and instructions to protect bees and other insect pollinators.

This product can kill bees and other insect pollinators.

Bees and other insect pollinators will forage on plants when they flower, shed pollen, or produce nectar. Bees and other insect pollinators can be exposed to this pesticide from:

- Direct contact during foliar applications, or contact with residues on plant surfaces after foliar applications.
- Ingestion of residues in nectar and pollen when the pesticide is applied as a seed treatment, soil, tree injection, as well as foliar applications.

When Using This Product Take Steps To:

- Minimize exposure of this product to bees and other insect pollinators when they are foraging on pollinator attractive plants around the application site.
- Minimize drift of this product on to beehives or to off-site pollinator attractive habitat. Drift of this product onto beehives or off-site to pollinator attractive habitat can result in bee kills.

Information on protecting bees and other insect pollinators may be found at the Pesticide Environmental Stewardship website at: http://pesticidestewardship.org/PollinatorProtection/Pages/default.aspx.
Pesticide incidents (for example, bee kills) should immediately be reported to the state/tribal lead agency. For contact Information for your state, go to: www.aapco.org/officials.html. Pesticide incidents should also be reported to the National Pesticide Information Center at: www.npic.orst.edu or directly to EPA at: beekill@epa.gov

Figure 9.22: Product label with pollinator protection directions for use. Credit: CDMS.

Bees and other pollinators can also collect contaminated pollen or nectar from the treated plants and bring it back to their colony, creating high risk of harm to the colony. Research studies have demonstrated native bees and honey bees can be harmed by small amounts of pesticides in nectar and pollen. When a neonic is applied as a soil drench (a dilute solution poured around the plant base), it may persist for a year or more, especially in woody plants, and can also move into weeds or flowers growing over the drenched soil. If some of the insecticide moves into pollen or nectar it may not kill bees directly, but it can act as a stressor to affect larval growth, susceptibility to diseases, navigation or winter survival.

How we manage pests in ornamental landscapes has an impact on pollinators. The following section will explain the best ways minimize pollinator exposure to pesticides.

Risk-Reduction Approaches for Professional Applicators

Beyond complying with the label, applicators are urged to consider and use the following additional approaches to reduce the duration and risk of pesticide impacts to honey bees and other pollinators. The below-mentioned practices can aid in the protection of managed and non-managed pollinators and should be taken into consideration even if the landscape is not actively hosting honey bee colonies (or other managed bees). Pest management approaches by professionals vary, so each recommendation below may not be applicable to every situation.

- **Consult the FDACS-Division of Plant Industry (DPI) geographic information system (GIS) tool to identify beekeepers with hives in your area.** This tool can be found at **www.FloridabeeProtection.org** and will allow you to become aware of the locations of commercially managed bee hives. Select "Information for Growers." On the Information for Growers page, click "Online Map."

- **Use pesticides only when and where needed.** Pesticides should never be applied unless they are necessary to maintain plant health. Using preventive blanket sprays, where pesticides are sprayed several times a year on a calendar basis, has been shown to create more pest problems than it solves. Not only do cover sprays create potential for pesticide runoff and increased human and pet exposure, they actually create pest problems by suppressing predators, parasitoids and diseases that keep plant pests under control. It is not unusual to observe outbreaks of spider mites, aphids and scale insects where pesticides are used. Only spray plants and portions of the landscape infested with pests, and only if it is necessary.

- **Know key aspects of pollinator biology and behavior.** First, most bees and other pollinators forage during the day from 8:00 a.m. to 5:00 p.m., so if you can spray at night or in the early morning, if feasible, you can reduce the risk of accidentally spraying them. Be conscious of early days and longer hours in the peak of the summer, when bees will typically forage earlier and longer. Second, pollinators are attracted to flowers. Anything that has flowers or is about to flower is a higher risk than a plant that is past bloom. If you can remove the flowers by mowing or pruning from around the treated plant, and anywhere your application may drift, you can significantly reduce risk to bees and other pollinators. Third, honey bees fly when the air temperature is above 55°F to 60°F. Finally, always check the landscape for bee activity immediately before an application, when the pesticide label bee protection statements apply.

- **Do not contaminate water.** Bees require water to cool the hive and feed the brood. Avoid contaminating standing water with pesticides or draining spray tank contents onto the ground, creating puddles to which bees may be attracted. Be mindful that contaminated water can also come from runoff, improper storage, or spills.

- **Do not spray highly attractive plants with insecticide before or during flowering.** It is clear to most people that insecticides sprayed onto open flowers can be highly toxic to bees, even if they are sprayed early in the morning or at night when bees are not present. However, some may not realize insecticides sprayed in the two-week period before a tree flowers can also be toxic to bees. Insecticides that tend to volatilize, especially those formulated as emulsifiable concentrates (E or EC), can vaporize off the leaf surface and contaminate flowers after they open. Although this level of contamination is very low, it may still affect bees because some insecticides, like the neonics, can affect bees at concentrations as low as 10 ppb (part per billion).

- **Understand systemic insecticide activity.** Some systemic insecticides like most of the neonics may be partially absorbed by sprayed leaves and move systemically in the plant. Only a very small amount of residue is absorbed into leaf tissue, not enough to provide control of insect pests, but it may be enough to cause sublethal effects to bees if it moves into the pollen or nectar. Recent studies on cherry trees indicate if they are sprayed with imidacloprid after the flowering period is over, the amount of imidacloprid found in nectar the following year (1 to 6 ppb) is not a serious threat to pollinators.

- **Avoid spraying flowers with fungicides.** Recent research indicates fungicide brought back to the hive on contaminated pollen or on workers' bodies interferes with the function of beneficial fungi in the hive. Several types of fungi grow in hives and the chemicals they secrete provide a natural defense against bee diseases. They also play an important role in producing bee bread, a fermentation product of pollen which requires fungi. Bee bread is a critical protein source for bee larvae and adults. Recent studies have shown bees exposed to fungicides do not produce as much bee bread in their hives. Furthermore, certain fungicides can disable the detoxification enzymes of insects, which can greatly increase the toxicity of certain insecticides to bees (e.g., acetamiprid). Several studies have reported pollen contaminated with captan, ziram, iprodione, chlorothalonil and mancozeb may be harmful to bee larvae when they eat it.

- **Beware of pesticide interactions.** Some mixtures of fungicides with insecticides may be more toxic to bees than the insecticide alone. When propiconazole is mixed with pyrethroid insecticdes, it may increase the toxicity of the insecticide to bees. Also when propaconizole and other fungicides in that class, such as tebuconazole, myclobutanil and triflumizole, are mixed with acetamaprid, the solution becomes fivefold or more toxic to bees than acetamaprid by itself.

Low Impact Pesticides

Choose insecticides that are highly selective to a specific type of insect and so have low toxicity for others (signal word of Caution on the label or EPA Reduced Risk product). An EPA Reduced Risk product is a conventional pesticide that poses less risk to human health and the environment than existing conventional alternatives. Other characteristics of low impact pesticides are those that break down rapidly after application and therefore have minimal impact on pollinators and natural enemies. However, using these products requires some knowledge about their relative toxicity to beneficial insects and their potential to cause phytotoxicity. The following types of products have a minimal impact on beneficial insects, such as pollinators.

Insecticidal soaps. Insecticidal soaps are applied as a foliar application (sprayed on plant leaves) and are effective on a wide range of plant pests when the soap spray comes into contact with the pest. Most commercially available insecticidal soaps are made of potassium salts of fatty acids and kill by disrupting the structure and permeability of insect cell membranes. Insecticidal soaps are most effective on soft-bodied arthropods such as aphids, lace bugs, leafhoppers, mealybugs, thrips, spider mites and whiteflies. They are not effective on pests as a residue on the plant surface, and therefore are not toxic to pollinators after the spray dries. They can be safely used at any time to control pests on plants that are not attractive to pollinators, but on pollinator-attractive plants spray at dawn or dusk when pollinators are not present.

Be aware that some landscape plants are known to be sensitive to insecticidal soap. Always use a commercial brand, as some homemade concoctions using dish-washing detergents or other household cleaners may be more toxic to plants.

Horticultural oils. Horticultural oil is a term for the various oils used for pest control on plants. Most horticultural oils are lightweight and petroleum-based, but some are made from grains, vegetables or neem tree seeds. Like insecticidal soap, horticultural oils work best when the spray comes in contact with the pest. Once the oil spray dries, it does not have much effect and becomes safe for pollinators and other beneficial insects. Horticultural oil can be safely used at any time to control pests on plants that are not attractive to pollinators, but on pollinator-attractive plants they should be sprayed at dawn or dusk when pollinators are not present.

Horticultural oils give excellent control of armored scales and can also be used for aphids, whiteflies, spider mites, true bugs, caterpillar and sawfly larvae and more. The recommended concentration of horticultural oils for pest control is usually two percent. However, even at two percent, some plants are sensitive to oils. Another precaution is that applying oils during high humidity or high temperatures may cause phytoxicity. Plant injury symptoms following an application of horticultural oil are discoloration, yellowing, necrosis, black spots and terminal or branch dieback. Many horticultural oil products have been approved and listed by the Organic Materials Review Institute (OMRI) for organic use.

Bacillus thuringiensis (Bt). Products containing Bt are made from a naturally-occurring soil bacterium. Many different Bt products are available for landscape professionals and homeowners. Different strains of Bt target specific pest groups, making them selective pesticides. For example, spores and crystals of *Bacillus thuringiensis* var. *kurstaki* (Btk) are highly toxic when ingested by butterfly and moth larvae (caterpillars). The crystals containing the toxin dissolve only at an extremely high pH found in the caterpillar's gut. Btk is not toxic to bees. However, avoid spraying or allowing spray to drift onto favored food plants of caterpillars such as milkweed, the primary food source for monarch butterfly caterpillars.

Another strain of Bt, *B.t. galleriae* (Btg), targets several species of beetles in the adult and larval stages including scarab beetles (e.g., Japanese beetle), weevils, and leaf beetles. Btg is not toxic to bees or butterflies, but applications should be avoided where predatory beetles are active.

While a Bt strain works well for its target pest, it also breaks down quickly in sunlight, becoming ineffective after a few days. This makes Bt very safe for pollinators, predatory insects and mammals. Bt can be sprayed even when bees or butterflies are present. Many Bt products are OMRI listed.

Chromobacterium subtsugae. This naturally occurring bacterium is used in a fermentation process that produces a product with insecticidal properties (e.g., Grandevo PTO). It is a broad spectrum bio-insecticide/miticide that controls or suppresses insect and mite pests on ornamentals and turf. It has multiple modes of action including oral toxicity (stomach poison), repellency and reduced reproduction. This product is applied as a foliar application and targets numerous caterpillar species in addition to aphids, whiteflies, thrips, psyllids, chinch bugs, mites and certain beetles. It suppresses a broad number of caterpillar species and should not be sprayed or allowed to drift in known habitats for threatened or endangered species of caterpillars and butterflies. This product may repel bees for up to six days, so time applications to avoid disrupting pollination. Grandevo PTO (active ingredient C. *subtsugae*) is an OMRI listed product.

Azadirachtin. Azadirachtin is the active ingredient extracted from seeds of the tropical neem tree. Bio-insecticides with azadirachtin act as an insect growth regulator (IGR) in addition to being an anti-feedant and repellant to insects. It is effective at controlling insect immature stages and is broadly labeled for aphids caterpillars such as budworms, tent caterpillars and webworms, beetles such as Japanese beetles, weevils, leafhoppers, leafminers, mealybugs, psyllids, sawflies, scales, thrips, and whiteflies. Azadirachtin must be ingested to be toxic and, when applied as a foliar spray, has short residual activity, making it unlikely bees and other pollinators will be affected as it's no longer toxic for bees after about two hours. Direct contact has shown no effect on worker honey bees. Azadirachtin products can be safely used at any time to control pests on plants that are not attractive to pollinators. However, on pollinator-attractive plants they should be sprayed during late evening, night, or early morning when pollinators are not present to minimize contact with adult bees that could potentially bring azadirachtin back to the nest where larvae are present. Many azadirachtin products are OMRI listed.

Spinosad. Spinosad is derived from a soil bacterium and affects the nervous system of insects and mites. It has contact activity, but is even more active when ingested. Several products containing spinosad are labeled for ornamental (e.g., Conserve) and agricultural uses to control a broad spectrum of pests including caterpillars, sawfly larvae, leaf beetle adults and larvae, thrips, leafminers, and gall-making flies. Spinosad is highly toxic to bees. However, toxicity is greatly reduced once the product has dried on the foliage, within three hours to one day depending on the product. Therefore, avoid use if bees are active, and if applications are needed, apply in the evening when bees are not active and product has time to dry. This product suppresses a broad number of caterpillar species and should not be sprayed or allowed to drift in known habitats for threatened or endangered species of caterpillars and butterflies. Some spinosad products are OMRI listed and on the EPA Reduced Risk list.

Chlorantraniliprole. This EPA Reduced Risk chemical interrupts the normal muscle contraction of insects, resulting in paralysis and death. It has limited systemic activity and can be applied as a foliar spray or through the soil. It is labeled against turf pests including caterpillars, white grubs, crane flies, billbugs, and spittlebugs, and ornamental pests including leaf-feeding caterpillars, lace bugs, aphids, and as a bark spray for clearwing borers. Due to the activity of chlorantraniliprole against caterpillars and its long residual activity, applications should not be made on larval host plants of butterfly and moth pollinators. Chlorantraniliprole has negligible toxicity to bees, and is shown to have no impact on bumble bees. It has no direct impact on natural enemies, and so is compatible with IPM programs.

Acetamiprid. This neonicotinoid is classified as Reduced Risk by EPA. It kills insects by disrupting the nerve function. Acetamiprid is systemic and absorbed through the foliage or when applied as a basal bark spray. It is labeled to control a broad range of pest insects on ornamental plants including aphids, caterpillars, mealybugs, leafhoppers, armored and soft scales, plant bugs, whiteflies, fungus gnat larvae, thrips and leafmining flies. Because acetamiprid is toxic to multiple caterpillar species, this product should not be sprayed or allowed to drift into known habitats for threatened or endangered species of caterpillars and butterflies. Although acetamiprid is less toxic to bees than other neonicotinoids, it is still toxic to bees directly exposed to the chemical. Apply acetamiprid in the evening, night, or early morning when bees are not visiting blooming plants and the residue will not be harmful to bees. When the fungicide fenbuconazole is combined with acetamiprid, the mixture is about fivefold more toxic to honey bees than acetamiprid alone.

Tebufenozide. This EPA Reduced Risk chemical is an IGR that disrupts the molting of early instar caterpillars following ingestion. Tebufenozide is a selective chemical specific to caterpillars. It is labeled for use on ornamentals for a broad range of caterpillars. Tebufenozide is selective, making this product nontoxic to bees and most natural enemies. However, caution should be used to avoid application or drift to larval (caterpillar) food plants of butterfly and moth pollinators.

Pyriproxyfen. Pyriproxyfen is an EPA Reduced Risk chemical that acts as an IGR disrupting the molting process of immature insects (juvenile hormone disrupter). It has translaminar activity (moves through the leaves) and ovicidal activities (kills eggs). Pyriproxyfen provides very good control of certain scale insects. It also controls whiteflies, and suppresses aphids and mealybugs. Pyriproxyfen has low to moderate toxicity to bees. Be careful to avoid spraying or drift near honey bee hives and bumble bee nests. There should be little impact on butterflies or other beneficial insects. Phytotoxicity has been observed on the following plants: Salvia (*Salvia* spp.), Boston fern (*Nephrolepis exaltata*), Schefflera (*Schefflera* spp.), Gardenia (*Gardenia* spp.) and coral bells (*Heuchera sanguinea*).

Pymetrozine. This EPA Reduced Risk pesticide disrupts the normal feeding behavior of aphids and whiteflies on ornamentals. The Endeavor label (active ingredient pymetrozine) states no precautions for honey bees and bumble bees. However, some toxicity has been observed in field studies. As a caution, apply pymetrozine in the evening, night or early morning when bees are not visiting blooming plants. Since this product is selective for aphids and whiteflies, there should be no impact on other pollinators or natural enemies.

Spiromesifen. Spiromesifen is a mite IGR labeled as an EPA Reduced Risk chemical. It is a lipid biosynthesis inhibitor and targets all stages of a broad range of mite species and immature stages of whitefly species. The Forbid label (active ingredient spiromesifen) states no precautions for bees, but there are concerns about the systemic nature of this product and the potential exposure of bee larvae to this class of insecticide. Due to this concern, spiromesifen should be applied after bloom for flowering plants attractive to bees.

Acequinocyl. This EPA Reduced Risk miticide is a metabolic poison that kills spider mites by affecting energy production. It provides quick knockdown and long residual control. Plants should be tested for sensitivity to acequinocyl, especially roses and impatiens. The Shuttle label (active ingredient acequinocyl) states no precautions for bees. Acequinocyl is considered nontoxic to bees and can be applied at any time. Since acequinocyl is selective for mites, other pollinators and natural enemies should not be affected.

Hexythiazox. This mite growth regulator disrupts mites' normal development. It is effective against immature spider mites and eggs, has long residual activity and is applied at low rates. Hexygon (active ingredient hexythiazox) is selective for spider mites in the Tetranychidae family, which includes a wide range of mite species. There is no bee precautionary statement on the Hexygon label and it is generally considered nontoxic to bees, although there is a caution there may be a short residual effect (about two hours) on alfalfa leafcutting bees. As a caution, apply hexythiazox in the evening, night or early morning when bees are not visiting blooming plants. Since hexythiazox is selective for mites, other pollinators and natural enemies should not be affected.

Buprofezin. Buprofezin is an IGR effective against nymphal stages of soft and armored scales (crawler stage), whiteflies, psyllids, mealybugs, planthoppers and leafhoppers. It works by inhibiting chitin synthesis, suppressing oviposition of adults and reducing egg viability. It is nontoxic to bees and is not disruptive to other beneficial insects and mites.

Etoxazole. Etoxazole is a selective miticide effective against most plant-feeding mites, but fairly safe for most predatory insects and mites. Etoxazole is practically nontoxic to adult honey bees.

Test Your Knowledge

Q: Match the pesticide class with the major pest group it targets:

1. Fungicide	A. Weeds
2. Herbicide	B. Insects
3. Insecticide	C. Plant pathogens

A: 1-C, 2-A, 3-B

Q: Match the term with its meaning:

1. Mode of action	A. The manner in which a pesticide destroys or controls a pest
2. Mechanism of action	B. The exact location of inhibition

A: 1-A, 2-B

Q: On which life stage are insecticides usually most effective?
A. Adult
B. Pupa
C. Larva or nymph
D. Egg

A: C

Q: What are reasons why a pesticide may fail to control a target pest? (Select all that apply)
A. Improper pest identification (incorrect pesticide selection)
B. Incorrect pesticide dosage
C. Application when the moon is not in the proper phase
D. Pesticide does not reach target pest
E. Unfavorable environmental conditions
F. Applying with fossil fueled-power equipment rather than solar-powered
G. State of poor pesticide condition
H. Pesticide resistance

A: A, B, D, E, G, H

Q: Match the terms with their definitions:

1. Tolerance	A. The acquired ability of a pest to survive and reproduce following exposure to a dose of pesticide normally lethal to the wild type
2. Resistance	B. The inherent ability of a species to survive and reproduce after herbicide treatment

A: 1-B, 2-A

Q: What is the key factor in delaying or preventing the onset of pesticide resistance?
A. Rotating different brands of pesticide products
B. Incorporating spray applications with granular treatments
C. Rotating pesticides with different mechanisms of action
D. Avoiding applications to the same site at the same time of year

A: C

Q: What is the purpose of assigning a group number to a pesticide active ingredient?
A. The group number expedites the active ingredient through EPA's registration process
B. The group number assists managers in identifying the mechanism of action
C. The group number serves as an indicator of the active ingredient's acute toxicity
D. The group number identifies the location of the product's manufacturer

A: B

Q: What is the primary reason pesticide resistance develops?
A. An induced genetic change brought on by use of a pesticide
B. Applying sub-lethal doses of pesticide
C. The presence of a resistant biotype within the normal

population

D. The continuous use of contact pesticides through spray gun applications.

A: C

Q: What is the best way to minimize potential problems with pesticide storage?

A. Minimize the amounts of pesticides stored
B. Store only products that are relatively non-toxic
C. Surround the facility with razor-tipped wire fencing
D. Build the facility using only concrete cinder blocks

A: A

Q: True or False:
Florida law requires an air gap or back-siphoning device between the water supply and the application equipment to prevent backflow into the water supply.

A: True

Q: What is the appropriate first step to take in cleaning up a pesticide spill?

A. Store containers of spilled material
B. Control spilling or leaking materials
C. Collect spilled material
D. Contain spilled material

A: B

Q: To meet federal and state law requirements, how much pesticide must be spilled to require reporting to authorities?

A. 10 or less pounds or gallons
B. At least 100 pounds or gallons
C. At least 500 pounds or gallons
D. It depends on the specific pesticide

A: D

Q: True or False:
Drift is the unintentional airborne movement of pesticides to nontarget areas.

A: True

Q: What are the consequences of pesticide drift? (Select all that apply)

A. Damage or contamination of sensitive crops
B. Poisoning of bees and other pollinators
C. Health risks to humans and animals
D. Contamination of soil and water in adjacent areas
E. Litigation

A: A, B, C, D, E

Q: What is the most likely reason why there have been declines in bee and pollinator populations in recent years?

A. Parasites, particularly the Varroa mite
B. Pathogens
C. Pesticide exposure
D. A combination of factors

A. D

Q: Which of the following statements is ***false*** regarding the neonicotinoid (neonic) class of insecticides?

A. They are a selective class of insecticides that act on the insect's nervous system
B. They are are the only class of insecticides that are highly toxic to honey bees
C. The most widely used neonics include imidacloprid, thiamethoxam, clothianidin and dinotefuran
D. Neonics move upwards in xylem sap internally within plants where they can later reach nectar and pollen

A: B

Q: Which types of insects do insecticidal soaps generally control well?

A. Larvae, such as those of fall armyworms, corn earworm, and tropical sod webworm
B. Beetles, such as Japanese beetle and other scarab beetles
C. Soft-bodied insects, such as aphids, mealybugs, and whiteflies
D. Borers, such as flatheaded, roundheaded, and clearwing borers

A: C

Q: When is the best time to make pesticide applications so as to have minimal impacts on honey bees and other pollinators?

A. First thing in the morning
B. Around noon
C. Mid-afternoon
D. During the night

A: D

Q: Hexythiazox and spiromesafen are_____.

A. Insect growth regulators (IGRs) that target mites
B. Naturally-occurring bacteria that target caterpillars
C. Anti-feedants that repel insects
D. Extractants from seeds of the tropical neem tree that target a wide range of insects

A: A

CHAPTER 9

Q: Which of the following statements is ***false*** regarding horticultural oils?

A. Most horticultural oils are lightweight and petroleum-based
B. Horticultural oils work best when the spray comes in contact with the pest
C. Once the oil spray dries, it still has effects on target insects
D. Horticultural oils give excellent control of armored scales

A: C

Chapter 10

Ornamental Plant Diseases

In this Chapter

Learning Objectives

After you complete your study of this chapter, you should be able to:

- Name and describe the three major microorganisms that cause plant disease.
- Explain the concept commonly known as the "plant disease triangle."
- Describe the primary dispersal means of the three major microorganisms that cause plant disease.
- Describe the difference between plant disease signs and symptoms.
- Define "abiotic disorder" and provide examples of them and their effects on ornamental plants.
- Provide examples of how each of the following IPM methods are employed to manage diseases of ornamental plants:
  - Genetic control;
  - Cultural methods;
  - Physical methods;
  - Biological control; and
  - Chemical control.
- Describe the activity of a systemic fungicide.
- Describe why resistance is more likely to quickly develop to a systemic fungicide than a contact fungicide.
- Describe the factors that determine how well a fungicide works.
- For five fungal, three bacterial, and two viral pathogens causing Florida's most common ornamental plant diseases, name and describe the following:
  - Symptoms/signs;
  - Factors favoring the disease; and
  - Control and treatment.

Terms to Know

Bacteria: A microscopic single-celled organism.

Abiotic disorder: A nonpest problem (such as extreme temperatures) that causes abnormal functioning of a plant.

Fungicide: Pesticide that is toxic to fungi.

Fungus: Non-chlorophyll-bearing plant, living as saprophytes or parasites; some infect and cause diseases of plants.

Hyphae: The growing filaments of a fungus that form a web as they seek nutrients.

Mycelium (pl. mycelia): A mass of fungal filaments.

Phytotoxicity: Injury symptoms on plants (usually described by chemical injury).

Plant disease: Abnormal functioning of a plant caused by pathogens, including fungi, bacteria, and viruses.

Plant disease triangle: A memory aid that diagrams the three important components necessary for disease: susceptible plant, pathogen, and favorable environment.

Plant pathology: The study of plant diseases.

Sclerotia: Small, hard masses of fungal filaments.

Sign: Indication of plant disease from direct observation of a pathogen or its parts, such as spores, mushrooms, or bacterial ooze.

Symptom: Indication of plant disease by reaction of the host, such as a canker, leaf spot, or wilt.

Virus: A submicroscopic parasite consisting of a core of genetic material surrounded by a protein coat.

Introduction

Plant pathology is the study of plant diseases. Diseases are caused by microorganisms such as fungi, bacteria, and viruses. Some disease symptoms, such as leaf spots and wilting, are easily seen or measured. Others are difficult to observe (for example, root decay) or are very subtle (for example, shorter growth flushes). Detecting the less-obvious symptoms is more difficult when the diseased plant is the only specimen of its kind in the landscape and cannot be compared with a healthy one.

Normally, nonparasitic plant disorders are not included in the study of diseases, but it is still important to recognize them. These disorders include improper planting depth, nutrient imbalances, temperature extremes, toxic chemicals, mechanical injury, water imbalances, and air pollution. Most environmentally induced problems tend to be uniform, whereas disease may show up in spots throughout a site.

Types of Pathogens

To diagnose plant diseases effectively, it is necessary to understand the biology of the microorganisms that cause them: fungi, bacteria, and viruses. Three conditions are required for a disease to develop in plants:

1. An organism (pathogen) that causes disease;
2. A host plant susceptible to the pathogen; and
3. An environment conducive to disease development, such as a particular temperature, wet plant surface or overly wet soil.

These three conditions, commonly known as the "plant disease triangle" (Figure 10.1), must all exist at the same time and in the same place. When the three conditions above occur at the same time, the pathogen infects the susceptible host and the disease starts. The disease continues until a change in the environment works against the pathogen (Figure 10.2).

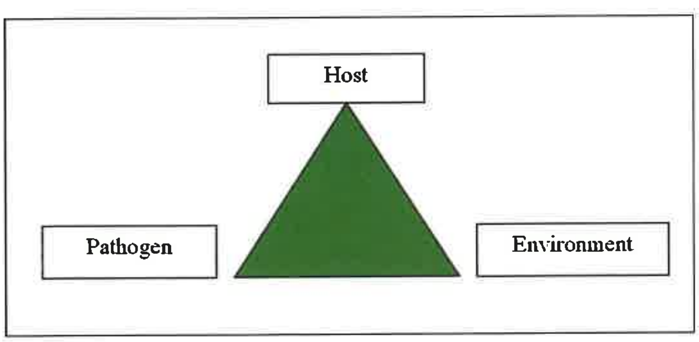


Figure 10.1: The plant disease triangle: pathogen, host, and environment. Credit: Phil Harmon, UF/IFAS Plant Pathology.

Figure 10.2: Botrytis sporulating on a blighted rose flower. Credit: Bruce Watt, University of Maine, Bugwood.org.

Fungi

About 85 pecent of plant diseases are caused by fungi, multi-celled microorganisms that may be seen without a microscope during certain stages of their life cycles. Fungi have no chlorophyll and their cell walls are composed of chitin and other polysaccharides instead of cellulose, which composes plant cell walls. Many species of fungi can be identified by the microscopic spores they produce—reproductive structures that aid in dispersal and survival (Figure 10.3). Some fungi develop masses of hyphae, collectively referred to as mycelia, and spores that are readily visible. Examples: conks, rusts (Figure 10.4), molds, mildew, sclerotia, and mushrooms. Some fungi have no spores, such as *Rhizoctonia*, which can be identified microscopically by the very characteristic right angle branches of its fungal threads, hyphae.

Figure 10.3: Fungi reproduce by producing spores. Credit: Tim Momol, UF/IFAS Plant Pathology.

Figure 10.4: This pine tree has fusiform rust on it. Credit: Andrej Kunca, National Forest Centre - Slovakia, Bugwood.org.

Wind often disperses many fungal pathogens. Spores can be carried for miles by wind. Splashing water from rainfall or irrigation will also move fungal spores from plant to plant. Fungi that live in the soil can move from plant to plant by growing along intermingled roots or out from infested plant debris in the soil. Some fungi (e.g., *Rhizoctonia*) can survive on their own for long periods of time without a host by living in plant debris or soil. Fungi can also be spread by human activity, through movement of already diseased plants or the use of gardening tools. While fungi may enter a plant through its natural openings (e.g., stomates), or through wounds, they can also penetrate directly through the plant's cuticle.

Bacteria

Bacteria are one-celled microorganisms that are so small they can be seen only with a powerful light microscope (Figure 10.5). Most plant pathogenic bacteria do not produce spores.

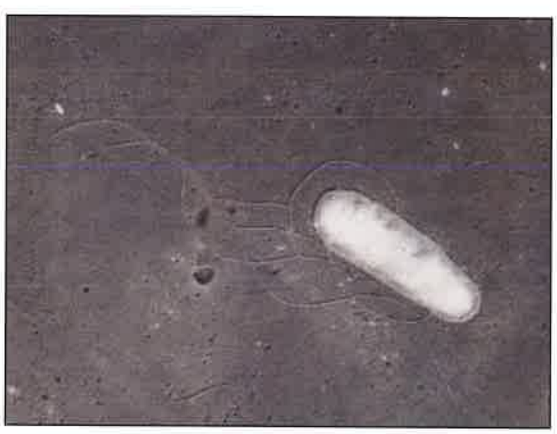


Figure 10.5: Bacteria cell. Credit: Ken Pernezny, retired UF/IFAS Plant Pathology.

Although some bacteria can survive in the soil in decaying plant material for a time, they usually need a host to survive.

Bacteria are dependent on outside agents for dispersal from plant to plant. Splashing water (irrigation, wind-driven rain) is the chief means by which bacteria are disseminated. Another important means of dispersal is through human contact. Many bacterial diseases can be spread simply through the process of touching an infected plant and then touching a healthy plant with hands or pruning tools. Bacteria cannot penetrate the cuticle of plants, but must enter the plant through a wound or natural opening to initiate disease. A special sub-group of bacteria called phytoplasmas require an insect host for dispersal and entry into the plant.

Pseudomonas (Figure 10.6) and *Xanthomonas* are common bacterial organisms that cause disease in plants. Bacterial diseases can be divided into 2 types: systemic and localized. Systemic bacterial diseases can invade plant tissues that carry water and nutrients. Then the disease spreads throughout all parts of the plant. Under certain conditions, the bacterial pathogen may grow in only one area of the infected plant. This localized infection can cause stem rots, leaf spots and blights, wilts, and root rots.

Figure 10.6: Pseudomonas caused the black spots on this hibiscus leaf. Credit: Florida Division of Plant Industry, Florida Department of Agriculture and Consumer Services, Bugwood.org.

Bacterial diseases often produce water soaking around the area where the bacteria entered the leaf. Later, the lower surface of the leaf has a dark and greasy appearance. You most often see the greasy appearance in leaf infections. These are common symptoms of a bacterial disease. But you also need to look for signs of the pathogen, such as bacterial ooze as it transpires from a lesion. You can see ooze most often in the morning. Some bacterial diseases have strong odors.

Other symptoms are:

- Galls
- Leaf scald
- Cankers
- Stem or leaf rots
- Wilts
- Leaf spots and blights
- Scabs
- Soft decay of fruit, roots and stems
- Sour-smelling roots, stems or fruit

Many of these symptoms are the same as those that fungi cause. This can make identifying a disease and what caused it challenging unless you send a plant sample to a diagnostic lab. Sometimes, you can distinguish the difference between leaf diseases that bacteria and fungi cause by the location

Figure 10.7 here. Blight on cedar caused by bacteria. Credit: Andrej Kunca, Ntional Forest Centre - Slovakia, Bugwood.org.

and appearance of the spots. Spots that bacteria cause often are along the margins of the leaf (Figure 10.7) or adjacent to leaf veins. The spots sometimes have angular corners (Figure 10.8), caused by the proximity of the leaf veins around the spots. Early in the morning or after heavy watering or rain, the margins of bacterial spots have a water soaked appearance. This wet appearance is ooze emerging from the stem or leaf lesions (Figure 10.9). When the leaf is dry, the ooze dries and appears as a shiny, thin flake.

Figure 10.8 : Bacteria caused the angular spots on this strawberry leaf. Credit: Gary Simone, retired UF/IFAS Plant Pathology.

Figure 10.9: Ooze emerging from this leaf is a bacterial sign. Credit: Gary Simone, retired UF/IFAS Plant Pathology.

Check for bacterial streaming to determine if bacteria are causing wilt: Make a horizontal cut in a stem and place it in a jar of water. If bacteria are present, a cloudy stream will emit from the cut in the stem within a few minutes. Millions of bacteria compose this stream (Figure 10.10).

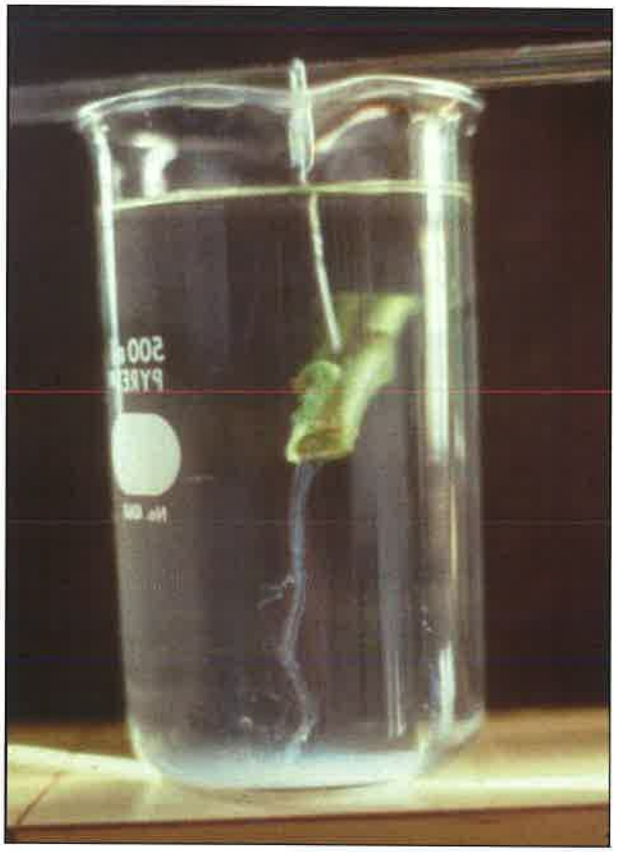


Figure 10.10: The cloudy stream is an indication of the presence of bacteria.Credit: Tim Momol, UF/IFAS Plant Pathology.

Viruses

Viruses are the smallest of the three pathogens described here, and can only be seen with an electron microscope (Figure 10.11). They are made up of genetic material (RNA or DNA), which is usually wrapped in a protein coat. They must have a living host in order to reproduce, because they use plant host cells in the reproduction process. Most fungi and bacteria reproduce Independent of the plant host. Viruses are usually spread from diseased to healthy plants by insects, but can also be spread by mites, nematodes, fungi and even humans. The organism spreading the virus is referred to as a vector. In Florida, although most viruses are vectored by insects, primarily aphids or whiteflies, viruses can also gain entry into plants through openings made during pruning and grafting and from equipment injury.

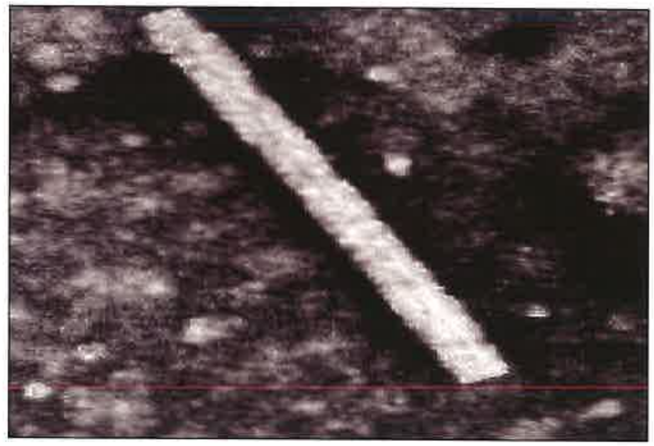


Figure 10.11: An electron microscope is necessary to view a virus rod. Credit: Scot Adkins, USDA.

Viral diseases are recognized by the symptoms on the plant. Symptoms depend on the type of virus, the type of plant and environmental conditions. Viral disease symptoms include:

- Curling leaves
- Stunted plants
- Wilting
- Mosaic patterns of spots on leaves and fruit (Figure 10.12)
- Misshaped leaves
- Chlorotic leaves (Figure 10.13)

Figure 10.12: Mosaic pattern on beach naupaka caused by cucumber mosaic virus. Credit: Florida Division of Plant Industry, Florida Department of Agriculture and Consumer Services, Bugwood.org.

Figure 10.13: Chlorotic leaves caused by virus. Credit: Jason Sharman, Vitalitree, Bugwood.org.

Abiotic Disorders of Ornamental Plants

"Abiotic" literally means without life. Abiotic plant disorders are nonbiological factors, usually associated with the plant's environment that affect plants adversely.

Environmental Stress

These environmental factors include:

- Extreme temperatures (Figure 10.14)
- Strong winds
- Too much or too little moisture
- High or low soil pH
- Poor air quality
- Too much or too little light
- Nutritional problems (Figure 10.15)

If one or more of these factors goes above or below the optimum range for a given plant species, plant growth might be abnormal or adversely affected. Abiotic disorders may also be caused by human activities, such as pesticide (Figure 10.16) and fertilizer applications.


Figure 10.14: Frost caused the crack on this azalea. Credit: Clemson University—USDA Cooperative Extension Slide Series, Bugwood.org.

Figure 10.15: Glossy abelia with an iron deficiency. Credit: John Ruter, University of Georgia, Bugwood.org.

Figure 10.16: Herbicide drift to holly. Credit: Charles T. Bryson, USDA Agricultural Research Service, Bugwood.org.

Pests are more likely to infect plants that have the following stresses:

Nutrients. The low-organic, highly porous soils in Florida do not hold high levels of nutrients. Many Florida soils have the added problem of an alkaline pH (measuring above pH 7). Because of this alkaline pH, some essential nutrients are often not available for plant roots to take up.

Too much water. After an abundance of rain, plant roots may not be able to absorb oxygen because water fills the space that usually holds air. Feeder roots die, which can damage the plant. This problem can occur in compacted soils, too. Soil fungi that cause root disease may easily infect a plant's roots.

Light and temperature problems. Plants can get sunburned (Figure 10.17) from dramatic fluctuations in the amount of light after tree branches or entire trees are removed. A rapid drop in temperature close to or below freezing kills soft herbaceous plant tissue. Cold temperatures can damage tender new growth, branches, stems, and trunks of woody plants.

Figure 10.17: This hawthorn leaf is sunburned.Credit: William M. Brown Jr., Bugwood.org.

Not enough water. Plants will often wilt and leaves will scorch when temperatures are high and the soil is deficient of moisture. New leaves on plants that do not obtain enough water may show leaf scorch. This is especially true when plants are in bright light and drying winds. Recognizing the causes of these stresses and eliminating them helps protect plants from diseases caused by plant pathogens.

Mechanical or Equipment Stress

Be careful when you use lawnmowers, line trimmers and other edging equipment around woody plants, as this equipment can cause wounding. These plants are more likely to be injured if they do not have any mulch around their base, since mulch helps prevent the equipment from contact (Figure 10.18). Woody plants along driveways and parking areas can be injured by the repeated opening of vehicle doors against them or by the bumper hitting them. These injuries cause stress and can provide openings for plant pathogens and other pests.

Figure 10.18: Mulch serves to protect landscape plants from mechanical injury.

Disease Management in Ornamental Plants

Remember that IPM involves all of the methods discussed earlier in this publication. The following section will provide some practical uses of IPM methods, including chemical control as related to ornamental plants.

Genetic Control

Immunity is the rule in the plant kingdom; most plants are immune to most pathogens. Therefore, one does not have to worry that the black spot on roses will next appear on a different species of ornamental plant in the landscape. Ornamental plant cultivars generally are not selected based on their resistance to plant pathogens. However, there can be differences in the relative susceptibilities of cultivars to some pathogens, which should be considered when and where appropriate. Antique roses, for example, are generally more tolerant of black spot and other diseases than most of the more recently developed rose hybrids. Natchez is a crape myrtle cultivar that is commonly used in Florida because of its resistance to powdery mildew. Many cultivars of ornamental plants can be found with some level of resistance to the targeted plant pathogen. Merely choosing and planting these cultivars will reduce disease problems and can be considered as your first line of defense. There are also cultivars that show more tolerance for specific diseases. In spite of the fact that these plants may seem to have as many symptoms as those that are not tolerant, somehow they still thrive and produce.

Likewise, plants that are adapted for the local environment are more likely to remain disease free than non-adapted plants. This is often referred to as selecting the right plant for the site. A plant that prefers well-drained soils will not thrive in a site that is often water-logged. Plants that prefer low pH soil (acid soil) will not thrive in an alkaline soil (high pH soil). In these situations, the plants are weakened and may develop diseases they would otherwise resist. This is even true for "native" plants, which are not just native to Florida, but also to a particular environment (swamp, sand, rock, salt-spray, etc.).

Cultural Methods

Cultural methods can also be used to help manage disease; these include sanitation, plant rotation, host eradication and improvement of the local environment surrounding the plant or plant grouping.

Sanitation. Sanitation practices are cleanliness measures that can reduce unintentional spread of plant pathogens from diseased to healthy plants directly through mechanical transmission or indirectly from pathogen reservoirs.

Hands and pruning tools can be readily contaminated when working with diseased plants, especially if the causal agent is bacterial, viral, or present in the vascular system as some wilts. *Fusarium* wilt of queen palms is a devastating disease that can be transmitted through pruning, thus readily spreading to other queen palms in a nursery or landscape. Routinely sanitize all items that come into contact with plants, soil, or debris. A 10% to 20% solution of household bleach in water makes a good disinfectant for tools and soles of shoes but is quite corrosive. Examples of commercial disinfectants marketed toward plant production personnel include Consan Triple Action 20, Green Shield, and Physan 20. Sanitizer dispensers for hands, tools, and foot baths should be set up at production house entrances. Washing followed by steam sterilization is an excellent method of reducing pathogen populations on

Figure 10.19: Irrigate the landscape early enough to allow for fairly rapid drying. Credit: UF/IFAS Image Database.

trays, pots, and other production tools. Read and follow the temperature recommendations in manufacturers' guidelines to avoid heat damage. The use of disposable transplant trays may also reduce the spread of disease. Concrete walkways in production houses are helpful because they can be regularly cleaned and disinfested easily.

Always move diseased plants away from healthy plants and either destroy them or treat them in an isolated area. Plant debris and cull piles are excellent reservoirs for plant pathogens and should be kept away from and downwind of healthy plants and production areas. Personnel should disinfest hands, shoes, and tools after handling rogued, diseased, or decaying plant material before resuming regular duties.

Rotation. Many plant pathogens cause disease only on a narrow range of closely related hosts. Continuous cultivation of the same types of plants in an area for long periods of time can result in elevated populations of pathogens and other pests in the soil. Periodic rotation of plants that are susceptible to different pathogens may decrease populations of harmful organisms and reduce the incidence of these problems. Pest outbreaks tend to spread quickly within monoculture systems. When appropriate, use plants of many different families and species, or at least use different cultivars. Plant diversity decreases damage from pathogens and pests that attack specific kinds of plants.

Host eradication. Sometimes the best approach is to thoroughly remove all plants that might be possible pathogen hosts. For instance, the weeds surrounding a landscape may be host plants and should be eradicated. Another example can be found among certain plant species, especially trees and palms, for which there are no known resistant varieties to a particular disease and no known controls. If that plant species dies from a particular disease, the best recommendation is to avoid planting the same species in its former location.

Water management. Most fungi and bacteria that cause leaf diseases require free water (rain, dew, irrigation water) or very high humidity (>90%) in order to infect the host tissue and initiate disease. Therefore, water management is an important disease management tool. Hand watering is preferable because it can be restricted to the soil around the roots of plants and not the foliage. It is also important to water after dew has formed, but early enough to allow for fairly rapid drying of the irrigation water (Figure 10.19). The early morning hours are a good choice for watering. Water requirements vary for each plant species, and each season. This means your watering schedule will change throughout the year. Often, the "dry" season in Florida coincides with the coolest time of year, when most ornamental plants are not actively growing and do not require as much water. Reduce the need to irrigate the entire landscape by grouping plants that have the same water requirements; put the plants that need the most water in one place, and those that are drought tolerant in another place, being sure to schedule your irrigation system or hand watering accordingly.

Other cultural methods. While water management is one way to improve the localized environment to minimize disease development, other cultural methods should be used in the landscape. Knowing the proper time to plant and the proper depth to place the seeds, seedlings, plant or tree is important. Poorly drained soil should be avoided. If possible, consider raised beds to ensure good drainage. For annual ornamental gardens, fertilizer should only be applied after the soil has been tested to determine which nutrients are deficient. For perennial ornamental plants, palms and fruit trees, use appropriate slow-release fertilizers and monitor for nutrient deficiencies based on the symptoms and leaf tissue analysis.

Knowing the site's disease history can help with planting decisions. Wider plant spacing provides for good air movement and promotes more rapid drying after rains or irrigation (Figure 10.20). Plant injuries provide access for pathogens, so care should be taken with plants and plant parts during production and distribution. Plants will do better in looser soil. Mulching can also help keep weeds down, retain soil moisture and prevent foliage and fruit from touching plant pathogen-infested soil.

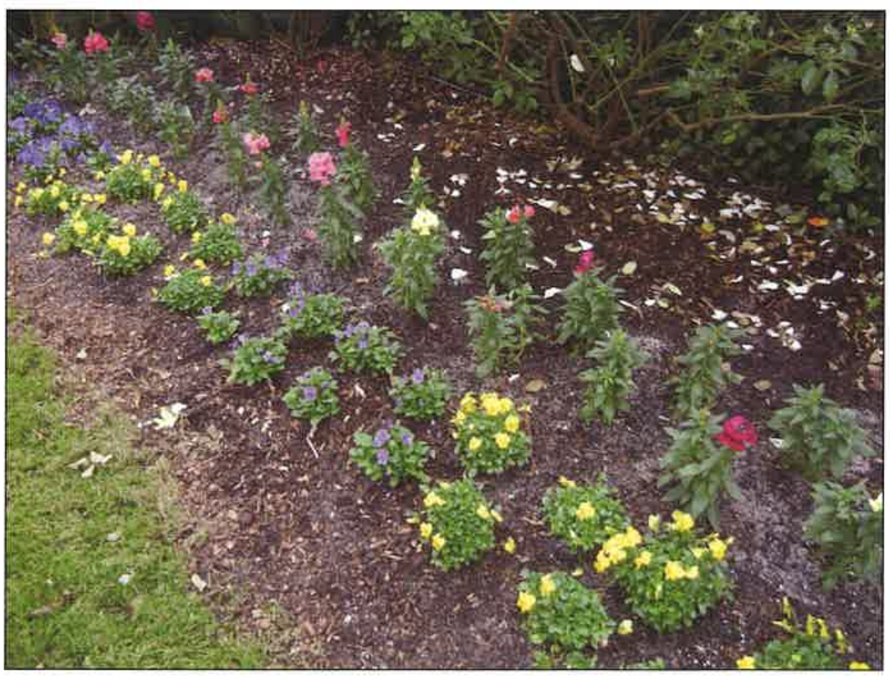


Figure 10.20: Wider plant spacing provides good air movement to facilitate drying.

Physical Methods

Physical control of disease-causing organisms is obtained through mechanical procedures applied directly to plants or substrates that reduce or eradicate pathogen populations.

Steam sterilization. Steam has been used to disinfest soil for over 100 years, and it is practical for the sterilization of soil to be used for potting and transplanting and for intensive in-soil production of high-value crops. An application of aerated steam to maintain a uniform soil temperature of 140°F to 158°F for 30 minutes is sufficient to eliminate most disease-causing organisms present in the soil. Be sure the soil is free of clods, large pieces of plant debris, and excessive moisture, which will hamper the penetration of the steam if present.

Soil solarization. Soil solarization is an option for managing soilborne pests in production systems and sunny landscape settings during periods of little cloud cover and rain. This technique uses clear plastic to trap the radiant energy of the sun, which heats the soil to temperatures sufficient to destroy many plant pathogens and other pests without completely eliminating beneficial organisms. Soil solarization is often used when producing high-quality bedding plants, such as cut flowers.

Hot water treatment. Seeds, bulbs, tubers, and cuttings can be immersed in hot water to kill potential pests, including pathogens. Daffodil and Easter lily bulbs are commonly treated with hot water to kill any nematodes that may be present. Accurate time and temperature controls must be in place for the hot water treatment to be successful. The temperature for pathogen inactivation must not exceed the critical damage threshold for the propagative material being disinfested.

Biological Control

Biological control is the use of beneficial microorganisms to suppress soilborne and foliar plant pathogens. Products containing bacteria, such as *Bacillus, Pseudomonas,* and *Streptomyces*, and fungi, such as *Gliocladium* and *Trichoderma*, have reduced a variety of fungal plant pathogens in various experiments, especially when incorporated into transplant media or used as seed treatments. Products containing biological control agents that are currently available for disease management of ornamentals are listed in UF/IFAS EDIS Publication PP-202, *Professional Disease Management Guide for Ornamental Plants*, available at **http://edis.ifas.ufl.edu/pp123**. Ongoing research at universities and federal facilities continues to evaluate and develop new biocontrols as well as expand the labeling of existing products. The use of organic soil amendments (e.g., compost, sewage sludge, etc.) may enhance populations of beneficial microorganisms already present in the soil. Biological control technologies are environmentally friendly IPM tools with great potential, but currently, biological controls do not adequately control ornamental plant diseases on their own in most cases.

Chemical Control

Regardless of what other IPM strategies are used, it is sometimes necessary to apply pesticides to manage plant diseases (Figure 10.21). Pesticide application should be based on scouting reports and the presence of environmental conditions conducive to disease development in established planting systems. Avoid using routine "calendar sprays," which can be wasteful and may impact populations of beneficial organisms.

Figure 10.21: Despite using other IPM methods, it's sometimes necessary to apply pesticides for disease control in the landscape.

Fungicides are pesticides that kill fungi or stop the spread of fungi to other plants. A fungicide's activity refers to its mobility in the plant and should be considered when choosing a product. Systemic fungicides usually move upward within a plant, though there are a few that also move downward. They may be applied as foliar sprays, seed treatments, root dips, soil drenches, or tree injections. Locally systemic fungicides have limited mobility in the direct vicinity of application. Almost all systemic fungicides disrupt only one or a few steps in fungal metabolism. Therefore, resistance to these chemicals usually occurs within a few years if used frequently. It is best to use these products in combination or rotation with broad-spectrum contact fungicides to delay development of resistance. Advantages of using systemic fungicides include longer residual activity and survival of possible beneficial organisms on the plant surface. Fungicides may have protective or curative activity. Most fungicides and bactericides are protectants and must be present on or in the plant in advance of the pathogen in order to prevent infection. These chemicals may be applied when environmental conditions are conducive to a disease outbreak. Products with curative activity may be applied after infection but prior to severe disease symptoms. Some chemicals have both protective and curative activity that may depend on the rate of application. Resistance to many contact fungicides is slow to develop or nonexistent because many different metabolic pathways of target organisms are disrupted.

Besides resistance issues mentioned above, several factors determine how well fungicides work:

Coverage. Insufficient coverage is one of the most common reasons for fungicide failure.

Application time. Enough of the fungicide should be in or on the plant before or during the time the fungus infects the plant.

Life stages. How often you apply fungicides depends on the type of fungus. If the fungus is short-lived, it may infect a plant several times which would require repeated fungicide applications.

Rate of plant growth. As new leaves grow, you may have to apply fungicides repeatedly to protect the new growth.

Weather. If the weather is not suitable for fungal growth, you may not have to apply a fungicide. At other times rain might wash off the fungicide, requiring a repeat application. If the fungicide breaks down quickly, you may have to apply the chemical more frequently. Phytotoxic effects may occur if applied under extremely hot or dry conditions.

Use the appropriate fungicide for plants and their diseases. Make sure the product label lists the plants and the plant site on which you want to apply it. Some products can be used in a greenhouse but not in the landscape.

Refer to UF/IFAS EDIS Publication PP-202, *Professional Disease Management Guide for Ornamental Plants*, available at **http://edis.ifas.ufl.edu/pp123** for selection of chemical control options.

Common Diseases of Ornamental Plants

Florida's warm, humid environment makes Florida a compatible location to mass produce numerous plant species. These ideal conditions also are suitable for the development of a wide variety of plant pathogens, including bacteria, fungi, and viruses. This section will present only a few of the common ornamental plant diseases encountered in Florida. This publication will devote separate chapters to address palm and turfgrass diseases. For more information on the many ornamental plant diseases which occur in Florida, see UF/IFAS Extension's EDIS publication site at **https://edis.ifas.ufl.edu/**.

Bacterial Diseases

Crown gall

Symptoms/signs: Crown gall is characterized by the formation of galls that resemble tumors (Figure 10.22). Galls may form on the surface of stems or internally within stems, causing large, swollen sections. Galls can also form on roots. The first observable symptom is swelling of the plant tissue. This is usually associated with a wound; therefore, the initial swelling is often dismissed as normal callus formation. Within a matter of weeks after initial infection, this swelling takes on a spherical shape and becomes light green to tan in color. The gall then becomes irregular in shape and turns dark brown or black because of plant cells dying on the gall surface. As the gall enlarges, it crushes the plant's conducting tissue and blocks water movement to the foliage.

Causal agents: *Agrobacterium tumefaciens*

Figure 10.22: Crown gall on rose. Credit: Jennifer Olson, Oklahoma State University, Bugwood.org

Factors favoring the disease: *Agrobacterium* can live in the soil without a host for a number of years. Avoid contact with unsterilized native soil. Root-chewing insects can inflict wounds that can become infected.

Control: No known bactericides are effective against crown gall. A strict sanitation program is the best method of disease management. Obtain clean, disease-free stock plants. During propagation and pruning, cutting utensils should be sterilized between each cut. If pots and trays from contaminated plants must be reused, they should be scrubbed free of adhering soil, then soaked in a disinfectant to kill any remaining bacteria. When removing galls from plants, cuts should be made several inches below the gall tissue.

Xanthomonas leaf spot

Symptoms/signs: Small, water-soaked, angular lesions appear on the leaves as the first sign of infection. These lesions become chlorotic and eventually turn brown (Figure 10.23). When infections are severe, leaf drop may occur.

Causal agent: *Xanthomonas* spp.

Factors favoring the disease: Summer conditions with warmer temperatures and a wet, humid environment favor *Xanthomonas* development.

Control and treatment: Minimize overhead watering. Infected lesions exude bacteria that are easily splashed from plant to plant. Minimize worker handling of plants. Bacteria exuded onto leaves can easily be moved between plants by workers, especially if plants are wet. Eliminate diseased stock plants. The first line of defense with this disease is exclusion, which can best be achieved if stock plants are disease free. Refer to UF/IFAS EDIS Publication PP-202, *Professional Disease Management Guide for Ornamental Plants*, available at **http://edis.ifas.ufl.edu/pp123** for chemical control options.

Figure 10.23: Bird-of-paradise infected with Xanthomonas leaf spot. Credit: Jeffrey W. Lotz, Florida Department of Agriculture and Consumer Services, Bugwood.org

Pseudomonas leaf spot

Symptoms/signs: This bacterial disease has many similarities to Xanthomonas leaf spot. *Pseudomonas* forms circular lesions on some species and angular lesions on others (Figure 10.24). These lesions are water-soaked and randomly spaced on the leaves.

Causal agent: *Pseudomonas* spp.

Factors favoring the disease: The warm temperatures and high humidity commonly seen during summer favor the pathogen.

Control and treatment: The first line of defense with this disease is exclusion; therefore, eliminate any plants showing disease. Minimize overhead watering since bacteria are easily splashed from plant to plant and can reinfect via stomatal openings. Minimize worker contact, especially if plants are wet. Refer to UF/IFAS EDIS Publication PP-202, *Professional Disease Management Guide for Ornamental Plants*, available at **http://edis.ifas.ufl.edu/pp123** for selection of chemical control options.

Figure 10.24: Hibiscus leaves showing symptoms of Pseudomonas leaf spot. Credit: Florida Division of Plant Industry, Florida Department of Agriculture and Consumer Services, Bugwood.org.

Fire blight

Symptoms/signs: This disease infects members of the Rosaceae plant family, which includes numerous species of trees and shrubs in landscapes. The bark at the base of blighted twigs becomes water-soaked, then dark, sunken and dry; cracks may develop at the edge of the sunken area. Young twigs and branches die from the terminal end and appear burned or deep rust colored. Branches may be bent, resembling what is commonly referred to as a "shepherd's crook" (Figure 10.25). Dead leaves and fruit remain on the branches.

Causal agent: *Erwinia amylovora*

Factors favoring the disease: The bacteria spread rapidly through the plant tissue in warm temperatures (65° F or higher) and humid weather.

Control and treatment: Prune out infected brancheseight inches below the damage. Avoid heavy nitrogen fertilization, especially in summer, when succulent growth is most susceptible to fire blight infection. Chemical control is not always effective and needs to be applied preventively. Refer to UF/IFAS EDIS Publication PP-202, *Professional Disease Management Guide for Ornamental Plants*, available at **http://edis.ifas.ufl.edu/pp123** for selection of chemical control options.

Figure 10.25: Bradford pear with fire blight. Credit: Florida Division of Plant Industry, Florida Department of Agriculture and Consumer Services, Bugwood.org

Bacterial leaf scorch

Symptoms/signs: Bacterial leaf scorch is a chronic, eventually fatal disease. The pathogen infects the xylem where it partially blocks the flow of water to the leaves, resulting in leaf scorch symptoms. Symptoms include premature leaf browning, marginal necrosis and defoliation (Figure 10.26). Infected trees leaf-out normally the following year; however leaves on a few more branches turn prematurely brown in late summer. These events repeat themselves over a period of several years until the entire tree turns prematurely brown.

Causal agent: *Xylella fastidiosa*

Factors favoring the disease: Some researchers working with this disease suggest that leaf scorch symptoms are more severe during times when other stresses are placed on the tree. Timing of symptom development in mid to late summer is often associated with various moisture and heat stresses occurring that season.

Control and treatment: There is no cure for bacterial leaf scorch, so one should expect diseased trees to be gradually lost over the years. Because infected trees decline gradually, it may be 5 to 10 years before there are many dead limbs and branches present. In the meantime, tree owners can provide good growing conditions for the trees to prolong their survival and to enhance their aesthetic value. Chemical control, including tree injections, has not proven to be a long-term solution.

Figure 10.26: Oak showing symptoms of bacterial leaf scorch. Credit: Brian Olson, Oklahoma State University, Bugwood.org.

Fungal Diseases

Sphaeropsis gall

Symptoms/signs: The Sphaeropsis gall fungus is a serious disease throughout Florida. This gall appears on bottlebrush, holly, oleander and wax myrtle. The fungus causes swollen, woody galls in the branches of holly and bottlebrush. Sphaeropsis gall also forms witch's broom growth on wax myrtle, oleander, holly, and other woody plants.

Causal agent: *Sphaeropsis tumefaciens*

Factors favoring the disease: Periods favoring new shoot expansion. The disease is disseminated by wind and rain.

Control and treatment: During dry conditions, prune branches at least six inches below where symptoms are seen. Refer to UF/IFAS EDIS Publication PP-202, *Professional Disease Management Guide for Ornamental Plants*, available at **http://edis.ifas.ufl.edu/pp123** for fungicide selection.

Figure 10.27: Blackening of stem near base of plant beneath bark and aboveground symptoms. Credit: Elizabeth Bush, Virginia Polytechnic Institute and State University, Bugwood.org

Phytophthora and Pythium

Symptoms/signs: *Phytophthora* and *Pythium* infections commonly attack the root systems of landscape ornamental plants. Plants infected with either of these pathogens exhibit yellowing of leaves, wilting, root dieback, root discoloration, and sloughing of root tissue (Figure 10.27). Under wet conditions, the foliage may exhibit black to brown lesions (Figure 10.28). Mycelial growth in the soil or on stems is rarely observed with either *Phytophthora* or *Pythium* infections.

Causal agent: *Phytophthora* spp. and *Pythium* spp.

Factors favoring the disease: Wet conditions, saturated soils.

Control and treatment: Use well-drained soil mixes. Avoid saturated conditions. Discard plants that have disease symptoms. Sterilize used pots and trays. Refer to UF/IFAS EDIS Publication PP-202, *Professional Disease Management Guide for Ornamental Plants*, available at **http://edis.ifas.ufl.edu/pp123** for fungicide selection.

Figure 10.28: Pythium causing a lesion on the stem near base of plant. Credit: Mary Ann Hansen, Virginia Polytechnic Institute and State University, Bugwood.org.

Anthracnose

Symptoms/signs: Anthracnose is characterized by necrotic spots on the leaf surface (Figure 10.29). Under humid conditions, brown masses of spores can form into concentric rings. Necrotic spots eventually become dark brown, and the leaves may fall off. Anthracnose can also cause tip dieback.

Causal agent: Several, including *Glomerella cingulata* and *Colletotrichum* spp.

Factors favoring the disease: The disease favors wet conditions when cuttings are rooted under mist and high humidity in the summer months. This disease frequently occurs after misuse of pesticides has caused tissue damage.

Control and treatment: Minimize overhead irrigation and exposure to rainfall. A number of fungicides can effectively control anthracnose. Refer to UF/IFAS EDIS Publication PP-202, *Professional Disease Management Guide for Ornamental Plants*, available at **http://edis.ifas.ufl.edu/pp123** for fungicide selection.

Figure 10.29: Dogwood Anthracnose. Credit: Mary Ann Hansen, Virginia Polytechnic Institute and State University, Bugwood.org.

Figure 10.30: Rhizoctonia symptoms on a rose. Credit: Florida Division of Plant Industry, Florida Department of Agriculture and Consumer Services, Bugwood.org.

Rhizoctonia

Symptoms/signs: Young, tender stems are girdled, become water soaked, and are unable to support the plant's weight. The term "damping-off" is used to describe these classic symptoms (Figure 10.30).

Causal agent: *Rhizoctonia solani*

Factors favoring the disease: Water-saturated soils are conducive to disease development. *Rhizoctonia* can spread within soil without having a host plant present. It produces constricted small mats of tightly woven mycelia called sclerotia. Irregular in shape, brown in color, and resembling soil particles, *Rhizoctonia* sclerotia provide a seed-like mechanism for the fungus to survive unfavorable conditions, such as drought or cold weather. These small sclerotia are one of the ways the fungus spreads.

Control and treatment: Use disease-free transplants. Many fungicides are effective against *Rhizoctonia*. Refer to UF/IFAS EDIS Publication PP-202, *Professional Disease Management Guide for Ornamental Plants*, available at **http://edis.ifas.ufl.edu/pp123** for fungicide selection.

Southern blight

Symptoms/signs: The pathogen grows as a white, feathery mycelial mat along the soil surface and on plant parts (Figure 10.31). *Rhizoctonia*, on the other hand, always produces brown-colored mycelia. The mycelia eventually form small, circular, brown sclerotia. Sclerotia resist penetration by fungicides.

Causal agent: *Sclerotium rolfsii*

Factors favoring the disease: Growth of this fungus is especially rapid when soils are wet and weather is hot. Southern blight is common in warm climates.

Control and treatment: Use disease-free plants to exclude fungal access. Plants that have disease symptoms should be discarded and the rest should be treated with a fungicide drench. Controlling outbreaks of southern blight with fungicides is difficult, but a few have been found effective. Refer to UF/IFAS EDIS Publication PP-202, *Professional Disease Management Guide for Ornamental Plants*, available at **http://edis.ifas.ufl.edu/pp123** for fungicide selection.

Figure 10.31: Mycelial mat on the soil surface and growing onto a schefflera. Credit: Florida Division of Plant Industry, Florida Department of Agriculture and Consumer Services, Bugwood.org.

Powdery and downy mildew

Symptoms/signs: Powdery mildew infects young, succulent tissues and extra new growth (water sprouts) on the main branches of plants (Figure 10.32). This mildew covers entire plant surfaces. It is visible on the top surfaces of leaves. Downy mildew favors young, succulent tissues also. However, it appears only on the underside of leaves (Figure 10.33). Plants trapping water vapor from moist soil surfaces creates favorable conditions for disease development.

Causal agent: Several, including *Podosphaera* spp. (powdery mildew) and *Plasmopara* and *Peronospora* spp. (downy mildew)

Factors favoring the disease: Mildew diseases usually appear during fall and spring, when humid periods accompany cool nights and warm days. Rain or prolonged irrigation are ideal conditions for mildew diseases.

Control and treatment: Powdery mildew can be suppressed by planting landscape plants in open, sunny areas and not overcrowding plants to allow air movement. Do not irrigate plants at night and do not over-fertilize. Remove infected leaves and other plant parts. Refer to UF/IFAS EDIS Publication PP-202, *Professional Disease Management Guide for Ornamental Plants*, available at **http://edis.ifas.ufl.edu/pp123** for fungicide selection.

Figure 10.32: Powdery mildew developing on a crape myrtle. Credit: Florida Division of Plant Industry, Florida Department of Agriculture and Consumer Services, Bugwood.org.

Figure 10.33: Downy mildew on the underside of a viburnum leaf. Credit: Sandra Jensen, Cornell University, Bugwood.org.

Leaf spot diseases

Symptoms/signs: Many ornamental plants are susceptible to numerous species of fungi that cause leaf spots. Lesions usually start out small, but can vary in size and have unique features. In severe cases, leaves subsequently turn yellow and darker, and finally lead to defoliation. Several common examples include black spot of rose (Figure 10.34), pseudocercospora leaf spot (Figure 10.35), and oak leaf blister (Figure 10.36).

Causal agent: Many. A few examples include *Diplocarpon rosae* (black spot of rose), *Cercospora* spp. (various hosts of Cercospora leaf spot), and *Taphrina* spp. (oak leaf blister).

Factors favoring the disease: Varies widely depending upon pathogen and host plant.

Control and treatment: Use rigorous IPM methods, especially sound cultural practices. Refer to UF/IFAS EDIS Publication PP-202, *Professional Disease Management Guide for Ornamental Plants*, available at **http://edis.ifas.ufl.edu/pp123** for fungicide selection.

Figure 10.34: Black spot of rose. Credit: Florida Division of Plant Industry, Florida Department of Agriculture and Consumer Services, Bugwood.org.

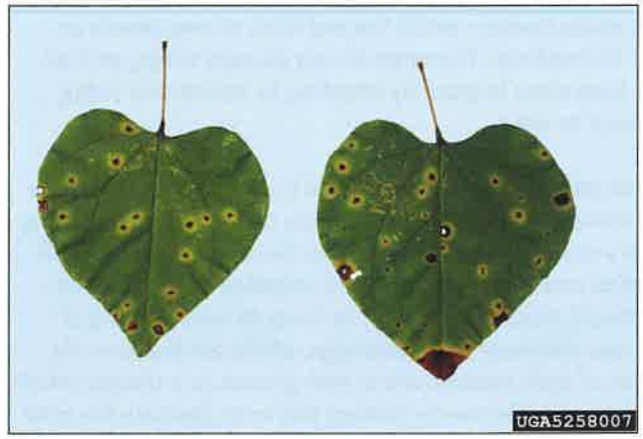


Figure 10.35: Pseudocercospora leaf spot on eastern red bud. Credit: Florida Division of Plant Industry, Florida Department of Agriculture and Consumer Services, Bugwood.org.

Figure 10.36: Oak leaf blister is very common. Credit: Joseph OBrien, USDA Forest Service, Bugwood.org.

Viral Diseases

Rose rosette disease

Symptoms/signs: Rose rosette disease causes red coloration of new growth, excessive thorniness, elongated shoots, deformed blooms, witches broom of shoots (Figure 10.37) and, ultimately, death of the plant.

Causal agent: A mite vectors this disease by its feeding activity.

Factors favoring the disease: In early spring, the vectoring mites migrate onto developing shoots, where females lay eggs.

Young mites develop within the leaf folds of new shoots or under leaf petioles. The mites do not possess wings, so they move from plant to plant by attaching to insects and being dispersed by wind.

Control and treatment: Once a rose is identified infected, the plant should be removed immediately by burning or disposing of it in a sealed plastic bag. Because the disease can possibly spread to a neighboring rose plant, removal of the infected rose should include removal of its roots as well. Pruning of roses may eliminate mites and eggs, which are found in the crevices of cane petioles and in new growth. It is unclear which pesticides are effective to manage this mite. Because the mite is hidden in the buds on the growing tips, coverage is difficult to achieve. However, it is known there are natural enemies of many mite species, so the use of soft pesticides, such as light horticultural oils, sulfur, soaps, etc., may preserve the naturally occurring natural enemies.

Figure 10.37: Rose rosette is caused by a virus. Credit: Jennifer Olson, Oklahoma State University, Bugwood.org.

Impatiens necrotic spot virus (INSV)

Symptoms/signs: Hundreds of plant species are susceptible to INSV. One or more of the following symptoms may be present on a plant infected with INSV: stunting, ringspots, brown-to-purple spots on leaves or stems, stem browning (cankers), flower breaking, and plant death (Figure 10.38). Symptoms of INSV can easily be confused with symptoms of diseases caused by other viruses, fungi, bacteria or nutritional disorders.

Causal agent: Western flower thrips vector this disease by its feeding activity.

Factors favoring the disease: High nitrogen fertility that stimulates tender new growth and the presence of weeds and thrips in the landscape.

Control and treatment: Remove and destroy infected plants. Control weeds in the landscape, as they serve as alternate hosts for both the pathogen and thrips. There are insecticides registered for the control of thrips.

Figure 10.38: Chrysanthemum showing symptoms of INSV. Credit: Department of Plant Pathology, North Carolina State University, Bugwood.org.

Diagnostic Assistance

The primary role of the Florida Extension Plant Diagnostic Clinics (FEPDC) is to determine whether symptoms in submitted plant samples involve an infectious causal agent, e.g. fungus, bacterium, or virus, or other cultural or environmental factor that causes similar symptoms (Figure 10.39). The goal of the FEPDC system is to educate clientele by providing plant disease and disorder diagnoses and recommendations for preventative and therapeutic measures. The FEPDC is a fee-based service provided to any Florida resident by the Plant Pathology Department of the Institute of Food and

Agricultural Sciences (IFAS), University of Florida, in conjunction with the Cooperative Extension Service. For more information, the nearest laboratory, and fees, see *Sample Submission Guide for Plant Diagnostic Clinics of the Florida Plant Diagnostic Network*. Available at: **http://edis.ifas.ufl.edu/SR007**.

Figure 10.39: The UF/IFAS Extension Plant Diagnostic Clinic in Gainesville.

Test Your Knowledge

Q: Which of the following form the components of the "plant disease triangle?" (Select all that apply)

A. Susceptible host
B. Proper fertility practices
C. Sufficient moisture supply
D. Favorable environment
E. Pathogen

A: A, D, E

Q: Match the characteristics with the plant disease microorganisms.

1. Fungi	A. Can only be seen with an electron microscope
2. Bacteria	B. Multi-celled microorganisms
3. Virus	C. One-celled microorganisms

A: 1-B, 2-C, 3-A

Q: Match the dispersal means with the plant disease microorganisms.

1. Fungi	A. Splashing water
2. Bacteria	B. Vector transmission
3. Virus	C. Wind-blown spores

A: 1-C, 2-A, 3-B

Q: Which plant disease microorganism is responsible for causing the majority of ornamental plant diseases?

A. Fungi
B. Bacteria
C. Virus

A: A

Q: Curling leaves, stunted plants, wilting, mosaic patterns of spots on leaves and fruit, and misshaped leaves are all likely symptoms of:

A. Environmental stress
B. Fungal disease
C. Bacterial disease
D. Viral disease

A: D

Q: True or False:
Many of the bacterial disease symptoms are the same as those that fungi cause.
A: True

Q: For the following, indicate if it is a sign or a symptom of an ornamental plant disease.
1. Galls
2. Spores
3. Leaf scald
4. Cankers
5. Stem or leaf rots
6. Wilts
7. Masses of hyphae
8. Leaf spots and blights
9. Scabs
10. Ooze
11. Soft decay of fruit, roots, and stems
12. Sour-smelling roots, stems, or fruit
13. Mushroom

A: 2,7,10,13-Signs; 1,3,4,5,6,8,9,11,12-Symptoms

Q: Which of the following are considered "abiotic disorders" of ornamental plants? (Select all that apply)
A. Mechanical injury
B. Nutrient deficiency
C. Drought stress
D. Air pollution

A: A,B,C,D

Q: Planting the Natchez crape myrtle cultivar because of its resistance to powdery mildew is an example of:
A. Cultural control
B. Mechanical control
C. Genetic control
D. Physical control

A: C

Q: Proper sanitation and water management are examples of:
A. Cultural control
B. Mechanical control
C. Genetic control
D. Physical control

A: A

Q: Which of the following statements is false regarding fungicides?
A. Almost all systemic fungicides disrupt only one or a few steps in fungal metabolism
B. Resistance to many contact fungicides is likely to develop quickly
C. Most fungicides are protectants and must be present on or in the plant in advance of the pathogen
D. Insufficient coverage is one of the most common reasons for fungicide failure

A: B

Chapter 11

Ornamental Plant Arthropod Pests

In this Chapter

Learning Objectives

After you complete your study of this chapter, you should be able to:

- Describe gradual and complete metamorphosis.
- Describe two main types of arthropod mouthparts and provide specific examples of these that are common in landscape ornamental plantings.
- Describe four types of damage that arthropods cause and provide specific examples of these that are common in landscape ornamental plantings.
- Explain the importance of identifying arthropods.
- Explain how and why you need to monitor and scout arthropods.
- Explain why you need to know the life cycles of arthropods.

Terms to Know

Cambium: A thin formative layer between the xylem and phloem of most vascular plants that gives rise to new cells and is responsible for secondary growth.

Complete metamorphosis: Insect life cycle in which the insect passes through four stages of development: egg, larva, pupa, and adult.

Gradual metamorphosis: Insect or mite life cycle in which the arthropod passes through three different stages of development: egg, nymph, and adult.

Metamorphosis: A change in the shape, size, and/or form of an animal.

Introduction

Arthropods are a group of invertebrate animals that includes centipedes, millipedes, spiders, mites, horseshoe crabs, scorpions, insects and crustaceans. There are more than one million arthropod species that have been identified by scientists, and there are estimated to be many millions that have not yet been identified.

The exoskeleton of an arthropod is a hard external structure made of chitin that protects the arthropod, prevents desiccation and provides structural support. Since the exoskeleton is rigid, it cannot grow with the arthropod and must be molted periodically to allow for increases in size. After molting, a new exoskeleton is secreted by the epidermis. Muscles connect to the exoskeleton and enable the animal to control the movement of its joints.

The muscle structure of arthropods is more complex than that of most other invertebrates. Arthropods have longitudinal and circular bands of muscle tissue, as well as isolated muscles that together enable a wide range of movements. Additionally, arthropods have a well-developed nervous system. In more advanced arthropods, the nervous system consists of a brain and a double nerve cord.

Many insects and other related pests attack ornamental plants in Florida. In this section, you will learn about:

- types of arthropod mouthparts;
- types of feeding damage; and
- common species of arthropod pests of landscape ornamental plants.

The two main types of mouthparts are 1) chewing or piercing, and 2) sucking. Chewing insects use the front part of their mandibles for grinding. Piercing and sucking insects have a tube-like structure, similar to a drinking straw, to extract plant sap.

The four most common types of feeding damage are stippled or chlorotic leaves, defoliation, dieback, and distortion.

Life Cycles of Arthropods

Most insect reproduction results from males mating with females. The females of some aphids and parasitic wasps produce eggs without mating. Some bear live young, but most insects hatch from eggs.

Insect eggs come in many sizes and shapes (Figures 11.1 and 11.2): elongate, round, oval, and flat. Eggs of grasshoppers and praying mantids are laid in capsules. Stink bug eggs are barrel-shaped. Eggs may be deposited singly or in masses on or near the host—in soil or water or on plants, animals, or structures.

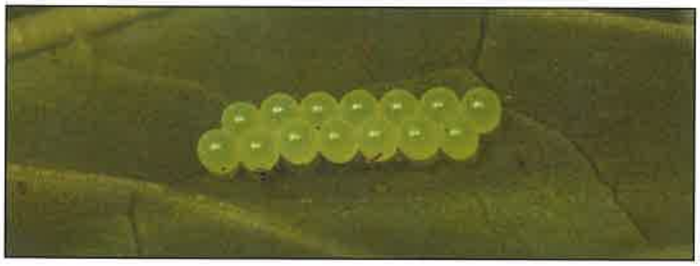


Figure 11.1, 11.2: Insect eggs vary in shape and size. Credit: L.J. Buss, UF/IFAS Entomology and Nematology.

The change through which an arthropod passes in its growth from egg to adult is called metamorphosis. When a young arthropod hatches from an egg, it is called either a larva or nymph, depending on the species. After a time, the young grows to a point where the skin cannot stretch further. The young insect sheds its skin (molts), and forms a larger one. The number of these developmental stages (called instars) varies with different insect species, and may vary with the temperature, humidity, and food supply. The heaviest feeding generally occurs during the final two instars.

The mature (adult) stage is when it is capable of reproduction. Some mature insects do not feed, and in many cases, the adults do not feed on the same material as the immature forms. Winged insects develop their wings at maturity.

Insects that undergo gradual metamorphosis pass through three different stages of development: egg, nymph, and adult (Figure 11.3). The nymphs look like small versions of the adult form. Mites also undergo gradual metamorphosis. Both nymphs and adults usually eat the same kind of food, and live in the same environment. The change of the body is gradual, and the wings become fully developed only in the adult stage. Examples are mites, grasshoppers, stinkbugs, lice, termites, aphids, and scales.

Figure 11.3: Example of gradual metamorphosis. Credit: J.L. Castner

Insects undergoing complete metamorphosis pass through four stages of development: egg, larva, pupa, and adult (Figure 11.4). The earlier stages (called larvae, caterpillars, maggots, or grubs) look entirely different than the adults. Larvae usually live in different situations and (in many cases) eat different foods than adults eat. Examples of insects that undergo complete metamorphosis include beetles, butterflies, flies, moths, bees, and ants.

Larvae hatch from eggs. Larvae grow, molt, and pass through several instar stages. Moth and butterfly larvae are called caterpillars; some beetle larvae are called grubs; most fly larvae are called maggots. Caterpillars often have legs; maggots are legless. Weevil grubs are legless; other kinds of beetle larvae usually have legs. It is usually the larval stage that does the most feeding.

The pupa is the stage when the larva changes into an adult. Some insects spin a silken cocoon and pupate inside of it. Pupae do not feed.

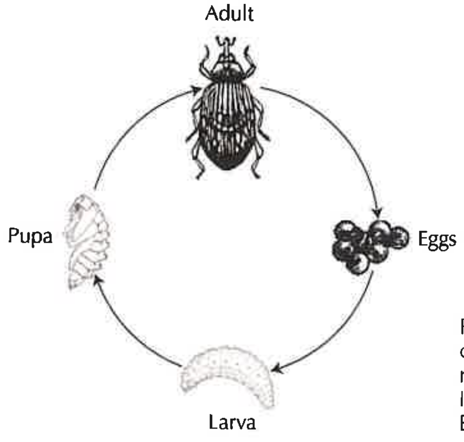


Figure 11.4: Example of complete metamorphosis. Credit: Invasive.org/The Bugwood Network.

Types of Plant Damage

Stippled or Chlorotic Leaves

Arthropods with piercing and sucking mouthparts cause this damage. Symptoms appear when an insect inserts its mouthparts into the plant. The insect extracts sap and chlorophyll from the plant cells. Chlorophyll is a plant pigment responsible for imparting plants' green color. The plant parts without chlorophyll often appear chlorotic and unhealthy. A lightly stippled leaf is green with tiny yellow flecks on the upper leaf surface (Figure 11.5). A heavily damaged leaf may be yellow or bronzed.

Figure 11.5: Lace bug damage on azaleas. Credit: J.L. Castner, retired UF/IFAS Entomology and Nematology.

Defoliation

Arthropods with chewing mouthparts can feed on practically all plant parts. This feeding results in holes in the leaves or removes portions from the margins. The pest may eat some or all of the leaves.

Dieback

Some arthropod pests feed on roots or in stems and branches of plants. This may cause branch dieback or plant death. The tip of the branch may wilt or leaves may turn yellow or brown initially. After a period of time, all the leaves die and the branch dries out and breaks readily. If roots are infested, you can easily pull the plant out of the ground.

Distortion

When arthropods feed on new plant growth, the leaves do not develop properly. They may curl or fold and shoots may bend rather than grow straight.

Arthropod Feeding Groups

Insects and Other Pests with Piercing and Sucking Mouthparts

Scales, mealybugs, aphids, whiteflies, lace bugs, mites, and thrips have piercing and sucking mouthparts (Figure 11.6). These pests insert their straw-like mouthparts into the plant.

Then they extract sap from the plant. Many of these insects feed on the underside of leaves, but you can see the damage on the surfaces of leaves. The leaves appear stippled or chlorotic.

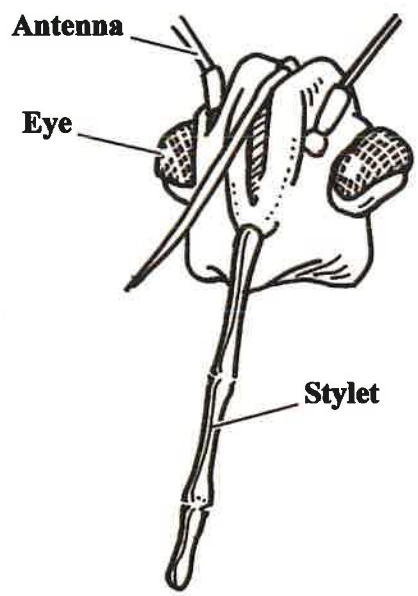


Figure 11.6: The head of an insect with piercing and sucking mouthparts. Credit: IPM in Practice, UC-Davis.

Soft scales (not armored scales), mealybugs, whiteflies and aphids are insects that excrete large amounts of honeydew, a sugary waste product. A black fungus known as sooty mold grows on the honeydew. Sooty mold imparts a black appearance on the plant and slows plant growth. Once you control the insects, honeydew and sooty mold usually diminish. Mites, although not true insects, also possess piercing and sucking mouthparts.

Scales. Scales are serious pests on many ornamental plants. Most ornamentals are susceptible to one or more kinds of scales. They extract juices from the plants, causing an unhealthy appearance. Scales cause leaf drop and twig dieback, resulting in little new growth. Scales are divided into several groups, including armored scales, soft scales, and mealybugs. Armored scales secrete a hard, waxy protective covering over their bodies (Figure 11.7). They do not produce honeydew. These scales may be circular, oval, oblong, threadlike or pear-shaped. Tea scales are an example of armored scales.

Figure 11.7: An armored scale with its eggs. Credit: L.J. Buss, UF/IFAS Entomology and Nematology.

Young nymphs hatch from eggs. Nymphs, also known as "crawlers," move around to find new feeding sites. After they begin feeding, they remain in that same location for most of their lifespan.

Soft scales also secrete a waxy covering over themselves. This covering is not hard and attaches to the scales' bodies. They secrete honeydew, which may result in sooty mold (Figure 11.8). Soft scales are different colors, sizes, and shapes. The scales may move around in any of their life stages. Florida wax scales (Figure 11.9) are soft scales.

Figure 11.8: Sooty mold from honeydew excretion. Credit: L.J. Buss, UF/IFAS Entomology and Nematology.

Figure 11.9: Florida wax scale on schefflera. Credit: L.J. Buss, UF/IFAS Entomology and Nematology.

Mealybugs. Mealybugs are covered with a white, waxy material that looks like powder or cotton. They can easily move around on branches or leaves, and wind may disperse them. Mealybugs accumulate in masses that appear like fluffs of cotton on leaves or branches (Figure 11.10). These insects can be major pests on many plants in greenhouses and landscapes.

Figure 11.10: Mealybug infestation. Credit: L.J. Buss, UF/IFAS Entomology and Nematology.

Aphids. Aphids have soft bodies shaped like pears (Figure 11.11). The color is variable; they can be green, black, brown, red, or yellow. Aphids feed on young, developing leaves, buds, and shoots of many plants. Their feeding distorts new growth and causes leaves to curl. Several types of aphids carry viruses that they vector to plants during feeding. These viruses may be more damaging or lethal to plants than the aphids themselves. Aphids are unusual compared to other insects – almost all of them are females that reproduce without mating; thus, they hardly ever produce eggs. Instead, many aphids give birth to live young, producing large populations very quickly. Aphids are an example of an arthropod that has traits contributing to resistance development, such as having many generations per year, exposure of multiple generations to a pesticide, having a lot of offspring, limited dispersal, and exposure to sublethal (less than optimal) pesticide doses.

Figure 11.11: Green peach aphid nymphs. Credit: L.J. Buss, UF/IFAS Entomology and Nematology.

Whiteflies. Whiteflies are common pests of ornamental plants. These insects extract sap from leaves, causing the upper surfaces of leaves to become stippled.

Adult whiteflies look like tiny white moths. Their four wings and bodies are covered with an even, fine white powder of wax. Adults are 1/16 to 1/8 inch long.

Whitefly nymphs look like clear-colored, translucent scales. The silverleaf whitefly (Figure 11.12) is one of the most damaging of these insects in Florida. Whiteflies can carry many viruses that cause disease.

Figure 11.12: Silverleaf whitefly adult and nymphs on poinsettia. Credit: L.J. Buss, UF/IFAS Entomology and Nematology.

Since its first report from Miami-Dade County in 2009, the rugose spiraling whitefly has become an escalating problem for homeowners, landscapers, businesses, and government officials throughout the southern coastal counties of Florida.

Lace bugs. Lace bugs are small, broad, flat insects (Figure 11.13). They are about 1/8 of an inch long. Adult bodies are brown or black. Their wings look like lace under a hand lens or microscope. Nymphs have spines.

Lace bugs feed on the undersides of leaves. Damage appears as white stippling on the upper surfaces of leaves.

Lace bugs leave brown spots of excrement and discarded skins on the undersides of leaves. The fecal spots cover each egg a lace bug produces. The most common lace bugs are the azalea, hawthorn, pyracantha and sycamore. Their names are derived from their host plants.

Figure 11.13: Adult lantana lace bug. Credit: L.J. Buss, UF/IFAS Entomology and Nematology.

Thrips. Thrips are very small, thin, yellow-brown, orange or black insects (Figure 11.14). They are only 1/25 to 1/8 of an inch long. They are most abundant in the spring. These insects roughly rasp new leaves and flowers when they feed. Rasping results in uneven streaks on the plant instead of stippling.

Some thrips leave fecal spots on the undersides of leaves. Infested buds do not open or flowers do not develop normally. Damaged flowers lose their color and buds usually drop.

Like aphids and whiteflies, thrips also carry viruses that can damage plants.

Figure 11.14: Adult Florida flower thrips. Credit: L.J. Buss, UF/IFAS Entomology and Nematology.

Mites. Mites are relatives of insects. They are more closely related to spiders and ticks. Adult mites, spiders, and ticks have eight legs and teo body sections, whereas adult insects have six legs and tree body sections. Adult mites feed on the underside of leaves. You often do not know that these very tiny mites are present until damage appears.

Mites have needlelike, piercing mouthparts that insert into leaves and extract plant sap. Damage from a few mites appears as yellow or gray stippled patterns on the upper leaf surface. Some mites, such as spider mites, spin fine strands of webbing on the host plant, hence their name (Figure 11.15).

Figure 11.15: Red spider mite webbing over pittosporum foliage. Credit: J.L. Castner, retired UF/IFAS Entomology and Nematology.

Webs may also entirely cover branches or plants. Large populations of mites cause the leaves to turn yellow, gray or brown. Leaves may drop early. Damage is most severe during hot, dry weather.

You can see mites if you inspect the undersides of leaves with a 10× or 15× magnifying glass. You can also hold a piece of white paper below a plant part that you suspect has mites. Tap the plant so some of them fall on the paper. Watch for mites as they appear like tiny dots moving around on the paper. Mites vary in color and may be green, red, yellow, purple, black or transparent. You may see their gray cast skins among the live mites.

The two-spotted spider mite (Figure 11.16) is the most common mite pest on ornamental plants in Florida. Broad mites and cyclamen mites also damage many ornamentals. Their bodies are translucent. Injured leaves are distorted or cupped and smaller than normal. These mites are most active in cooler temperatures and high humidity.

Figure 11.16: Twospotted spider mite. Note that mites have two body regions and eight legs. Credit: J.L. Castner, retired UF/IFAS Entomology and Nematology.

Insects with Chewing Mouthparts

Caterpillars, beetles, beetle larvae, sawfly larvae, grasshoppers and others have chewing mouthparts (Figures 11.17 and 11.18). The immature larvae are usually the most damaging; however, adults may also feed. These insects may feed almost anywhere on plants.

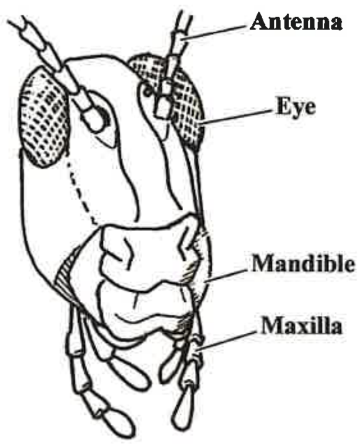


Figure 11.17: The head of an insect with chewing mouthparts.

Figure 11.18: Close-up of the head of the banded sphinx moth caterpillar, showing the mandibles. Credit: L.J. Buss, UF/IFAS Entomology and Nematology.

Larvae are the active feeding stage of the insects. Most larvae appear as worms with segments and legs.

Chewing insects are divided into defoliators, borers, leafminers, and gall makers.

Defoliators. Caterpillars and adult beetles are the most common insects that can strip leaves from plants.

Caterpillars begin feeding immediately after hatching. After they feed for several days, most of the leaf tissue is eaten, leaving the midribs or veins, which is known as skeletonizing (Figure 11.19). As they mature, caterpillars may consume all of the leaf tissue. Some plants may grow new leaves; other plants, like pines or evergreens, die.

Figure 11.19: Laurelcherry smoky moth caterpillar skeletonizing a leaf. Credit: L.J. Buss, UF/IFAS Entomology and Nematology.

Some caterpillars, such as the fall webworm (Figure 11.20), make silk webs around branches in many species of trees. Fall webworms prefer hickory, elm, sweet gum, and oak trees. The caterpillars feed on leaves in their webs and can defoliate trees.

Figure 11.20: Tent of fall webworms in a tree. Credit: L.J. Buss, UF/IFAS Entomology and Nematology.

Fall webworms have either black heads with yellowish white bodies or red heads with brown bodies. Both color forms have pairs of obvious dark spots on each section of their backs. Long, silky gray hairs cover their bodies, which are one inch long.

Some caterpillars are concealed by rolling leaves around themselves. These leaf rollers tie leaves together with strands of silk. Other caterpillars, such as the bagworm, form a case or covering around themselves for protection (Figure 11.21). Bagworms construct their cases from silk and plant pieces, including leaves, needles, or twigs. The bags hang from plants, from which the caterpillars extend their heads out to feed. The bags are often mistaken for cones on pines or evergreens.

Figure 11.21: A bagworm covered with bits of foliage and twigs. Credit: J.L. Castner, retired UF/IFAS Entomology and Nematology.

The azalea caterpillar (Figure 11.22) feeds on azalea leaves. Mature caterpillars are 2 inches long and have red heads and legs. Broken yellow or white stripes run the length of their bodies. When it is disturbed, this caterpillar raises its front and rear ends. Although it possesses long hairs, it does not sting or irritate the skin.

Figure 11.22: A disturbed azalea caterpillar raising its front and rear ends. Credit: L.J. Buss, UF/IFAS Entomology and Nematology.

The larvae of the spotted oleander caterpillar moth are bright orange with groups of long stiff hairs. These larvae feed only on oleander bushes, and are poisonous to people, birds, and small animals. The pale cream- to light-yellow eggs are laid in masses of 12 to 75 on the underside of leaves.

Larvae are from 3 to 40 mm long. They are orange with tufts of stiff reddish-brown hairs emerging from spots along their bodies. Young larvae (Figure 11.23) skeletonize new oleander shoots, which turn light brown. Older larvae can completely defoliate oleander bushes.

Figure 11.23: Spotted oleander caterpillar moth larva. Credit: L.J. Buss, UF/IFAS Entomology and Nematology.

The adult stage of the oleander caterpillar is sometimes called the polka-dot wasp moth (Figure 11.24). Its wings and body are iridescent, continuously changing between green and blue. The body, wings, legs, and antennae have small white spots on them. Their rear ends are red-orange. The moths fly slowly and are active during daylight.

Figure 11.24: Spotted oleander caterpillar moth adult. Credit: J.L. Castner, retired UF/IFAS Entomology and Nematology.

Some immature and adult beetle species will also feed on leaves (Figure 11.25). Adult beetles are hard-shelled insects varying widely in color, including black, brown, or brightly colored. Adults may chew holes in leaves, flowers, or fruit. Because they can fly, adult beetles move from plant to plant. Some are active in the day, others at night.

Figure 11.25: Cottonwood leaf beetle adult feeding on foliage. Credit: L.J. Buss, UF/IFAS Entomology and Nematology.

Grasshoppers and katydids sometimes consume a great amount of foliage on ornamental plants. Some adults can be black, brown or yellow with varying patterns on their wings and are very visible. Immatures, the nymphs, have a similar appearance to adults but are smaller.

The eastern lubber grasshopper (Figure 11.26) is the largest grasshopper in Florida. Adults can grow longer than 2½ inches. They have short wings and cannot fly. They will often invade residential areas and feast on flowering plants, especially amaryllis, narcissus, and crinum.

Figure 11.26: Eastern lubber grasshopper on a crinum lily. Credit: L.J. Buss, UF/IFAS Entomology and Nematology.

Borers. Some insects are referred to as borers because they bore into trunks, stems, branches, bark, or roots. Common examples are flatheaded, roundheaded, and clearwing borers, and ambrosia and bark beetles.

Borers may attack plants and trees weak from stress or injury. Stress problems include:

- Drought
- Saltwater flooding
- Too much soil or mulch added or removed
- Compacted soil caused by construction equipment and vehicle and foot traffic
- Injuries to the trunk or roots from lightning, lawnmowers and other machinery, digging, herbicides and vehicles
- Transplant shock when plants get moved

The redbay ambrosia beetle (Figure 11.27) was introduced into the southeastern United States in 2002 and has since become economically important in Florida. The pest continues to expand rapidly to new areas, posing a threat to redbay and avocado trees. The beetle and its associated fungus transmit the causal pathogen of the very serious laurel wilt disease among plants in the Laurel family and can cause whole tree death.

A related species leaves a tell-tale sign of infestation. The granulate ambrosia beetle attacks the trunk of the tree and pushes frass out of galleries in a typical toothpick fashion (Figure 11.28).

Figure 11.27: Redbay ambrosia beetle larvae carving galleries into a trunk. Credit: L.J. Buss, UF/IFAS Entomology and Nematology.

Figure 11.28: Frass toothpicks are signs of granulate ambrosia beetle infestation. Credit: Byron Rhodes, University of Georgia, Bugwood.org.

Exit holes of adult flatheaded borers are often shaped like the letter "D." These adults have an appearance similar to bullets or shiny metal. Exit holes of roundheaded borer adults are often round (Figure 11.29). Adults have long antennae.

Figure 11.29: Exit hole of a roundheaded borer. Credit: L.J. Buss, UF/IFAS Entomology and Nematology.

Clearwing borers are moth caterpillars. The moths fly during the day and may have a wasp-like appearance. Several of these borers, including the peachtree borer, (Figure 11.30) are common pests and can cause serious damage. All stone fruits in the genus Prunus, which include peach, and ornamental shrubs are susceptible to damage by the peachtree borer. Unlike most other borers, the peachtree borer prefers healthy plants.

Figure 11.30: Peachtree borer larvae cause serious damage. Credit: Eugene E. Nelson, Bugwood.org.

Bark beetles are especially damaging to pine trees. They tunnel into the inner bark and feed on the cambium or living part of the tree. The tunnels the bark beetles create are visible if you remove the bark. The ips engraver, black turpentine beetle, and southern pine beetle are the most common bark beetles. Of those, the southern pine beetle is the most destructive in the southern United States.

Bark beetles often attack trees in massive numbers. These beetles are inside trees if you see:

- Reddish-colored dust from the boring around the entrance holes and in cracks in the bark
- Sap oozing and hardening at the entrance holes, known as pitch tubes (Figure 11.31)
- Many small, round exit holes giving the bark an appearance it has been blasted by a shotgun

Figure 11.31: Pitch tubes from southern pine beetle tunneling. Credit: Erich G. Vallery, USDA Forest Service - SRS-4552, Bugwood.org.

Leafminers. Leafminers tunnel or "mine" between the upper and lower surfaces of leaves. These insects can be serious pests of commercial flowers, especially lantana, chrysanthemums, bedding plants, and citrus.

Leafminers have very short lives; therefore, they spend little time actually causing damage.

Leafminers are the larvae of flies, moths or beetles. Flies are the most common. The leafminer that does the most damage in Florida is the serpentine. These miners leave winding trails in the leaves (Figure 11.32).

The blotch leafminers cause blotches or blisters instead of serpentine patterns. Blotches are wide brown spots on leaves.

Figure 11.32: Evidence of the serpentine leafminer. Credit: L.J. Buss, UF/IFAS Entomology and Nematology.

Gall makers. Galls are growths on plants, and you may often find them on oak trees. Insects develop and feed inside galls, forming the gall. They can cause an unsightly appearance to plants, leaf-drop, and branch dieback. Galls can form on leaves, buds, flowers, twigs, stems, or roots. Depending on the kind of gall, galls may range in size from slight swellings to large growths the size of golf balls or baseballs.

Fungi, bacteria, nematodes, mites, or insects may cause galls. Insects that most commonly cause galls are:

- Gall wasps (Figure 11.33)
- Gall midges
- Aphids
- Psyllids
- Thrips
- Phylloxerans

Figure 11.33: Mature spine-bearing potato gall caused by the gall wasp. Credit: L.J. Buss, UF/IFAS Entomology and Nematology.

Test Your Knowledge

Q: True or False:
The two main types of arthropod mouthparts are piercing/sucking and chewing.
A: A: True

Q: Which arthropods gather in groups and appear like fluffs of cotton on leaves or branches?
A. Spider mites
B. Mealybugs
C. Whiteflies
D. Ambrosia beetles
A: A: B

Q: Which insects come in a variety of colors, are primarily female, and reproduce without mating?
A. Aphids
B. Whiteflies
C. Leafminers
D. Azalea caterpillars
A: A

Q: Which pest would you scout for by holding a white piece of paper below a plant part that you think is injured and tapping the plant to see if some of them fall onto the paper?

A. Whiteflies
B. Mites
C. Leafminers
D. Oleander caterpillars

A: B

Q: Which of the following have chewing mouthparts?

A. Mites
B. Thrips
C. Caterpillars and beetles
D. Lace bugs

A: C

Q: Which insects tunnel into plants?

A. Grasshoppers
B. Aphids
C. Leafminers
D. Thrips

A: C

Q: What is the correct sequence of simple metamorphosis?

A. Adult
B. Egg
C. Nymph

A: B, C, A

Q: What is the correct sequence of complete metamorphosis?

A. Larva
B. Egg
C. Adult
D. Pupa

A: B, A, D, C

Q: Which arthropod pest has piercing and sucking mouthparts, eight legs, and two body regions?

A. Southern pine beetle
B. Scales
C. Azalea caterpillar
D. Spider mite

A: D

Chapter 12

Ornamental Plant Nematodes

Learning Objectives

After you complete your study of this chapter, you should be able to:

- Describe nematodes in general.
- Describe the two types of plant-feeding nematodes.
- Explain how nematodes damage plants.
- Describe root-knot and other parasitic nematodes of ornamental plants.
- Describe the aboveground symptoms of nematodes on ornamental plants.
- Describe the belowground symptoms of nematodes on ornamental plants.
- Describe the most reliable method to identify nematode damage.
- Explain the information provided by a nematode assay.
- Describe how some nematodes may be beneficial.
- Explain the most effective manner to control nematodes.
- Describe ways to prevent nematode problems.
- Describe soil solarization.
- Explain why nematicides cannot be used in existing landscapes.

Terms to Know

Corm: Thick, vertical underground stem.

Ectoparasite: Nematode that feeds only from outside the plant roots.

Endoparasite: Nematode that feeds and lives inside the plant.

Nematicide: Pesticide that controls nematodes.

Stylet: A hollow mouth spear, like a hypodermic needle, used to puncture plant cells, to withdraw food and also to secrete protein and metabolites that aid the nematode in parasitizing the plant.

Introduction

Nematodes cause serious damage to ornamentals throughout Florida. Most nematodes are too small to be seen without the aid of a microscope (Figure 12.1). As a result, you often may not realize they are causing problems, and instead blame plant damage on a disease, insects, or nutrient deficiency.

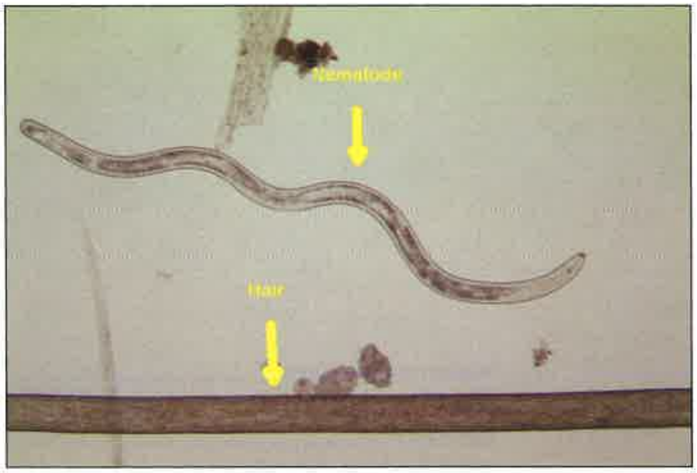


Figure 12.1: Size of a lance nematode (one of the larger plant-parasitic nematodes) compared to a human hair. Credit: Billy Crow, UF/IFAS Entomology and Nematology.

What are Nematodes?

Nematodes are unsegmented roundworms, different from earthworms and other familiar worms that are segmented or, in some cases, flattened and slimy. Many kinds of nematodes may be found in the soil of any landscape. Most are beneficial, feeding on bacteria, fungi, or other microscopic organisms. Some nematodes are used as biological controls to help manage important insect pests. Plant-parasitic nematodes are nematodes that feed on live plants.

All plant-parasitic nematodes have a stylet (or mouth-spear) that is similar in structure and function to a hypodermic needle. The stylet is used to puncture plant cells and then inject digestive juices and ingest plant fluids. Most of the plant-parasitic nematodes that are important on ornamental plants in Florida feed on roots. Some plant-parasitic nematodes, called ectoparasites, remain in the soil and feed by inserting only their stylet into the root. Other nematodes enter the plant with part or all of their bodies and are called endoparasites. Some endoparasites, called migratory endoparasites, continually burrow around inside the root. Other endoparasites, called sedentary endoparasites, establish permanent feeding sites inside the root and remain in one place. As it matures, a sedentary endoparasite's body changes shape, and adult females are usually swollen.

Figure 12.2: Angular leaf spots caused by foliar nematodes. Credit: Jody Fetzer, Maryland National Capital Park and Planning Commission, Bugwood.org

Types of Nematodes

Foliar Nematodes

Foliar nematodes are important pests in some ornamental nurseries in Florida. Occasionally, these nematodes also damage landscape plants. These endoparasites parasitize the parts of the plant that are above the ground. They feed inside the leaves and buds of ferns, chrysanthemums, strawberries, and many foliage ornamentals. They cause angular spots on leaves that are similar to those caused by bacterial leaf spot pathogens. In landscapes, these are typically problematic only in shady areas with poor air movement.

These nematodes can:

- Distort or kill buds
- Distort leaves
- Cause yellow to dark-brown lesions between major veins of leaves (Figure 12.2)

Pine wilt nematode infects pine trees. These nematodes are spread by certain beetles. The nematodes plug up the vascular system and reduce the flow of water up to the foliage. The pine needles droop, turn brown, and die. Pine wilt nematode is native to the United States, and our native pines are usually tolerant of them. However, in times of drought, pine wilt nematodes will cause additional stress to the trees. Pine species that originate in Asia and Europe, where pine wilt nematodes are not native, are very susceptible to pine wilt nematodes. Susceptible pines include Scotch pine, Austrian pine, Japanese black pine, mugo pine, and Japanese red pine.

Root-knot Nematodes

Root-knot nematodes are the most well-known of the plant-parasitic nematodes and the most important nematodes on ornamentals in Florida. These are sedentary endoparasites. These nematodes can damage most woody ornamentals. Root-knot nematodes inject hormones into the roots that cause knots or galls to form (Figure 12.3). These galls are one of the few nematode symptoms that are easily recognized. Root-knot nematodes cause extensive physical and chemical changes in the plant that can make it more susceptible to fungal and bacterial pathogens. Some of these plant pathogens cause rotting of the root systems, and others cause vascular wilts. Sometimes the damage caused by the nematodes and the other organisms together is worse than that caused by either organism separately.

Figure 12.3: Galls or knots on liriope roots caused by root-knot nematodes. Credit: Billy Crow, UF/IFAS Entomology and Nematology.

Woody ornamentals that are most often damaged by root-knot nematodes include:

- Boxwood (Figure 12.4)
- Butterfly bush
- Hibiscus
- Gardenia Bottlebrush
- Pittosporum
- Japanese holly
- Rose
- Lantana
- Ixora

Root-knot nematodes also harm many popular annual bedding plants, such as impatiens, coleus and salvia, and potted plants (Figures 12.5).

Figure 12.4: These boxwoods have root problems caused by root-knot nematodes. Credit: Billy Crow, UF/IFAS Entomology and Nematology.

Figure 12.6: Nematode-infected pittosporum (four plants on left) is stunted compared to non-infested plants (two plants on right). Credit: Billy Crow, UF/IFAS Entomology and Nematology.

Other Nematodes

Several genera of nematodes are sedentary endoparasites that occasionally damage ornamental plants in Florida. These nematodes do not cause galls like root-knot nematodes. The most typical symptom is an unthrifty root system.

Reniform nematodes are limited to soils with high silt content. In Florida they are found most often in the Miami-Dade County area and parts of the panhandle. Reniform nematodes are damaging to some ornamental plants and tropical fruits in the limited areas where they occur.

In Florida, the citrus nematode is a common problem on citrus, but also can damage olives and persimmons. This nematode normally does not kill trees, but causes them to be unthrifty and have reduced fruit production. This nematode causes a disease known as "slow decline" of citrus.

Lesion nematodes are migratory endoparasites common in Florida soils. These nematodes usually cause dark, sunken lesions on roots. Lesion nematodes are particularly damaging to ferns, bulbs, and citrus, but some species can damage other perennial plants as well. The coffee lesion nematode causes "citrus slump," a devastating disease of citrus (Figure 12.6).

Burrowing nematodes are very damaging but not widespread in Florida. Citrus nursery stock are regularly inspected for this nematode, which is a regulated pest in Florida. "Spreading decline" is the disease of citrus caused by burrowing nematodes. Burrowing nematodes cause lesions and rotting of roots. In Florida, these nematodes are damaging to citrus, banana and its relatives, palms, and other ornamental plants.

Several ectoparasitic nematodes are capable of causing damage to many landscape plants in Florida. The most destructive of these are the sting, awl, and stubby-root nematodes. Feeding by these nematodes usually causes a root system to be stunted or stubby-looking.

Sting nematodes are found in sandy soil and are common throughout much of Florida. Awl nematodes usually are found in wet habitats such as near ditches, ponds, or poorly drained areas. Several stubby-root species are found in Florida, and one or more usually can be found in most Florida habitats. Other ectoparasitic nematodes that parasitize some landscape plants are spiral, ring, stunt, sheath, sheathoid, dagger, and needle nematodes.

Not all nematodes are harmful to plants. Some are beneficial because they parasitize pest insects; others, known as predatory nematodes, feed on other nematodes. They help minimize the number of parasitic nematodes that parasitize desirable plants. Other nematodes feed on bacteria; they may play key roles in the decay and return of nutrients from organic materials to the soil.

Determining the Problem

With any plant problem, an accurate diagnosis is important to address the problem and to avoid wasting effort and making unnecessary pesticide applications. Generally, nematode symptoms are similar to other disorders, so visual inspection is not enough. The only reliable way to determine if plant-parasitic nematodes are involved in a plant problem is by having a nematode assay conducted by a professional nematode diagnostic lab. The Florida Nematode Assay Lab at the University of Florida will evaluate nematode samples for a cost of $20 each. See the Florida Nematode Assay Lab website at **http://nematology.ifas.ufl.edu/assaylab/** for information on forms, fees, and sample submission. The lab staff will assign a level of risk to the sample based on what kind of nematodes are found, how many of them there are, and the type and age of the plants involved. To make an accurate nematode diagnosis, the lab must have a quality sample. Whether you are submitting a sample to the Florida Assay Lab or another lab, following the guidelines below can help ensure that the results will be as accurate as possible.

Figure 12.6: Citrus slump, caused by coffee lesion nematode. Credit: Billy Crow, UF/IFAS Entomology and Nematology.

Sampling

Sometimes samples are collected before planting to find out if nematodes are a potential problem, and if so, to take protective measures. Pre-plant samples will typically only consist of soil. After planting, samples are collected from sick plants to determine if nematodes are the cause of plant decline. These samples require both soil and roots.

Before planting: Collect soil from 8 to 12 locations in the area where you intend to plant. Samples should be taken about six to eight inches deep. If the soil is dry, dig down to where there is some soil moisture to collect the samples, and do not include the dry soil. A small handful of soil from each location is adequate. Combine all the soil into a single plastic bag. The total volume of soil from the samples should be about one pint. Samples may be taken with a shovel, trowel, or other device. If using a shovel, you can put part of the soil from 8 to 12 shovels full into a bucket. Thoroughly mix the soil in the bucket, and then take out a pint to submit for analysis.

After planting: Often a nematode assay is needed to determine if nematodes are causing a plant to get sick. For this type of sample, both soil and roots are required. Dig soil and roots from underneath the canopy of the symptomatic plants. Soil should be collected from where most of the fibrous roots are. Usually six inches deep is sufficient. Collect roots that are less than ¼ inch in diameter. If multiple plants are affected, collect some soil and roots from several plants. Place the soil and roots together in the same plastic bag. A minimum of one pint of soil and one to two cups of roots are required.

The following practices are recommended regarding sampling:

- Nematode samples should be kept in plastic bags to keep the sample moist. Do not send samples in soil test bags! Soil testing bags are designed to dry soil out. Dried-out samples are no good for nematode diagnosis. If using a self-sealing bag, tape the seal shut so that the bag does not come open in the mail.
- If submitting more than one sample, make sure that the outside of each bag is labeled with a permanent marker. You can also write on masking tape stuck to the bag. Do not put paper labels inside of bags, because they decompose and become illegible.
- Keep samples out of direct sunlight or heat. Heat and ultraviolet light kill nematodes. Even a few minutes on the dashboard or in the back of a pickup can invalidate assay results. Keep the samples in an air-conditioned room until they can be shipped.
- Handle the sample gently and pack it well. The more the soil gets banged around, the more the nematodes may get destroyed.

Fill out the information on the forms with as much information as possible. The diagnostician needs detailed information about the type of plant or plants in question and the cultivar, if known. Make sure that the information on the form matches the identification on the sample bag (i.e., front yard, back yard).

Managing Nematodes on Ornamentals

Chemical nematicides. There are no chemical nematicides labeled for use on landscape plants that have been effective in University of Florida trials.

Bionematicides. The bionematicide MeloCon WG contains a fungus that parasitizes nematode eggs. Results from University of Florida trials indicate that MeloCon can suppress but not eliminate nematodes on shallow-rooted perennial plants. When purchasing MeloCon, have it delivered directly to you from the manufacturer, and keep it frozen until it is used. To apply, mix MeloCon with water, and then either drench or spray it onto the soil around the base of the plant(s).

Organic amendments. Organic amendments can be added to soil as compost, manure, mulch, or other materials. Organic matter can help prevent nematode damage in several ways. The organic matter increases the ability of the soil to hold water and nutrients and to improve soil structure. This makes a better environment for most plants and can help the plants survive in spite of the nematodes. Organic amendments also can increase natural enemies of nematodes that suppress the nematode populations. Some organic amendments can release chemicals or gases that are toxic to the nematodes.

There are several organic nematode management products for sale. Researchers with the University of Florida have worked with a number of these, but probably not all of them. In the majority of cases, these products work no better than adding any other, less expensive, organic material.

For more detailed information on these topics see UF/IFAS publication ENY-59 *Soil Organic Matter, Green Manures, and Cover Crops for Nematode Management* online at **http://edis.ifas.ufl.edu/vh037** or visit your UF/IFAS Extension county office.

Cultural practices. There are many steps you can take to avoid, or at least minimize, nematode interference with growing perennial plants. Combine as many of these steps as possible into an integrated nematode management program to get the best chance of managing a nematode problem successfully. Some of these tactics may seem futile or even silly, but each can make a real contribution to suppression of nematode problems.

- Pest exclusion is the most important strategy to prevent nematode problems. Sometimes plants come from the nursery already infested with nematodes. Avoid introducing nematodes that you do not have on your property already by carefully inspecting plant roots before planting. Do not use plants whose roots have galls (Figure 12.7), are rotten, or have other abnormalities.

Figure 12.7: Inspect plants for root galling before introducing. Credit: Billy Crow, UF/IFAS Entomology and Nematology.

- Do not plant an ornamental plant that is highly susceptible to one or more kinds of nematodes present on your site.

- If you must plant in areas with high risk of nematodes, consider soil replacement, which requires you to dig out and remove all soil from a generous planting hole (at least 3 feet diameter × 2 feet deep) and replace it with soil free of nematodes and other pests. The plant roots eventually will grow out of the clean soil volume and there will be some movement of nematodes into the clean soil, but the plant will have a jump-start on them by having some time to grow nematode-free.

- Soil solarization (**https://edis.ifas.ufl.edu/in856**) involves covering soil with clear polyethylene for an extended period in the summer. Solarization of field planting sites in Florida may be disappointing, because it rarely heats soil sufficiently at the recommended depth (five to six inches is common) to provide adequate control for the entire root zone area. However, a limited volume of otherwise good topsoil or soil mix can be solarized by completely enclosing it in clear polyethylene film and keeping the soil depth at no more than six inches. The soil should be located to receive full sun all day, and should be exposed six weeks or longer in June and July. This might be a good way to reduce nematodes and fungi problems in existing soil or in a soil mix to be used in soil replacement.

Test Your Knowledge

Q: Which of the following statements is ***false*** concerning nematodes?

A. All nematodes are parasitic and feed on plants.
B. Nematodes are very tiny, round worms that live almost everywhere.
C. All plant-parasitic nematodes have a stylet (or mouth-spear)
D. Most parasitic nematodes require a microscope to be seen.

A: A

Q: Match the following nematode descriptions.

1. Nematode that feeds and lives inside the plant.
2. Nematode that feeds only from outside the roots.

A. Ectoparasite
B. Endoparasite

A: 1-B; 2-A

Q: What is the only way to distinguish nematode damage from other plant problems?

A. Drop the roots in a glass of water and look for nematodes swimming away.
B. Look at the plant roots with a magnifying lens.
C. Look for foliar chlorosis.
D. Have a nematode assay conducted.

A: D

Q: Match the feeding habit with the type of nematode.

1. Ectoparasite	A. Sting
2. Endoparasite	B. Lesion

A: 1-A; 2-B

Q: True or False:
There are effective chemical nematicides labeled for use on landscape plants.
A: False

Q: What is the most important strategy to prevent nematode problems in ornamental plants?
A. High rates of nitrogen fertilizer
B. Use of soil amendments
C. Pest exclusion
D. Soil solarization
A: C

Q: When is the best time of the year to use soil solarization for the control of nematodes?
A. June and July
B. September and October
C. December and January
D. March and April
A: A

Q: What type of nematode most likely caused the damage to the root system seen in this photo?

Credit: Billy Crow, UF/IFAS Entomology and Nematology.

A. Lesion nematode
B. Sting nematode
C. Awl nematode
D. Root-knot nematode
A: D

CHAPTER 13

TURFGRASS DISEASES

IN THIS CHAPTER

Learning Objectives

After you complete your study of this chapter, you should be able to:

- Define "abiotic disorder" and provide examples of them and their effects on turfgrass.
- Provide examples of how each of the following IPM methods are employed to manage diseases of turfgrass:
  - Cultural methods;
  - Biological control; and
  - Chemical control.
- Explain why fertilizers containing slow-release nitrogen and potassium are optimal for turfgrass.
- Explain why the best time to water lawns is between 2 a.m. and 8 a.m.
- Describe the activity of a:
  - Contact fungicide;
  - Systemic fungicide;
  - Local-penetrant fungicide; and
  - Mesostemic fungicide.
- Describe why resistance is more likely to quickly develop to a systemic fungicide rather than a contact fungicide.
- For six fungal pathogens causing Florida's most common turfgrass diseases, name and describe the following:
  - Symptoms/signs;
  - Factors favoring the disease; and
  - Control and treatment.
- Name and describe a relatively new virus disease occurring in St. Augustinegrass in Florida.

Terms to Know

Abiotic disorder: A nonpest problem (such as extreme temperatures) that causes abnormal functioning of a plant.

Fungicide: Pesticide that is toxic to fungi.

Fungus: Non-chlorophyll-bearing plant, living as saprophytes or parasites; some infect and cause diseases of plants.

Guttation: Loss of water droplets from the leaf tips or margins.

Hyphae: The growing filaments of a fungus that form a web as they seek nutrients.

Mycelium (pl. mycelia): A mass of fungal filaments.

Phloem: The vascular tissue in plants that conducts sugars and other metabolic products downward from the leaves.

Phytotoxicity: Injury symptoms on plants (usually described by chemical injury).

Plant disease: Abnormal functioning of a plant caused by pathogens, including fungi, bacteria, and viruses.

Plant disease triangle: A memory aid that diagrams the three important components necessary for disease: susceptible plant, pathogen, and favorable environment.

Plant pathology: The study of plant diseases.

Saprophyte: A plant, fungus, or microorganism that lives on dead or decaying organic matter.

Sign: Indication of plant disease from direct observation of a pathogen or its parts, such as spores, mushrooms, or bacterial ooze.

Symptom: Indication of plant disease by reaction of the host, such as a canker, leaf spot, or wilt.

Vascular system (tissues): Plant tissue system consisting of xylem and phloem which transport water and other nutrients throughout the plant.

Virus: A submicroscopic parasite consisting of a core of genetic material surrounded by a protein coat.

Xylem: The vascular tissue in plants that helps provide support and conducts water and nutrients upward from the roots.

Introduction

Turfgrass diseases are often overlooked because the plant pathogens causing the problems are rarely observed and commonly mistaken for other injuries or disorders. Use of proper cultural practices (i.e., water, mowing, and fertility) will reduce the risk of grasses becoming diseased or severely damaged by turfgrass pathogens.

Fungal pathogens cause most of the turfgrass diseases. The absence of turfgrass disease does not indicate that the turfgrass area is free of fungal pathogens. The pathogens are likely surviving in the environment in a state of dormancy or as a saprophyte (nonpathogenic phase), living off dead organic materials in the thatch and soil layers.

This chapter discusses turfgrass diseases, their causal agents, diagnosis, and management. Refer to Chapter 10 for a general discussion of pathogen types.

Abiotic Disorders of Turfgrass

Diseases are the exception and not the rule for lawns. Spots and patches of yellow or brown turfgrass do not necessarily mean the lawn has a disease. Various injuries or disorders may cause the turf to appear diseased. Turfgrass diseases can be difficult to diagnose, so involvement of these other factors should first be ruled out. An injury to turfgrass is a destructive physical occurrence, such as pesticide damage, mowing the grass too short, or a fuel leak (Figure 13.1). A turfgrass disorder is associated with imbalances of physical or chemical requirements for turfgrass growth. Examples include nutritional deficiencies, cold temperatures, drought (Figure 13.2), and excessive rainfall. While these problems may appear to be diseases, there are no pathogens involved. However, these injuries or disorders may weaken the turf so much that a pathogen may attack the plants and cause a disease.

Figure 13.1: Dead spot in lawn caused by fuel. Credit: Mary Ann Hansen, Virginia Polytechnic Institute and State University, Bugwood.org.

Figure 13.2: Lawn suffering from drought stress.

Chemical, equipment, and fuel damage. Applying excessive rates and applications of pesticides, especially some herbicides, can damage or kill turfgrass. Use the recommended label rate and number of applications of the correct pesticide only when needed.

Mowing turf at heights shorter than the proper height can harm the grass (Figure 13.3). To grow, leaf blades absorb carbon dioxide and water from the air. When mowing removes large amounts of the grass blades, turf cannot capture carbon dioxide from the air to efficiently grow new leaves, causing severe stress. Stress predisposes turf to be more susceptible to invasion from insects, diseases and weeds.

Figure 13.3: Bermudagrass damaged by mowing too short. Credit: Bryan Unruh, UF/IFAS Environmental Horticulture.

Grass will not grow normally when it is under environmental stress. Shade, drought and low fertility are environmental stresses or disorders.

Oil, gasoline and diesel fuel may leak from turf-care equipment onto grass. The fuel can kill the grass. The grass may die or recover slowly. The fuel can also leach through the grass and soil into the groundwater and contaminate it.

Low temperatures. Freezing temperatures can damage lawn grasses in Florida. The main causes of injuries to turfgrass in winter include:

- Desiccated grass
- Death from low temperatures
- Frost injury
- Damage from foot and vehicle traffic

Lower fall temperatures and shorter days cause warm-season grasses to stop or slow their growth. Some grasses enter dormancy, as evidenced by their brown color. This is dead tissue that remains throughout the winter in north Florida. In central and southern Florida, grass growth rates are reduced during this time. These are natural conditions and protect the grass from cold temperatures. The grass will resume growth when the temperatures warm. Severe freezing temperatures can kill some grasses, which will not resume growth in the spring.

Other factors that make cold injury more damaging include:

- Poor drainage or soil compaction
- Deep shade
- Excessive thatch
- Excessive nitrogen applied in the fall, which induces succulent, tender growth

The weather before a severe and sudden cold wave also influences how well turf tolerates low temperatures. In general, several frosts before a severe drop in temperature help turf survive the cold.

Example: In 1989 to 1990, three to five frosts occurred before a cold snap in much of north and central Florida. These frosts facilitated an increase in stored carbohydrates and proteins in the grass. This helped the crown tissue harden off and survive the low temperatures without severe injury.

No frosts occurred before the freezes in the early 1980s. Because of this, the freezes severely damaged the turf. The grass was still green so that crown tissues were sensitive to cold temperatures.

Some grass may be green in medium shade during the spring. Grass in deep shade may have more severe damage from cold. The shade prevents normal warming of the soil during the day. Because of this the grass stays colder for a longer period of time. Deep shade also slows the turf 's production of carbohydrates needed to tolerate cold.

Foot traffic and vehicles may worsen injury to turf from cold (Figure 13.4). Do not allow people and vehicles on frozen turf until the soil has thawed.

Figure 13.4: Damage to a lawn caused when people walked across it during heavy frost. Credit: William M. Brown Jr., Bugwood.org.

How can you determine if low temperatures have damaged turf? Look for symptoms that occur in this order:

1. Wilted leaves;
2. Leaves may then appear as if they are saturated with water—they turn whitish brown;
3. Leaves turn dark brown;
4. Finally, damaged leaves form a thick mass on the soil. The mass may have a rotten odor.

Damage to grass is usually greatest in areas that stay saturated for long periods. Water does not drain properly from these areas, particularly low spots in the soil.

Incorrect amount of fertilizer or nutrients. Turfgrass requires both nitrogen (N) and potassium (K) to grow. Both very high and very low N levels may induce turfgrass diseases. Over-fertilization with N increases large patch and gray leaf spot diseases. Low N levels encourage dollar spot disease.

Remember: You can easily apply too much N, but you cannot remove it. So apply the least amount of N required for turfgrass. K seems to be instrumental in preventing diseases in turfgrass. This may be because K helps prevent plant stress. To maintain turf health, apply the same amount K as N, or less. In areas that are more prone to disease, increasing the amount of K may help to prevent disease.

K leaches just as readily as N. However, K does not harm the environment like N. Use both slow-release N and slow-release K. If you cannot obtain slow-release K, then apply smaller amounts of quick-release K more often. This is especially beneficial during the rainy season.

Drought. Turfgrass, like all green plants, must have water to grow. When there is insufficient rain, watering maintains turf growth and vigor.

Drought takes place when there is insufficient rainfall. A drought may extend for months or years. In Florida's sandy soils, drought symptoms may occur after only a few days without rain.

Without enough water from either rain or irrigation, turf starts saving water. This is visibly evident because:

- Grasses wilt by rolling or folding their leaf blades to prevent the loss of water (Figure 13.5).
- Grasses do not grow new shoots until conditions are more conducive for growth. During a drought, leaf blades may die and fall off. Usually grasses will resume growth when they are supplied with adequate water.

Figure 13.5: Stress from lack of water caused the top blade to fold. Credit: Doug Caldwell, UF/IFAS Collier County Extension.

As grasses are in drought stress and recover from drought, they will be more susceptible to other stresses, including low temperatures, traffic, insects and diseases. Stressed grass will not grow as well as grass that is not stressed.

Excessive water. Excessive water damages turfgrass and causes:

- A less-developed root system. The system has less ability to obtain water and nutrients deeper in the soil. Insects, some diseases and nematodes are far more likely to attack the root system.

- Weaker cell walls in the shoot tissue, which reduce the strength of leaf tissue.
- Excessive thatch, particularly in St. Augustinegrass.
- Water prevents air, which includes oxygen, from filtering into the soil. Roots require oxygen.

Disease Management in Turfgrass

Disease control is often not a simple process. Control recommendations are aimed at: 1) altering the environment so it is less favorable for disease development; 2) suppressing pathogen growth; and 3) decreasing stress on turfgrass. An integrated management program that includes cultural and chemical methods is the key to preventing and controlling turfgrass diseases.

There are three steps to disease management. First, it is necessary to correctly identify the disease. Next, the conditions that promote disease development should be delineated. Then management techniques can be outlined to alter or eliminate the conditions conducive to disease development.

The primary obstacle that landscape maintenance companies and pest control companies face is lack of control over all management practices. For example, the homeowner may control the irrigation system, but will contract out the mowing and application of fertilizer and pesticides with multiple companies. Coordination and clear communication among all those involved with maintenance is required to ensure healthy turfgrass.

Cultural Methods

Proper cultural practices can create an environment that does not promote disease development. While not possible to change weather patterns (the overall environment), it is possible to change localized environments. For example, limiting water-saturated soils by reducing excessive irrigation is a way the local environmental condition can be controlled by humans to reduce disease risk. Every maintenance practice, fertilizer application, and chemical (especially herbicide) application has an impact on turfgrass health.

If turfgrass becomes diseased, cultural practices should be implemented first or at the same time that fungicides are applied. If a home lawn, recreational site, or commercial landscape has a history of developing a particular disease at a certain time of year, then it makes sense to implement cultural practices to prevent this yearly reoccurrence.

Landscape maintenance professionals can explain to the landscape owner the reasons for altering a practice. Records indicating disease outbreaks, cost of fungicide applications, and turf replacement can provide justification for changes in maintenance practices. The landscape owner may be more accepting of these changes if they understand the potential benefits of altering a maintenance practice in both economical and ecological terms.

The cultural practices discussed in this section are designed to alter the turfgrass environment to prevent diseases or, at least, lessen their severity.

Turfgrass selection. The selection of turfgrass species (e.g., St. Augustinegrass, centipedegrass, bahiagrass, etc.) and cultivars within that species (e.g., Floratam vs. Raleigh St. Augustinegrass) should be based on location and how the turf will be used and maintained. Selections that are not suited for a particular area are continually stressed and more susceptible to diseases and pests, requiring increased maintenance costs in terms of labor and pesticides. For example, St. Augustinegrass does not tolerate shade conditions and requires supplemental irrigation, while centipedegrass should be grown in soils with low pH (i.e., less than 6.0). For more detailed information, refer to Chapter 4 of this publication, *Best Management Practices for Design and Installation of Landscapes*.

Mowing practices. Mowing is the most common turfgrass maintenance practice and can be the most damaging when done improperly. Mower blades must be sharp so they cut rather than tear the turf leaves. Mowing should occur as frequently as necessary so that no more than one-third of the leaf is removed at any one time. Turfgrasses that are cut below their optimum height become stressed and more susceptible to diseases, especially root rots. The actual recommended turf height depends on the turfgrass species being grown (refer to Chapter 6 for recommended mowing heights). It is especially important not to mow St. Augustinegrass too low. Wet grass should not be mowed due to the potential for spreading water-borne pathogens.

When any disease occurs, the cutting height should be raised. A low cutting height reduces the leaf tissue necessary for photosynthesis, the process by which the plant produces energy for growth. An active disease eventually reduces the leaf canopy, and photosynthesis is reduced even further. Raising the cutting height increases the green plant tissue available for photosynthesis, resulting in more energy for turfgrass growth and subsequent recovery from the disease.

Mulching mowers do not increase diseases. However, if an area of the lawn has an active leaf disease, this area should be mowed last to prevent the spread of the disease. After mowing the diseased area, the mower should be washed with water to remove diseased leaf clippings.

Water management. Irrigation is essential to prevent drought damage during the dry season. Yet the amount and the timing of application can either prevent or facilitate disease development (Figure 13.6). This balance exists because most fungal pathogens that cause leaf diseases require free water, including rainfall, irrigation, and dew on the leaf, or very high humidity to initiate the infection process.

Figure 13.6: Applying the correct amount of water is a delicate balance. Credit: Luana Vargas, Bugwood.org.

Dew formation and the length of the dew period is dependent on temperature and humidity. The length of the dew period is a critical factor for leaf disease development. Irrigating in the evening before dew forms or in the morning after dew evaporates extends the dew period. One strategy to reduce the risk of disease development is to irrigate when dew is already present. Dew is usually present in the predawn hours, between 2 and 8 a.m. This also dilutes or removes the guttation fluid (fluid being forced out of the leaf tips by internal plant pressure) that can accumulate at the cut leaf tip and may provide a food source for some pathogens.

Turfgrass should only be irrigated when drought stress is observed, as evidenced by curled leaf blades. When irrigation is necessary, it should be applied as to only saturate the root zone of the turfgrass. Irrigating every day for a few minutes can be detrimental to the turfgrass because it does not provide enough water to the root zone, but it is beneficial for the turfgrass pathogens. The irrigation system should apply the water uniformly across the lawn.

Nutrition (fertilizer) management. Many diseases are also influenced by the nutritional status of the grass, especially nitrogen (N). Both excessively high and excessively low nitrogen fertility contribute to turfgrass diseases. For example, excessive nitrogen applications encourage large patch and gray leaf spot diseases, while very low nitrogen levels are conducive for the development of dollar spot disease. The minimal amount of nitrogen required for the particular species of turfgrass in the lawn should be applied because it is easy to add nitrogen but impossible to remove it.

Potassium (K) is also an important component in the prevention of diseases, possibly because it prevents plant stress. To maintain healthy turfgrass, the amount of elemental potassium applied should be either the same as or greater than the amount of nitrogen. It is beneficial to increase the amount of potassium in an area prone to disease. The use of both nitrogen and potassium from slow-release sources is highly encouraged because both are readily leached from the soil. If it is not possible to obtain slow-release potassium, apply smaller amounts of quick-release potassium more frequently. This is especially critical during the rainy season. Damaged roots have a difficult time absorbing nutrients from the soil. When turfgrass roots are damaged or not functioning properly—whether from diseases, nematodes, or water-saturated soils—it is beneficial to apply nutrients in a liquid solution sprayed on the leaf tissue. Frequent applications of small amounts of nutrients to the leaves help keep the plant alive until new roots are produced. Application frequency is dependent on the severity of the root problem, but could be as often as twice a month.

Thatch management. Thatch is the tightly bound layer of living and dead stems and roots that develops between the zone of green vegetation and the soil surface. It is a natural component of turfgrass. Bacteria, fungi, earthworms, and other organisms that naturally live in the soil decompose thatch. When excessive thatch accumulates, it means plant tissue is being produced more quickly than it is being decomposed.

Excessive thatch often causes the mower to sink because the turfgrass is "spongy." This produces a lower cutting height than desired and potential scalping of St. Augustinegrass, which results in stressed turf. Physical removal is the best way to eliminate excessive thatch. Review maintenance practices to prevent excessive thatch from occurring again. The cause could be too much nitrogen being applied or too much or too little water being used for irrigation. Correcting those practices that promoted excess thatch development should prevent it from occurring again.

Soil physical and chemical status. There are several soil conditions that can lead to a weakened plant, resulting in higher disease susceptibility. Compacted soils prevent proper drainage, resulting in areas that remain excessively wet. Once they dry out completely, they are often difficult to re-wet. Turfgrass in these areas may have root systems that are deprived of oxygen, creating an ideal situation for root rots to develop. If soil compaction is the primary problem, it can be alleviated by aeration of the soil, which helps loosen the soil and allows oxygen to reach the roots. Aeration can be as simple as using a small foot-press aerator in small areas, or as complex as a job requiring commercial equipment to drill holes in the soil (Figure 13.7). This procedure should be followed by topdressing, which is the application of light amounts of soil (approximately ¼-inch application) over the top of the turfgrass (Figure 13.8). Over time, topdressing may minimize compaction, reduce thatch, and improve the drainage or water retention of the site. High soil pH can affect nutrient uptake, while high salt concentrations also impact turfgrass health.

If areas in the lawn or landscape appear to dry out first or are the first to appear sick, a metal rod can be used to be sure that there is nothing buried at that location. It is not uncommon to find building materials buried in the landscape. If an area is waterlogged for long periods, building that area up so that it is level with the rest of the lawn could correct the problem.

Figure 13.7: Professional aeration of a residential lawn.

Figure 13.8: Top dressing with sand following aeration.

Biological Control

When naturally occurring microorganisms are allowed to flourish in the turfgrass ecosystem, they can help reduce disease potential or disease damage. They accomplish these tasks by: 1) competing with the pathogens for food sources; 2) producing chemicals that inhibit the growth of the pathogens; or 3) physically excluding the pathogens from the plant by occupying the space first. Therefore, it is just as critical to keep the soil microbial population healthy as it is the turfgrass. Reducing pesticide use is one way this may be accomplished. Although many products (e.g., sugars, enzymes, carbohydrates, etc.) on the market claim to increase natural microbial populations, there is no documentation that this occurs in home lawns or landscapes in Florida.

Microorganisms not naturally present in the turfgrass environment can be introduced in an attempt to control diseases. This can be done by applying organic materials that have natural microbial populations (i.e., composts) or have had microbial populations added to them (i.e., natural organic fertilizers with microbial supplements). However, there is little documentation that these products consistently prevent diseases. For both types of products, they must be applied prior to disease development because they work preventively, not curatively. Natural organic fertilizers should be used for their nutrient value (i.e., nitrogen and potassium) and not for any possible secondary effects.

There are many products composed of living organisms, primarily bacteria and fungi, on the market that *claim* they increase turfgrass health. However, for any material to be considered a biological fungicide or microbial biopesticide, the U.S. Environmental Protection Agency (EPA) must register it. EPA registration indicates that the *safety* of the product to humans, nonhumans (e.g., fish), and the environment has been determined. Materials that have not been approved by the EPA should be used with caution. Many naturally occurring bacteria and fungi are also secondary human pathogens, especially for people with weak immune systems. As part of the natural ecosystem, they cause few problems. However, caution should be exercised when concentrated formulations of these organisms are applied through a pesticide sprayer. Also, many of these products have not been evaluated using proper experimental protocols.

Chemical Control

What is a fungicide? Fungicides are pesticides that are toxic to fungi, thus theyare used to control the diseases they cause. Fungicides are effective because they can: 1) suppress or slow down fungal growth; or 2) prevent the fungus from reproducing. Most fungicides are active against a limited group of fungi. This is why it is important to know what disease you need to control.

Fungicides do *not* promote the growth of the turfgrass. The only way healthy turfgrass reappears is when new growth occurs. For example, a leaf spot will remain on the leaf even after a fungicide is applied. This diseased leaf area will remain until it is removed by mowing and a new leaf replaces it, or until the leaf dies and begins to decompose. Since many turfgrass diseases occur when the grass is not actively growing, complete recovery may be very slow. It may seem like the turfgrass is not responding to the fungicide application, when in fact the fungicide has been effective against the fungal target. It is simply that the turfgrass has not grown enough to replace the diseased tissue.

When to use a fungicide. It is acceptable to use fungicides on a preventive basis—that is, prior to disease development—as long as it is understood which diseases/pathogens are likely to occur in a particular location at any given time of the year. For example, it is not necessary to apply a fungicide to protect against Pythium blight on St. Augustinegrass because this is an extremely rare disease. Also, a fungicide to prevent take-all root rot is unwarranted when this disease has never been observed on that particular lawn.

Fungicides should only be used when absolutely necessary. A lawn disease in one location does not mean it will occur on adjacent landscapes/properties/lawns, as management techniques or turfgrass cultivars may be different. The primary factor for turfgrass disease development in Florida is the environment—not just the overall environment, but also the microenvironment created by building placement in the landscape or by management practices. In fact, each side of a building may have its own microenvironment influenced by factors such as trees, other buildings, bodies of water, and soil type.

When using a fungicide, label directions must be read and followed. Labels are important to determine the proper application rates; amount of water needed to apply the product effectively; irrigation requirements; and safety instructions for mixing, applying, and storing the product. Almost all pesticide failures are due to misapplication, including misidentification of the problem. Misuse of a product can waste money, become a safety risk, and pollute the environment.

Other maintenance practices must be considered relative to fungicide applications. Unless the clippings are returned to the turfgrass, mowing should be postponed for at least 24 hours (preferably longer). The fungicide is probably on the leaf. If the clippings are collected when the yard is mowed, the fungicide is also collected. Unless the product is supposed to be irrigated into the soil, irrigation should also be postponed for at least 24 hours after a fungicide application. Ideally, the turf area should be mowed and irrigated *prior* to a fungicide application to allow a maximum time interval between fungicide application and the next turfgrass maintenance operation.

Fungicide categories. Turfgrass fungicides can be divided into four broad categories based on the location of their activity: 1) contact fungicides; 2) systemic fungicides; 3) local-penetrant fungicides; and 4) mesostemic fungicides. They can also be divided into very small groups based on chemical properties.

Contact fungicides are generally applied to the leaf and stem surfaces of turfgrasses. They are considered protective or preventive fungicides. They inhibit the fungi on the plant surface so the fungus is not able to enter/infect the plant. These fungicides remain on the plant surface and do not penetrate the plant. They remain active only as long as the fungicide remains on the plant surface in sufficient concentration to inhibit fungal growth, usually 7 to 14 days. Leaves that emerge after the fungicide has been applied are *not* protected. Any fungus already in the plant will *not* be affected. To obtain optimum protection, it is important that contact fungicides evenly coat the entire leaf surface and are allowed to dry completely before irrigating or mowing.

Contact fungicides are normally used to control foliar diseases, not root diseases. The exceptions are those used to control Pythium root rot (i.e., chloroneb and etridiazole). Contact fungicides have a broad spectrum of disease control activity and have been used extensively in the turf industry for a number of years. However, changes in labeling have occurred, so always read the label prior to fungicide use. Some of the major changes in recent years involve several commonly-applied fungicides. For example, mancozeb can now only be applied by a professional pesticide applicator. Chlorothalonil can no longer be applied to the turfgrass in residential landscapes (i.e., single-family homes, condominiums, and apartment complexes); however, it can be applied to the turfgrass of commercial landscapes and to the ornamentals in a residential landscape.

Systemic fungicides are chemicals that penetrate plant surfaces and are then translocated (moved) within the plant vascular system, usually limited to the xylem. The exception is fosetyl-Al (Aliette®), which is translocated in xylem and phloem (primarily phloem) tissue.

In general, systemic fungicides have curative and protective properties with extended residual activity. Because systemic fungicides are absorbed by the plants, they work inside the plant to 1) control pathogenic fungi that have already entered the plant and initiated a disease (curative action); and 2) inhibit fungi that enter the plant from initiating a disease (preventive action). Their residual activity is also due to the fact that the plant absorbs them. Once a systemic fungicide is inside the plant, it cannot be removed by water or degraded by sunlight. Newly emerged plant tissue may contain sufficient concentrations of the fungicide to protect it from fungal infection. Therefore, systemic fungicides do not need to be applied as often as contact fungicides; usually 21- to 30-day intervals are adequate.

Systemic fungicides usually have a very specific mode of action and do not have as broad a spectrum of disease control as contact fungicides. However, they control both foliar and root pathogens. When attempting to control root diseases, systemic fungicides may need to be watered into the root zone for maximum effectiveness. As indicated above, the majority of systemic fungicides are xylem limited. If the fungicides are only applied to the leaf tissue, the compounds may never reach their root target in the amount needed for control.

Local-penetrant fungicides are capable of penetrating the plant surface, but they only move very short distances within the plant. These fungicides do not enter the xylem or phloem tissue, so the majority of the fungicide remains on or near the plant surface. Included in this group of fungicides are iprodione and vinclozolin. These fungicides are considered protective/preventive fungicides. The discussion on contact fungicides applies to this group of fungicides also.

Mesostemic fungicides are a relatively new group of fungicides that includes trifloxystrobin (e.g., Compass™). This fungicide is strongly attracted to the plant surface and is absorbed by the waxy plant layers. It appears to continuously penetrate the leaf surface. However, it is not translocated in the plant vascular system (xylem or phloem), and so is not truly systemic. These fungicides redistribute on the plant surface via localized vapor movement and surface moisture. This group of fungicides works best as a preventive fungicide. Because the fungicide is not directly exposed to weathering factors, reapplication intervals are 14 to 21 days.

Common Diseases of Turfgrass

Florida's warm, humid environment makes ideal conditions suitable for the development of a wide variety of plant pathogens, including bacteria, fungi, and viruses. This section will present several of the common turfgrass diseases encountered in Florida. This publication will devote separate chapters to address palm and ornamental plant diseases. For more information on the many turfgrass diseases that occur in Florida, see UF/IFAS Extension's EDIS publication site at **https://edis.ifas.ufl.edu/**.

Fungal Diseases

Dollar spot

Symptoms/signs:

- Small (1 to 3 inches wide), brown to straw-colored patches of dead grass (Figure 13.9).
- Uneven, light tan lesions with obvious brown borders on the leaves at the outside edge of the patches.
- Patches do not enlarge. As the number of patches increases, they may coalesce to form larger patches.
- Mycelia may appear in early morning hours when dew is present. Mycelia are masses of fungal filaments that appear similar to cotton (Figure 13.10). You can see mycelia in or around lesions on turfgrass.

Causal agent: *Sclerotinia homoeocarpa*

Factors favoring the disease: Dollar spot most commonly occurs from fall through spring. This disease appears on turfgrass that is deficient in nitrogen. This disease will also occur in turfgrass that has a dry root system along with a humid leaf canopy. The humid leaf cover may be due to:

- High humidity
- Light rainfall
- Irrigating too frequently or at the wrong time

Control and treatment: To prevent this disease, do not allow turfgrass to become deficient in nitrogen and potassium. Use slow-release nitrogen and slow-release potassium fertilizers. However, if dollar spot is already active, apply a quick-release source of nitrogen. Use ½ pound of nitrogen per 1,000 square feet. Examples: Ammonium sulfate, ammonium nitrate or quick-release urea without a coating. Irrigate the turfgrass with ¼ inch of water. Follow up with an application of slow-release nitrogen balanced with slow-release potassium. During dry weather, apply enough water so the root zone is totally saturated each time. Irrigate during early morning hours between 2 a.m. and 8 a.m. when dew is present. If the soil is dry, irrigate to thoroughly saturate the root zone 8 to 12 inches deep. Then allow the root zone to dry before irrigating again.

Refer to UF/IFAS EDIS Publication SS-PLP-14, *Turfgrass Disease Management*, available at **https://edis.ifas.ufl.edu/lh040** for fungicide selection.

Figure 13.9: Dollar spot on St. Augustinegrass. Credit: Florida Division of Plant Industry, Florida Department of Agriculture and Consumer Services, Bugwood.org.

Figure 13.10: Mycelia are the white fungal masses. Credit: Monica Elliott, UF/IFAS Plant Pathology.

Fairy rings

Symptoms/signs:

- Type 1 rings have an area of dead grass just inside a zone of dark green grass (Figure 13.11).

- Type 2 rings (Figure 13.12) have only a band of dark green turf with or without mushrooms.

- Type 3 rings (Figure 13.13) do not have a dead zone or a dark green zone. They only have a ring of mushrooms. At the onset, rings may be very small—less than one foot wide. Normally they get larger each year. Rings can be six feet or more in diameter. The size and shape of the bands (circle, half circle, quarter circle) vary.

Causal agent: Fairy rings can be caused by multiple fungi, including *Chlorophyllum* spp., *Marasmius* spp., *Lepiota* spp., *Lycoperdon* spp., and other basidiomycete fungi.

Factors favoring the disease: Fairy rings, especially consisting of mushrooms, are most common during the summer months when Florida receives most of its rain. These rings occur when large amounts of organic matter (lumber, tree stumps, logs) are naturally in or have been buried under a lawn. The fungi live on this material. The mushrooms vary in sizes and shapes. They are the fruiting stage of these fungi.

Control and treatment: Remove and discard mushrooms because some of them are poisonous. Light applications of nitrogen can mask the dark green symptoms of the rings. You can remove the soil. However, the ring probably will return if the nutritional source the fungi subsist on remains. The nutritional source is large amounts of organic matter, such as decaying lumber, tree stumps, logs, etc., under the turf. Fairy rings may disappear on their own, but it may require several years. Refer to UF/IFAS EDIS Publications SS-PLP-14, *Turfgrass Disease Management* (**http://edis.ifas.ufl.edu/lh040**) and SS-PLP-7, *Fairy Rings* (**http://edis.ifas.ufl.edu/lh046**) for fungicide selection. Fungicides inhibit the fungus only. They do not eliminate the dark green or dead rings of turfgrass, and they do not solve the dry soil problem.

Large (brown) patch

Symptoms/signs:

- A soft, dark rot appears at the base of the turfgrass leaf (Figure 13.14). This is caused by a fungus that infects the leaf area closest to the soil. You can easily remove a leaf from a stem. The base of the leaf will have a rotten odor. The fungus does not attack roots.

- Small patches (about one foot wide) turn yellow and reddish-brown, brown or straw-colored as the leaves start to die.

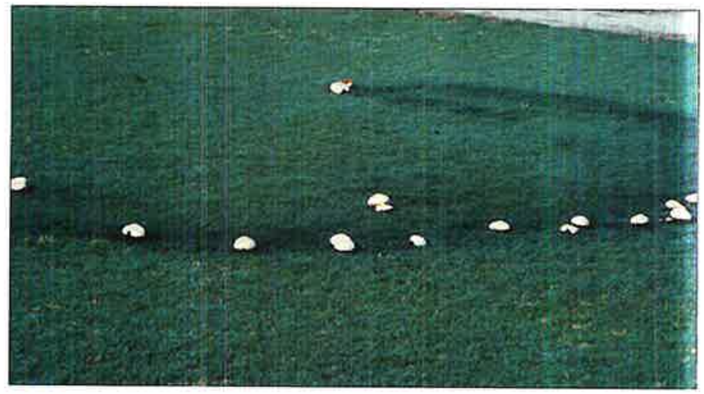


Figure 13.12: Type 2 fairy ring – band of dark green turf. Credit: Monica Elliott, UF/IFAS Plant Pathology.

Figure 13.11: Type 1 fairy ring – note the dead grass. Credit: William M. Brown Jr., Bugwood.org.

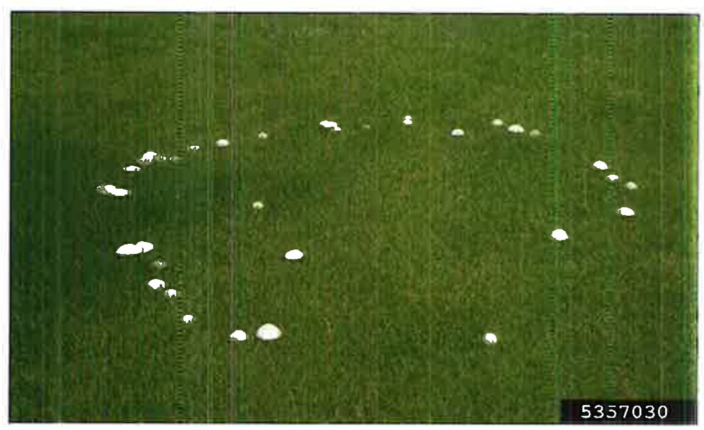


Figure 13.13: Type 3 fairy ring – note only a ring of mushrooms. Credit: William M. Brown Jr., Bugwood.org.

- The patches can become several feet wide.
- Rings of yellow and brown turf with healthy-looking turf in the center are not unusual (Figure 13.15).
- Turf at the outer edge of a patch may be dark and wilted.
- Brown patch is often confused with herbicide damage on St. Augustinegrass. Herbicide damage may cause the same symptoms of yellow or brown patches. The leaf may still be easily removed; however, the base of the leaf is not dark and rotten. Instead, the leaf base is dry and tan colored without a rotten smell.

Causal agent: *Rhizoctonia solani.*

Factors favoring the disease: Large patch usually appears from November through May when temperatures are below 80°F. This disease does not normally appear in the summer. The following conditions that cause grass to be wet for 48 hours or more are conducive to initiate large patch:

- Rain
- Excessive irrigation
- Extended periods of high humidity

Control and treatment: Since mowers can spread large patch, mow diseased areas last. Then wash turf clippings off the mower before you mow on the next property. Do not apply excess nitrogen during colder temperatures in the fall, winter and spring when this disease can develop. Do not use soluble nitrogen or quick-release nitrogen products just before or after large patch appears. Instead, use slow-release sources. Apply fertilizer that contains equal amounts of slow-release nitrogen and slow-release potassium. Irrigate only when necessary. Do so only in the early morning hours between 2 a.m. and 8 a.m., when dew is already on the ground. Refer to UF/IFAS EDIS Publications SS-PLP-14, *Turfgrass Disease Management* (**http://edis.ifas.ufl.edu/lh040**) and SS-PLP-5, *Large Patch* (**http://edis.ifas.ufl.edu/lh044**) for fungicide selection.

Figure 13.14: The brown, rotted area at the leaf base is a sign of large patch. Credit: Staci Priest, former UF/IFAS Pesticide Information Office.

Figure 13.15: Large patch damage on St. Augustinegrass. Credit: Matthew Zidek, Texas A&M Agrilife Extension Service, Bugwood.org.

Take-all root rot and centipedegrass decline

Symptoms/signs:

Aboveground:

- Irregular, chlorotic or light green patches. Patches are a few inches to a few feet wide, with no distinct shape. Fungi on the root system cause these patches. This pathogen does not infect the leaves.
- Stolons and rhizomes may also have black lesions. If the disease is severe, the stolons and rhizomes may begin to rot. Grass plants may die resulting in irregular patches of thinning grass (Figure 13.16). If you do not manage take-all root rot, bare patches may develop.

Belowground:

- Initially, roots are thin and off-white in color with a few black lesions. Eventually, roots are shortened, black and rotten (Figure 13.17).

Causal agent: *Gaeumannomyces graminis* var. *graminis*.

Factors favoring the disease: This pathogen is always present on the roots of warm-season turfgrass. Take-all root rot can cause disease on all warm-season turfgrasses. Abundant rain and turfgrass under stress are conducive to this disease. Take-all root rot spreads during the summer and early fall months when Florida receives the most rainfall. Take-all root rot of St. Augustinegrass and centipedegrass decline can appear in the spring when the grasses begin actively growing. Prolonged rain and stress worsens this disease.

Control and treatment: The turfgrass must be mowed at the correct height during the summer. Turfgrass should be mowed as frequently as necessary so that only one third of the leaf tissue is removed during any one mowing event. Removing too much of the leaf tissue in a single mowing, or scalping the grass, damages the growing point. Apply equal amounts of nitrogen and potassium. Use slow-release nitrogen and slow-release potassium. If slow-release potassium is unavailable, apply quick-release potassium to the turfgrass between nitrogen applications. Extra potassium may be beneficial in late summer and early fall. Avoid nitrate-nitrogen fertilizer and quick-release urea products that do not have a coating on them. Refer to UF/IFAS EDIS Publications SS-PLP-14, *Turfgrass Disease Management* (**http://edis.ifas.ufl.edu/lh040**) and SS-PLP-16, *Take-all Root Rot* (**http://edis.ifas.ufl.edu/lh079**) for fungicide selection.

Figure 13.16: Aboveground symptoms of take-all root rot on St. Augustinegrass. Credit: Clarissa Balbalian, Mississippi State University, Bugwood.org.

Figure 13.17: Blackened, shortened, and rotted roots of zoysiagrass. Credit: Elizabeth Bush, Virginia Polytechnic Institute and State University, Bugwood.org.

Rust

Symptoms/signs:

- Light yellow flecks appear on the leaves.
- Flecks broaden and form spots that are parallel to leaf veins.
- Later, orange pustules form along the leaf veins. They contain spores that are easily removed (Figure 13.18). Very heavily infected areas appear thin and chlorotic to light brown.

Causal agent: *Puccinia* spp.

Factors favoring the disease: This disease can occur from late fall to early spring when the turfgrass growth is slowed as a result of cool weather. In most situations, the disease disappears as soon as the weather warms and the turfgrass starts to grow vigorously again. It is more severe on turfgrass areas that are stressed from nutrient deficiencies or shade, such as areas under trees or on the north side of a building. The leaves must be wet for infection to occur. This wetness may be from dew, high humidity, rain, or irrigation.

Control and treatment: It is important to maintain an adequate, balanced fertility program using slow-release nutrient sources. In shady areas, irrigation should be monitored closely to keep the leaves as dry as possible. It is best to water in the early morning hours (between 2:00 and 8:00 a.m.) when dew is already present, so as not to extend the dew period. Refer to UF/IFAS EDIS Publications SS-PLP-14, *Turfgrass Disease Management* (**http://edis.ifas.ufl.edu/lh040**) and SS-PLP-12, *Rust* (**http://edis.ifas.ufl.edu/lh051**) for fungicide selection.

Figure 13.18: Rust spores on the leaf of zoysiagrass. Credit: Clarissa Balbalian, Mississippi State University, Bugwood.org.

Helminthosporium leaf spot

Symptoms/signs:

- Depending on the fungus, the size and color of the symptoms vary. They may be very small (the size of the head of a straight pin), solid brown to purple lesions. These lesions can get larger. They may have very white centers that cover leaf blades.
- Seriously infected leaves turn purple or reddish-brown. This gives the turfgrass a purplish appearance. These leaves eventually dry and become a light tan color.
- Distinct patches or patterns of the disease are usually not obvious on St. Augustinegrass. They are obvious on bermudagrass.
- Severe infections cause melting-out as turf areas thin and die (Figure 13.19). Lesions on stolons are dark purple to black.

Causal agent: *Bipolaris*, *Drechslera*, and *Exserohilum* spp. (previously classified as *Helminthosporium* fungi).

Factors favoring the disease: All warm-season turfgrasses can be affected, but the disease is usually most serious on bermudagrass. Different species of these fungal pathogens affect different species of turfgrass. This disease is caused by a group of fungi that is active over a wide range of temperatures. At any given time of the year, at least one species within this fungal group can be isolated. Thus, diseases caused by these fungi can occur at any time of year. However, as a general rule, the leaf spot disease occurs during mild, wet periods during fall and winter months.

Control and treatment: Proper nutrient management can reduce the risk of Helminthosporiium leaf spot disease. Excess nitrogen during potential disease development periods should be avoided. The nitrogen level must be balanced with potassium at a recommended ratio of 1:2 (N:K). In areas that are affected routinely by this disease, the potassium level should be increased before the disease normally occurs. Slow-release potassium sources or frequent applications of quick-release potassium sources are suitable for use. Mowing height should be raised during disease outbreaks. Refer to UF/IFAS EDIS Publications SS-PLP-14, *Turfgrass Disease Management* (**http://edis.ifas.ufl.edu/lh040**) and SS-PLP-9, *Helminthosporium Leaf Spot* (**http://edis.ifas.ufl.edu/lh048**) for fungicide selection.

Figure 13.19: Lawn devastated by Helminthosporium leaf spot. Credit: William M. Brown Jr., Bugwood.org.

Gray leaf spot

Symptoms/signs:

- The first symptoms are olive-green to brown spots the size of the head of a straight pin.
- The spots enlarge and have a circular pattern. They may also become oblong-shaped (Figure 13.20). These are tan to brown with dark brown edges. When the weather is humid, the fungus produces masses of spores in the center of these spots. The spores give the spots a silky gray appearance (Figure 13.21).
- Many spots can appear on a single leaf. This can cause the leaves to dry and turn brown. No obvious patches appear but turf areas may become thin. Turfgrass that is severely infected with gray leaf spot may appear very dry.
- On more mature St. Augustinegrass lawns, gray leaf spot is common, but is not severe. In the summer, certain St. Augustinegrass plants will always have a few spots on their leaf blades. These spots will not injure the turfgrass unless it is under severe stress.

Causal agent: *Pyricularia grisea*, also referred to as *Magnaporthe grisea*.

Factors favoring the disease: Gray leaf spot, a disease of St. Augustinegrass, often occurs from late spring to early fall, especially during prolonged periods of rain. Compacted soil and over-fertilization of quick-release nitrogen make this disease more severe. Application of the herbicide atrazine also increases the probability that gray leaf spot will develop on St. Augustinegrass.

Control and treatment: Proper irrigation management by making applications in early morning (between 2:00 a.m. and 8:00 a.m.). Avoid excess applications of nitrogen fertilizer to minimize lush growth. The timing of any atrazine application should be chosen carefully, since this chemistry can stress the grass, especially when temperatures may climb above 85°F. Atrazine applications made before or during disease-favorable conditions increase the likelihood of severe gray leaf spot symptom development. Refer to UF/IFAS EDIS Publications SS-PLP-14, *Turfgrass Disease Management* (**http://edis.ifas.ufl.edu/lh040**) and PP-204, *Gray Leaf Spot of St. Augustinegrass: Cultural and Chemical Management Options* (**http://edis.ifas.ufl.edu/pp126**) for fungicide selection.

Figure 13.20: Lesions on a leaf blade. Credit: Paul Bachi, University of Kentucky Research and Education Center, Bugwood.org.

Figure 13.21: Advanced development of gray leaf spot on St. Augustinegrass. Credit: Phil Harmon, UF/IFAS Plant Pathology

Anthracnose

Symptoms/signs:

- Leaf infection appears as reddish-brown to brown spots that are often surrounded by a narrow yellow halo. Single spots may span the blade width, causing leaf yellowing and death.
- Tiller infection results in stem death and the development of small, yellow patches of turfgrass.

Causal agent: *Colletotrichum graminicola*.

Factors favoring the disease: This disease primarily affects centipedegrass; however, it is known to occur on all warm-season turfgrasses. It is normally observed in the spring months during periods of high moisture (rain or heavy fog) and warm temperatures. Disease severity is often greater on stressed turfgrass, especially during springs that follow cold winters.

Control and treatment: A balanced fertilizer containing equivalent amounts of potassium and nitrogen, preferably a slow-release potassium form, can be applied. Just prior to or during disease development periods, slow-release nitrogen sources should be used as opposed to readily available forms. Irrigation should saturate the root zone so that drought stress is avoided. Irrigation should only occur in the early morning hours (between 2:00 and 8:00 a.m.) when dew is already present. If the diseased areas are associated with compacted soils, alleviating the compaction should be beneficial. Refer to UF/IFAS EDIS Publications SS-PLP-14, *Turfgrass Disease Management* (**http://edis.ifas.ufl.edu/lh040**) and SS-PLP-56, *Anthracnose* (**http://edis.ifas.ufl.edu/lh043**) for fungicide selection.

Pythium root rot

Symptoms/signs:

Aboveground:

- A nonspecific decline in turf quality.
- Small or large turf areas become a general yellow, light green, or brown color and display thinning – a gradual decrease in density
- Turf seldom dies from Pythium root rot, so no distinct patches are observed.

Belowground:

- Roots appear thin, with few root hairs and have a general discoloration.
- Roots do not appear black and rotted as they are with take-all root rot.

Causal agent: *Pythium* spp.

Factors favoring the disease: Symptoms may appear at any time of the year, but they are always associated with wet soil conditions, either from excessive rainfall or from irrigation. Poor drainage conditions compound this problem.

Control and treatment: Improved drainage and reduced irrigation, especially before periods of high rainfall, will help prevent infection. Irrigation should be managed so that the soil is not constantly wet. It may be necessary to raise the mowing height during periods of weather that are conducive to disease, as improper mowing is a major stress on turfgrass. Nitrogen applications should be balanced with equal amounts of potassium. Extra potassium may be useful in late summer and early fall months for those areas that are routinely affected by Pythium root rot. Refer to UF/IFAS EDIS Publications SS-PLP-14, *Turfgrass Disease Management* (**http://edis.ifas.ufl.edu/lh040**) and SS-PLP-11, *Pythium Root Rot* (**http://edis.ifas.ufl.edu/lh050**) for fungicide selection.

Fungal-like Organisms

Slime molds

Symptoms/signs:

- Slime molds impart a greasy appearance on leaf surfaces (Figure 13.22).

Causal agent: Although at one time they were considered to be fungi, they are no longer classified as such. At the present, they are considered a class of the protozoans known as the Myxomycetes.

Factors favoring the disease: These molds appear suddenly during wet weather.

Control and treatment: Mow or wash off molds with a strong stream of water. Slime molds do not harm turfgrass. No chemical control is needed.

Figure 13.22: Slime mold on St. Augustinegrass. Credit: Monica Elliott, UF/IFAS Plant Pathology.

Viral Diseases

Mosaic disease of St. Augustinegrass

Symptoms/signs:

- Blotchy or streaky patterns of yellow and green color (Figure 13.23).
- Broken yellow streaks running between veins on an otherwise green blade.

Causal agent: Sugarcane mosaic virus (SCMV).

Factors favoring the disease: SCMV can be efficiently transmitted by mechanical means. Lawn mowers, line trimmers, and other equipment can transfer clippings and sap containing virus from lawn to lawn. Aphids are known to transmit the virus as well, but it is not known how important aphids or other potential insect vectors are for disease spread. The virus also can be spread on infected sod during the times of year when symptoms are mild and not obvious. Sod with SCMV should not be used.

Control and treatment: Plant host resistance is the best management tool for viral diseases. Palmetto and Bitterblue may get the disease but are more resistant than Floratam. When resodding, choose a cultivar other than Floratam. Mowers and other equipment should be sanitized between properties. When mowing multiple lawns where the virus is known to occur, mow apparently healthy lawns before those with mosaic symptoms and avoid mowing symptomatic lawns when the turfgrass canopy is wet. Fungicides and other pesticides are ineffective and cannot stop development or spread of this viral disease. Also, there are no known agronomic inputs that lawn care companies can use to cure a lawn once it has become infected.

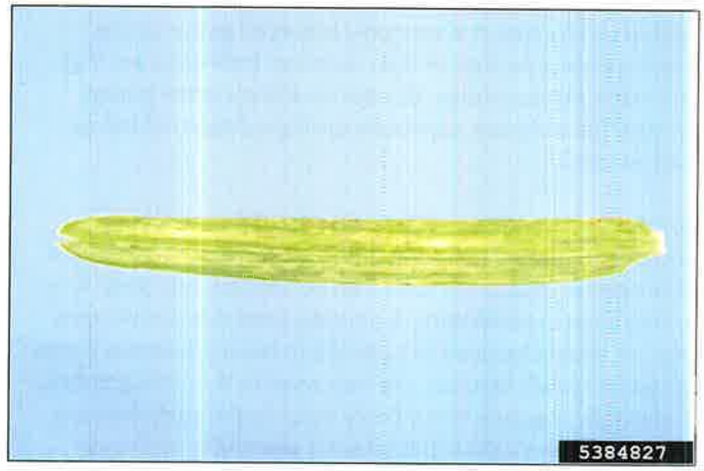


Figure 13.23: SCMV symptoms on a St. Augustinegrass leaf blade. Credit: Jeffrey W. Lotz, Florida Department of Agriculture and Consumer Services, Bugwood.org.

Diagnostic Assistance

The UF/IFAS Rapid Turfgrass Diagnostic Service was designed and implemented for managers of high quality turfgrass in Florida. The biggest distinction between this and the standard services provided by the Plant Disease Clinic is the turn-around time for sample results, the direct involvement of the UF/IFAS Extension Turfgrass Pathologist, and the price charged for the service. The price is $75 and reflects the added costs associated with a full time student dedicated to turfgrass diagnostics with rapid turn-around time. For information, see **http://turf.ufl.edu/rapiddiag.shtml**.

Test Your Knowledge

Q: Which of the following are considered to be abiotic disorders of turfgrass? (Select all that apply)
A. Dollar spot
B. Dead spot caused by a fuel leak
C. Frost injury
D. Drought stress
E. Gray leaf spot
F. Scalped lawn

A: B, C, D, F

Q: From a disease management standpoint, when is the best time to irrigate lawns?
A. Shortly after sunrise, between 8 a.m. and noon
B. During predawn hours, between 2 a.m. and 8 a.m.
C. During the peak afternoon, between 1 p.m. and 5 p.m.
D. During the evening, between 5 p.m. and 10 p.m.

A: B

Q: Which turfgrass disease is favored by low nitrogen fertility?
A. Gray leaf spot
B. Large patch
C. Pythium root rot
D. Dollar spot

A: D

Q: Which of the following statements is ***false*** regarding biological control of pathogens in turfgrass?
A. It is beneficial because it can compete with the pathogens for food sources.
B. It is beneficial because it can produce chemicals that inhibit the growth of the pathogens.
C. There is documentation that these products consistently prevent diseases in turfgrass.
D. It is beneficial because it can physically exclude the pathogens from the plant by occupying the space first.

A: C

Q: Match the turfgrass fungicide category with its location of activity.
1. Contact
2. Systemic
3. Local-penetrant
4. Mesostemic

A. Penetrates plant surfaces and then translocated
B. Generally applied to leaf and stem surfaces
C. Strongly attracted to plant surfaces and absorbed by waxy plant layers
D. Penetrates plant surfaces; only moves very short distances within plant

A: 1-B; 2-A; 3-D; 4-C

Q: Which of the following statements is false regarding turfgrass fungicides?
A. They are considered protective or preventive fungicides.
B. Leaves that emerge after the fungicide has been applied are protected.
C. They remain active on the plant surface to inhibit fungal growth, usually 7 to 14 days.
D. Contact fungicides have a broad spectrum of disease control activity.

A: B

Q: True or False:
Fungicides are effective for control of mosaic disease of St. Augustinegrass.

A: False

Q: Match the following turfgrass diseases with the photos of their symptoms/signs.

1. Dollar spot
2. Fairy rings
3. Large patch
4. Take-all root rot
5. Rust
6. Gray leaf spot
7. Anthracnose

A.

B.

C.

D.

E.

F.

G.

A: 1-G; 2-F; 3-E; 4-D; 5-C; 6-B; 7-A

Chapter 14

Turfgrass Arthropod Pests

In this Chapter

Learning Objectives

After you complete your study of this chapter, you should be able to:

- Name a mite pest of turfgrass and describe:
  - The turfgrass host it affects;
  - The damage it causes;
  - Practical cultural control measures.
- Name the most important insect pest of St. Augustinegrass and describe:
  - The damage it causes;
  - Its biological and identifying characteristics;
  - Methods to monitor its presence;
  - Practical cultural control measures.
- Name four insect pests of turfgrass with chewing mouthparts and for each, describe:
  - The turfgrass host it affects;
  - The damage it causes;
  - Its biological and identifying characteristics;
  - Methods to monitor its presence;
  - Practical cultural control measures.
- Describe why USDA-APHIS developed a quarantine program for imported red fire ants.
- Describe behavioral characteristics of imported red fire ants that allow you to identify them.
- Describe recommended chemical control programs for imported red fire ants in and around:
  - Home lawns;
  - Electrical equipment and utility housings;
  - Home gardens;
  - Compost piles, mulched flower beds, pavement cracks;
  - Bodies of water.
- Describe the best biological control method for imported red fire ants.
- Describe several physical control methods for imported red fire ants.
- Know that various control devices and home remedies are generally ineffective for control of imported red fire ants and the reasons why.
- Describe baiting practices that help to achieve satisfactory control of imported red fire ants.
- Name several pesticide active ingredients that are OMRI Listed® for control of imported red fire ants.
- Describe the social organization of the typical imported red fire ant colony.
- Describe the reasons why eradication of imported red fire ants has not been successful.
- For chemical insecticides used in controlling imported red fire ants, name:
  - five active ingredients used as baits;
  - two active ingredients used as insect growth regulators;
  - five active ingredients used for contact activity.

Terms to Know

Cambium: A thin formative layer between the xylem and phloem of most vascular plants that gives rise to new cells and is responsible for secondary growth.

Complete metamorphosis: Insect life cycle in which the insect passes through four stages of development: egg, larva, pupa, and adult.

Cytotoxin: Substance toxic to cells.

Dactyls: Large, blade-like feet.

Endophyte: Often a bacterium or fungus that lives within a plant for at least part of its life cycle without causing apparent disease.

Gradual metamorphosis: Insect or mite life cycle in which the arthropod passes through three different stages of development: egg, nymph, and adult.

Metamorphosis: A change in the shape, size and/or form of an animal.

Polygyne: A hive or colony of a social insect, such as imported fire ants, that has more than one active queen.

Introduction

Several insect and mite species live and feed in landscape turfgrass. Many are harmless, some are beneficial, and some are pests. Only a few cause significant damage and need immediate control. It is important to remember that arthropod pests are only one of many potential causes of thin, brown, or dead grass. Disease, nematodes, drought, and nutritional deficiencies can also be damaging. Proper identification is the first step of an integrated approach to managing arthropod pests of turfgrass, which can save money and prevent unnecessary pesticide applications. The intensity of turfgrass arthropod management largely depends on the turf species, variety, and its intended use.

In general, healthy turf is less vulnerable to pests and can recover faster from a pest infestation. Avoid unnecessary applications of soluble nitrogen fertilizers, mow at the correct height for the grass species, minimize thatch, and avoid over-watering. During active seasons, check every seven to ten days for pest activity, especially in "hot spots" where damage tends to reoccur.

Refer to Chapter 11 for a general discussion of arthropod characteristics, including life cycles and types of plant damage. This chapter describes the biology and management of the most important pests of turfgrass in Florida. They are presented by the type of plant damage they cause due to their feeding characteristics.

Insects and Other Pests with Piercing and Sucking Mouthparts

Bermudagrass mites

Description/biology:

- Tiny, about 0.2 mm (1/125-inch) long, and just visible with a 15 to 20x magnification hand lens.
- Creamy white in color (Figure 14.1), somewhat carrot-like in shape, and have two pairs of legs, which is unique among mites.
- One generation develops in five to ten days.
- Eggs are deposited under the leaf sheath, and after hatching, the mites molt twice before reaching adulthood.
- All life stages (eggs, nymphs, and adults) live under the leaf sheath and hundreds of them can be found under a single leaf.
- Mites may disperse by wind, other insects, or grass clippings.

Scientific name: (*Eriophyes cynodoniensis*)

Damage: Bermudagrass is the only host for this mite species. The mite causes damage characteristic of mites: grass blade tips turn light green to yellow and curl abnormally. The internodes shorten, tissues swell, and the grass becomes tufted (called "witches broom") so that small clumps appear (Figure 14.2). Large areas of grass may die and become infested with weeds. Damage is worse during hot, dry weather and when the grass is stressed.

Control and treatment: Bermudagrass cultivars Tifsport and Tifway both exhibit resistance to bermudagrass mite feeding. However, Tifway has previously shown susceptibility to feeding damage, so damage may occur in some instances. Infestations usually develop in taller grass (along canals, fence rows, etc.). Mow as close as practical (i.e., scalp the infested turf) and collect and destroy grass clippings from heavily infested areas. Chemical control is limited for mites, so implementing cultural and mechanical strategies may provide the best success. Refer to UF/IFAS EDIS Publication ENY-300, Insect Pest Management on Turfgrass (**https://edis.ifas.ufl.edu/ig001**) for insecticide selection.

Figure 14.1: Bermudagrass mites. Credit: L.J. Buss, UF/IFAS Entomology and Nematology.

Figure 14.2: "Witches broom" caused by Bermudagrass mites. Credit: L.J. Buss, UF/IFAS Entomology and Nematology.

Southern chinch bugs

Description/biology:

- Chinch bug adults (Figure 14.3) are about 5 mm (0.2 in) long and black with white patches on their wings, which are folded over the back.
- Young nymphs (Figure 14.4) are reddish-orange with a white band across the back. Body color darkens and becomes black as nymphs become adults.
- Eggs are laid in leaf sheaths or crevices and cracks in nodes and other protected places. Each female chinch bug lays an average of 300 eggs during her lifetime.
- In the summer months, the eggs hatch in seven to ten days.
- The nymphs pass through five nymphal instars, requiring four to five weeks to reach adulthood.
- Adults can live up to two months. Chinch bugs have at least three generations a year in northern Florida and seven to ten in southern Florida.

Scientific name: *Blissus insularis*

Damage: The southern chinch bug (SCB) is the most important pest of St. Augustinegrass, the most commonly planted turfgrass species for Florida lawns. Chinch bugs feed on sap from within St. Augustinegrass at the crown or stem, near the soil surface. The pests often feed in aggregations, so damage tends to be concentrated and spread outward. Injured plants look stunted, yellowed, wilted, or dead. Yellow to burnt-brown patches are often first noticed along sidewalks, in poorly irrigated areas, or sun-exposed locations (Figure 14.5).

Control and treatment: To monitor for chinch bugs, part the yellowing or declining grass to look for insects crawling on plants and within the thatch. Insert an open-ended cylinder or metal can with both ends cut out near damaged turf. Some companies sell cylinders specifically for this purpose. Fill the can with water and wait five minutes for chinch bugs to float to the top. Examine at least three or four places. Another monitoring option is to sample areas of declining turfgrass using a battery-powered, handheld vacuum. Push the opening of the vacuum down into the thatch in several areas, then empty the filter and look for chinch bugs.

Cultural controls include reducing the amount of water-soluble nitrogen fertilizer used, mowing at the recommended height for St. Augustinegrass, minimizing thatch buildup, and monitoring and spot treating the damaged area and a five foot area surrounding it, if necessary. Chinch bug-resistant St. Augustinegrass cultivars should be used when available, although previously resistant varieties like Floratam have become susceptible. Currently, Captiva is the only commercially available resistant St. Augustine variety. Bigeyed bugs prey upon chinch bugs, but do not always provide adequate control.

Some chinch bug populations have become resistant to several insecticide chemical classes including pyrethroids. Refer to UF/IFAS EDIS Publication ENY-300, *Insect Pest Management on Turfgrass* (**https://edis.ifas.ufl.edu/ig001**) for insecticide selection.

Figure 14.3: Chinch bug adult. Credit: L.J. Buss, UF/IFAS Entomology and Nematology.

Figure 14: Chinch bug nymph. Credit: L.J. Buss, UF/IFAS Entomology and Nematology.

Figure 14.5: Chinch bug damage. Credit: David Shetlar, The Ohio State University, Bugwood.org.

Ground pearls

Description/biology:

- Ground pearls are a type of scale insect that feeds on the sap from plant roots.
- Clusters of pinkish-white eggs, covered in a white waxy sac, are deposited in the soil from March to June.
- Small nymphs (called crawlers) emerge from eggs approximately 9 to 15 days later, attach to the roots, and enclose themselves in a hard, yellow-brown, globular shell.
- These "pearls" (also called cysts) (Figure 14.6) range in size from about 0.5 to 1.5 mm (0.02 to 0.06 in). They may occur as deep as ten inches in the soil.
- Ground pearls overwinter in the cyst stage and females reach maturity in late spring.
- The adult female is wingless, 1.5 mm (0.06 in) long, pink in color, with well-developed forelegs and claws.
- Females can reproduce without mating.
- Adult males are not commonly seen, but have wings and are gnat-like.
- One generation may last from one to two years.

Scientific name: *Margarodes* sp. and *Eumargarodes* sp.

Damage: Ground pearls feed on the roots of bermudagrass, St. Augustinegrass, and zoysiagrass, but prefer centipedegrass. They occur throughout Florida, Georgia, Alabama, South Carolina, and North Carolina. Ground pearl feeding causes irregular patches of yellow, brown, or dying grass. Damage is most commonly noticed during spring green-up, especially during hot, dry weather. Grass rarely recovers in damaged areas, and weeds often invade the damaged areas.

Control and treatment: No management strategies, including insecticides, are currently available for ground pearls. Use best management practices (BMP) to minimize plant stress and maintain proper fertility and soil moisture to help grass tolerate the damage.

Figure 14.6: Ground pearl adult. Credit: L.J. Buss, UF/IFAS Entomology and Nematology.

Twolined spittlebugs

Description/biology:

- Spittlebug nymphs may be yellow, orange, or white.
- The bugs, themselves, are less noticeable than the frothy spittle that covers them (Figure 14.7).
- Adults are about 6 to 12 mm (0.25 to 0.5 in) long, black with dark red eyes and two orange lines across the wings (Figure 14.8).
- The first generation adult population begins to emerge in June.
- Adults deposit eggs at the base of the grass in the thatch, in hollow grass stems, or behind the leaf sheaths.
- There are five nymphal instars and usually two generations per year.
- The first generation develops in about 2.5 months.
- Second-generation adults peak in early August to September.
- Eggs laid by second-generation adults overwinter and, depending upon temperature and precipitation, hatch from March to April.

Scientific name: *Prosapia bicinta*

Damage: The twolined spittlebug is occasionally an important pest of warm-season turfgrasses, including bermudagrass, St. Augustinegrass, centipedegrass, and bahiagrass. Spittlebugs are present throughout the entire state, but are most abundant in northern and northwestern Florida. Nymphs and adults both extract plant juices through their straw-like mouthparts. Infested turf wilts, purple-colored streaks develop on grass blades, sometimes the turf turns yellow and eventually brown, and the blades curl. Heavy infestations may kill, wither, or reduce turfgrass growth. Most of the spittle masses are usually located near the soil surface or in the thatch. Spittlebugs damage is often associated with an overdeveloped thatch layer, which provides high-humidity conditions optimal for insect development.

Control and treatment: Over-fertilization can increase spittlebug populations and subsequent damage. Follow approved practices regarding mowing, fertilizing, and irrigating to reduce thatch buildup. If a thatch problem exists, dethatching or verticutting will reduce spittlebug problems. No turfgrasses are resistant, but Emerald zoysiagrass, Tifway bermudagrass, and Sea Isle 2000 paspalum were most tolerant to feeding damage. Refer to UF/IFAS EDIS Publication ENY-300, *Insect Pest Management on Turfgrass* (**https://edis.ifas.ufl.edu/ig001**) for insecticide selection.


Figure 14.7: Spittlebug spittle mass. Credit: J.L. Castner, retired UF/IFAS Entomology and Nematology.


Figure 14.8: Adult spittlebug. Credit: J.L. Castner, retired UF/IFAS Entomology and Nematology.

Insects with Chewing Mouthparts

Fall armyworm

Description/biology:

- The caterpillar (damaging life stage) is green to brown in color when small, dark brown when mature, and can reach up to 1.5 inches in length (Figure 14.9).
- It has a light-colored stripe along the middle of its backside, with darker bands along each side.
- There are four dark dots on the dorsal side of each abdominal segment.
- Its head is dark and marked with a light colored, inverted "Y."
- Adult moths are brown with white on the tips of each forewing and have a wingspan up to 1.5 inches.
- Eggs are circular, light green when deposited, and darken with age; they are dusted with gray, fuzzy scales from the female's body (Figure 14.10).

Scientific name: *Spodoptera frugiperda*

Damage: Despite its name, the fall armyworm can damage turfgrass in the spring and fall in Florida. Larvae feed any time during the day or night, but are most active early in the morning or late in the evening. Larval feeding occurs uniformly in groups over larger areas, rather than in patches. Caterpillars first skeletonize the grass blades and later create bare spots in the lawn.

Monitor for fall armyworms by mixing one tablespoon of liquid dishwashing soap in one gallon of water. Pour the solution onto a four-square-foot area near the damage. Insects will crawl to the surface if present. Examine several suspected areas. Areas under lights can be monitored for adults because the adults fly to lights at night. Also, check light colored surfaces near turfgrass for egg clusters.

Control and treatment: Several natural enemies, including wasps and predatory bugs, attack fall armyworm caterpillars. It is important to remember that cultural practices and pesticide applications can affect the abundance and efficacy of natural enemies. Caterpillars tend to become a problem in newly established turf, especially if the turf was fertilized heavily in late summer. Treat at the first sign of damage for best results. Insecticides are more effective against younger caterpillars. Refer to UF/IFAS EDIS Publication ENY-300, *Insect Pest Management on Turfgrass* (**https://edis.ifas.ufl.edu/ig001**) for insecticide selection.

Figure: Fall armyworm larva. Credit: J.L. Castner, retired UF/IFAS Entomology and Nematology.

Figure 14.10: Fall armyworm egg mass. Credit: J.L. Castner, retired UF/IFAS Entomology and Nematology.

Cutworms

Description/biology:

- Several species of cutworms occur in Florida, but seldom are serious pests in turfgrass.
- Larvae (Figure 14.11) are mostly hairless, have three pairs of true legs and five pairs of fleshy prolegs on the abdomen. Cutworms tend to curl up when disturbed.
- Adults (Figure 14.12) are generally dull-colored, with wingspans up to 1.5 inches. At rest, wings are folded flat over the abdomen.
- Eggs are round, a c randomly on leaf blades, and hatch within ten days.
- Three to seven generations may occur each year.
- Cutworms remain active all year in southern Florida and are active from early spring to late fall in central Florida.

Scientific name: *Agrotis* spp.

Damage: Lawns rarely have problems with cutworm infestations. Monitor for cutworms by mixing one tablespoon of liquid dishwashing soap in one gallon of water. Pour the solution onto a four-square-foot area near the damage. Insects will crawl to the surface if present. Examine several suspected areas. Areas under lights can be monitored for adults because the adults fly to lights at night.

Control and treatment: Promote healthy turf with proper cultural management. Mechanical removal of clippings during mowing can effectively reduce populations by removing eggs deposited on grass tips. Treat at the first sign of damage for best results. Insecticides are more effective against younger caterpillars. Caterpillars tend to become a problem in newly established turf or in early fall, especially if the turf was fertilized heavily in late summer. Refer to UF/IFAS EDIS Publication ENY-300, *Insect Pest Management on Turfgrass* (**https://edis.ifas.ufl.edu/ig001**) for insecticide selection.

Figure 14.11: Granulate cutworm larvae. Credit: L.J. Buss, UF/IFAS Entomology and Nematology.

Figure 14.12: Granulate cutworm adult. Credit: L.J. Buss, UF/IFAS Entomology and Nematology.

Hunting billbugs

Description/biology:

- Adult beetles are about 0.4 inch long and weevil-like in appearance with a short, fairly broad, downward-curved snout (Figure 14.13).
- They are gray to black in color, but are often coated with soil.
- The hunting billbug, has a Y-shaped marking, with a parenthesis-shape on either side.
- The larvae are also 0.4 inch long in their final stage and legless. The body is white with a tan head capsule.

Scientific name: *Sphenophorus venatus vestitus*

Damage: Adult billbugs chew small holes in grass stems near the crown and deposit eggs in some of the stems. Larvae hatch in eight to ten days and feed inside the grass stem and crown area. Eventually, larvae go into the soil and feed on the roots. Because larvae do not move far, small, irregular areas of dead grass develop that resemble dollar spot disease. The larvae and pupae occur one to three inches deep in the soil, among roots and runners. One generation develops in 8 to 10 weeks and multiple generations occur per year throughout Florida.

Zoysiagrass and bermudagrass are preferred hosts, but bahiagrass, St. Augustinegrass, and centipedegrass are also attacked. Injury is more pronounced during extended periods of heat and drought. Adults cause the most damage, which is often noticed in the spring as dead patches or areas that are slow to green-up. Billbug damage is often mistaken for drought stress, chinch bug or white grub damage, or disease. Billbug feeding in sod may prevent it from holding together when cut.

Control and treatment: Monitor turfgrass root zones to determine if billbugs are responsible for damage. Turfgrasses containing fungal endophytes have enhanced tolerance and resistance to stress and feeding from certain insects. Overseeding with an endophytic ryegrass in the fall can reduce hunting billbug infestations. There are also resistant and tolerant varieties of bermudagrass and zoysiagrass available. Diamond and Pristine Flora zoysiagrass are recommended to reduce hunting billbug damage. As always, proper irrigation and fertility management can increase the plant's natural defense and tolerance to pest damage. Refer to UF/IFAS EDIS Publication ENY-300, *Insect Pest Management on Turfgrass* (**https://edis.ifas.ufl.edu/ig001**) for insecticide selection.

Figure 14.13: Hunting billbug adult. Credit: L.J. Buss, UF/IFAS Entomology and Nematology.

Mole crickets

Description/biology:

- Three exotic mole cricket species: tawny, southern, and shortwinged were introduced from South America around 1900 and are significant pests of turfgrass in Florida (Figure 14.14).
- The front legs of mole crickets are flattened and adapted for digging.

- Tawny and southern mole cricket adults grow to be 1.5 inches long, whereas the shortwinged mole cricket adults only reach one inch.

- The tawny mole cricket is a light, creamy brown color and the southern is gray to dark brown with four distinct light spots on its prothorax (the area immediately behind the head).

- Tawny and southern mole crickets can also be distinguished by their dactyls (digging claws): the southern has a U-shaped space between them, while the tawny has a V-shaped space. The shortwinged mole cricket also has a U-shaped dactyl space.

- In northern and central Florida, egg laying begins in March with a peak in May. Eggs hatch in 20 to 25 days, and emergence is mostly complete by late June.

- Nymphs feed through the summer, molting five to eight times before becoming adults in the fall.

- Tawny mole crickets overwinter mostly as adults, and southern mole crickets overwinter mostly as late instar nymphs. There is only one generation of both species per year in northern and central Florida.

- In southern Florida, tawny mole cricket oviposition and egg hatch occur a few weeks earlier than in central or northern Florida.

- The southern mole cricket has two generations a year in southern Florida. Egg laying occurs in early spring and again in summer.

- Generations of shortwinged mole crickets overlap and egg laying occurs year-round, with a peak in late spring or summer and a smaller peak in winter.

Scientific name: *Scapteriscus* spp.

Damage: Bermudagrass, bahiagrass, and centipedegrass are most often attacked by mole crickets. Tawny and shortwinged mole crickets are herbivorous and consume all parts of the grass plant. The southern mole cricket is a predator and scavenger. All three species tunnel through the surface layer of the soil (Figure 14.15), causing considerable damage to the grass roots. The tunneling also loosens the soil so that the grass is often uprooted and dries out. Most mole cr cket tunneling occurs at night, a few hours after dusk, and again just before dawn.

Control and treatment: Monitor for mole crickets using a soap flush early in the day. For a demonstration of how to do a soap flush, visit **https://www.youtube.com/watch?v=sx_o4EMXsCo**. Southern and tawny mole cricket adults are also attracted to lights, especially in the spring. Warm, moist weather and soil conditions increase mole cricket activity. Mole cricket management depends on the condition, use, and demand of the turf as well as the life stage of the insect. Extensive research has been conducted on biological control of mole crickets in Florida with varying success. Nematodes, especially *Steinernema scapterisci*, can reduce mole cricket populations, as well as the parasitoid wasp, *Larra bicolor*, and parasitoid fly, *Ormia depleta*. Unfortunately, none of these biological controls are commercially produced.

It is important to get insecticides into the soil, either by slit-injection, pre- or post-treatment irrigation, or by using a wetting agent in the spray solution. Apply insecticides as late in the day as possible, because mole crickets are deeper in the soil during the day and closer to the soil surface at night. Baits are most effective later in the summer, when older nymphs come onto the soil surface at night. Do not get baits wet. Refer to UF/IFAS EDIS Publication ENY-300, *Insect Pest Management on Turfgrass* (**https://edis.ifas.ufl.edu/ig001**) for insecticide selection.

Figure 14.14: Left to right: shortwinged, tawny, and southern mole cricket. Credit: L.J. Buss, UF/IFAS Entomology and Nematology.

Figure 14.15: Mole cricket damage to bermudagrass. Credit: J.L. Castner, retired UF/IFAS Entomology and Nematology.

Tropical sod webworms

Description/biology:

- Tropical sod webworm is a sporadically damaging caterpillar pest of most warm season turfgrasses, including Zoysiagrass, bermudagrass, bahiagrass, centipedegrass, St. Augustinegrass, and seashore paspalum.
- Larvae (Figure 14.16) are gray-green, have brown spots on each segment, and a light brown head. Mature larvae can be about 0.75 to 1 inch in length.
- Larvae progress through seven or eight instars before becoming adults.
- Sod webworms form cocoons in the soil or thatch made from plant debris and soil particles.
- Sod webworm adults (Figure 14.17) are small, tan to gray moths with a wingspan of 0.75 to 1 inch.
- Moths hide in shrubs and other sheltered areas during the day and begin flying at dusk.
- The adults do not cause damage, but deposit small clusters of 6 to 15 round, flat eggs on grass blades at nighttime, which take about one week to hatch.
- The life cycle from egg to adult requires five to six weeks at 78°F and 12 weeks at 72°F.

Scientific name: *Herpetogramma phaeopteralis*

Damage: Newly hatched larvae skeletonize the grass blades, while older larvae chew on grass blades near the soil surface. They remain curled up in the soil during the day and feed at night. Damage begins in small patches of brown, short-clipped grass, about 0.1 to 0.3 inch inch diameter. Small, green frass can be seen on the ground surface. Larvae chew notches in the leaves, causing the grass to look ragged or irregularly shaped (Figure 14.18). Larger larvae build silken tubes through the thatch or on the ground surface. Sod webworms can be especially damaging to close-cut turf, but rarely cause lasting damage to high-cut turf. This pest is most active from April through November, but may occur year-round in southern Florida. Three generations occur in northern Florida and four generations in southern Florida.

Control and treatment: Most tropical sod webworm problems are associated with turfgrass cultivated under high maintenance or drought conditions. Larger populations can attract birds, which may cause additional damage because the birds will tear up the turf in search of caterpillars. Monitor for damaging populations with soapy water flushes. Endophyte-enhanced grasses are toxic to sod webworms and should be implemented when available. Treat at the first sign of damage for best results. Insecticides are more effective against younger caterpillars. Caterpillars tend to become a problem in newly established turf or in early fall, especially if the turf was fertilized heavily in late summer. Refer to UF/IFAS EDIS Publication ENY-300, *Insect Pest Management on Turfgrass* (**https://edis.ifas.ufl.edu/ig001**) for insecticide selection.

Figure 14.16: Tropical sod webworm larva. Credit: L.J. Buss, UF/IFAS Entomology and Nematology.

Figure 14.17: Adult tropical sod webworm. Credit: L.J. Buss, UF/IFAS Entomology and Nematology.

Figure 14.18: St. Augustinegrass lawn damaged by a tropical sod webworm infestation.

White grubs

Description/biology:

- White grubs, larvae of scarab beetles, are sporadic problems of turfgrass in Florida.
- Certain species can be very damaging in coastal regions. At least five common genera occur in Florida. The masked chafers, *Cyclocephala* spp. (Figure 14.19), are most frequently encountered; sugarcane grubs, *Tomarus* spp. (Figure 14.20), are the second most common.
- The larvae are plump-looking grubs that rest in a C-shaped position.
- They are white in color with dark areas at the rear, three pairs of legs, and a tan to reddish-brown head.
- Depending on the species, the larvae range from 0.4 to 2 inches long in their final stage. Billbug larva can look similar; however, billbug larvae do not have legs.
- Development through one generation may take six months to one year in Florida.
- Eggs are laid one to two inches below the surface of the soil, usually during April or May.
- The grubs feed on the grass roots until mid- to late summer, and pupate in the soil in August and September.
- Adults emerge September through October, mate, and lay eggs.

Scientific name: *Cyclocephala* spp. and *Tomarus* spp.

Damage: White grubs feed on the roots of all turfgrass species. They occur at or just below the soil-thatch interface. Mild damage may make the turf yellow, which could be misdiagnosed as a nutrient deficiency or disease. Severe damage results in large areas of dead turf due to a lack of roots. Damage can be masked if the turf is frequently irr gated, but if drought or another stress affects the infested turf, the grass will die quickly. Damage from mature grubs is most pronounced during late summer and early fall.

Control and treatment: To monitor for adults, watch for scarab beetles flying at night near lights. To monitor white grub populations, cut three sides of a one-foot square piece of sod about two inches deep at the edge of one of the off-color areas and pull the sod back. See if the grass roots are chewed off and sift through the soil and thatch looking for grubs. Check several places in symptomatic turf. When turf is easily pulled from the soil with little evidence of roots snapping and some grubs are present, it is likely that white grubs are responsible. Refer to UF/IFAS EDIS Publication ENY-300, *Insect Pest Management on Turfgrass* (**https://edis.ifas.ufl.edu/ig001**) for insecticide selection.

Figure 14.19: Masked chafer adult (left) and larva (right). Credit: J.L. Castner, retired UF/IFAS Entomology and Nematology.

Figure 14.20: Sugarcane grub adult (left). Credit: L.J. Buss, UF/IFAS Entomology and Nematology.

Managing Imported Fire Ants in Urban Areas

Imported fire ants are a special concern. The two species of imported fire ants, red imported fire ant, *Solenopsis invicta* Buren (Figure 14.21), and black imported fire ant, *Solenopsis richteri* Forel, and their sexually reproducing hybrid are invasive insects whose stings can cause serious medical problems. In the Southeast, the black imported fire ant is confined to portions of Mississippi, Alabama, and Tennessee. Imported fire ants interfere with outdoor activities and harm wildlife throughout the southern United States and elsewhere. Ant mounds are unsightly and may reduce land values (Figure 14.22). Although fire ants do prey on flea larvae, chinch bugs, cockroach eggs, ticks and other pests, the problems they cause usually outweigh any benefits in urban areas. While it may not be possible to eradicate fire ants, we can make them easier to live with. The best management programs use a combination of non-chemical and chemical methods that are effective, economical, and least harmful to the environment.

Figure 14.21: Red imported fire ant. Credit: J.L. Castner, retired UF/IFAS Entomology and Nematology.

Figure 14.22: Red imported fire ant mound. Credit: L.J. Buss, UF/IFAS Entomology and Nematology.

USDA Quarantine Program

Because fire ants are easily transported in nursery stock and soil, the United States Department of Agriculture's Animal and Plant Health Inspection Service (USDA-APHIS) developed a quarantine program for this pest in the 1950s.

Fire ants must be eliminated from regulated articles that will be transported, which requires treatments different from the management type treatments described in this publication. These regulations are administered by state regulatory agencies, including the Florida Department of Agriculture and Consumer Services. The purpose of the quarantine program is to minimize the spread of imported fire ants by requiring proper inspection and treatment of all nursery stock, turfgrass, hay and other articles shipped out of quarantined areas. Inspectors also survey non-quarantined counties for fire ants and occasionally treat small, isolated infestations. The public should do its part to avoid spreading the ants by not transporting or purchasing items infested with fire ants. The *PPQ Treatment Manual* contains all Plant Protection and Quarantine approved treatments for both import and domestic programs at **http://bit.ly/aphis_manual**.

Figure 14.23: Pustules from red imported fire ant stings. Credit: L.J. Buss, UF/IFAS Entomology and Nematology.

Management Options

Properly identifying an ant species is the first step in determining whether the ants should be managed and how to do so (see the section on Fire Ant Biology and Identification in this chapter). Doing nothing is an option that should be considered in areas where imported fire ants are not present or are present in very low numbers and do not pose a problem. Most management options require repeated treatments to maintain suppression, which requires a commitment to continued labor and expense. In the following sections are options for managing various kinds of imported fire ant problems. There may be other effective methods not mentioned, and there is rarely a single best method of control.

Home Lawns and Other Ornamental Turf

Fire ants commonly infest lawns, schoolyards, athletic fields, golf courses, and parks, where they pose a medical threat to people and animals (Figure 14.23). Their mounds also detract from the appearance of the landscape and can damage lawn care equipment.

Program 1. The "Two-Step Method." This program suppresses ants in ornamental turf and non-agricultural lands, including roadsides. It is also suitable for pasture and rangeland if the products selected are specifically registered for use in these sites. Similarly, an "organic two-step" program can be implemented using a bait and a mound treatment combination considered "organic" or using products certified by the Organic Materials Review Institute (OMRI). This approach is best suited to medium-sized or large areas, and the cost is moderate. It is not suggested for use in previously untreated areas with few fire ant mounds (20 per acre or fewer, or 0.46 or fewer per 1,000 square feet). Some bait products may affect native ants that compete with imported fire ants. The goal of this program is to reduce fire ant problems while minimizing the need to treat individual mounds.

The two steps involve: 1) broadcasting a bait product (see the section on Baits in Fire Ant Treatment Methods), followed by 2) treating nuisance mounds with a faster acting individual mound treatment or with a mound re-treatment of the bait.

Step 1: Once or twice per year, usually in spring and fall, broadcast a bait-formulated insecticide or use an outdoor bait station product as directed on the label. Most conventional baits are applied at a rate of 1 to 1½ pounds of product per acre, although some products are applied at higher rates. Periodic broadcast applications of fire ant baits will provide about 90 percent control when properly applied. A bait can be broadcast with hand-held, vehicle-mounted or aerial applicators. The speed and duration of ant suppression differs with the product used. Hydramethylnon, fipronil, indoxacarb, metaflumizone and spinosad baits (see the section on Fire Ant Insecticides) provide maximum control one to four weeks after application, while insect growth regulator (IGR) bait products (i.e., those containing methoprene or pyriproxyfen) provide maximum suppression two to six months after treatment depending on environmental conditions. Abamectin baits act more slowly than hydramethylnon, fipronil, indoxacarb, metaflumizone and spinosad, but more quickly than IGR products. A late summer IGR application provides maximum suppression the following spring. Using higher rates of an IGR bait does not eliminate colonies more quickly. The blending of half rates of a faster acting bait plus an IGR (such as hydramethylnon plus methoprene as in the product Extinguish® Plus and Amdro® Yard Treatment Fire Ant Bait, or as directed on AmdroPro® and Extinguish® product labels) can provide faster and longer-lasting suppression. Where there are many mounds per acre (200 or more), a second application may be needed after the maximum effects of the first treatment have occurred, because not all mounds are affected by a single bait application. Follow label instructions on any time interval requirements between applications and limits on number of applications per year.

Step 2: Preferably, wait several days or more after broadcasting the bait, and then treat nuisance ant colonies (such as those in sensitive or high-traffic areas) using an individual mound treatment method (see Program 2, Step 1, below). Otherwise, be patient and wait for the bait treatment to work. Any nuisance mounds that escaped the effects of bait treatment, and any colonies migrating into treated areas, should be treated as needed. In large areas, individual mound treatment may not be feasible and routine broadcast bait treatments alone may provide sufficient control. Repeat the bait application when ants re-invade the area and mound numbers reach about 20 per acre or exceed the tolerance level for a situation. Bait products do not protect against reinvasion by ant colonies from surrounding land or by newly mated queens. Ant populations can fully recover within 12 to 18 months of the last bait treatment. Low-lying, moist and flood-prone areas are more prone to re-infestation.

Program 2. Individual Mound Treatments. This approach is best used in small areas of ornamental turf (usually one acre or less) where there are fewer than 20 to 30 mounds per acre or where preservation of native ants is desired. This program selectively controls fire ants, but rapid re-invasion should be anticipated. It generally requires more labor and monitoring than other programs, and is not suggested for large or heavily infested areas.

1. Treat undesirable fire ant mounds using an individual mound treatment (see the section on Individual Mound Treatments with Contact Insecticides under Fire Ant Treatment Methods). Products are applied as dusts, dry granules, granules drenched with water after application, liquid drenches or baits. Non-chemical treatment methods such as drenching mounds with very hot water also may be used. Mound treatments may need to be repeated to eliminate the colony if queen ants are not all killed with the initial treatment. When treating an ant mound with a liquid product or watering a product into a mound, begin on the outside of the mound and circle into the center of the mound. Application of faster-acting granular ant bait formulations are made around the mound as directed.

2. Continue treating undesirable mounds that appear, as needed.

Program 3. The Long-Residual Contact Insecticide Treatment Method. This program eliminates many ant species in treated areas and it reduces re-invasion of treated areas as long as the contact insecticide remains effective. However, these products are more expensive, use more insecticide, and have greater environmental impact than other methods. This approach is frequently used by commercial applicators for treating ornamental turf. Long-residual products that contain a pyrethroid usually work most rapidly. Fipronil granular products eliminate ant colonies more slowly but have longer residual effects.

1. (Optional) Broadcast a bait-formulated insecticide in areas where there are many mounds (more than 20 per acre), or individually treat fire ant mounds. Wait 2 to 3 days after applying a bait before conducting the next step.

2. Apply a contact insecticide with long residual activity (i.e., fipronil or a pyrethroid such as bifenthrin, deltamethrin, gamma-cyhalothrin, or lambda-cyhalothrin) to turfgrass as directed (generally every four to eight weeks for most products, or once per year using a granular fipronil product). Liquid or granular products (which are usually watered in after application) that can be evenly applied to an area are appropriate for this use. With most products, the initial surface treatment may not eliminate ants located deep in mounds, but routine re-application will eventually eliminate most colonies. Fipronil, a non-repellent contact insecticide that can be used with bait products, will eliminate ant colonies within 4 to 10 weeks of treatment, even those nesting well beneath the surface. However, ants migrating into treated areas may take more than a week to be eliminated.

Program Combinations. Any of the three programs can be mixed and matched within a managed area where different levels of fire ant control are desired. On golf courses, for instance, Program 3 might be suitable for high-use areas such as putting greens and tee boxes. In fairways and rough areas, Program 1 might be sufficient. On athletic fields, where as many ants as possible must be eliminated, Program 3 should be used, and the program should begin early enough to attain maximum suppression by the time the field is in full use. People with severe allergies to fire ant stings should follow Program 3 for their lawns or use a bait on a calendar schedule. For grounds around schools, day care centers, mental health facilities, and other sensitive sites, broadcast application of a fire ant bait product twice per year is one of the least-toxic methods of control. Control should be monitored with routine surveillance for re-invading ant mounds that need to be treated.

Homes and Buildings

Fire ants from colonies close to homes and other buildings sometimes forage indoors for food and moisture, particularly during the hot, dry, summer months. Entire colonies occasionally nest in wall voids or rafters, or behind large appliances, sometimes moving into buildings during floods or drought. They are a nuisance and can threaten sleeping or incapacitated people and pets. Treatment options:

1. It is best to control imported fire ants in the landscape, using one of the programs described for Home Lawns and Other Ornamental Turf Areas, before they move into structures. If ants are entering the home from outdoor colonies, locate and treat mounds near the building. A contact insecticide with a long residual effect, such as fipronil or a pyrethroid, also can be applied as directed around the base of the structure as a barrier, but this treatment alone may not be effective at keeping ants out of the structure, particularly if overhanging vegetation or electrical wires allow ants to enter above the barrier treatment. It is important to caulk cracks and crevices, and screen weep holes to prevent ants from entering.

2. If ants are foraging indoors, remove any food items on which the ants are feeding. Then use an insecticide bait product labeled specifically for fire ant control indoors. Examples are products containing abamectin or hydramethylnon or bait stations containing indoxacarb or other ingredients. Bait products not specifically registered for fire ant control may not be effective. Bait treatment alone may not control fire ants.

3. Follow trails of foraging ants to colonies located indoors and treat them with contact insecticide dusts or sprays injected into the nest. Treating ant trails rarely eliminates an ant problem, and sometimes interferes with use of toxic baits. Some insecticides, such as chlorfenapyr (Phantom®) and imidacloprid (Premise®), which are available to professional applicators, are non-repellent to many ants and are compatible with the use of bait products. Most over-the-counter insect sprays, however, are repellent to ants and should not be used indoors when also using bait products.

4. Vacuum indoor ant trails and dispose of the vacuum bag immediately. A knee-hi stocking can be placed over the end of the vacuum hose prior to attachment placement to prevent ants from clinging to the hose or other vacuum parts. Tie off the stocking and place in soapy water or use another method to kill the ants prior to disposal. Treat the source colony or the point at which ants are seen entering a room using options described above.

Electrical Equipment and Utility Housings

Fire ants frequently infest electrical equipment (Figure 14.24). They chew on insulation, can cause short circuits, and can interfere with switching mechanisms. Air conditioners, traffic signal boxes, and other devices all can be damaged. Fire ants also nest in the metal housings that surround electrical and utility equipment. They frequently move soil into these units, which can cause corrosion, electrical short circuits, and other mechanical problems. See *Ants and Electrical Equipment* at **http://articles.extension.org/pages/30057/ants-and-electrical-equipment.**

Note: *For safety reasons, only electricians or licensed pest control operators should treat electrical equipment. Specialized products and training are necessary to treat these sites safely and effectively.*

Figure 14.24: Fire ant mound near high voltage electrical unit. Credit: Jake Farnum, Bugwood.org.

Step-by-step treatment program:

1. Before treating any equipment, unplug the unit or turn off all electrical service. Use an individual mound treatment method with a faster-acting contact insecticide to eliminate colonies around electrical and plumbing casings and housings. Injectable aerosol products containing pyrethrins, or similar products, give rapid control. Hydramethylnon, abamectin, indoxacarb or spinosad baits applied near or on fire ant mounds provide control after about one week, even if the colony is located within the structure. Do not use liquid drenches, sprays, or products that may damage insulation around electrical fixtures. Treating a larger area around the electrical structure is optional, but will provide longer-term protection. Mound and area treatments are described in the section on Home Lawns and Other Ornamental Turf. Be extremely careful when applying pesticide around water systems and well heads to prevent contamination of wells and ground water. Once ants are eliminated, remove debris and soil from the equipment housings to reduce the possibility of short circuits.

2. To prevent ants from entering, treat the inside of equipment housings with specialty products labeled for such use, such as those containing propoxur (Rainbow® High Tech Insect Tag), permethrin (AntGuard®, Arinix®), synergized pyrethrins and silica gel (Stutton®JS 685 Powder), or dichlorvos (Hot Shot® No-Pest Strip). Some bait and bait station products also can be used inside equipment housings, but they provide little or no residual control.

3. Maintenance. After ants are removed from electrical equipment, prevent re-infestation and damage by sealing all sensitive electrical components, particularly those that are not insulated. Examples are plastic housings containing contact points of switches, relays and circuit breakers. Apply a long-residual contact insecticide around housings, making sure to avoid the electrical circuitry or components. Apply specifically labeled products to the housing itself or to the mounting pad (see Step 2 in the treatment program above).

Home Gardens

Ants occasionally feed on vegetable plants in home gardens. They tunnel into potatoes underground and feed on okra buds and developing pods. The worst damage usually occurs during hot, dry weather. Ants may be a nuisance to gardeners during weeding and harvesting. Ants prey on some garden pests such as caterpillars, but protect or "tend" others, such as aphids, by keeping their natural enemies away. Treatment options:

1. Ant mounds can be shoveled out of the garden or treated with very hot water, taking care not to disturb plants or allow hot water to contact them. If you choose to use hot water, be extremely careful not to burn yourself.

2. Only a few bait products are specifically registered for treating imported fire ants in home gardens, including Ferti-lome Come and Get It! and Payback Fire Ant Bait (both contain spinosad). The bait product Extinguish® Professional Fire Ant Bait, which contains methoprene, is registered for use in "cropland." Esteem® (pyriproxyfen) is another bait that is registered for use near 400+ edible food crops. Currently Extinguish Professional Fire Ant Bait and Esteem Ant Bait are sold in 25 pound bags, enough to treat 17-25 acres, which will be too large for most home gardeners unless they can use the bait on other labeled sites. Other bait products are not specifically registered for use inside home vegetable gardens, although they can be applied outside the garden's perimeter. Foraging ants from colonies both inside and outside the garden will collect the bait and take it to their colonies.

3. A number of contact insecticides are registered to treat general insect problems in home vegetable gardens. Those labeled for control of "ants" include products containing deltamethrin, es-fenvalerate, pyrethrins, pyrethrins plus diatomaceous earth, and spinosad (such as Entrust® SC, Green Light® Lawn & Garden Spray, Ferti-lome® Borer, Bagworm, Tent Caterpillar and Leafminer Spray, Monterey Garden Insect Spray or Conserve® Naturalyte Insect Control). The Entrust, Green Light, Monterey and Conserve products containing spinosad

are OMRI certified for use in organic gardens. Some granular products contain carbaryl, or pyrethroid insecticides, including deltamethrin, bifenthrin or es-fenvalerate. These are available for treating other "soil insects" and may provide some control of fire ant foragers. Other products may be labeled for "fire ant control" but do not specify home gardens as the use site. Products containing the active ingredient, d-limonene (Orange Guard, also OMRI-certified), for treating ant mounds are available. D-limonene is the major ingredient in orange oil, which is sold as a soil amendment for use in the garden. Contact the manufacturer if there is a question about site use of any insecticide product. Follow directions and pre-harvest intervals indicated on the product label when using a pesticide on and around food plants. GreenLight Many Purpose Dust containing deltamethrin can be used in vegetable gardens for fire ants and other insects.

4. To keep ants from entering a garden, manage them properly in the surrounding landscape. Products registered for controlling ants in turf areas can be applied outside the perimeter of the garden as a barrier, or used to treat individual mounds near the garden.

Compost Piles, Mulched Flower Beds, Pavement Cracks, etc.

Fire ants invade compost piles and mulched flower beds seeking warmth and moisture. They also nest under cracked pavement, removing dirt from underneath sidewalks and roadways and aggravating structural problems. Grounds around these areas can be treated as described for Home Lawns and Other Ornamental Turf. However, colonies nesting in these sites may be difficult to locate precisely. When the exact location of a fire ant colony is unknown, treat the area of greatest ant activity with a fast-acting bait product containing hydramethylnon, abamectin, indoxacarb, metaflumizone or spinosad.

Around Bodies of Water

Fire ants require water to survive and are often found near creeks, run-off ditches, streams, rivers, ponds, lakes and other bodies of water. If surface water is unavailable, they tunnel down to the water table many feet below the ground. Every effort must be made to avoid contaminating water with pesticides. Some ant control products, such as those containing fipronil and methoprene, have specific restrictions on the label regarding their use near bodies of water. Fire ant bait products contain very small amounts of active ingredients and can be applied up to the water's edge, but not directly to the water. A formulation of methoprene, the ingredient in Extinguish® bait, is registered for control of mosquito larvae in ponds and other bodies of water, but Extinguish® should not be applied to bodies of water.

To decrease the risk of pesticide runoff into waterways, apply baits when ants are actively foraging. Read the label carefully and do not apply closer to the edge of the body of water than allowed on the label. When treating individual mounds near the water's edge or in drainage or flood-prone areas, exercise special care and use products such as acephate (Orthene®) that have relatively low toxicity to fish and apply the product according to label directions. Pyrethrins, pyrethroids and rotenone products should be avoided because of their high toxicity to fish. Do not apply surface, bait or individual mound treatments if rains are likely to occur soon after treatment. Nearly all insecticides can be toxic to aquatic organisms if applied improperly.

Fire Ant Treatment Methods

Treatment methods and products vary greatly in effectiveness, speed of activity, practicality (labor requirements), toxicity to the user and the environment, compatibility with other options, and cost. Carefully study available treatment methods and their proper use in order to choose the best one for a particular situation. Many methods and products have been evaluated. Information is available from county Extension agents and Extension entomologists. Individual mound treatment cost ranges from about $0.02 to more than $7.00 per mound, and bait treatments cost $8.00 per acre or more excluding application equipment and labor costs. See *Fire Ant Control Materials for Alabama Homeowners* at **http://bit.ly/aces_edu_FireAnt** for current products and treatment cost estimates.

Natural and biological control. Currently, the best biological control method for fire ants is to preserve other ant species that compete with them for food and nesting sites, attack small fire ant colonies, or kill newly mated queen ants. In some areas outbreaks of other exotic ant species, such as Argentine ants and tawny crazy ants, have displaced imported fire ants. Even imported fire ants from single-queen or polygyne colonies will prey upon newly mated fire ant queens and eliminate small, neighboring colonies. Ants, in general, are considered beneficial insects because they prey upon many other arthropods (Figure 14.25) and collectively till more earth than earthworms, thereby reducing soil compaction. Ways to preserve native ants include preserving their habitat and using insecticides judiciously.

Figure 14.25: Red imported fire ants eating a moth. Credit: L.J. Buss, UF/IFAS Entomology and Nematology.

Introducing or conserving the natural enemies (diseases, parasites and predators) of imported fire ants can help control them. These natural enemies kill fire ants or make them less able to compete with other ant species. The most effective biological control organisms for large-scale programs are those that spread by themselves from mound to mound and persist from year to year. A number of species of parasitic "phorid" flies (Diptera: Phoridae), including *Pseudacteon tricuspis*, *P. curvatus*, *P. obtusus* and *P. litoralis*, have been released and established in parts of most southeastern states. A disease of fire ants, *Kneallhazia* (=*Thelohania*) *solenopsae*, is also widespread in some states. Although natural enemies will not eliminate fire ants and it may be several years before their effect is known, it is hoped that introducing natural enemies of fire ants in the U.S. will reduce their populations indefinitely. In South America, where imported fire ants and their natural enemies originate, fire ant species are not usually considered pests but rather just another ant species. See *Natural Enemies of Fire Ants* at **http://bit.ly/articles_FireAntEnemies**.

Several other parasites and pathogens have been marketed for fire ant control. The predatory straw-itch mite, *Pyemotes tritici*, feeds on and paralyzes developing fire ants but has not been effective when applied as directed and is potentially hazardous to the user. Parasitic nematodes such as *Steinernema* spp. are roundworms that enter insects, paralyzing them and developing in their bodies. Species and strains vary in their effectiveness. Strains tested to date caused ants to temporarily move away from the treated mound, but few colonies were actually eliminated. Parasitic fungi, such as *Beauveria bassiana* strains and formulations, also have been evaluated as individual mound and broadcast bait treatments. However, these agents have not been shown to persist or spread in the environment.

Newly mated fire ant queens, which can start new colonies, are killed by a number of organisms. These include birds, lizards, spiders, toads, dragonflies, robber flies, other ant species, and ants from surrounding colonies. Animals that eat ants, such as armadillos, may disturb mounds and eat some workers, but they are not really useful in control.

Physical and mechanical methods. Pouring very hot or boiling water on a mound is a fairly effective treatment, particularly when ants are close to the mound surface such as on a cool, sunny morning or after heavy rainfall. Approximately 3 gallons of very hot (almost boiling) water poured on each mound will eliminate about 60 percent of the mounds treated. Be careful handling large volumes of hot water to prevent serious burns, and keep hot water off of desired plants and grass. A number of hot water or steam injection devices have been produced for treating individual ant mounds.

Sometimes it may be sufficient to move colonies away from sensitive areas such as gardens. Disturbing or knocking down mounds frequently will cause colonies to move. Individual mounds can be carefully shoveled into a bucket dusted on the inside with baby (talcum) powder and the ants drowned with soapy water, but this rarely eliminates all ant colonies in the area. Some people believe shoveling one mound on top of another will force ants to kill each other, but this is not true.

Certain barriers can keep ants out of sensitive areas such as duck nesting boxes or greenhouse benches. Talcum powder and Teflon®-like tape or spray products can be used on vertical surfaces, but these treatments lose their effectiveness in humid or damp conditions. Tanglefoot®, a petroleum-based, sticky material available as a gel or aerosol, is effective temporarily until it becomes coated with dust and other debris. Plates or wires heated to about 140°F form a hot barrier that ants will not cross. Some plastic repellent barrier products impregnated with permethrin are now available (AntGuard®, Arinix®).

Control devices. Various mechanical and electrical products have been marketed for fire ant control. One device was designed to electrocute fire ant workers as they climb onto an electric grid inserted into the mound or into a cone. These devices kill many worker ants, but the queens and brood are unaffected. There have been vibrating and sound-producing units designed to repel colonies, and devices that use microwaves or explosive elements to heat mounds or blow them up. Such products are often marketed without scientific evaluation. The fact that a "control" device is on the market does not indicate that it is effective. These products may kill some ants, but rarely eliminate a colony. Deceptive or fraudulent claims concerning fire ant control devices should be reported to the state's attorney general or the Federal Trade Commission. See *Museum of Novel Fire Ant Control Methods and Products* at **http://bit.ly/articles_novelFireAntCtrl**.

Home remedies. In addition to very hot or boiling water, other "home remedies" have been tried. While these methods sometimes appear to work, they rarely eliminate colonies. Usually, the ant colony simply moves to a new location because of the disturbance, or the queen and a few workers temporarily remain hidden underground.

Gasoline and other petroleum products do kill some fire ant colonies. However, petroleum products are dangerously flammable or explosive, kill grass and plants around the treated mounds, and can seriously pollute the soil and ground water. All too often they cause the colonies to move instead of killing them. Using petroleum products, solvents, battery acids, bleaches or ammonia products can be dangerous and is strongly discouraged, except when they are ingredients in a registered pesticide product accompanied by usage directions.

Soap solutions, cleaning products or wood ashes soaked into the mound are believed to remove the protective wax coating from the ants or suffocate them. Generally, their use is discouraged because they have not been proven effective or this use is not supported by the product(s) manufacturer. Some solutions containing citrus oil and other ingredients may be effective as mound drench treatments. Citrus oil contains a natural extract of citrus peels (d-limonene, the active ingredient in Victor Safer Brand Fire Ant Killer) that is toxic to fire ants and has been advocated for use in some home recipes as an ant mound drench.

Sprinkling grits or other solid food substances onto fire ant mounds is ineffective. It has been suggested that when the ants eat the grits their stomachs will swell and rupture. In fact, only the last larval stage of the developing fire ant is known to digest solid food. All other life stages feed only on liquids or greasy materials. Likewise, club soda is also not an effective strategy. See *Are there any home remedies that will kill fire ants?* at **http://articles.extension.org/pages/34814/are-there-any-home-remedies-that-will-kill-fire-ants** and *Will club soda kill fire ants?* at **http://articles.extension.org/pages/42294/will-club-soda-control-fire-ants**.

Chemical control. Chemical insecticides (both "organic" and man-made or synthetic products) continue to be the main method of battling fire ants. Insecticides registered by the EPA are considered to pose minimal risk to the user and the environment when used as directed. Insecticide applications can be aimed at the foraging ants and/or at the entire colony. The section on Fire Ant Insecticides (see below) refers to fire ant insecticides by generic names of active ingredients. These active ingredients are sold under various trade names. Carefully follow directions on the product label to understand the proper method of application, what protective clothing must be worn, re-entry intervals to observe, and proper watering practices before and after treatment.

Chemical control—baits. Most conventional bait formulations combine pesticide ingredients with soybean oil, which is absorbed onto processed corn grit (Figure 14.26). Soybean oil is an attractive food for ants that is important to the success of the bait. Because these baits are granular in texture, be careful not to confuse them with granular products that contain contact insecticides. Fire ant baits should have the word "BAIT" clearly listed on the label. Baits can be applied as spot treatments to individual mounds, in a bait station, or broadcast over large areas (for additional information, see the *Southern IPM Center's Broadcast Baits for Fire Ant Control* at **http://bit.ly/aces_ANR-1297**).

Figure 14.26: Red imported fire ant bait. Credit: USDA APHIS PPQ - Imported Fire Ant Station, USDA APHIS PPQ, Bugwood.org.

To achieve satisfactory results:

- Use fresh bait, preferably from a just-opened container or an opened one stored for no more than two years. Purchase only enough bait to make one treatment and do not store large quantities once the containers have been opened. Bait is collected by ants only when it is fresh. It is then carried back to the colony and shared with other members of the colony. Rancid or stale bait is ignored by foraging ants. To check the quality of your bait, place a little near an ant mound to see if ants are attracted to it as described below. It is important not to smoke while using the bait or place the bait near gasoline. The ants detect the smell and are repelled.

- Apply when worker ants are actively foraging. This can be determined by leaving a small pile (1 to 2 tablespoons) of bait in the area to be treated. If you see ants actively removing the bait 10 to 45 minutes later, you will know that the bait is attractive and that ants are foraging. You can also use tuna fish, pet food, hot dog slices or potato chips to see if ants are foraging. Foraging activity slows when soil temperature is lower than 65 to 70°F or higher than 90°F. In mid-summer, apply bait in late afternoon or early evening, because foraging ants are less active during the heat of the day. Applying bait in early evening also prevents it from being degraded by sunlight. In the winter, ants may not be foraging or be attracted to bait products.

- Apply baits when the ground and grass are dry and no rain is expected.

- Do not mix bait with other materials such as fertilizer or seed unless directions are provided for such mixtures.

- Use appropriate application equipment and calibrate it properly. Differences in the oiliness of bait brands and production batches can cause variations in applicator output. Temperature and humidity also affect the rate at which bait flows through the applicator opening. The speed at which the applicator is moving is an important factor, particularly with factory-calibrated settings. Over-application provides little or no increase in control and adds greatly to the cost. Under-application may decrease effectiveness.

- Do not store bait products near gasoline, fertilizer, or odorous pesticides, and do not smoke during bait treatments as these odors may reduce the bait's attractiveness to ants.

The availability of bait products is a problem, especially in areas recently invaded by fire ants. If you cannot find some of the products mentioned in this publication, speak with the store manager, visit your local farmers co-op, or contact your county Extension agent to determine whether the product is available in your area. Some of the bait products listed here are sold only through specialty stores such as lawn and garden supply stores or pesticide wholesalers that sell professional products.

Hand-operated spreaders, such as the Scott's® HandyGreen hand-held spreaders, are the least expensive applicators and are adequate for treating small areas. The operator can walk or ride on the back of a vehicle. Some push-type applicators also may be suitable, but some modification (attaching a fire ant plate) is required to keep from applying too much material. Most rotary and drop-type fertilizer spreaders will not apply fire ant baits at the recommended rate.

Electric spreaders such as the Herd® Model GT-77A or similar applicators are best for treating large areas. These spreaders have vibrating agitators that prevent clogging. Swath width is determined by spreader fan speed and the weight of bait particles and is usually fixed. Applicators can be mounted on any vehicle that will maintain a low speed. Do not use ground-driven or power takeoff-driven equipment, because it can rarely be set to apply such a low rate. A description of these relatively simple modifications and calibration methods can be obtained from bait product manufacturers.

In addition to their use as a broadcast treatment, baits can be used as an individual mound treatment or dispensed in a bait station. Bait products containing hydramethylnon, abamectin, indoxacarb, metaflumizone, or spinosad often work faster when used to treat individual mounds than when broadcast. This is not the case with insect growth regulator (IGR) baits containing methoprene or pyriproxyfen.

Chemical control—individual mound treatments with contact insecticides. In addition to baits, mound treatment insecticides are often formulated as dusts, liquids or granules. Their effectiveness depends on proper application. Contact insecticides must contact ants to work and should be applied during times of the year (and times of the day) when ants are close to the mound surface. It is also important not to disturb the mound during treatment if the product label so directs. Individual mound treatments selectively eliminate only the ant colonies treated to help preserve desirable native and competitor ant species. However, repeated treatments may be necessary for persistent mounds or nests that are not initially visible.

Although a few mound drenches are ready-to-use, most fire ant mound drenches are formulated as liquid concentrates that must be diluted with the amount of water specified on the label. Avoid skin contact with the concentrate or mixture. Mix the proper amount in a gallon container, such as a sprinkling can, plainly marked POISON. Do not use the container for any other purpose. Properly store or discard containers after use. Pour the solution on top of and around an undisturbed mound. Most mound drenches require an hour to several days to eliminate the colony, although those containing pyrethrins and d-limonene are effective almost immediately.

To treat a single mound with a granular product, measure the recommended amount in a measuring cup labeled "POISON" for pesticide use only. Then sprinkle it on top of and around the mound. Do not disturb the mound. If the label says to water in the insecticide, use a sprinkling can and water the mound gently to avoid disturbing the colony. Several days may pass before the entire colony is eliminated.

Some products, such as those containing acephate (Orthene®) or pyrethroids (including beta-cyfluthrin, deltamethrin and permethrin), are specially labeled for dusting individual fire ant mounds. Distribute the recommended amount of the powder evenly over the mound. Treatments work best when ants are near the top of the undisturbed mound. Treated colonies are usually eliminated in several days.

Devices used to inject or "rod" insecticides into mounds are also sold as application equipment and are occasionally used by commercial applicators.

Chemical control—surface applications and barriers in and around structures. Products used to treat ant trails and colonies located in wall voids are usually dusts or sprays, although some surface treatments are mixtures of insecticide and latex paint. Unless the colony itself is treated, these products only reduce the number of foraging worker ants. Surface treatments are also used to create barriers to protect items or areas from foraging worker ants.

Chemical control—surface applications outdoors. Granular insecticides are applied with fertilizer spreaders. These materials must be thoroughly watered into soil after application as directed. Liquid formulations are applied with a pump-up, high-volume, hydraulic, hose-end or boom sprayer. Some contact insecticides are relatively long-acting (weeks to months), suppress foraging ants quickly, and prevent small mounds from becoming established. Through repeated use, these treatments can eliminate most colonies. When applied as directed, granular products containing fipronil eliminate fire ant colonies slowly, requiring four or more weeks. A single treatment will continue to eliminate most ant colonies for about one year. However, the treatment is non-repellent to ants and new colonies migrating into treated areas can survive temporarily.

"Organic" insecticides. Several products said to be "organic" (of natural origin) are currently marketed for fire ant control. These products may or may not be registered as pesticides by the EPA and FDACS. In 1996 the EPA established that certain ingredients that pose minimum risk to users no longer require EPA approval to be marketed as insecticides. These products are called "25 b" products, referring to that clause in FIFRA, the Federal Insecticide, Fungicide and Rodenticide Act. Some of the "organic" products fall into the minimal risk category. Therefore, not every product sold for fire ant control is supported by research-based evidence that it is effective against fire ants.

Note that not all products that contain naturally occurring active ingredients are completely organic; some contain non-organic inert ingredients. Products approved as organic are certified by the OMRI. OMRI provides an independent review of products intended for use in certified organic production, handling, and processing. Acceptable products are listed at **http://www.omri.org/omri-lists/**. State and federal organic certification programs are limited to food crop and livestock production systems where only approved organic products are allowed for use. In other use sites such as landscapes including turfgrass and ornamental plant maintenance, "organic" products are defined by the user and may include home remedies and physical and mechanical methods. In this section, we will discuss the use of organic insecticides and not consider these other methods that some may consider "organic." Please remember, some "organic" treatments are not necessarily safer or less toxic than conventional insecticides and should always be used as directed and with care.

Payback® Fire Ant Bait (spinosad) is currently an OMRI Listed® organic fire ant bait product.

OMRI Listed® fire ant products for individual mound treatments contain either spinosad or d-limonene (a component of citrus or orange oil). Apply mound drenches by mixing the specified amount of insecticide per gallon of water and pouring onto the fire ant mound. The ants are killed by contact with the insecticide. Therefore the amount of drench needed to saturate the mound depends on the size of the mound. One gallon is sufficient for small mounds, but two gallons or more may be needed for large mounds. Use a watering can, or similar container, to mix and apply the drench according to label directions. Do not disturb the mound before drenching. Be sure to use enough drench volume to saturate the mound. Not using enough drench to thoroughly soak the mound is the main reason for control failures with mound drenches. D-limonene kills contacted ants within minutes but has little residual effect, so mounds need to be drenched thoroughly and quickly in order for the drench to be effective. Any granular products (other than baits) should be applied to the mound according to label directions. These are usually watered in using one or two gallons of water depending on mound size.

One of the most effective ways to control fire ants with these organic treatments is to use the broadcast applied ant baits as the primary control program. Then, a week or two later use individual mound treatments to spot treat mounds that survive the bait treatments or that "pop up" between bait treatments. The individual mound treatments can be either mound drenches or individual mound bait applications. This is called the Two-Step Method.

There are several other products that are OMRI Listed® for general ant control. Some of the active ingredients contained in these certified organic products are spinosad, d-limonene or orange oil, mint oil, clove oil, diatomaceous earth, pyrethrins, pyrethrum, cottonseed oil and canola oil. These products can be used for fire ants if label directions are followed. There are other products on the market that contain naturally occurring active ingredients that are completely organic along with naturally occurring inert ingredients that are not OMRI Listed®. However, some products sold as "organic" or "eco-friendly" with naturally occurring active ingredients may contain non-organic inert ingredients. So, you need to read the label carefully if the product is not OMRI Listed® to make sure you are getting an all-natural, wholly organic product.

Fire Ant Biology and Identification

Properly identifying ant species is the first step in determining the need and approach for control (see *Identifying Fire Ants* at **http://articles.extension.org/pages/11278/identifying-fire-ants**). Where imported fire ants are common, such as in Florida, most homeowners recognize them by the mounds they build or the stings they inflict. However, there are also other characteristics to look for. Their aggressive nature compared to other ant species is one such trait. If a mound is disturbed, usually hundreds of fire ant workers will swarm out and run up vertical surfaces to sting. If you are unsure of the ant species you have, contact your local UF/IFAS Extension office for help identifying them.

Imported fire ants (red imported fire ant, *Solenopsis invicta* Buren, and black imported fire ant, *Solenopsis richteri* Forel and their sexually reproducing hybrid) are social insects. Unlike many insect pests, they are very organized. Colonies consist of the brood and several types (castes) of adults. The whitish objects often found at the top of the mounds are actually the ant's developmental stages or brood—the eggs, larvae and pupae. Types of adults are:

- winged males (Figure 14.27) (distinguished from females by their smaller heads and black bodies except in black or hybrid imported fire ants that may have darker females);
- red-brown winged females;
- one or more queens (Figure 14.28) (wingless, mated females); and
- workers (Figure 14.29).

Figure 14.27: Red imported fire ant winged male. Credit: Jake Farnum, Bugwood.org.

Figure 14.28: Red imported fire ant queen. Credit: L.J. Buss, UF/IFAS Entomology and Nematology.

Figure 14.29: Red imported fire ant workers. Credit: L.J. Buss, UF/IFAS Entomology and Nematology.

Worker ants are wingless, sterile females. They vary in size within a colony from 1?16 to 3?16 inch long. They protect the queen by moving her from danger, defend the nest from intruders, and feed the queen only food that the workers or larvae have eaten first. They also forage for food and care for the developing brood.

Winged forms, or reproductives, live in the mound until their mating flight, which usually occurs in the late morning and afternoon soon after a rainy period. Mating flights are most common in spring and fall. Males die soon after mating, while the fertilized queen lands and walks around to find a suitable nesting site, sheds her wings, and begins digging a chamber in which to start a new colony. Sometimes, several queens can be found within a single nesting site.

The newly mated queen is 3/8 inch long, red-brown, and initially lays about a dozen eggs. When they hatch 7 to 10 days later, larvae are fed by the queen. These larvae will develop into small worker ants that will feed the queen and her subsequent offspring. Later on, a queen fed by worker ants can lay from 800 to 1,000 eggs per day. Larvae develop in 6 to 10 days and then pupate. Adults emerge 9 to 15 days later. The average colony contains 100,000 to 500,000 workers and up to several hundred winged forms and queens. Queen ants can live seven years or more, while worker ants generally live about five weeks in summer and longer in cooler months. Larger workers generally live longer than smaller workers.

In addition to sexually reproductive hybrid imported fire ants, there are two kinds of red imported fire ant colonies—the single-queen and multiple-queen forms. Workers in single-queen colonies are territorial. Workers from multiple-queen colonies move freely from one mound to another. This lack of territorial behavior by the multiple-queen form causes a dramatic increase in the number of mounds per acre. Areas infested with single-queen colonies contain 40 to 150 mounds

Figure 14.30: Red imported fire ant mound-infested lawn. Credit: Jake Farnum, Bugwood.org.

per acre (rarely more than 7 million ants per acre), whereas areas with multiple-queen colonies may harbor 200 or more mounds and 40 million ants per acre.

Red imported fire ants build mounds in almost any type of soil, but prefer open, sunny areas such as pastures, parks, lawns, meadows and cultivated fields (Figure 14.30). Mounds can reach 18 to 24 inches in height, depending on the type of soil. Often mounds are located in rotting logs and around stumps and trees. Colonies also can occur in or under buildings.

Colonies frequently migrate from one site to another. A queen needs only half a dozen workers to start a new colony, and they can build a new mound dozens of feet away from their previous location almost overnight. Fresh water flooding causes colonies to leave their mounds and float until they can reach land to establish a new mound. Colonies also can migrate indoors.

History of Control Efforts

Around the 1930s, the red imported fire ant was accidentally brought into Mobile, Alabama from South America. It now infests more than 325 million acres, comprising most of twelve southern states and Puerto Rico, with infestations also in New Mexico and California. It has recently been reported in northern Mexico, Australia, Taiwan and China. Another species, the black imported fire ant, also was introduced, but this species is limited to northeastern Mississippi, northwestern Alabama, and southern Tennessee. Fire ants can travel long distances when newly mated queens land on cars, trucks, trains, or aircraft cargo containers, or when winged forms are carried by the wind. Shipments of nursery stock or soil from an infested area may relocate entire colonies.

Attempts in the late 1960s and early 1970s to eradicate the red imported fire ant were not successful. Why did early attempts of eradication fail? The pesticides used, although effective, were no match against a species capable of re-invading treated areas. The reasons for failure are debatable, but it is now known that eradication is hindered by the ant's biology and by problems with treatment methods. Recent attempts to eradicate this ant from parts of California and Australia using new products and treatment methods have shown very promising results. Successful eradication of the imported fire ant in large areas has yet to be documented. There were also other reasons why eradication has not been successful, including:

1. Technological obstacles. Pesticide treatments are expensive and time-consuming, and there are only three basic approaches. The first is surface treatment using a residual contact poison. This approach is the least environmentally sound because the treated surface remains toxic for a long time. The ants may survive by foraging underground. The second is individual mound treatment, which involves applying a large volume of pesticide to reach the queen. However, it is nearly impossible to locate all of the colonies in an area and difficult to manipulate large volumes of liquid. Also, mound treatment is more expensive and time-consuming than broadcast treatments. Colonies not eliminated may move or split into several colonies. The third method is bait treatment, which uses some sort of attractive substance the ants like to eat. Unfortunately, baits are not always consumed, and the bait's attractiveness is short-lived. The bait must be slow-acting and effective over a range of doses, since the dose the ants get cannot be controlled. Baits may also be attractive to and kill some native ant species that compete with fire ants.

2. Economic, regulatory and environmental obstacles. The best way to treat large areas (hundreds of acres) is by an aerial application of bait. However, not all areas can be treated because of label restrictions and application limitations. Even with a bait product, it is not feasible to treat the entire infested area or even a large part of a single state, and untreated areas are sources for reinfestation. The larger the treatment area the more slowly reinfestation occurs. If periodic treatments are discontinued, the area may become more infested than it originally was within a year or two because treatments may have eliminated competing ant species.

3. Biological obstacles. In the southeastern U.S., the pest infests such an extensive area that it would take years and massive resources to apply a single treatment to the entire infested area. Fire ants have a high reproductive rate, disperse easily and easily reinvade treated areas. Thousands of reproductive females are produced per colony, and mated females begin a colony wherever they land. Queens can fly up to a mile on their own or even farther when assisted by the wind. Once colonies are established, the ants eliminate competing insects and then rapidly overwhelm an area. Whole colonies can move, and in the multiple-queen form, the colonies can split into many new colonies. If a poison works too rapidly, the worker is killed before the poison is passed to the queen. Finally, worker ants from well-fed colonies may not forage on a bait product, or a bait may not be as attractive as some abundant natural food. Colonies move vertically and horizontally in the soil profile to escape floods, droughts and extreme temperatures. When worker ants from new colonies are not actively foraging, they may be unaffected by baits or

other pesticides applied to the soil surface. Such undetected ant mounds could escape eradication efforts.

Medical Problems

Fire ants are aggressive and will defensively attack anything that disturbs them. Fire ants can sting repeatedly (Figure 14.31). Symptoms of a fire ant sting include burning, itching and a white, fluid-filled pustule that forms a day or two afterward. Often people note a circular pattern of pustules, which may be caused by one ant stinging several times. Although the stings are not usually life threatening, they can be easily infected if the skin is broken, and may leave permanent scars.

Figure 14.31: Victim of multiple stings by red imported fire ants. Credit: Murray S. Blum, University of Georgia, Bugwood.org.

If the only symptoms are pain and the development of pustules, stings can be treated with over-the-counter products that relieve insect bites and stings (see *Fire Ant Stings* at **http://articles.extension.org/pages/11124/fire-ant-stings** for more information). If a sting leads to severe chest pain, nausea, sweating, difficulty breathing, serious swelling or slurred speech, the person should be taken to an emergency medical facility immediately. Some allergic people may lapse into a coma from just one sting. Compared to deaths from bee and wasp stings, relatively few deaths from fire ant stings have been documented. People sensitive to fire ant stings should seek the advice of an allergist. Once a person has discovered that he/she is allergic to the fire ant venom, extra care must be taken to avoid stings. Often individuals allergic to the venom will carry epinephrin ("Epi pens") or undergo treatment in an attempt to desensitize their reaction to the venom.

Tips for avoiding medical emergencies and for treating ant stings:

- Teach children and visitors about the hazard of fire ants and to be aware of ant mounds.
- Wear protective clothing during outdoor activities. Wear shoes or boots and/or tuck pant legs into socks.
- Treat stings with an insect bite remedy that deadens pain and protects against infection.
- Control fire ants in areas used most frequently by people and pets.

Use insect repellents on clothing and footwear. These treatments can temporarily discourage foraging ants, but will not deter the defensive reaction of ants emerging from a disturbed mound.

Flooded fire ants float on water. These ants should be especially avoided as they carry more venom, inject more venom per sting and are very aggressive.

Fire Ant Insecticides

The following section lists and briefly describes insecticide active ingredients and example trade products currently registered for control of imported fire ants. For more information, visit **http://fireant.tamu.edu/controlmethods/products/**.

Baits. *Hydramethylnon* kills ants by preventing them from converting food into energy. These baits eliminate fire ant colonies within a week when applied to individual mounds, but take several weeks when broadcast. They are also formulated in bait granules and stations. Example trade products: Amdro® Fire Ant Bait, Amdro®Pro Fire Ant Bait, MaxForce® Complete, Probait® and others.

Abamectin is derived from a soil fungus and inhibits nerve transmission. As a mound treatment it kills worker ants and colonies quickly, but as a broadcast treatment it acts more like an insect growth regulator, preventing the production of viable eggs. Formulations include bait granules and stations. Example trade products: Ascend™, Award® II, and, Optigard™ Fire Ant Bait.

Indoxacarb is a member of a class of insecticides that has a unique mode of action. Indoxacarb undergoes bio-conversion in the insect to a more toxic form. When ingested it irreversibly blocks sodium channels in nerve cells, resulting in paralysis and death. The compound is quick-acting and controls ants in 3 to 14 days even when broadcast. Example trade product: Advion® Fire Ant Bait.

Metaflumizone blocks the sodium channel of the nervous system causing "relaxed" paralysis of the insect. Susceptible insects have no known cross-tolerance by insect strains resistant to carbamates, organophosphates, pyrethroids, or benzoylureas. No metabolism of the insecticide is required for toxicity to target insects. This compound has the ability to eliminate fire ant activity in as few as seven days. Example trade products: Altrevin™ and Siesta™.

Spinosad, which belongs to a group of chemicals known as the spinosyns, is derived through the fermentation of a naturally occurring soil microorganism. These insecticides have a unique mode of action that is different from all other known insect control products. Spinosad causes excitation of the insect nervous system, leading to involuntary muscle contractions, prostration with tremors, and finally paralysis. These nerve toxin effects are consistent with the activation of nicotinic acetylcholine receptors by a mechanism that is novel and unique among known insecticidal compounds. Several of the spinosad liquid products also have fire ant mound drench instructions on their labels. Example trade products: Ferti-lome® Come and Get It and Pay Back Fire Ant Bait.

Fipronil is a member of the phenylpyrazole chemical class. As a nervous system toxicant, it blocks the passage of chlorine ions by interacting with gamma-aminobuteric acid (GABA) -gated chloride channels on nerve cell membranes. A bait formulation is available for broadcast or individual mound treatment. Broadcast application provides maximum control 6 to 12 weeks after treatment. Formulations include bait granules and stations. Example trade product: MaxForce® FC.

Several fipronil products are granular formulations and are broadcast on turfgrass areas and control ants about four to eight weeks after application. Control continues for up to a year. Example trade product: Topchoice® Insecticide. It is a RESTRICTED USE product for purchase and use only by licensed pesticide personnel.

Insect growth regulators. *Methoprene* and *pyriproxyfen* are materials that mimic the effects of the insect's own juvenile hormone, reducing the production of viable eggs and preventing the development of worker ants for up to a year after application. They do not kill adult ants, but render sterile winged female reproductives developing after treatment. Treated ant colonies persist for several months after treatment, until worker ants present at the time of treatment die naturally. Ants do not die faster when more product is applied than directed. These products are formulated as baits to be applied to individual mounds or broadcast. Example trade products: Extinguish® Professional Fire Ant Bait, Distance® Fire Ant Bait, and Esteem® Ant Bait.

Product mixtures. *Hydramethylnon* plus *methoprene*. Both the Amdro® Pro and Extinguish® labels provide blending directions for applying both products as a combination treatment. The blend is both fast-acting like hydramethylnon, and long-lasting, like methoprene. It is also available as pre-blended products. Example trade products: Extinguish® Plus Fire Ant Bait and Amdro® Kills Fire Ants Yard Treatment Bait.

Contact insecticides. *d-limonene, pyrethrins, rotenone, pine oil, cedar oil*, and *turpentine* are botanicals, all derived from plants. The citrus or orange oil component, d-limonene, is a cytotoxin that kills cells after entering the insect body through direct contact. Other essential oils or components of essential oils have come on the market in the last few years in a variety of pesticides. Essential oils are volatile, highly concentrated substances extracted from plant parts, including the oils of cedar, cinnamon, citronella, citrus, clove, eugenol (a component of clove oil), garlic, mints, rosemary, and several others. As insecticides, they vary in their modes of action, but most work as contact killing agents only, so re-treatment may be needed. Some are promoted as repellents. Some essential oils used as pesticides may work by disrupting an insect neurotransmitter that is reported to be not present in people, pets, or other vertebrates. Most of these ingredients are generally regarded as safe for mammals by the United States Food and Drug Administration when used as directed. Many are even used extensively as flavorings and scents in foods, cosmetics, soaps, and perfumes. Pyrethrum is the source of natural insecticides made from the ground dried flowers of certain species of a chrysanthemum plant. The ground flowers contain a mixture of several different compounds called pyrethrins and cinerins. Pyrethrins are natural insecticidal compounds that are extracts of the chrysanthemum plant.

Pyrethroid insecticides, such as permethrin, bifenthrin, cypermethrin and others, are synthetic versions of this naturally occurring insecticide. Pyrethrins, like pyrethroid insecticides, bind to sodium channels that occur along the length of nerve cells. Sodium channels are responsible for nerve signal transmission along the length of the nerve cell by permitting the flux of sodium ions. When pyrethrins bind to sodium channels, normal function of the channels is obstructed, thereby resulting in over-excitation of the nerve cell and, consequently, a loss of function of the nerve cell. Pyrethrins are often combined with diatomaceous earth (see inorganic compounds below). Rotenone acts on respiratory tissues, nerves and muscles. Pyrethrins and rotenone products break down rapidly in the environment. Rotenone, cedar oil and pine oil (turpentine) products are relatively slow-acting (days to weeks) and are applied as mound drenches. Example trade products: numerous.

Allethrin, resmethrin, sumithrin, tetramethrin are synthetic derivatives of pyrethrins. These were the earliest synthetic pyrethrin-like materials and were originally referred to as "synthetic pyrethroids." Like pyrethrins, these products destabilize nerve cell membranes and kill quickly, but are quickly deactivated and have little residual activity. They are contact insecticides applied as aerosol injections, mound drenches or surface sprays. Example trade products: numerous.

Bifenthrin, cyfluthrin, cypermethrin, deltamethrin, fenvalerate, fluvalinate, lambda-cyhalothrin, permethrin, s-bioallethrin, es-fenvalerate, tefluthrin, and *tralomethrin* are among the later generation of insecticides synthetically derived from pyrethrins, and as a group today, are referred to as the "pyrethroids." These products also destabilize nerve cell membranes. They can persist in the environment longer than pyrethrins and their early derivatives because of their photostability. They kill ants relatively quickly and are applied as mound drenches, dusts, surface sprays or granules. Example trade products: numerous.

Carbaryl is in the carbamate family of insecticides. These materials disrupt nerve transmission (cholinesterase inhibitor). They are relatively quick-killing contact insecticides used as mound drenches, soil treatments and surface sprays. Example trade product: Sevin®.

Acephate is a member of the organophosphate family of insecticides. These products are very similar to the carbamates in that they also interfere with nerve cell transmission (cholinesterase inhibitor). They are relatively quick-killing and are formulated as aerosols, liquids, dusts, or granules. They can be applied as mound treatments. Example trade product: Orthene®.

Boric acid and Diatomaceous earth (DE) are inorganic compounds. Boric acid is a slow-acting stomach poison. It is commonly formulated as a dust or liquid bait for control of ants.

Diatomaceous earth (DE) acts as a desiccant by scratching and absorbing the waxy layer that makes up part of the insect's exoskeleton. DE is most commonly applied as a dust to ant foraging trails to kill foraging ants; however, this use will have little or no effect on the ant colony or nest. Insecticide grade DE products are available, but when applied as a dry dust to the top of an ant mound or as a drench, fail to contact ants. Also, high humidity in ant mounds prevents desiccation. Thus, this ingredient acts more as a carrier in fire ant products that list DE as an active ingredient. When DE is used as a carrier in formulations of pyrethrins, it may enhance the penetration of this botanical insecticide into the body of an insect.

Test Your Knowledge

Q: True or False:
Most of the insect and mite species that live and feed in landscape turfgrass are pests.
A: False

Q: Which turfgrass arthropod pest causes the internodes to shorten, tissues to swell, and the grass to become tufted into "witches brooms"?
A. Spittlebugs
B. Chinch bugs
C. Bermudagrass mites
D. Ground pearls
A: C

Q: Which turfgrass arthropod pest is the most important in St. Augustinegrass?
A. Fall armyworms
B. White grubs
C. Mole crickets
D. Chinch bugs
A: D

Q: Identify this arthropod pest of turfgrass.

A. Chinch bug
B. Ground pearl
C. Bermudagrass mite
D. Hunting billbug

A: A

Q: Identify this arthropod pest of turfgrass.

A. Chinch bug
B. Ground pearl
C. Spittlebug
D. Hunting billbug

A: C

Q: Identify this arthropod pest of turfgrass.

A. Chinch bug
B. June bug
C. Spittlebug
D. Hunting billbug

A: D

Q: Identify this arthropod pest of turfgrass.

A. Cut worm
B. Tropical sod webworm
C. White grub
D. Fall armyworm

A: D

Q: Which arthropod pest of turfgrass has flattened front legs adapted for digging?
A. White grubs
B. Mole crickets

C. Cut worms
D. Fall armyworms

A: B

Q: For which arthropod pest of turfgrass are there no current available management strategies?
A. Ground pearls
B. Spittlebugs
C. White grubs
D. Mole crickets

A: A

Q: Which of the following insecticides registered for imported red fire ant control is classified as an insect growth regulator (IGR)?
A. Hydramethylnon
B. Abamectin
C. Methoprene
D. Spinosad

A: C

Q: Which of the following statements is ***false*** regarding individual mound treatments for control of the imported red fire ant?
A. This approach is suggested for large or heavily infested areas.
B. This program selectively controls fire ants.
C. Rapid re-invasion should be anticipated.
D. It generally requires more labor and monitoring than other programs.

A: A

Q: Which of the following insecticides registered for imported red fire ant control is used as a bait?
A. Hydramethylnon
B. Bifenthrin
C. Pyriproxyfen
D. Acephate

A: A

Q: Which of the following insecticides registered for imported red fire ant control is OMRI- certified for use in organic gardens?
A. Carbaryl
B. Fipronil
C. Indoxacarb
D. Spinosad

A: D

Q: Why did attempts of imported red fire ant eradication fail? (Select all that apply)
A. Not all areas can be treated because of label restrictions and application limitations.
B. Fire ants have a high reproductive rate, disperse easily and easily reinvade treated areas.
C. Fire ants developed resistance to insecticides during the early years of use.
D. Pesticide treatments are expensive, time-consuming, and there are only three basic approaches.

A: A,B,D

CHAPTER 15

TURFGRASS NEMATODES

IN THIS CHAPTER

Learning Objectives

After you complete your study of this chapter, you should be able to:

- Describe the two types of plant-feeding nematodes.
- Describe the aboveground symptoms of nematodes on turfgrass.
- Describe the belowground symptoms of nematodes on turfgrass.
- Name the most destructive plant-parasitic nematode species on turfgrass in Florida.
- Name the major plant-parasitic nematode species of St. Augustinegrass lawns in Florida.
- Describe the most reliable method to identify nematode damage.
- Describe the procedure for sampling a turfgrass site for the presence of nematodes.
- Explain the information provided by a nematode assay.
- Describe the best practices to control nematodes in home lawns.
- Explain why nematicides cannot be used in existing home lawns.

Terms to Know

Ectoparasite: Nematode that remains in the soil and feeds by inserting only its stylet into roots and feeds only from outside the roots.

Endoparasite: Nematode that uses its stylet to puncture an entry hole in the root and crawls inside the root tissue to feed.

Nematicide: Pesticide that controls nematodes.

Stylet: A hollow mouth spear, like a hypodermic needle, used to puncture plant cells, to withdraw food and also to secrete protein and metabolites that aid the nematode in parasitizing the plant.

Introduction

Plant-parasitic nematodes are among the least understood and most difficult pests to manage on turfgrass in Florida. For a general description of nematodes, refer to Chapter 12 of this publication, *Ornamental Plant Nematodes*. This chapter will address plant-parasitic nematodes that affect turfgrass.

How Do Nematodes Damage Turfgrass?

All of the plant-parasitic nematodes that are important turfgrass pests in Florida feed on or in roots. Some plant-parasitic nematodes, called ectoparasitic nematodes, remain in the soil and feed by inserting only their stylet into roots. Other plant-parasitic nematodes, called endoparasites, use their stylets to puncture an entry hole in the root and crawl inside the root tissue to feed. Among the major nematodes that cause damage to turfgrasses in Florida, sting, stubby-root, ring, and spiral nematodes are ectoparasites, while root-knot and lance nematodes are endoparasites.

Plant-parasitic nematodes damage roots as they feed, reducing the ability of the grass to obtain water and nutrients from the soil. Roots damaged by nematodes may be abnormally short and stubby, or they may appear darkened or rotten. Root galls or knots associated with certain nematode damage to other landscape ornamental plants are usually not evident on grasses. When nematode population densities get high enough, or when environmental stresses such as high temperatures or drought occur, aboveground symptoms may become evident. These symptoms include yellowing, wilting, browning, thinning, or plant death. Weeds such as spurge may increase as the grass cover thins. Nematode damage usually occurs in irregularly shaped patches that may enlarge slowly over time. Be aware that similar conditions may be caused by other factors such as localized soil conditions, fungi, or insects.

Which Kinds of Turfgrass Are Damaged by Nematodes?

All types of grasses are affected by nematodes to some extent. However, certain nematodes are more problematic or some grasses than others. The most common nematodes that

Table 15.1. Common Florida turfgrasses and nematodes species which cause damage.

Turfgrass species	Nematode species					
	Lance	Ring	Root-knot	Spiral	Sting	Stubby-root
Bahiagrass[1]						
Bermudagrass	√				√	
Centipedegrass		√			√	
St. Augustinegrass	√					√
Seashore paspalum				√	√	
Zoysiagrass	√		√		√	
[1]Bahiagrass is the most nematode-tolerant turfgrass and rarely has nematode problems.						

damage each type of turfgrass used in Florida lawns are shown in Table 15.1. This section also provides general information on the most common nematode species affecting turfgrass in Florida.

Sting Nematodes

Sting nematodes are the most destructive plant-parasitic nematodes on turfgrass in Florida. These ectoparasites insert a long stylet into root tips, then inject enzymes into root tissues and extract plant juices out through the stylet. Root tips typically cease growing in response to feeding by sting nematodes (Figure 15.1). Sting nematodes cause particular damage to young plants with a developing root system.

Figure 15.1: Sting nematode-damaged root system (right) appears cropped off. Credit: Billy Crow, UF/IFAS Entomology and Nematology.

Sting nematodes reproduce sexually, so both males and females are common in soil. After mating, the female lays eggs in pairs in the soil and will continue to lay eggs as long as food is available. The eggs hatch after about five days. The young nematodes must locate a plant root and begin feeding to survive. Once feeding commences, the juvenile nematodes grow and undergo three molts before becoming adults. The total life cycle from egg to reproducing adult takes 18 to 24 days. Sting nematodes require at least 80 percent sand content in soil to survive, so they are typically only found in sandy soil environments, typical of much of Florida.

Lance Nematodes

In Florida, lance nematodes are right behind sting nematodes as the worst nematode pests of turfgrass. They are very common in home lawns and are the major nematode pest of St. Augustinegrass in the Southeast. While it takes fewer sting nematodes to cause damage to turfgrasses, lance nematodes have a much larger distribution and are much more difficult to control with chemicals.

Damage may show up as patches of yellowing, dying, or unthrifty grass, not unlike that caused by chinch bugs or some fungal pathogens. These symptoms can also be caused by drought or nutrient deficiency. Examination of the roots of a lance-nematode-infested lawn often will reveal thorough damage to the root system. Small feeder roots are gone, and root tips appear dead (Figure 15.2). If new roots have begun to grow, they usually are injured as well. The lance nematode may attach itself to the roots by embedding its anterior end, or sometimes its entire body, inside. As it feeds, it destroys the root system, causing outer layers of the dead roots to slough away. This kind of damage is often a sign of lance nematode infestation, but may also be caused by fungal root rot. It is this damage to the root system that is responsible for the yellow or dying patches of grass.

Figure 15.2: Lance nematode-damaged root system (right) appears dark and is missing small feeder roots. Credit: Billy Crow, UF/IFAS Entomology and Nematology.

Lance nematodes may also harm plants indirectly. By feeding on the roots, the lance nematode opens wounds through which microorganisms in the soil can enter, causing the root to rot. These microorganisms are usually present in the soil, but it is not until the lance nematode provides easy entry to the root that they cause damage.

Chemical controls have proven relatively ineffective on lance nematodes, even when they do the job on other types of nematodes. Careful turf management may help minimize the turf damage caused by lance nematodes. Deep watering, only as often as necessary, encourages the growth of deep roots more resistant to nematode damage. Balanced fertilizer applications are helpful, but too much nitrogen can cause roots to grow too rapidly and make them more susceptible to nematodes. Mowing at the recommended height, rather than too short, can prevent the problem of having insufficient foliage to provide food for the root system.

Stubby-root Nematodes

Several species of stubby-root nematodes attack turfgrass; however, one species (*Trichodorus obtusus*) is very damaging on St. Augustinegrass. In Florida, it is one of the most common nematode problems diagnosed on St. Augustinegrass lawns. By damaging the turf root system, it makes the turf more prone to environmental stresses and may lead to increased use of water and fertilizer inputs. It also makes turf less competitive with weeds and may lead to increased herbicide usage.

Stubby-root nematodes are unique among plant-parasitic nematodes because they have a curved, solid stylet they use in feeding. All other plant-parasitic nematodes have straight, hollow stylets. Stubby-root nematodes use their stylet like a dagger to puncture holes in plant cells. The stubby root nematode then secretes from its mouth salivary material into the punctured cell. The salivary material hardens into a feeding tube which functions as a "straw" enabling the nematode to withdraw and ingest the cell contents through the tube. After feeding on an individual cell, the stubby-root nematode will move on to other cells, leaving old feeding tubes behind and forming new ones.

On turfgrasses, damage caused by stubby-root nematodes usually occurs in irregularly shaped patches within a given area (Figure 15.3). Symptoms are usually worse in sandy soils than in heavy soils. The turf may wilt in these areas, thin out, and die if stresses such as drought occur. Roots may appear abbreviated or "stubby" looking. However, these symptoms can be caused by other factors, so the only way to verify if stubby-root nematodes are a problem is to have a nematode assay conducted by a credible nematode diagnostic lab.

Figure 15.3: Nematode-damaged St. Augustinegrass lawn declining in patches. Credit: Billy Crow, UF/IFAS Entomology and Nematology.

Spiral Nematodes

Spiral nematodes are so called because their bodies tend to curl into a spiral when they are relaxed or dead. Spiral nematodes of the genus *Helicotylenchus* are among the most ubiquitous plant-parasitic nematodes worldwide. *Helicotylenchus pseudorobustus*, is a species common in Florida and the southeastern United States, and is frequently associated with turfgrasses and other grass hosts in the region. It is less affected by soil type than many other nematodes and can be found in heavy, sandy, and organic soils.

On most plants, this nematode is not considered particularly damaging, but recent research has shown that *H. pseudorobustus* suppresses growth of certain turfgrass hosts (the exception is seashore paspalum). The symptoms of an infestation are more subtle than those of certain other nematodes, such as sting nematodes. Heavy infection causes a reduction in the root system, leading to unthrifty plants. On turfgrasses, spiral nematode has been shown to reduce root length and cause thinning of turf. Generally the turf decline will occur in patches, and is often accompanied by proliferation of weeds in the affected areas.

Ring Nematodes

Ring nematodes are common problems on centipedegrass. They seldom damage other grasses.

Root-knot Nematodes

Root-knot nematodes damage turfgrass in Florida only on occasion. For a general description of root-knot nematodes, refer to Chapter 12 of this publication, *Ornamental Plant Nematodes*.

Sampling Turfgrass for Nematodes

With any plant problem, an accurate diagnosis is important to address the problem and to avoid wasting effort and applying unnecessary pesticides. The most reliable way to determine whether plant-parasitic nematodes are involved in a turf problem is to have a nematode assay conducted by a professional nematode diagnostic lab. The Florida Nematode Assay Lab (**http://nematology.ifas.ufl.edu/assaylab/**) is the University of Florida's nematode diagnostic facility. This lab will diagnose nematode samples for a current cost of $20 for each sample from within Florida, and $25 for each sample submitted from outside Florida.

Collect 10 to 20 cores from areas of declining but not yet dead turf. Collect cores three to four inches deep near the desired plant species, avoiding bare spots and weeds. The sample must consist of mostly soil with a few roots—discard foliage. Cores are most easily taken with a soil sampling tube, auger, shovel, or trowel. Use a shovel to cut a 1-inch-thick slice of soil through the soil profile, and then collect a 1- to 2-inch vertical band from the slice. It is often best to discard the top one inch from each core, since nematode numbers may be very low there.

If more than one area is to be sampled, use different plastic bags for each sampling area. The approximate soil volume for a properly collected sample should be one to two pints. Include as many fine roots as possible (up to ½ cup) mixed in with the soil sample. A two-pint sample in the bag should fit in a small box (like those provided at United States Postal Service offices). Seal the sample in the bag to reduce moisture loss. The soil should be handled carefully, because rough handling will crush nematodes living among soil particles.

Provide a sample number or other identification of your own on each bag, and fill out the Nematode Assay soil submission form so that the lab cannot confuse your sample with that of someone else. Label the plastic bags by writing directly on them with a permanent black felt-tip marker or with a permanent pen or pencil.

Nematodes will die from overheating, freezing, or drying. Do not leave samples exposed to sunlight or carry them in a hot car trunk or on the dashboard. Do not add water to the sample, even if it seems dry to you. Just package and send it so that the lab will get it in the same condition as when you collected it. If nematodes are killed in handling, they cannot be recovered in the laboratory, and you will receive false results.

Complete the Nematode Assay Form, available here: **https://edis.ifas.ufl.edu/pdffiles/SR/SR02300.pdf**. Complete the form with all requested information, being sure to print or write clearly. Also ensure that your sample identification on the bag and the information on the form are correctly matched. Deliver samples Mondays through Fridays between 8:00 a.m. and 5:00 p.m.

The Nematode Assay Laboratory will determine the quantity of each kind of plant-parasitic nematode recovered from the sample. These results and the appropriate recommendations will be written on the Nematode Assay Form. You and your county Extension agent will each be sent a copy of the assay form no later than 10 working days after we receive the sample in the laboratory. In some instances, identifying nematodes to species is necessary to select the best management program. If requested, we will use molecular tools to identify nematodes to the species level. This may require three to four weeks of additional time. When such a delay is required, the normal report will be returned within 10 days after sample receipt; a supplementary report will be provided when final results are available.

Managing Nematodes on Turfgrass

Many of the highly effective nematicides used in the past are no longer available because of their risks to humans and the environment. There are a number of products available for use on home lawns that are marketed as "organic," "biological," or "non-toxic" that claim to be suppressive to plant parasitic nematodes. However, for many of these there is no field effectiveness data conducted by credible scientists that indicates they work. Nematologists at the University of Florida have tested many of these products for effectiveness, generally with disappointing results. Two bionematicides that have shown some degree of effectiveness in University of Florida research trials are Nortica and MustGrow Invest.

The active ingredient in Nortica is the bacterium *Bacillus firmus* strain I-1582. This bacterium colonizes the root system of the turf and produces compounds that protect the root system from nematode feeding and damage. Nortica is a solid formulation that disperses in water and is sprayed onto the turf surface before being moved into the soil with irrigation. University of Florida research has shown this biological agent to be effective in protecting turfgrass roots from nematode damage when it is applied properly. However, to achieve good results timing is critical with this product. An application schedule map for Florida counties is available from Bayer Environmental Sciences at **http://www.backedbybayer.com/**nortica. The map should be consulted when scheduling applications. Since Nortica has more of a root-protecting mode of action than a nematode-killing one, it works better when it is used in the early season to prevent a nematode problem. It will not be as effective if you use it to "fix" an existing nematode problem.

MustGrow Invest is a bionematicide derived from oriental mustard seeds grown in Canada. Following application and watering, it reacts with water to produce the active ingredient in the form of a soluble volatile gas, allyl isothiocyanate (AITC). It is OMRI-approved as an organic product.

Organic amendments such as compost, mulch, municipal sludge, and manure can help the grass tolerate nematode damage by improving plant health. Remember that anything that can be done to improve root health will help plants tolerate nematode damage. In addition, some organic amendments may stimulate soil microbes that can help suppress nematodes in some situations.

Some of the best practices for managing nematode damage in home lawns are targeted at avoiding other stresses on the grass. Grass that is given proper watering and fertilization can often withstand higher levels of nematode infestation than grass suffering from drought or nutrient deficiencies. Following the guidelines presented in this publication's chapters discussing mowing, fertilization, and irrigation for Florida lawns and landscapes should ensure a properly cared-for lawn.

If you are considering a recommendation of replanting to a client who has had a history of nematode problems, choosing a different type of grass may help. Bahiagrass is generally more tolerant of plant-parasitic nematodes than are other common lawn grasses and is often a good choice. Deed restrictions in some parts of Florida require that bermudagrass lawns be used. University of Florida research has shown Celebration bermudagrass to be more tolerant to certain nematodes than some other bermudagrass cultivars, indicating that it might be a good choice in nematode-prone landscapes. In some cases, turf can be replaced with an alternative groundcover such as perennial peanut (**http://edis.ifas.ufl.edu/ep135**) that will not be damaged by the nematodes.

Test Your Knowledge

Q: Match the following nematode descriptions:

1. Nematode that feeds and lives inside the plant.
2. Nematode that feeds only from outside the roots.

A. Ectoparasite
B. Endoparasite

A: 1-B; 2-A

Q: What is the most reliable way to determine whether plant-parasitic nematodes are involved in a turf problem?

A. Drop the roots in a glass of water and look for nematodes swimming away.
B. Look at the plant roots with a magnifying lens.
C. Look for foliar chlorosis.
D. Have a nematode assay conducted.

A: D

Q: Match the feeding habit with the type of nematode.

1. Ectoparasite	A. Sting
2. Endoparasite	B. Root-knot
	C. Stubby-root
	D. Lance
	E. Ring
	F. Spiral

A: 1-A; 2-B; 1-C; 2-D; 1-E; 1-F

Q: What is the most destructive plant-parasitic nematode species on turfgrass in Florida?
A. Lance
B. Stubby-root
C. Sting
D. Ring
A: A: C

Q: What is the major plant-parasitic nematode species of St. Augustinegrass lawns in Florida?
A. Lance
B. Stubby-root
C. Sting
D. Ring
A: A

Q: What is the best approach for managing nematode damage in home lawns?
A. Use chemical nematicides
B. Use organic suppressive nematicides
C. Avoid other stresses on the grass
D. Excavate the lawn and fill with gravel
A: C

Q: Which species of grass is generally more tolerant of plant-parasitic nematodes than other common lawn grasses?
A. Zoysiagrass
B. Bahiagrass
C. St. Augustinegrass
D. Seashore paspalum
A: B

Chapter 16

Weeds

In this Chapter

Learning Objectives

After you complete your study of this chapter, you should be able to:

- Recognize and describe the three main types of weeds and give an example of each.
- Describe the three main weed life cycles.
- Explain why you need to know the life cycles of weeds.
- Describe five proper management practices that encourage a dense, thriving turf which does not create a favorable environment for weed invasion.
- Explain the difference between preemergence and postemergence herbicides.
- Explain the difference between selective and nonselective herbicides.
- Explain the difference between contact and systemic herbicides.
- Describe the advantages and disadvantages of using "weed-n-feed" treatments.
- Know the general rules-of-thumb for timing applications of preemergence and postemergence herbicides to newly seeded, sprigged, plugged, or sodded turfgrass.
- Explain why preemergence herbicides must be activated with irrigation or moderate rain shortly following application.
- Know the limitations of using certain herbicides in areas in which ornamental plants will be transplanted.
- Know the effects of excessive irrigation and fertilizer use in landscape planting beds.
- Describe a practice that is one of the most effective non-herbicide weed control strategies in landscape planting beds.
- Describe precautions to avoid injuring ornamental plants with preemergence and postemergence herbicide applications in landscape planting beds.

Terms to Know

Annual weed: A weed that grows, flowers, produces seed, and dies in a year or less.

Biennial weed: A weed that grows vegetatively during the first year, then flowers, produces seed, and dies during the second year.

Contact herbicide: Herbicide that only affects the plant parts that are sprayed.

Herbicide: Pesticide that kills plants, especially weeds.

Node: The part or joint of a stem from which a leaf starts to grow.

Nonselective herbicide: Herbicide that injures almost all plants.

Perennial weed: A weed that lives more than 2 years.

Phytotoxicity: Herbicide injury to plants.

Postemergence herbicide: Herbicide applied to the foliage of emerged weeds.

Preemergence herbicide: Herbicide applied to the ground to prevent weeds from emerging.

Rhizome: A specialized primary stem, which grows horizontally at the ground surface or underground.

Selective herbicide: Herbicide that is only effective on certain types of plants.

Stolon: A specialized horizontal aboveground stem that takes root at the nodes.

Systemic herbicide: Herbicide that is absorbed into and moves throughout the plant (also known as a translocated herbicide).

Volatile: Readily able to pass from a liquid to a gaseous state.

Introduction

Weeds can be defined as unwanted plants or plants growing out of place. Proper identification and some understanding of how and why weeds are present in a landscape are important when selecting the best control strategy. Knowing whether or not weeds were previously present in a particular area also helps prepare control measures in the future. Weed control should be a carefully planned and coordinated program.

Controlling weeds in landscapes can be a difficult endeavor because most landscapes contain a variety of trees, shrubs, and bedding plants, which makes choosing herbicides difficult. There are many often overlooked chemical and non-chemical weed control methods that can significantly improve weed control and reduce maintenance costs.

Healthy turfgrass and ornamental plants improve the attractiveness of landscapes. Landscapes infested with weeds are not attractive (Figure 16.1). How serious a problem weeds are depends on customers' or other people's individual values. Turfgrass, ornamental plants, and weeds have the same basic requirements: soil nutrients, water, space and light. These are limited, so desirable plants and weeds are in competition for them.

Figure 16.1: Weeds make the landscape unattractive.

Weed Types

The three main types of weeds are grassy, broadleaf and sedge. **Grassy weeds** have blades that are much longer than they are wide. The blades have parallel veins. The stems are hollow and round with nodes. The nodes are closed and hard. The leaf blades alternate on each side of the stem (Figure 16.2). Examples: Crabgrass (Figure 16.3), goosegrass (Figure 16.4), crowfootgrass, sandbur, annual bluegrass, cogongrass, and torpedograss.

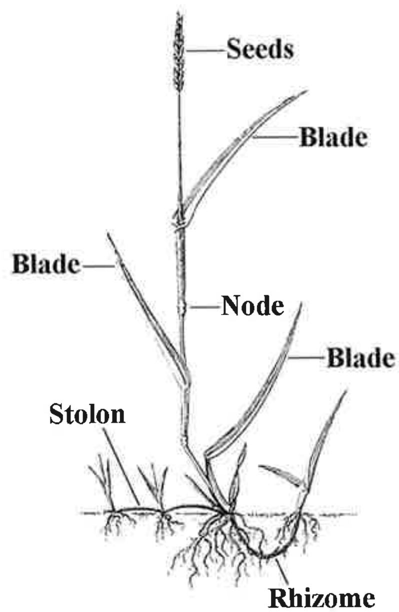


Figure 16.2: Important structures of grassy weeds. Credit: Jim Converse, The Scotts Company, Marysville, Ohio.

Figure 16.3: Crabgrass.

Figure 16.4: Goosegrass. Credit: John D. Byrd, Mississippi State University, Bugwood.org.

Figure 16.6: Asiatic hawksbeard. Credit: Karan A. Rawlins, University of Georgia, Bugwood.org.

Broadleaf weeds usually have net-like veins in their leaves. These veins are connected to a main vein. This vein usually divides the leaf in half (Figure 16.5). You can easily distinguish these weeds from grassy weeds as their veins and leaf shapes are different. Stems of broadleaf weeds are round and solid. Many broadleaf weeds have brightly colored, showy flowers (Figure 16.6). Examples: Woodsorrel, Florida pusley (Figure 16.7), henbit, dollarweed, matchweed, and creeping beggarweed.

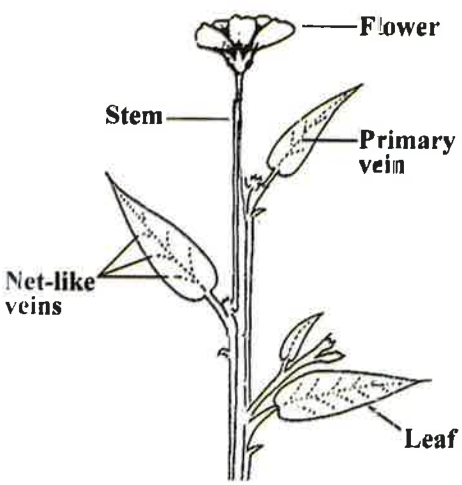


Figure 16.5: Important plant parts of broadleaf weeds. Credit: Oklahoma Cooperative Extension Service.

Figure 16.7: Florida pusley.

Sedges have triangular-shaped, solid stems (Figure 16.8), while **rush** stems are round and solid. Both sedges and rushes favor a moist habitat. Important members include yellow and purple nutsedge (Figure 16.9) and, to some degree, globe, Texas, annual, and water sedge, plus path and beak rush and perennial kyllinga.

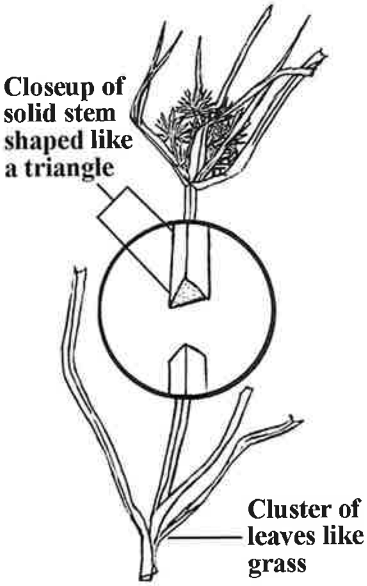


Figure 16.8: Sedge weed. Credit: UF/IFAS Communication Services.

Figure 16.9: Purple nutsedge. Credit: Joseph LaForest, University of Georgia, Bugwood.org.

Weed Life Cycles

Weeds can have one of three different life cycles: annual, biennial, or perennial. Knowing the life cycles of different weeds is important because it will help you manage weeds. For example, effective control methods for perennial and annual weeds differ.

For warm-season annuals that grow in the summer, do not apply herbicides late in the fall, as these weeds will die with the onset of cold weather. Also, you do not need to apply control measures to cool-season annual weeds in the winter. They will die with the arrival of warm weather.

Annual Weeds

Annual weeds germinate from seed. These weeds grow, flower, produce seed and die in a year or less. Grasses, sedges and broadleaf weeds can all be annuals. These weeds are grouped by the season in which they germinate and grow.

Warm-season annuals germinate and emerge in the spring. They actively grow in the summer and early fall and they die in the late fall or early winter. Examples: Spotted spurge (Figure 16.10), crabgrass, chamberbitter, and common purslane (Figure 16.11).

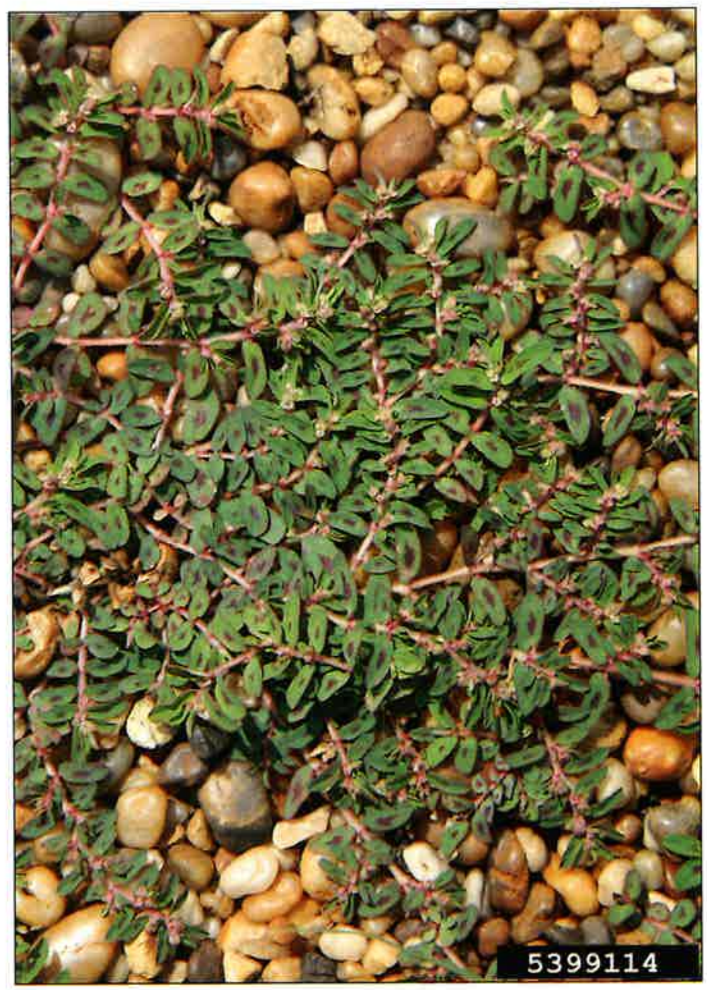


Figure 16.10: Spotted spurge. Credit: Robert Vidéki, Doronicum Kft., Bugwood.org.

Figure 16.11: Common purslane. Credit: Rebekah D. Wallace, University of Georgia, Bugwood.org.

Cool-season annuals germinate and emerge in the fall. They actively grow during the winter and early spring and die in the late spring or early summer. Examples: Common chickweed (Figure 16.12), annual bluegrass (Figure 16.13), and henbit (Figure 16.14).

Figure 16.12: Common chickweed. Credit: Rebekah D. Wallace, University of Georgia, Bugwood.org.

Figure 16.13: Annual bluegrass. Credit: Ohio State Weed Lab, The Ohio State University, Bugwood.org.

Figure 16.14: Henbit. Credit: Robert Vidéki, Doronicum Kft., Bugwood.org.

Biennial Weeds

Biennial weeds have a two year life cycle. They germinate from seed in the summer or fall. During the first year these weeds develop large root systems and a compact cluster of leaves close to the ground, known as a rosette. In the second year, biennials flower, produce seed and die. Examples: cudweed, old field toadflax, and Carolina false dandelion (Figure 16.15).

Figure 16.15: Carolina false dandelion. Credit: James H. Miller, USDA Forest Service, Bugwood.org.

Perennial Weeds

Weeds that live more than two years are perennials. Many reproduce from underground stems (rhizomes), other underground plant parts (bulbs or tubers) and aboveground stems (stolons). All of these are considered as vegetative reproductive structures of weeds that do not involve seed production. Many perennials also produce seed and can reproduce from these seeds.

In the winter some perennials are dormant. They lose their aboveground leaves or stems. In the spring, dormant perennials initiate growth from carbohydrate reserves stored in their roots. Florida betony (Figure 16.16) is an example of a perennial that does not start growing in the spring. This weed emerges in the fall, grows during the winter and enters dormancy during the summer. The shape of its tubers (Figure 16.17) gives Florida betony the common name "rattlesnake weed."

Figure 16.16: Florida betony. Credit: Rebekah D. Wallace, University of Georgia, Bugwood.org.

Figure 16.17: Florida betony tuber. Credit: John D. Byrd, Mississippi State University, Bugwood.org.

Perennial weeds are the most difficult to control. This is because they reproduce by both seed and underground vegetative structures. The underground structures are difficult to control because they are much more resilient than seedlings. Examples: Torpedograss, purple and yellow nutsedges, and vines such as the greenbrier.

Perennial weeds may also be grouped by type of root system and how they reproduce. Simple perennials reproduce by seeds. Root fragments also may spread by mechanical means such as plowing and produce new plants. Example: Florida betony.

Bulbous perennials reproduce by 1) seed and 2) bulbs above- or belowground. Examples: Yellow nutsedge and wild onions (bulbs or tubers belowground); wild garlic (aboveground bulbs, Figure 16.18).

Figure 16.18: Wild garlic above-ground bulbs. Credit: Ohio State Weed Lab, The Ohio State University, Bugwood.org.

Creeping perennials produce both seeds and rhizomes and stolons. The rhizomes and stolons store carbohydrate reserves and can initiate new shoot and root growth at nodes along a stem. Examples: Common Bermudagrass (seeds, rhizomes, and stolons, Figure 16.19), torpedograss (seeds and rhizomes) and purple nutsedge (rhizomes and tubers).

Figure 16.19: Common Bermudagrass stolons growing over a sidewalk.

You must properly identify weeds so you can choose the most effective control. You can get help identifying weeds at your University of Florida/IFAS county Extension office.

NOTE: Those preparing for the certification exam should also study UF/IFAS Publication SP499, *Identification Guide to Common Florida Lawn and Ornamental Weeds.*

Managing Weeds in Lawns

The first and best method of weed control begins with proper management practices that encourage a dense, thriving turf. Healthy turf shades the soil so sunlight can't reach weed seeds ready to germinate. A thick turf also minimizes the physical space available for weeds to become established. Several management practices promote a healthy, dense grass and help reduce the cost of weed control while maintaining the aesthetics of the lawn.

Proper turfgrass selection. The first management decision is selecting the best turf species or variety for a particular area. For example, moderately shaded areas support only a few turfgrass species. Growing bermudagrass or bahiagrass under any shade results in thin, weak turf that is very susceptible to weed invasion. Alternate grass choices for shady conditions include certain cultivars of St. Augustinegrass, zoysiagrass, and to a lesser degree, centipedegrass. It is important to note that no grasses perform well in heavily shaded areas, and an alternative to turf, such as a groundcover, should be considered.

Proper cultural practices. Proper fertilization, watering, mowing, and pest control are required to produce a dense turf that can prevent weed infestation. If turf is over- or underwatered, over- or underfertilized, or mowed too low or too infrequently, the turf is weakened and the weeds move in. Sharpening the mower blades can reduce turf damage and the chances for weed invasion. It is very important to understand that weeds don't *create* a void; they *fill* a void.

Traffic control. Turf damaged by foot or vehicle traffic invites weeds. Turf growing in soil compacted by excessive traffic, especially when the soil is saturated with water, cannot develop a healthy root system as well as it can under non-compacted soil conditions. Goosegrass, annual bluegrass, dollarweed, and certain sedges grow well in compacted and/or continuously wet soil. The first step to managing weeds in such a situation is to alleviate soil compaction and/or the saturated condition.

Pest control. Pest damage makes the turf more susceptible to weed infestations by creating spaces for weed establishment and reducing the turf's competitive ability. Specifically, tunneling from mole crickets disrupts the soil surface, enabling weed seeds to readily germinate. Other insects and diseases can cause areas of turf to become bare. These open areas are usually slow to recover and enable weeds to become established and grow quickly. High nematode populations also thin the turf and make it less able to recuperate from environmental stresses. Weeds that often become established in nematode-infested soil include spotted spurge and Florida pusley.

Sanitation. It is extremely important to prevent the introduction of weeds into lawn areas. If one can prevent weed establishment, control practices are not necessary. Areas adjacent to turf areas that are hard to mow, such as fence rows or ditch banks, often support a weed population. These weeds normally produce seed that infests the nearby turf. These areas should also receive weed management attention.

Another good practice is to wash off mowers and trimmers used in weed-infested areas before mowing or trimming in weed-free areas. Similarly, rototillers should be thoroughly cleaned prior to and after use to minimize weed seed dispersal in the soil. Yard clippings that contain weeds should be properly disposed of or composted to reduce the possibility of contamination. These sanitation practices are also important to prevent the introduction of other turfgrass species, which might reduce the purity and quality of the lawn.

If construction or renovation is planned, it is important to use weed-free soil. When planting, use only certified seed or weed-free sod to minimize weed spread. It is not unreasonable to request a tour of the sod farm where the sod will be purchased in order to inspect grass quality.

Methods of Turfgrass Weed Management

Mowing. Many annual weeds can be eliminated if proper mowing height and frequency are maintained. Mowing prior to weed seedhead formation also reduces weed seed reserves. Some weeds, however, readily establish below the desired mowing height. Management of these weeds requires additional control methods. As a rule of thumb, when mowing, remove only a third of the turf's leaf blade at a time. This maintains a turf canopy that can grow vigorously while shading weeds and suppressing their growth.

Hand pulling or rogueing. If only a few weeds are present, it's simpler and less time-consuming to physically remove the plant, but if weeds are a major problem, other alternatives should be considered. When hand-pulling weeds, it is critical to remove the roots and underground parts to ensure the weeds will not survive and produce new shoots. Weeds such as Florida pusley and Virginia buttonweed might require the use of a small shovel to properly dig out the roots.

Smothering. Smothering with nonliving material to exclude light is effective in certain areas, such as flower beds, foot paths, or nurseries, where turf is not grown. Materials used for this include mulch, leaves, rocks, and plastic film. To be effective, a minimum of two inches is required when using natural mulch materials. As an alternative, synthetic mats impregnated with herbicides can be used. These provide long-term weed control when properly used, but care must be taken to minimize the risk of desirable plant roots encountering these layers.

Herbicides. An herbicide is any chemical that injures or kills a plant. Herbicides are safe and effective if product label instructions are followed. Label instructions include proper application timing, rates, and application methods. Herbicide application timing during the plant's growth cycle is important. For example, weeds not controlled prior to seedhead formation are harder to control and are able to deposit new seeds in the future. Herbicides are classified based on how and when they control weeds.

A selective herbicide controls certain plant species (weeds) without seriously affecting the growth of other plant species (desired turfgrass). Most herbicides are selective herbicides. Herbicides are selected based on the turfgrass species (Refer to UF/IFAS Publication ENH884, *Weed Management Guide for Florida Lawns* **https://edis.ifas.ufl.edu/ep141**). This simplifies the application, because the herbicide can be applied over the turf without injuring it.

Nonselective herbicides control green plants regardless of species. They are generally used to kill all plants, such as in the renovation or establishment of a new turf area, as a spot treatment, or to trim along sidewalks. Glyphosate (Roundup), glufosinate (Finale), and diquat (Reward) are examples of nonselective herbicides. These herbicides injure turf. Therefore, in an established turf, their use is usually limited to spot applications for weedy patches, which must be followed by reseeding or resodding the treated area.

Contact herbicides affect only the portion of green plant tissue contacted by the herbicide spray. These herbicides are not translocated or moved in plants' vascular systems. Therefore, they do not kill underground plant parts, such as rhizomes or tubers. Repeat applications are often needed with contact herbicides to kill regrowth from these underground plant parts. Examples of contact herbicides include bentazon (Basagran), glufosinate (Finale), and diquat (Reward).

Systemic herbicides are translocated in the plant's vascular system. The vascular system transports the nutrients and water necessary for normal growth and development. Systemic herbicides generally are slower acting and kill plants over a period of days. Examples of systemic herbicides include glyphosate (Roundup), 2,4-D, dicamba (Banvel), imazaquin (Image), metsulfuron (Bonus S), and sethoxydim (Segment).

Two herbicide types, which differ based on application timing, are important in turfgrass weed management.

Preemergence herbicides form the basis for a chemical weed control program in turfgrasses and are used primarily to control annual grasses (e.g., crabgrass, goosegrass, and annual bluegrass) and certain annual broadleaf weeds (e.g., common chickweed, henbit, and lawn burweed). Preemergence herbicides are applied prior to weed seed germination. Knowledge of weed life cycles is important, especially when herbicide application is timed to attempt preemergence control. If the chemical is applied after weed emergence, preemergence herbicides have little or no effect. This narrow window of application timing is a potential disadvantage for many lawn care companies and homeowners, who often wait too late in the spring to apply the preemergence herbicide. A general rule of thumb for preemergence herbicide application is February 1 in South Florida, February 15 in Central Florida, and March 1 in North Florida (or before if day temperatures reach 65° F to 70° F for four or five consecutive days). These application timings generally coincide with blooming of landscape plants, such as azalea and dogwood. If goosegrass is the primary weed species expected, wait three to four weeks later than these suggested application dates, since goosegrass germinates later than most summer annual grasses.

For preemergence control of winter annual weeds such as annual bluegrass, apply an herbicide when nighttime temperatures drop to 55° F to 60° F for several consecutive days (early October for North Florida; late October to early November for Central and South Florida).

Irrigation, before and after application, is necessary to activate most preemergence herbicides. Preemergence herbicides are generally effective in controlling weeds from 6 to 12 weeks following application. Most herbicides begin to degrade soon after application when exposed to the environment. Therefore, to obtain season-long control, an additional application should follow six to nine weeks after the initial one.

NOTE: On those areas where turf is to be established (including sod and winter overseeded areas), most preemergence herbicides should not be used two to four months before planting. Otherwise, root damage and germination reduction of the turf seed may result.

Postemergence herbicides are active on emerged weeds. Weed size is very important for proper herbicide action. Generally, *the younger the weed seedling, the easier it is to control*. If the herbicides are sprayed when the weeds are mature, high rates are required for achieving control, which increases the risk of turf injury. Postemergence herbicide effectiveness is reduced when the weed is under drought stress, cold stress, has begun to produce seeds, or is mowed before the chemical has time to work (several days after application). Avoid application when these detrimental growing conditions exist.

Many herbicides are formulated with a fertilizer as the carrier. Fertilizer/herbicide mixtures allow a "weed-n-feed" treatment in the same application to the turfgrass. These materials should only be used when a lawn has a uniform weed population. If weeds exist only on a portion of the lawn, it may not be necessary to apply a "weed-n-feed" product to the entire lawn. If the situation warrants the use of a "weed-n-feed" product, it is important to determine if the manufacturer's recommended application rate supplies the amount of fertilizer needed by the turfgrass and the amount of herbicide required for weed control. Supplemental applications of fertilizer or herbicide may be required if the fertilizer/herbicide product does not supply enough fertilizer or herbicide to meet the fertility needs of the turfgrass or the amount of herbicide needed for weed control. Turfgrass fertilizer/herbicide products should be used with caution near ornamentals. Products containing dicamba, metsulfuron, or atrazine can be absorbed by the roots of ornamentals and cause severe injury. Do not apply products that contain these chemicals over the root zone of ornamental trees and shrubs.

Weed Control Prior to Turfgrass Establishment

A nonselective herbicide should be used to kill existing weeds such as contaminant bermudagrass or nutsedge, which must be eradicated prior to grass establishment. These nonselective herbicides control only emerged plants. For best results, apply two treatments of a nonselective herbicide 14 days apart.

Seeded areas. Do not apply preemergence herbicides prior to or immediately following seeding of grasses such as common bermudagrass, bahiagrass, centipedegrass, or ryegrass (winter overseed). Because of their root-pruning or seedling-kill modes of action, preemergence herbicides may be applied only after seeded grasses have emerged and are well established. A rule of thumb for timing is to make an application after the desired grasses are two to three inches tall or have begun to spread by stolons. At this time, the preemergence herbicide may be applied at *half* the normal rate of application. Postemergence herbicides may also be applied at *half* the rate at the same growth stage.

If a preemergence herbicide has been applied, wait nine weeks before attempting seeding. Use a small test area to determine when the herbicide residues permit seedling growth.

Sprigged, sodded, or plugged areas. After planting, preemergence herbicides may be applied at *half* the normal rate recommended for established grasses following signs of new growth. Water should be applied immediately to the treated areas to activate the herbicide. If herbicide is not applied soon after planting, weed seedlings will emerge and will not be affected by preemergence herbicides. If over half the recommended herbicide rate is applied, root pruning may result to the turf.

Postemergence herbicides, in general, should not be applied until the grass is visibly growing and spreading. Mowing helps control most broadleaf weeds until the lawn is well established. Spot spraying of weeds should be practiced until establishment occurs.

Weed Control in Established Turfgrass

Preemergence control. In established turfgrass, members of the dinitroaniline herbicide family (e.g., oryzalin [Surflan], benefin and trifluralin [Team Pro], prodiamine [Barricade], or pendimethalin [Pendulum, Pre-M]) control annual grass and some broadleaf weed species when applied prior to weed seed germination. Bensulide (Bensumec) and dithiopyr (Dimension) also provide preemergence annual grass and broadleaf control. Atrazine and isoxaben (Gallery) primarily provide preemergence control of broadleaf weeds. All these herbicides must be activated with irrigation or moderate rain within two days after application so they will be in direct contact with the germinating seeds and emerging weed seedlings. If the soil is dry, their weed-killing effect is greatly limited. On the other hand, if the turf is over-irrigated, most preemergence herbicides will be moved below the soil layer where the germinating weed seeds are, reducing weed control.

Postemergence control. Broadleaf weeds in turf have traditionally been controlled with members of the phenoxy herbicide family (e.g., 2,4-D, MCPA, and mecoprop) and the benzoic acid herbicide family (e.g., dicamba). All are selective, systemic, foliar-applied herbicides; few broadleaf weeds, especially perennials, are controlled with just one of these materials. Therefore, these materials are commonly found in three-way herbicide mixtures, such as Trimec Southern, Ortho Weed-B-Gon MAX, and Spectracide Weed Stop for Lawns. Volatile vapor drift from 2,4-D esters or spray drift from 2,4-D amines, dicamba, or other phenoxy or benzoic acid compounds may damage sensitive plants such as ornamentals, trees, vegetables, or fruits. Amine forms of phenoxy herbicides can be used with greater safety near sensitive plants, but caution should still be exercised. Products containing metsulfuron (e.g., Bonus S) can also provide effective control of broadleaf weeds. Additionally, repeat applications spaced 10 to 14 days apart are usually necessary for satisfactory weed control with any of the herbicides mentioned above.

Postemergence control of grassy weeds is a major challenge because few products selective to the turf also kill this type of weed. For this reason, preemergence control is key for successful management of grassy weeds. However, a few alternatives can be used when postemergence control is necessary. In centipedegrass, grass weed control can be achieved with sethoxydim, an herbicide sold under the trade name Segment. Additionally, atrazine-containing materials help control young grassy weeds with the added benefit of controlling many young broadleaf weeds in St. Augustinegrass and centipedegrass.

Yellow and purple nutsedge are the predominant nutsedge weed species in turfgrass (Figure 16.20). Other, more local nutsedge species include annual or water sedge, perennial and annual kyllinga, globe sedge, Texas sedge, flathead sedge, and cylindrical sedge. Path or slender rush, a member of the rush family, also can occur in some turf situations.

These weeds generally thrive in soils that remain wet for extended periods of time because of poor drainage or excessive irrigation. The first step in nutsedge control is to correct the cause of continuously wet sites. Do not overirrigate an area and, if necessary, provide surface and subsurface drainage.

Selective yellow nutsedge control is available with bentazon, an herbicide found in products such as Basagran T/O. Bentazon is a contact material, meaning it controls only those portions of the weeds treated with it. Complete coverage of weeds is therefore necessary for greatest bentazon activity. Even with good herbicide coverage, regrowth normally occurs from the roots and tubers, and repeat applications are necessary.

Purple nutsedge can be controlled with herbicides containing either halosulfuron or imazaquin, sold as SedgeHammer and Image, respectively. As with bentazon, repeat applications—possibly over several years—are required to control all the underground reproductive parts of purple nutsedge. These herbicides also control other less-aggressive sedges (e.g., cocks-comb, green kyllinga, and annual sedge), and they can be used in most warm-season turfgrass species.

Figure 16.20: Nutsedge-infested lawn.

Adjuvants

An adjuvant is a spray additive that enhances the performance or handling characteristics of an herbicide. Adjuvants include surfactants, crop oils, and crop oil concentrates, which if used indiscriminately may result in severe turfgrass injury or decreased herbicide performance. These additives do not improve the performance of preemergence herbicides and are used only with postemergence herbicides absorbed through the leaf. The herbicide label will indicate whether a spray additive is required as well as which type.

Managing Weeds in Landscape Planting Beds

The concept of "right plant, right place" has been embraced by many in the landscape design and maintenance industries as a way to avoid some of the most troublesome insect and disease pests. Though this design philosophy may also suppress weed growth, it has rarely been used for that sole purpose.

Light stimulates the germination of many different weed species. In nature, these species quickly colonize a site that has been opened up by some sort of disturbance. Weeds invade by filling in voids. Designing landscape beds so that ornamentals will occupy most of the space (without overplanting) will prevent many weeds from establishing. Choosing dense-growing plants that are best suited for your area will help fill in voids more quickly and potentially shade out weeds (Figure 16.21). Using fast, dense-growing groundcovers in areas not suitable for turf can suppress weed growth and, in most cases, reduce the need for water and fertilizers. Lists of possible groundcovers for Florida can be found at the Florida-Friendly Landscaping Plant Database **http://floridayards.org/fyplants/**.

Figure 16.21: Begonias can quickly fill shaded landscape beds and shade out weeds.

Weed Control Prior to Planting

The best time to control existing weeds in an ornamental bed is before anything has been planted. Herbicides such as glyphosate (Roundup and others) can be used to control both annual and perennial weeds. Depending upon the weed species, these herbicides typically take seven or more days to completely kill larger weeds (six inches or taller). After the existing weeds die (no green tissue remaining), the area can be tilled, graded, and prepared for planting.

It is very important to know what kind of plants will be planted into an area before using any herbicide. For example, imazaquin (Image) is a common turf and landscape herbicide used to control purple nutsedge and other weed species, but it should not be applied to areas where ornamentals, especially bedding plants, will be planted within 1 year. Halosulfuron (SedgeHammer and others) is another herbicide that should not be applied to areas in which ornamentals will be transplanted within three months. A list of postemergence herbicides labeled for use in landscape planting beds is given in UF/IFAS Publication ENH1262, *Improving Weed Control in Landscape Planting Beds* at **https://edis.ifas.ufl.edu/ep523**. A more complete list of postemergence herbicide labeled for use in and around ornamentals in landscapes is available in UF/IFAS Publication ENH95, *Postemergent Herbicides for Use in Ornamentals* at **http://edis.ifas.ufl.edu/wg059**.

An effective non-chemical method of reducing annual weed pressure is to repeatedly till, allow weeds to germinate, and then hoe or till again. This process works by essentially depleting the weed seed bank in the upper layers of the soil surface. Each time the area is tilled and small weeds are allowed to germinate, the amount of weed seeds lying dormant in the soil can be reduced.

Soil solarization can also be a very economical and effective method of controlling weeds and other pests before planting, though it is typically only effective if done during the summer months in full-sun areas. This process also takes about 6 weeks to be effective, so it may not be feasible in some landscape situations. More information can be found in UF/IFAS Publication ENY062, *Introduction to Soil Solarization* at **http://edis.ifas.ufl.edu/in856**.

Container-grown plants may contain weeds. Always check the media surface for presence of small weeds and remove them before planting. While most of the weeds on the media surface may be buried during planting, many weed species can continue to grow, especially since supplemental irrigation will likely be applied to new planting areas. Eliminating these weeds before planting will help to reduce future weed pressure.

Irrigation. Properly irrigating landscape beds can go a long way in reducing weed growth. Many common landscape weeds such as eclipta (Figure 16.22) and chamberbitter (Figure 16.23) require high soil moisture levels in order to germinate. Using conventional overhead sprinkler systems to irrigate landscape beds can cause increased weed growth because bare areas (those without plants) will be irrigated. Using micro or drip irrigation systems instead of standard sprinklers helps to reduce weeds because water will be placed only where desirable plants need it. This practice also helps to conserve water and reduce water bills.

Figure: Eclipta. Credit: Rebekah D. Wallace, University of Georgia, Bugwood.org.

Figure 16.23: Chamberbitter-infested plant bed. Credit: Nancy Loewenstein, Auburn University, Bugwood.org.

Fertilization. Excessive fertilizer use in landscape beds promotes weed growth and may damage ornamental plants. Fertilizers should be applied to landscape plants only when needed and according to UF/IFAS recommendations. Most established trees and shrubs require very little fertilization, so any excess fertilizer may promote weed growth.

Weed-n-feed products should not be applied near ornamentals nor should they ever be applied in ornamental planting beds, which means multiple fertilizer types will need to be purchased to fertilize all areas of the landscape. In most cases, you will be able to better time your herbicide and fertilizer applications by applying them separately. In many cases, this practice may also be more affordable.

Weed Control after Planting

Mulching is one of the most effective weed control strategies in landscape planting beds and provides additional benefits, including improved soil characteristics, increased growth of ornamental plants, decreased irrigation demand, and enhanced planting bed aesthetics. In many cases, mulching can be just as effective for weed control as herbicides.

Apply organic (pine bark, pine straw, etc.) mulches at depths of two to three inches. This depth effectively controls weeds without causing damage to ornamentals by smothering their root systems. Inorganic mulch (rocks, pebbles, etc.) can often be applied at shallower depths (1 to 1.5 inches) while still providing weed control; however, it should be noted that these products are more expensive, more difficult to apply, and do not add organic matter to the soil. More details concerning mulching may be reviewed in Chapter 6 of this publication.

There are several other non-chemical weed control methods that are effective, including hand-pulling (Figure 16.24) and cultivation (tillage), though the major disadvantage of these methods is that they are typically time-consuming and can damage ornamentals. More information on advantages and disadvantages of each of these methods and other non-chemical methods is available in UF/IFAS Publication HS1170, *Non-chemical Weed Control for Home Landscapes and Gardens* at **http://edis.ifas.ufl.edu/hs1170**.

Figure 16.24: Hand-pulling weeds from landscape beds is time consuming.

Herbicide Use in Landscape Planting Beds

Preemergence herbicides. Use of preemergence herbicides can significantly reduce the amount of time and money needed to hand-pull or spot-spray weeds in ornamental beds. Many homeowners or landscapers avoid using preemergence herbicides in landscape beds for fear of damaging ornamentals. While it can be difficult to find preemergence herbicides that are safe to use on tropical species or annual bedding plants, if applied according to label instructions, many preemergence herbicides can be applied over-the-top of woody shrubs and trees without causing any damage. A list of preemergence herbicides labeled for use in landscape planting beds is in UF/IFAS Publication ENH1262, *Improving Weed Control in Landscape Planting Beds* at **https://edis.ifas.ufl.edu/ep523**.

Once applied, preemergence herbicides must be activated by rainfall or irrigation in order to work. Most products typically need to be watered-in with 0.25 inches or more of rainfall or irrigation soon after application (within three days to a week or more, depending on the product). If preemergence herbicides are not watered-in, erratic or inconsistent weed control may result. If overhead irrigation is not available, try to time the preemergence herbicide application with expected rainfall or use portable lawn sprinklers to water in the product. Irrigation is the preferred method because very heavy rainfall soon after application is likely to increase lateral off-site movement, which can lead to environmental concerns. Avoid preemergence herbicide applications if heavy rainfall is imminent.

Drip or mist irrigation (microirrigation) is recommended in planting beds to conserve water. These microirrigation systems also work to reduce weed pressure by placing water only where it is needed near plant roots (see "Irrigation" above). However, it should be noted that these systems will not properly activate preemergence herbicides. If microirrigation systems are used, the herbicide will still need to be watered in using the methods described above.

Disturbing the soil surface following an herbicide application will reduce herbicide efficacy. Remove existing weeds prior to herbicide application and try to avoid disturbing the soil surface (excessive walking, raking, hoeing, etc.) after application.

In order to avoid injuring ornamental plants with preemergence herbicide applications, the following precautions should be taken in most cases:

- Do not apply granular herbicides to wet foliage.
- Do not allow granular herbicides to become trapped in whorls of foliage or remain on leaf surfaces after application.
- Do not apply preemergence herbicides during times of bud swell, budbreak, or when ornamentals have tender, new flushes of growth.
- Before applying preemergence herbicides, ensure plants have been thoroughly watered after planting and that the soil is settled (no cracks).
- Do not apply preemergence herbicides to ornamentals that are not on the label.
- Irrigate as soon as possible after application to wash herbicides off of plant foliage and activate the herbicide.

However, it is important to note that these precautions are only general guidelines, and applicators should read product labels and follow instructions for each specific product they are applying.

Postemergence herbicides. If weeds still begin growing after following proper cultural practices (fertilization and irrigation), mulching, and using preemergence herbicides, postemergence herbicides can be used to spot spray weeds. While most postemergence herbicides should be applied as a directed application (making no contact with the ornamental plant), some can be applied over-the-top of certain ornamentals if listed on the herbicide label. While over-the-top applications can be a useful tool in some landscape situations, it is critical that the application be according to label instructions and that the application equipment is properly calibrated. If these herbicides are applied at higher than recommended rates, ornamental plants can be severely injured and may not recover.

In order to avoid ornamental plant injury from postemergence herbicides, the following precautions should be taken:

- Do not allow herbicide spray or drift to contact ornamental plant tissues unless the product label indicates otherwise.
- If accidental contact is made, wash herbicide off of plant foliage as soon as possible, or if a systemic (translocated to other parts of the plant) herbicide is used, prune the section of the ornamental that is contacted to minimize potential damage.
- Ensure over-the-top applications are made only to ornamentals listed on product labels.
- Systemic herbicides should be used with extreme caution around plants that sucker (i.e. crape myrtle and others). Some ornamentals may not recover from accidental contact.

Some turf herbicides can cause damage to ornamentals if applied near their root systems (Figure 16.25). Many ornamentals can have roots that extend well into turf areas. Closely read product labels and follow all precautions to avoid potential damage from root uptake.

Figure 16.25: Atrazine injury on a rose. Credit: Paul Bachi, University of Kentucky Research and Education Center, Bugwood.org.

Test Your Knowledge

NOTE: Those preparing for the certification exam should also study UF/IFAS Publication SP499, *Identification Guide to Common Florida Lawn and Ornamental Weeds.*

Q: What is this weed?

A. Dollarweed
B. Henbit
C. Florida betony
D. Black medic

A: C

Q: What is this weed?

A. Globe sedge
B. Yellow nutsedge
C. Purple nutsedge
D. Goosegrass

A: A

Q: What is this weed?

A. Black medic
B. Florida pusley
C. Spurge
D. Chamberbitter

A: D

Q: Match the following weed descriptions with the type of weed:

1. Blades are much longer than they are wide.
2. Triangular-shaped, solid stems.
3. Leaves with net-like veins connected to a main vein.

A. Grassy
B. Broadleaf
C. Sedge

A: 1-A; 2-C; 3-B

Q: Match the weed species with its life cycle:

1. Chamberbitter	A. Annual
2. Florida betony	B. Biennial
3. Purple nutsedge	C. Perennial
4. Crabgrass	
5. Yellow nutsedge	
6. Cudweed	
7. Common chickweed	
8. Common Bermudagrass	

A: 1-A; 2-C; 3-C; 4-A; 5-C; 6-B; 7-A; 8-C

Q: True or False:
The first and best method of weed control in lawns begins with proper herbicide selection.

A: False

Q: Match the type of herbicide with its description:

1. Preemergence herbicide	A. Only affects the plant parts that are sprayed.
2. Postemergence herbicide	B. Injures almost all plants.
3. Systemic herbicide	C. Applied to the ground to prevent weeds from emerging.
4. Contact herbicide	D. Only effective on certain types of plants.
5. Selective herbicide	E. Applied to the foliage of emerged weeds.
6. Nonselective herbicide	F. Absorbed into and moves throughout the plant.

A: 1-C; 2-E; 3-F; 4-A; 5-D; 6-B

Q: Which weed stage of growth are postemergence herbicides most effective?
A. Weeds in the seed production stage
B. Weeds in the flowering stage
C. Weeds approaching maturity
D. Seedling weeds

A: D

Q: Which situation would a “weed-n-feed” treatment be appropriate to apply to turfgrass?
A. When a lawn has a uniform weed population
B. When weeds exist only on a portion of the lawn
C. When it contains atrazine and will be applied around ornamentals
D. When it will be applied to a landscape containing lots of trees

A: A

Q: What is a rule of thumb for timing a preemergence herbicide to a newly seeded site?
A. After the desired grasses are two to three inches tall
B. After the desired grasses have begun to spread by stolons
C. After waiting for one year to elapse
D. Both A and B are correct

A: D

Q: Match the herbicides with their general activity.

1. Glyphosate	A. Selective and contact
2. Bentazon	B. Selective and systemic
3. Diquat	C. Nonselective and contact
4. Dicamba	D. Nonselective and systemic
5. Imazaquin	

A: 1-D; 2-A; 3-C; 4-B; 5-B

Q: Match the herbicides used in turfgrass with their use patterns:

1. Pendimethalin	A. Selective postemergence grass control in centipedegrass
2. Atrazine	B. Selective preemergence grass control
3. 2,4-D	C. Selective postemergence nutsedge control
4. Prodiamine	D. Selective postemergence broadleaf control
5. Halosulfuron	E. Selective preemergence broadleaf control
6. Sethoxydim	

A: 1-B; 2-E; 3-D; 4-B; 5-C; 6-A

Q: Which herbicide would be the best choice for control of existing weeds in an ornamental bed before anything has been planted?
A. Imazaquin
B. 2,4-D
C. Glyphosate
D. Halosulfuron

A: C

Q: Which herbicide should ***not*** be used where ornamentals, especially bedding plants, will be planted within 1 year?
A. Imazaquin
B. 2,4-D
C. Glyphosate
D. Halosulfuron

A: A

Q: What is one of the most effective weed control strategies following planting in landscape planting beds?
A. Use of postemergence herbicides
B. Mulching
C. Soil solarization
D. Tillage

A: B

Q: True or False
Some turf herbicides can cause damage to ornamentals if applied near their root systems.

A: True

CHAPTER 17

PALM PESTS AND DISORDERS

IN THIS CHAPTER

Learning Objectives

After you complete your study of this chapter, you should be able to:

- Describe the limitations of relying on a field diagnosis for a particular palm problem.
- Know that a laboratory disease diagnosis may be required to confirm the field diagnosis.
- Know the proper palm tissue to sample for laboratory diagnosis, after a preliminary field diagnosis has been made.
- Describe why relying on soil nutrient analysis for the diagnosis of palm problems has limited value.
- Describe the limitations and benefits of leaf nutrient analysis.
- Know the most common abiotic disorder of palms.
- Be able to recognize deficiency symptoms of palms for the following essential elements: potassium (K), magnesium (Mg), manganese (Mn), and Boron (B).
- Name and describe the following for five fungal and two phytoplasma pathogens causing Florida's most common palm diseases:
  - Symptoms/signs;
  - Factors favoring the disease; and
  - Control and treatment.
- Identify the following insects:
  - Palm aphid;
  - Royal palm bug;
  - Red date scale;
  - Palmetto weevil; and,
  - Palm leaf skeletonizer.

Terms to Know

Abiotic disorder: A nonpest problem (such as a nutrient deficiency) that causes abnormal growth or appearance of a plant.

Apical meristem (bud): The growing point of the palm stem; also referred to as the palm heart.

Basidiocarp: The fruiting body, e.g. a mushroom, conk, or puffball, of some types of fungi.

Cation exchange capacity: The sum total of exchangeable cations that a soil can adsorb.

Chlorosis: The normal green plant color has faded to light green or yellow color.

Distal: Portion of the leaf farthest away from its center.

Frond: Another name for a palm leaf.

Leaf primordium: A group of cells that will develop into a new leaf.

Lignin: Complex organic polymers that form important structural materials, particularly important in the formation of cell walls, especially in wood and bark.

Necrosis: Dead tissue.

Palmate leaf: A leaf resembling a hand. An example is a Mexican fan palm or a cabbage palm.

Petiole: The main stem of a palmate palm leaf.

Phytoplasma: A specialized group of extremely small bacteria lacking a cell wall that cause plant diseases by infecting phloem tissue and transmitted by insect vectors.

Pinnate leaf: A leaf resembling a feather; having the leaflets on each side of a common axis. An example is a date palm leaf.

Rachis: The main stem of a pinnate palm leaf. All the leaflets are attached to the rachis.

Spear leaf: The youngest leaf that has not yet opened.

Vascular tissue: Plant tissue system consisting of xylem and phloem which transport water and other nutrients throughout the plant.

Introduction

Many people—especially those living in cooler climates—associate palms with warm sunny tropical locations, beaches, and vacations. Floridians may immediately think of our state tree, the sabal palmetto palm, also known as the cabbage palm, when palms are mentioned (Figure 17.1). In reality, while most of the approximately 2,700 species of palms are found in tropical and subtropical climates, many species grow in temperate climates.

Figure 17.1: Sabal palm, the state tree of Florida. Credit: David Stephens, Bugwood.org.

Historically, humans have made good use of palms. Besides their pleasing aesthetic appearance in the landscape, food and wine have been derived from palms, and their fronds and trunks have been used for shelter construction.

Care of palms in the Florida landscape can be challenging due to several factors. Over the years, some species of palms have been transported to areas outside their native regions. In less favorable environments outside their native range, palms can face challenging growth conditions, which make them vulnerable to certain pests and disorders.

Another challenge is that palms are not true "trees." Although most people may refer to palms as "trees," in actuality, they are more anatomically similar to grasses. Unlike true trees, palms' vascular tissues are arranged in bundles scattered throughout their trunks, typical of grasses. This means that the trunks of palms do not produce secondary growth, thus no annual growth rings. Consequently, palms are unable to repair damage such as wounding to their trunks. Another factor is that each palm stem (trunk) possesses only a single apical meristem (bud) where new growth arises. True trees have, in addition to an apical meristem, lateral meristems that allow the tree to develop new shoots should damage occur to the apical meristem. In palms, damage to the apical meristem must be avoided or the palm will die.

This chapter focuses on the diagnosis and management of common pests and disorders of palms, including abiotic disorders, diseases, and arthropods. Refer to Chapter 10 for a general discussion of pathogen types and abiotic disorders and Chapter 11 for a general discussion of arthropods, including insects.

"What's Killing My Palm?": Diagnosing the Problem

Palms growing in the landscape are susceptible to a wide range of diseases, disorders, and pests. Diagnosis of a particular palm problem often requires either a comprehensive understanding of *all* of the possibilities, or a systematic key to help the diagnostician focus on the cause of the problem. Today there are many websites and mobile apps available to help diagnose the most common diseases and disorders affecting palms. These keys include damage caused by insects, identifying insect pests of palms, and links to fact sheets about each specific problem or pest. The following is a listing of keys that you may find useful:

- UF/IFAS FLREC Palm Problems Key:
  - **http://flrec.ifas.ufl.edu/palmprod/palm-problems-key/**
- LUCID KEYS: A Resource for Cultivated Palms from the United States and Caribbean Resource home page:
  - **http://itp.lucidcentral.org/id/palms/resource/index.html**

- Screening Aid to (Insect) Pests:
  - **http://bit.ly/idtools**
  - **http://bit.ly/itunes_screening**
  - **http://bit.ly/googleplay_lucidcentral**
- Symptoms of Diseases and Disorders:
  - **http://itp.lucidcentral.org/id/palms/symptoms/**
  - **http://bit.ly/palmsymptoms**
  - **http://bit.ly/googleplay_symptoms**

Field Diagnosis vs. Laboratory Diagnosis

Since few people have immediate access to analytical laboratories, most diagnostic keys are based solely on visible symptoms. Fortunately, visible symptoms are sufficient to diagnose many palm problems. Visual inspection is also the first step in determining which diagnostic lab to use for further analysis, and which tissue should be sampled for analysis. Table 17.1 provides guidelines regarding which tissue to sample. A laboratory analysis should **always** be used in conjunction with the field diagnosis of the problem. At the same time, never rely on a laboratory diagnosis without also making a good-faith attempt at the field diagnosis. The two diagnoses should agree.

Just because a laboratory report suggests deficiencies of one or more nutrient elements or the presence of potential pathogens does not mean that those deficiencies or pathogens are the actual cause of the particular problem. In the case of palm diseases, "false negatives" are a common problem, especially when the wrong tissue is sampled or a poor-quality sample is submitted to the laboratory. If field and lab diagnoses do not agree, you must re-examine the problem to determine which diagnosis is more likely and if the right sample received laboratory diagnosis. In some cases, you may need to start from the beginning, as neither field nor laboratory diagnosis may be correct.

Laboratory Disease Diagnosis

Sometimes a laboratory diagnosis is necessary because two diseases have identical symptoms. For example, Fusarium wilt and petiole (rachis) blight of Canary Island date palm have similar symptoms, but one is lethal (Fusarium wilt); the other is not. If confirmation of a field disease diagnosis is necessary, it should be conducted by a qualified plant-disease diagnostic laboratory. For example, molecular tests are necessary to confirm Fusarium wilt, lethal yellowing, and Texas Phoenix palm decline. Only the University of Florida currently offers these services in Florida (**https://edis.ifas.ufl.edu/sr007**).

Sampling the correct tissue is critical for an accurate laboratory diagnosis. For example, lethal yellowing is confirmed from internal trunk corings, while petiole (rachis) blight pathogens only infect the palm leaf petiole or rachis. In both cases. sampling, say, leaflet tissue of a palm affected by either of these diseases would have yielded a false negative. Thus, it is imperative to make the field diagnosis as accurate as possible in order to determine which tissue to sample.

Many potential plant pathogens are naturally part of the palm's environment, so it is easy to mistake these potential pathogens for the actual pathogen causing the symptoms observed. The laboratory only analyzes the tissue that you provide. Sampling the proper tissue and providing adequate background information on the problem increases the likelihood of obtaining an accurate diagnosis. A good series of photographs illustrating the problem is always helpful.

One common error in diagnosing palm problems is to sample roots. In the landscape and field nursery, root rots of palms are uncommon, and are usually the secondary result of a palm being planted incorrectly or in the wrong environment. Examples include planting a date palm in soils that are routinely water-logged or planting any palm too deep. A diagnostic laboratory will usually be able to isolate potentially pathogenic fungi from roots, but these fungi are seldom the primary cause of the problem observed. This is an important distinction for management purposes, as one needs to first correct the primary cause, if possible. Likewise, soil sampling for potential pathogens is not recommended, because there are always potential pathogens in the soil. Root rots of palms growing in containers are more likely to occur because of the poor soil aeration, but even in containers the root disease is usually secondary.

Sometimes it is not possible to make a confirmation of a field diagnosis until a dead or dying palm is cut down. For example, palms affected by Ganoderma butt rot may die without producing conks from the lower trunk area. However, when the palm is cut down and multiple cross-sections are made of the trunk, the disease will be easily confirmed based on

Table 17.1. Palm tissue to sample for laboratory diagnosis, after a preliminary field diagnosis has been made.

Preliminary field diagnosis	Palm tissue to sample for laboratory diagnosis[1]
Bud rot	Spear leaf or next youngest leaf exhibiting typical disease symptoms. If bud is already rotted, it is often not useful to sample the tissue, as secondary microorganisms hinder isolation of the primary pathogen. **http://edis.ifas.ufl.edu/pp144**
Fusarium wilt	Leaf exhibiting typical symptoms of the disease: entire leaf or, at a minimum, leaf petiole base (petiole portion from trunk to beginning of leaflets) **http://edis.ifas.ufl.edu/pp278** and **http://edis.ifas.ufl.edu/pp139**
Ganoderma butt rot	Laboratory diagnosis is not usually possible or necessary. Field diagnosis is based on presence of conk growing from trunk or during a palm autopsy where multiple cross-sections through lower three to four feet of trunk exhibit typical internal discoloration. **http://edis.ifas.ufl.edu/pp100**
Graphiola leaf spot (false smut)	Laboratory diagnosis is not necessary because fungal structures can be easily observed with hand magnifying glass. **http://edis.ifas.ufl.edu/pp140**
Lethal yellowing	Internal trunk tissue for detection of phytoplasma. Instructions at **http://flrec.ifas.ufl.edu/media/flrecifasufledu/pdfs/LY-TPPD-Trunk-Sampling.pdf http://edis.ifas.ufl.edu/pp146**
Leaf spots or leaf blights (numerous pathogens)	Leaf exhibiting typical symptoms of disease: entire leaf or, at a minimum, five to eight leaflets or leaf segments with symptoms. **http://edis.ifas.ufl.edu/pp142**
Nutrient deficiency	Select the youngest, fully expanded leaf. Remove four to six middle leaflets on both sides of rachis of a feather-leaved palm. Remove four to six middle leaf segments from blade of fan-leaved palm. **http://edis.ifas.ufl.edu/ep273**
Petiole (rachis) blight (numerous pathogens)	Leaf exhibiting typical symptoms of disease: entire leaf or, at a minimum, leaf petiole or rachis exhibiting symptoms. **http://edis.ifas.ufl.edu/pp145**
Texas Phoenix palm decline	Internal trunk tissue for detection of phytoplasma. Instructions at **http://flrec.ifas.ufl.edu/media/flrecifasufledu/pdfs/LY-TPPD-Trunk-Sampling.pdf http://edis.ifas.ufl.edu/pp163**
Thielaviopsis trunk rot	Select a cross section of the trunk that has both rotted and healthy trunk tissue. The interface between diseased and healthy tissue is the ideal sample. **http://edis.ifas.ufl.edu/pp143**

[1]Unless otherwise instructed, plant tissue samples for disease diagnosis should NOT be placed in a plastic bag. Instead, place tissue in a plain paper bag or in a box and pack with newspapers. If sending entire leaves or portions of the petiole, it is acceptable to cut the leaf or petiole into smaller sections and bundle together with tape or string. See the home page for the UF/IFAS Extension Plant Disease Clinic at **https://edis.ifas.ufl.edu/sr007** for further information on submission, submission sample form, and pricing.

the pattern of discoloration within the trunk, and without the necessity of a laboratory diagnosis.

Leaf Nutrient Analysis

Most nutrient deficiency problems can be readily diagnosed by visual symptoms alone. For most palm species, diagnosis should rely on visual symptoms rather than a leaf nutrient analysis. Baseline data for nutrient sufficiency has been developed for only a few palm species. Therefore, without a comparison to a known nutrient-sufficient palm of the same species, a leaf nutrient analysis can be misleading.

There are situations where multiple deficiencies may be present on a single palm. Symptoms of these deficiencies may be present on different parts of the palm (e.g., old vs. new leaves), but may occasionally be superimposed on the same tissue. A common example is potassium and magnesium deficiency symptoms, both of which may be present to some degree on the older leaves of a palm. For these situations, leaf nutrient analysis can be useful for distinguishing multiple deficiencies where the symptoms of one deficiency may be masking those of another.

Leaf analysis can also be used to confirm or clarify a diagnosis based on visual symptoms. However, there are exceptions. For example, leaf analysis is not particularly useful for diagnosing iron deficiency in any plant, and it may not accurately assess the boron levels of a palm at any given time, due to the often transient nature of boron deficiency. On the other hand, leaf analysis is useful for confirming chronic boron deficiency when symptoms are present on multiple leaves.

In order to obtain useful results from a leaf analysis, the proper leaves must be sampled. Leaf nutrient analyses are based on samples consisting of several leaflets (pinnate-leaved palms) or leaf segments (fan-leaved palms) taken from the center of the youngest, fully-expanded leaf. Depending on the nutrient deficiency, this may or may not be the leaf exhibiting symptoms. In pinnate-leaved palms, the youngest, fully-expanded leaf should have all of its basal leaflets (or spines in some species) expanded out and perpendicular to the petiole axis, as in older leaves.

Leaf Disease vs. Nutrient Deficiency

To complicate matters even further, it is possible to have both a nutrient deficiency and a leaf spot disease. Furthermore, some nutrient deficiencies look like a leaf spot disease. If you cannot decide which problem you are observing, then collecting samples for *both* a disease diagnosis and a leaf nutrient analysis may be necessary. However, this will require duplicate samples and may require sampling different tissue on the same plant. As explained above, leaf nutrient analysis is based on leaflets from the youngest fully expanded leaf. Leaf disease samples should be the leaves exhibiting the leaf spot or leaf blight symptoms.

Soil Nutrient Analysis

Soil nutrient analysis has often been employed in the diagnosis of plant problems in the landscape and field nursery. Unfortunately, this technique has limited value for this purpose, and often leads to erroneous conclusions. Just because a nutrient element is found to be "deficient" in the soil does not mean that the plant is unable to extract sufficient amounts of that element from the soil. Alternatively, a palm may be suffering from a deficiency of an element that is present in "sufficient" levels according to soil tests.

Soil analysis can be useful for diagnosing problems such as high soluble salts, a disorder with symptoms very similar to those of chemical toxicities or even potassium deficiency in some species. Soil analysis may also provide useful information regarding soil pH, which could affect your choice of corrective fertilizers or explain why a deficiency is occurring. For example, manganese availability in the soil is soil pH dependent.

When collecting soil samples for laboratory analysis, it is best to scratch away the mulch or other surface covering and obtain a cup or more of soil from the top 4 to 6 inches of the soil profile. Sample several areas under the canopy of a single palm, or from under the canopies of several palms, if they are all affected by a single problem. These samples should be thoroughly mixed, and about one cupful of the mixture taken to a soils laboratory for analysis.

Source: Elliott, M.L. and T.K. Broschat. 2014. *Palm Problems: Field and Laboratory Diagnosis.* UF/IFAS publication PP-246. **http://edis.ifas.ufl.edu/pp166**

Abiotic Disorders of Palms

Please refer to Chapter 10 of this publication for general discussion of abiotic disorders associated with plants in the landscape. This section will discuss several of the most common abiotic disorders of palms, all of which involve nutrient deficiency.

Potassium (K) Deficiency

Symptoms. K deficiency symptoms vary among species, but always appear first on the oldest leaves. Older leaflets of some palms, such as hurricane palm, are mottled with yellowish spots that are translucent when viewed from below (Figure 17.2). In other palms, such as cabada palm, kentia palms, and royal palms, symptoms appear on older leaves as marginal or tip necrosis with little or no yellowish spotting present (Figure 17.3). The leaflets of royal, cabada, and other pinnate-leaved species showing marginal or tip necrosis often appear withered and frizzled.

Figure 17.2: Older leaflet of hurricane palm displaying K deficiency. Credit: Tim Broschat, Symptoms of Palm Diseases and Disorders, USDA APHIS ITP, Bugwood.org.

Figure 17.3: Older leaflet of cabada palm displaying K deficiency. Credit: Tim Broschat, Symptoms of Palm Diseases and Disorders, USDA APHIS ITP, Bugwood.org.

In fan palms, such as Chinese fan palm, talipot palm, Washington palms, and Bismarck palm, necrosis is not marginal, but is confined largely to tips of the leaflets (Figure 17.4). In pygmy date palm, the distal parts of the oldest leaves are typically orange, with leaflet tips becoming necrotic (Figure 17.5). The rachis and petiole of the leaves usually remains green, however, and the orange and green are not sharply delimited as with magnesium (Mg) deficiency. This pattern of discoloration holds for most palm species that show discoloration as a symptom.

In Canary Island date palm, leaflets show fine (1-2 mm) necrotic and translucent yellow spotting and extensive tip necrosis. These necrotic leaflet tips in most related species are brittle and often break off, leaving the margins of affected leaves irregular.

Figure 17.4: Older leaflet of Chinese fan palm displaying K deficiency. Credit: Tim Broschat, Symptoms of Palm Diseases and Disorders, USDA APHIS ITP, Bugwood.org.

Figure 17.5: Older leaflet of pygmy date palm displaying K deficiency. Credit: Tim Broschat, Symptoms of Palm Diseases and Disorders, USDA APHIS ITP, Bugwood.org.

In fishtail palms and sugar palms, chlorotic mottling is minimal or non-existent, but early symptoms appear as irregular necrotic spotting within the leaflets. In most other palms, including coconut palm, African oil palm, areca palm, European fan palm, spindle palm, and others, early symptoms appear as translucent yellow or orange spotting on the leaflets and may be accompanied by necrotic spotting as well. As the deficiency progresses, marginal and tip necrosis will also be present. The most severely affected leaves or leaflets will be completely necrotic and frizzled, except for the base of the leaflets and the rachis (Figure 17.6).

Figure 17.6: Older leaflet of European fan palm displaying K deficiency. Credit: Tim Broschat, Symptoms of Palm Diseases and Disorders, USDA APHIS ITP, Bugwood.org.

For all palms, symptoms decrease in severity from tip to base of a single leaf and from old to new leaves within the canopy (Figure 17.7). Because K deficiency causes premature senescence of older palm leaves, the severity of this deficiency is best measured not by the number of discolored and symptomatic leaves, but rather by the number of living leaves in the canopy. In severe cases, the canopy will contain only a few leaves, all of which will be chlorotic, frizzled, and stunted. The trunk will begin to taper (pencil-pointing) and death of the palm often follows.

Figure 17.7: Spindle palm showing the increase in severity of symptoms from new to old leaves. Credit: Tim Broschat, Symptoms of Palm Diseases and Disorders, USDA APHIS ITP, Bugwood.org

Cause. Potassium deficiency is caused by insufficient K in the soil, but can be induced or accentuated by high N:K or Ca:K ratios in the soil. Potassium is readily leached from sand or limestone soils which have very low cation exchange capacities.

Occurrence. Potassium deficiency is very common on palms grown in highly leached sandy soils. It is less common in container substrates. Potassium deficiency is perhaps the most widespread of all palm nutrient deficiencies. It is quite severe in southern Florida and much of the Caribbean region. Although most species of palms are susceptible to some degree, some such as Montgomery, Christmas (Manila), Alexandra (King), and Piccabeen (Bangalow) palms are notably resistant to K deficiency. Potassium deficiency is a major cause of mortality in Caribbean and Cuban royal palms growing in southern Florida landscapes.

Diagnostic techniques. Visual symptoms alone may be sufficient for diagnosis of this disorder although leaf nutrient analysis may be helpful in distinguishing late stage K deficiency from manganese (Mn) deficiency (see UF/IFAS publication ENH-1015, *Manganese Deficiency in Palms*, **http://edis.ifas.ufl.edu/ep267**). These two deficiencies can be extremely similar from a distance, but close examination should reveal characteristic spotting and marginal necrosis in K deficiency or necrotic streaking for Mn deficiency (Figure 17.8). Potassium deficiency symptoms are also more severe toward the leaf tip and are less so at the leaf base. The reverse is true for Mn deficiency.

When sampling for leaf analysis, select four to six central leaflets from the youngest fully-expanded leaf. Soil analysis is not particularly useful for diagnosing palm nutrient deficiencies, since palm nutrient symptomology often bears little resemblance to soil nutrient profiles.

Figure 17.8: Mn deficient Cuban royal palm. Credit: Tim Broschat, Symptoms of Palm Diseases and Disorders, USDA APHIS ITP, Bugwood.org.

Management. Regular applications of K fertilizers will prevent K deficiency and treat palms already deficient. On sandy soils, or those having little cation exchange capacity, controlled-release K sources are much more effective than the easily leached water-soluble K sources. Sulfur-coated potassium sulfate has been shown to be the most effective and economical source for K in the landscape.

For mild to moderately K-deficient palms, application of a controlled release 8-2-12+4Mg palm maintenance fertilizer every three months should be sufficient to treat and prevent K deficiencies. Treatment of K deficient palms may require one to two years or longer, since the entire canopy of the palm may need to be replaced with new symptom-free leaves. Removal of discolored older K-deficient leaves on a regular basis has been shown to accelerate the rate of decline from this disorder and can result in premature death of the palm. Severely K-deficient palms should be fertilized with a no-nitrogen, no-phosphorus controlled-release palm fertilizer (e.g., 0-0-16-6Mg plus micronutrients) instead of the 8-2-12-4Mg material for the first two applications, but subsequent fertilizations should be with the 8-2-12-4Mg material.

See also UF/IFAS publications ENH-1009, *Fertilization of Field-grown and Landscape Palms in Florida*, **http://edis.ifas.ufl.edu/ep261** and ENH-1010, *Nutrition and Fertilization of Palms in Containers*, **http://edis.ifas.ufl.edu/ep262**.

Source: Broschat, T.K. 2011. *Potassium Deficiency in Palms.* UF/IFAS publication ENH-1017.

Magnesium (Mg) Deficiency

Symptoms. Mg deficiency appears on the oldest leaves of palms as broad chlorotic (yellow) bands along the margins with the central portion of the leaves remaining distinctly green (Figure 17.9). In severe cases, only the rachis and adjacent portions of the leaflets remain green on the oldest leaves, but younger leaves show progressively wider bands of green along the centers of leaves. In date palms, leaflet tips on the oldest leaves may be necrotic, but this necrosis is due to potassium (K) deficiency superimposed on Mg-deficient leaves (Figure 17.10). Where the two deficiencies coexist on the same palm, the oldest leaves will show typical K deficiency symptoms, while Mg deficiency symptoms will be visible on mid-canopy leaves. Transitional leaves will have K deficiency symptoms on the distal portion of the leaf, while Mg chlorosis will be seen on the basal leaflets (Figure 17.10). In fan palms with deeply dissected leaves, the chlorosis may appear as broad yellow bands along the margins of individual leaflets (Figure 17.11). Magnesium deficiency can be fatal in palms.

Figure 17.9: Mg deficiency in the mid-canopy and K deficiency in the lower canopy of Canary Island date palm. Credit: Tim Broschat, Symptoms of Palm Diseases and Disorders, USDA APHIS ITP, Bugwood.org.


Figure 17.10: A single old leaf of Canary Island date palm showing both K (tip) and Mg (base and middle) deficiency symptoms. Credit: Tim Broschat, Symptoms of Palm Diseases and Disorders, USDA APHIS ITP, Bugwood.org.

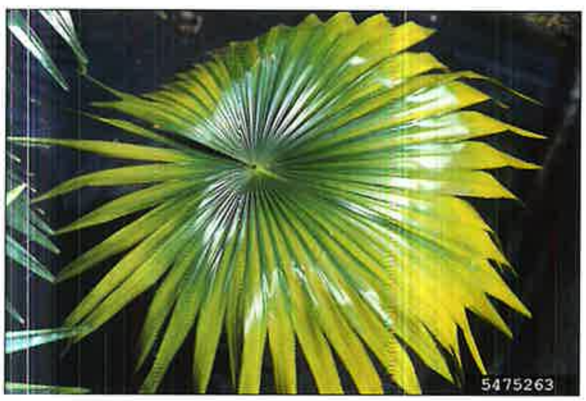


Figure 17.11: Mg deficiency symptoms in Chinese fan palm. Credit: Tim Broschat, Symptoms of Palm Diseases and Disorders, USDA APHIS ITP, Bugwood.org.

Cause. Magnesium deficiency is caused by insufficient Mg in the soil. Magnesium is readily leached from sandy soils and other soils having little cation exchange capacity. High levels of, N, K, or Ca in the soil can also induce or exacerbate Mg deficiencies.

Occurrence. Magnesium deficiency is very common on highly leached soils in Florida. It can also occur in container-grown palms if dolomitic limestone has not been added to the substrate. Also, since palms may remain in a container for up to a year or longer, any added dolomite is usually exhausted after six months or so with Mg deficiency symptoms becoming visible as a result. Most species of palms are susceptible to Mg deficiency to some degree, but Canary Island date palm is by far the most susceptible species to this disorder.

Diagnostic techniques. Visual symptoms alone are usually sufficient to diagnose Mg deficiency although leaf nutrient analysis can also be helpful. Magnesium deficiency symptoms differ from those of K deficiency (Figure 17.5) in that symptom severity of K-deficient leaves increases gradually from base to tip of the older leaf, whereas Mg deficiency symptoms are distributed uniformly from base to tip of the leaf. Discoloration of K-deficient leaves is usually orange to bronze, shading gradually to green at the base of the leaf, whereas Mg-deficient leaves have distinctly green leaf centers and bright lemon yellow to orange (depending on the species) margins. Necrosis is rarely associated with Mg deficiency, whereas leaflet necrosis is a common symptom on K-deficient palms. It is possible for a palm to show symptoms of both deficiencies on a single leaf.

When sampling for leaf analysis, select four to six central leaflets from the youngest fully-expanded leaf. Soil analysis is not particularly useful for diagnosing palm nutrient deficiencies, since palm nutrient symptomology often bears little resemblance to soil nutrient profiles.

Management. Magnesium deficiency is difficult to correct once symptoms are present. In container-grown palms, it is best prevented by amending all container substrates with 12 to 15 pounds of dolomite per cubic yard (see UF/IFAS publication ENH-1010, *Nutrition and Fertilization of Palms in Containers*, **http://edis.ifas.ufl.edu/ep262**). For palms in landscapes and field nurseries in areas prone to Mg deficiency, Mg should be included in all fertilizers in a controlled-release form. On acid soils, dolomite or magnesium oxide can be used as controlled release Mg sources, but on neutral to alkaline soils prilled kieserite (the less soluble monohydrate form of magnesium sulfate) is an excellent controlled-release source. Treatment of severely deficient palms can require one to two years or more and is accomplished by broadcasting magnesium sulfate (preferably in the less soluble prilled kieserite form) at rates of two to five pounds per tree four to six times per year to the area under the canopy. This treatment should be considered as a supplement to regular applications of a balanced 8-2-12+4Mg palm maintenance fertilizer. To reduce the potential for salt injury, Mg and maintenance fertilizer applications can be offset by six weeks. For mild to moderately severe Mg deficiencies, application of the 8-2-12+4Mg palm maintenance fertilizer at a rate of 1.5 pounds per 100 square feet of canopy area, bed area, or entire landscape area every three months should be adequate to treat and prevent Mg deficiencies. Foliar sprays with Mg fertilizers are generally ineffective in treating Mg deficiency since they supply very small amounts of Mg relative to the amount required by palms. See also UF/IFAS publication ENH-1009, *Fertilization of Field-grown and Landscape Palms in Florida*, **http://edis.ifas.ufl.edu/ep261.**

Source: Broschat, T.K. 2005. *Magnesium Deficiency in Palms.* UF/IFAS publication ENH-1014, **http://edis.ifas.ufl.edu/ep266.**

Manganese (Mn) Deficiency

Symptoms. The newest leaves of Mn-deficient palms emerge chlorotic with longitudinal necrotic streaks (Figure 17.12). As the deficiency progresses, newly emerging leaflets appear necrotic and withered on all but basal portions of the leaflets. This withering results in a curling of the leaflets about the rachis, giving the leaf a frizzled appearance ("frizzletop") (Figure 17.13). Within a single leaf, Mn deficiency symptoms are concentrated at the base of the leaf and are less severe or nonexistent towards the tip. On new leaves of Mn-deficient coconut palm, necrotic leaflet tips fall off and the leaf has a singed appearance (Figure 17.14). In severely Mn-deficient palms, growth stops and newly emerging leaves consist solely of necrotic petiole stubs (Figure 17.15). Palm death usually follows. Although the symptoms described above develop only on newly expanding leaves, the presence of symptomatic leaves lower in the canopy is an indication that Mn deficiency has occurred in the past.

Figure 17.12: Mn deficiency symptoms in pygmy date palm. Credit: Tim Broschat, Symptoms of Palm Diseases and Disorders, USDA APHIS ITP, Bugwood.org.

Figure 17.13: "Frizzletop" caused by Mn deficiency in pygmy date palm. Credit: Tim Broschat, Symptoms of Palm Diseases and Disorders, USDA APHIS ITP, Bugwood.org.

Figure 17.14: Mn deficiency in coconut palm. Credit: Tim Broschat, Symptoms of Palm Diseases and Disorders, USDA APHIS ITP, Bugwood.org.

Figure 17.15: Severe Mn deficiency in queen palm. Credit: Tim Broschat, Symptoms of Palm Diseases and Disorders, USDA APHIS ITP, Bugwood.org.

Cause. Manganese deficiency is caused by insufficient Mn in the soil or by high soil pH, which greatly reduces Mn availability (Figure 17.13). In soils where Mn is marginally sufficient, cold soil temperatures may cause temporary Mn deficiency by reducing root activity levels. This is particularly common on coconut palm in Florida. Composted sewage sludge and manure products have also been shown to strongly bind Mn when used as fertilizers or as soil amendments for palms (Figure 17.14).

Occurrence. Manganese deficiency is very common on alkaline soils, but can occur in containers if drainage is poor or soil temperatures are cool. Most species of palms can be affected, but queen, royal, paurotis, pygmy date, and African oil palms are particularly susceptible.

Diagnostic techniques. Visual symptoms may be sufficient to diagnose this disorder, but leaf nutrient analysis is also suggested, since symptoms of iron (Fe) and K deficiencies can be similar. Late stage K deficiency symptoms are virtually indistinguishable from those of Mn deficiency at a distance, and close examination is required to look for characteristic longitudinal streaking and basal (vs distal) symptom distribution of Mn deficiency.

When sampling for leaf analysis, select four to six central leaflets from the youngest fully-expanded leaf. Soil analysis is not particularly useful for diagnosing palm nutrient deficiencies, since palm nutrient symptomology often bears little resemblance to soil nutrient profiles.

Management. Fertilizers containing water-soluble Mn should be used routinely on soils where Mn deficiency is a problem. Although soil applications of manganese sulfate are effective, spraying the foliage with this product may achieve more rapid, though short-term results, especially on alkaline soils. This should be considered as a supplement to soil applications, not as a replacement. Manganese sulfate solutions to be applied to the foliage can be made by mixing three pounds of this product in 100 gallons of water. Soil application rates are dependent on palm species, soil type, and severity of Mn deficiency. These rates will range from as low as eight ounces for a small palm or one growing on an acid sand soil to eight pounds for a large palm growing on a limestone soil. Broadcast this product over the soil under the palm canopy. Applications can be repeated every two to three months, depending on the severity of the problem and soil type. However, a response may not be seen until three to six months after applications. Avoid using composted sewage sludge or manure products near palms. Excessive Mn applications normally result in an induced iron (Fe), with its characteristic new leaf chlorosis.

Source: Broschat, T.K. 2011. *Manganese Deficiency in Palms.* UF/IFAS publication ENH-1015, **http://edis.ifas.ufl.edu/ep267**.

Boron (B) Deficiency

Symptoms. B deficiency results in a wide array of symptoms, not only among species of palms, but also within a single species. Symptoms always occur on newly emerging leaves, but remain visible on these leaves as they mature and are replaced by younger leaves.

One of the earliest symptoms of B deficiency on areca palm and queen palm is transverse translucent streaking on the leaflets. In many species, including coconut palm, African oil palm, and queen palm, mild B deficiency can be manifested as sharply bent leaflet tips, commonly called "hookleaf" (Figure 17.16). These sharp leaflet hooks are quite rigid and cannot be straightened without tearing the leaflets.

Figure 17.16: "Hookleaf" in coconut palm. Credit: Tim Broschat, Symptoms of Palm Diseases and Disorders, USDA APHIS ITP, Bugwood.org.

B deficiency can be very transient in nature, often affecting a developing leaf primordium for a very short period of time (e.g., one to two days). This temporary shortage of B can cause dead tissue on the primordial spear leaf for a distance of about one to two centimeters. When such leaves eventually expand, this "point" necrosis affects the tips of all leaflets intersected by that necrotic point, the net result being the appearance of a blunt, triangular truncation of the leaf tip. This pattern can be repeated as many as three times during the development of a single leaf of coconut palm (about five weeks) (Figure 17.17).

Figure 17.17: Series of inverted V-shaped truncations on each leaf of a B-deficient coconut palm. Credit: Tim Broschat, Symptoms of Palm Diseases and Disorders, USDA APHIS ITP, Bugwood.org.

One of the most common symptoms of B deficiency is the failure of newly emerging spear leaves to open normally. They may be tightly fused throughout their entire length, or the fusion can be restricted to basal or distal parts of the spear leaf. In a chronic state, multiple unopened spear leaves may be visible at the apex of the canopy.

Perhaps the most unusual symptom of chronic B deficiency is the tendency for the entire crown to bend in one direction (Figures 17.18). This is one form of epinasty that can also cause twisting of petioles and leaves or sharp bends in the petiole, resulting in a single new leaf growing downward along the trunk.

Figure 17.18: Severe epinasty in manila palm. Credit: Tim Broschat, Symptoms of Palm Diseases and Disorders, USDA APHIS ITP, Bugwood.org.

B deficiency in its acute form produces yet other symptoms. Often leaves emerge greatly reduced in size and crumpled in a corrugated fashion ("accordion leaf") (Figure 17.19). Palms often grow out of these symptoms, but the deficiency may kill the meristem.

Figure 17.19: "Accordion" leaf of sagisi palm. Credit: Tim Broschat, Symptoms of Palm Diseases and Disorders, USDA APHIS ITP, Bugwood.org.

B-deficient palms often abort their fruits prematurely and inflorescences may have extensive necrosis near their tips. These symptoms are very similar to those of lethal yellowing (LY) in species affected by that disease. The calyx end of fallen coconuts from LY-infected coconut palm will be blackened, whereas coconuts from B-deficient trees will not have this blackened end.

Cause. B deficiency is caused by insufficient B in the soil. B is readily leached through most soils, with a single heavy rain event temporarily leaching most available B out of the root zone. When this leaching stops, B released from decomposing organic matter will again provide adequate B for normal palm growth in most cases. B deficiency is also common in deserts and seasonally dry areas where soil drying tightly binds B. Chronic B deficiency is believed to be caused by soil drying and high soil pH, while temporary B deficiency is caused by heavy leaching.

Occurrence. B deficiency is very widespread on palms growing in wet climates throughout the world, but can also occur in desert climates. B deficiency has been observed in container-grown palms, especially in seedlings.

Diagnostic techniques. B deficiency symptoms are quite distinctive and are usually sufficient for diagnosis by themselves. Mn deficiency in coconut palm produces symptoms similar to those of B deficiency, but Mn-deficient leaves show necrotic truncations of all leaflets, not just those near the tip of the leaf. No other common deficiency produces symptoms that could be confused with those of B deficiency.

Because B deficiency is often very transient in nature, the element is immobile within the palm (cannot move from one leaf to another), and deficiencies affect only leaf primordia developing within the bud area, leaf analysis is not particularly useful. Leaf analysis tells you the B status of the single leaf that you sampled, but that is not the current B status of the newly developing leaves within the bud area. Rather, it indicates the B status of the palm four or five months ago when the sampled leaf itself was in the developmental stage within the bud. The B status of the palm is likely to have changed considerably one way or another during four or five months since the affected leaf became old enough to sample. Thus, leaf analysis, or even leaf symptoms, unless the deficiency is regularly occurring, cannot tell you about the current B status of a palm. Similarly, soil analysis is not recommended for diagnosis of B deficiency.

Management. Because the difference between deficiency and toxic levels of B within plants is rather small, extreme caution should be exercised when applying B fertilizers. Recommended landscape maintenance fertilizers typically contain 0.10% - 0.15% B, and that appears to be sufficient to prevent B deficiencies in most cases. One product, Granubor®, has a longevity of about three months, making it suitable for blending with other slow-release fertilizers that have similar longevities. Its granular form also prevents it from settling out in mixed fertilizers. Water-soluble sodium borates such as Solubor® or Borax suffer from several problems when incorporated into granular fertilizer blends. First, they are typically powders, which tend to settle to the bottom of a fertilizer bag. Fertilizer taken from the top of the bag may contain insufficient B for plant needs, while fertilizer taken from the bottom may contain toxic concentrations of B. Also, water-soluble B fertilizers are readily lost to leaching during excessive rainfall, rendering them less effective than slow-release forms.

Current recommendations for correcting B deficiencies in palms are intentionally conservative because of the potential for toxicity. Dissolve about two to four ounces of Solubor® or Borax in five gallons of water and drench this into the soil under the canopy of a single palm. Do not attempt to apply dry B fertilizers to the soil, because turfgrass or other groundcovers in contact with it may be killed. Do not repeat this for at least five months, because it will take this long to see the results of the first application.

Source: Broschat, T.K. 2014. *Boron Deficiency in Palms*. UF/IFAS publication ENH-1012, **http://edis.ifas.ufl.edu/ep264**.

Common Diseases of Palms

This section discusses several of the more common diseases of palms, their causal agents, diagnosis, and management. Refer to Chapter 10 for a general discussion of pathogen types.

Fungal Diseases

Fusarium wilt of Canary Island date palm (Causal agent: Fusarium oxysporum *f. sp.* canariensis*)*

- As the name implies, Fusarium wilt of Canary Island date palm is primarily observed on Canary Island date palm.
- The leaf symptoms include a one-sided death (Figure 17.20), wherein the leaflets on only one side of the rachis are desiccated or dead. This is often accompanied by a reddish-brown or dark-brown streak on the petiole and rachis on the same side as the desiccated or dead leaflets. Eventually, the entire leaf dies.

- Internal discoloration can be observed in cross section (Figure 17.21). This internal discoloration is caused by the fungus infesting the xylem tissue.
- The disease symptoms normally appear first on the oldest (lowest) living leaves, and then progressively move upward in the canopy until the palm is killed.
- Transmission of the fungus from palm to palm is primarily through contaminated pruning tools.
- There is no cure for this lethal disease. Fungicides have not been effective against Fusarium wilt.
- Since there is no cure, disease management is aimed at disease prevention. A new or disinfected pruning tool should be used for pruning leaves from each individual Canary Island date palm. A list of materials that can be used as disinfecting agents is provided in Table 17.2.
- The only other disease that these symptoms could be confused with is petiole/rachis blight.
- A laboratory diagnosis using molecular techniques is required to confirm that the symptoms observed are caused by the Fusarium wilt pathogen.

Figure 17.20: "One-sided" death of leaflet. Credit: Monica Elliott, Symptoms of Palm Diseases and Disorders, USDA APHIS ITP, Bugwood.org.

Figure 17.21: Petiole internal discoloration. Credit: Tim Broschat, Symptoms of Palm Diseases and Disorders, USDA APHIS ITP, Bugwood.org.

Table 17.2. Suggested materials and soaking times for disinfecting pruning tools.

Material[1]	% Solution	Soaking time
Household bleach (e.g., Clorox®)	25% (1 part bleach or cleaner + 3 parts water)	5 minutes minimum
Pine oil cleaner (e.g., Pine Sol®)		
Rubbing alcohol (70% isopropyl)	50% (1 part alcohol + 1 part water)	
Denatured ethanol (95%)		

[1]The above materials were shown to be effective in eliminating the fungus from the wood dust or palm sap trapped on pruning tools (Simone 1998). It is suggested that the solution be replaced after 10 trees or every two hours. Rinse the tool with fresh water after soaking.

Source: Elliott, M.L. 2016. *Fusarium Wilt of Canary Island Date Palm*. UF/IFAS publication PP-215, **http://edis.ifas.ufl.edu/pp139**.

Fusarium wilt of queen palm and Mexican fan palm (Causal agent: Fusarium oxysporum *f. sp.* palmarum*)*

- As the name implies, Fusarium wilt of queen palm and Mexican fan palm is primarily observed on queen palm and Mexican fan palm (Washington fan palm). When this disease first appeared, it was called "Fusarium decline." That disease name is no longer valid.

- This disease is similar to Fusarium wilt of Canary Island date palm, but the pathogen subspecies and host range are different.

- The leaf symptoms include a one-sided chlorosis or necrosis of the leaf blades, with a distinct reddish brown or dark brown stripe on the petiole and rachis. The internal petiole and rachis tissue is discolored. Eventually, the entire leaf dies.

- The disease symptoms normally appear first on the oldest (lowest) living leaves, and then progressively move upward in the canopy until the palm is killed. Palms often die quickly, within two to three months after initial symptoms are observed. Due to the quick decline, the necrotic leaves do not necessarily droop or break and bend down around the trunk, but remain relatively rigid (Figure 17.22).

- It is not known exactly how the fungus spreads so widely in the landscape, but wind-blown spores are strongly suspected as a primary method. Local transmission of the fungus from palm to palm is possibly caused by contaminated pruning tools.

- There currently is no cure for this lethal disease.

- The only other disease that the leaf symptoms could be confused with is petiole (rachis) blight.

- A laboratory diagnosis using molecular techniques is required to confirm the Fusarium wilt pathogen.

Figure 17.22: Late-stage symptoms of Fusarium wilt on a queen palm. Credit: Monica Elliott, Symptoms of Palm Diseases and Disorders, USDA APHIS ITP, Bugwood.org.

Source: Elliott, M.L. 2013. *Fusarium Wilt of Queen Palm and Mexican Fan Palm.* UF/IFAS publication PP-278, **http://edis.ifas.ufl.edu/pp278**.

Petiole (rachis) blight of palm (Causal agent: several different groups of fungi)

- Petiole blight is caused by numerous fungal pathogens, but the symptoms these pathogens cause are similar for all of them.

- Palm host range is unknown for this disease.

- The disease often results in discolored, usually brown or reddish-brown, elongated lesions or streaks along the petiole and/or rachis of the oldest (lowest) leaves.

- The pathogens infect *only* the petiole or rachis, not the leaf tissue. However, destruction of vascular tissue (xylem and phloem) deep into the petiole results in a one-sided or uneven death in the leaf blade.

- Fungal structures can sometimes be observed on the infected petiole surface.

- Since very little is known about this disease, only general disease management strategies regarding sanitation, water management, and fungicide use can be provided.

- If the affected palm is a Canary Island date palm, queen palm or Mexican fan palm, the only other disease that the leaf symptoms could be confused with is Fusarium Wilt.

- Laboratory diagnosis is required to determine which pathogen is causing the symptoms observed.

Source: Elliott, M.L. 2013. *Petiole (Rachis) Blight of Palm.* UF/IFAS publication PP-221, **http://edis.ifas.ufl.edu/pp145**.

Ganoderma butt rot of palm (Causal agent: Ganoderma zonatum*)*

- This fungus degrades the lignin in the lower four to five feet of the trunk. It does not cause a soft rot, so the trunk seems hard.

- All palms are considered hosts of this fungus. This fungus is not a primary pathogen of any other plant family.
- Symptoms may include wilting (mild to severe) or a general decline (Figure 17.23). The disease is confirmed prior to palm death by observing the basidiocarp (conk) on the trunk. This is a hard, shelf-like structure that will be attached to the lower four to five feet of the palm trunk (Figure 17.24). However, many diseased palms do not produce conks prior to death.
- A palm cannot be diagnosed with Ganoderma butt rot until the conk forms on the trunk, or the internal discoloration of the trunk is observed after the palm is cut down (Figure 17.25).
- The fungus is spread by spores, which are produced and released from the conk.
- Conditions that are conducive for disease development are unknown. There are currently no cultural or chemical controls for preventing the disease or for curing the disease once the palm is infected.
- A palm should be removed as soon as possible after the conks appear on the trunk. Remove as much of the stump and root system as possible when the palm is removed, or grind the stump. If neither is possible, monitor the stump for conks, and remove from the stump as soon as they start to form.
- Because the fungus survives in the soil, planting another palm back in that same location is not recommended without special precautions.

Figure 17.23: Sabal palm with wilted and desiccated leaves from Ganoderma butt rot. Credit: Monica Elliott, Symptoms of Palm Diseases and Disorders, USDA APHIS ITP, Bugwood.org.

Figure 17.24: Developing conk from *Ganoderma zonatum*. Credit: Monica Elliott, Symptoms of Palm Diseases and Disorders, USDA APHIS ITP, Bugwood.org.

Figure 17.25: Internal discoloration of a queen palm trunk caused by *Ganoderma zonatum*. Credit: Monica Elliott, Symptoms of Palm Diseases and Disorders, USDA APHIS ITP, Bugwood.org.

Source: Elliott, M.L. and T.K. Broschat. 2015. *Ganoderma Butt Rot of Palms*. UF/IFAS publication PP-54, **http://edis.ifas.ufl.edu/pp100**.

Thielaviopsis trunk rot of palm (Causal agent: Thielaviopsis paradoxa*)*

- Due to this disease, the palm trunk either collapses on itself or the canopy suddenly falls off the trunk, often without warning. The palm canopy may appear healthy prior to collapse.
- Except for stem bleeding, which is common in coconut palm, there may be no symptoms prior to collapse of the palm.
- Only fresh trunk wounds will become infected by the fungus, so disease management includes limiting man-made wounds to the palm trunk, especially the upper third of the trunk. Over-trimming lower green leaves may also provide an infection site for this fungus, which will then move into the trunk.
- There are no methods to prevent or cure this disease. The palm should be removed immediately, and the diseased trunk portion destroyed but not recycled.

Source: Elliott, M.L. 2015. *Thielaviopsis Trunk Rot of Palm.* UF/IFAS publication PP-219, **http://edis.ifas.ufl.edu/pp143**.

Phytoplasma Diseases

Lethal yellowing of palm (Causal agent: Candidatus *Phytoplasma palmae subgroup 16SrIV, strain A)*

- Lethal yellowing (LY) is a systemic disease caused by a phytoplasma transmitted by a planthopper.
- Historically, LY has occurred only in the southern one-third of Florida. The disease was observed for the first time in Sarasota and Manatee Counties on the west coast of Florida in 2007 and in Indian River County on the east coast in 2012.
- LY symptoms are highly variable among coconut palm cultivars and among other palm genera (Figure 17.26).
- The first obvious symptom on mature palms is a premature drop of most or all fruits.
- Palms with greater than 25 percent leaf discoloration or a dead apical meristem (bud) due to LY should be removed.
- Management of LY includes trunk injections of oxytetracycline HCl (OTC) every three to four months, and planting of palm species that are not hosts of LY.
- Very few palm species native to Florida and the Caribbean Basin appear to be susceptible to LY.

Figure 17.26: Coconut palm dying from lethal yellowing. Credit: Monica Elliott, Symptoms of Palm Diseases and Disorders, USDA APHIS ITP, Bugwood.org.

Source: Harrison, N.A. and M.L. Elliott. 2015. *Lethal Yellowing (LY) of Palm.* UF/IFAS publication PP-222, **http://edis.ifas.ufl.edu/pp146**.

Texas Phoenix palm decline (Causal agent: Candidatus *Phytoplasma palmae - subgroup 16SrIV, strain D)*

- Texas Phoenix palm decline (TPPD) is a new disease in Florida. This disease is caused by a bacterium that has no cell wall—a phytoplasma.

- Texas Phoenix palm decline is a fatal, systemic disease that kills palms relatively quickly. The TPPD phytoplasma is spread naturally to palms by phloem-feeding insects, such as planthoppers.

- The symptoms of this new disease appear to be exactly the same as those associated with LY of date palm species with the first obvious symptom on mature palms a premature drop of most or all fruits at one time. Next, discoloration of the foliage begin with the oldest leaves turning yellow, but quickly turn varying shades of reddish-brown to dark brown or gray (Figure 17.27). The discoloration begins at leaf tips.

- Palms showing symptoms of more than 25 percent foliar discoloration or a dead spear leaf due to the disease should be removed immediately.

- A molecular diagnostic test is used to confirm the presence of the pathogen.

- Management of TPPD includes protection of susceptible palms in disease-active areas by:

  - trunk injection with oxytetracycline HCl (OTC) every three to four months, and

  - planting palm species that are not known to be susceptible to this disease.

- As of June 2016, palm species known to be most severely affected by TPPD were Canary Island date palm, edible date palm, wild date palm, and cabbage palm.

Figure 17.27: Discoloration of the oldest leaves is an early symptom of TPPD. Credit: Monica Elliott, Symptoms of Palm Diseases and Disorders, USDA APHIS ITP, Bugwood.org.

Source: Harrison, N.A. and M.L. Elliott. 2016. *Texas Phoenix Palm Decline.* UF/IFAS publication PP-243, **http://edis.ifas.ufl.edu/pp163**.

Common Arthropod Pests of Palms

Refer to Chapter 11 for a general discussion of arthropod characteristics, including life cycles and types of plant damage. This chapter describes the biology and management of the most important anthropod pests of palms in Florida. They are presented by the type of plant damage they cause due to their feeding characteristics.

Insects with Piercing and Sucking Mouthparts

Palm aphid (Cerataphis brasiliensis)

Description/biology:

- The palm aphid does not look like a typical aphid; rather, it resembles a whitefly or scale insect.

- Adult palm aphids are wingless and have an oval, slightly convex body that is dark brown and glossy with a peripheral fringe of white wax plates (Figure 17.28). They range in size from one to two millimeters long.

- Abdominal segments are evident on adult aphids, but they are more distinctive on nymphs.

- Nymphs are smaller (up to one millimeter long) than adults and have a light green to olive color body that is oval and slightly convex and contains a white waxy fringe on dorsal edges.

- The palm aphid is usually found on the unopened fronds and the youngest two or three fronds and occasionally on young fruits of the host palms.

- The aphids can appear motionless while feeding for long periods of time.

- The palm aphid can infest many palm species, but seems to be most often observed on coconut palm, date palm, Chinese fan palm, solitaire palm, and Mexican fan palm.

Figure 17.28: Adult palm aphid. Credit: L.J. Buss, UF/IFAS Entomology and Nematology.

Damage: High populations of palm aphids occasionally become severe in nurseries and the landscape. Palm aphids can cause substantial damage to young coconut palms. Palm aphids pierce palm foliage and extract the plant phloem content, causing yellowing of the tissues and loss of plant vigor. In addition, honeydew production by the aphids promotes sooty mold growth that can limit photosynthesis. Palms heavily infested with aphids can experience stunted growth.

Control and treatment: Carefully monitoring newly purchased palms for the presence of aphids is the first line of defense for their management in the landscape. Excluding these pests in the landscape will help prevent damaging outbreaks. If high populations of palm aphids are observed, the use of biological controls can be successful because of the aphids' limited mobility on plants. Syrphid and ladybird beetle larvae commonly feed on palm aphids. Palms should be monitored for sooty mold production to determine if they are infested with aphids. If high populations of aphids are observed with few to no natural enemies present, horticultural oil can be applied for control. For professionals, an insecticide may be necessary for control. Numerous insecticides are labeled for aphid control, yet the most efficacious product for control has not yet been determined. Pyrethroids can kill natural enemies and should be considered as a last option only.

Source: Wells, B.C. 2013. *Palm Aphid Cerataphis brasiliensis (Hempel) (Insecta: Hemiptera: Aphidae: Hormaphidinae)*. UF/IFAS publication EENY-520, **http://edis.ifas.ufl.edu/in924**.

Royal palm bug (Xylastodoris luteolus)

Description/biology:

- This true bug only infests royal palms (*Roystonea* sp.)
- There are five nymphal instars, each lasting several days. The time from egg to adult is 23 to 27 days.
- The royal palm bug is very small, with the adult reaching a length of only 0.1 in (Figure 17.29). Its general body shape is elongate-oval and somewhat flattened. Adults are pale yellow-green in color, except for the eyes, which are red. The immatures look similar to the adults, but lack wings.
- Females deposit eggs in the spring along the midribs of emerging leaflets. At the time of oviposition, leaflets are folded and the egg is placed inside of the fold. This helps protect the eggs. Females usually lay only one egg per day, which will hatch in eight or nine days. The time from the hatchling emerging to adult is about one month, coinciding with the emergence of new leaves.

Damage: Royal palm bugs feed on freshly opened leaves causing scattered yellow spots on the lower leaf surfaces. As feeding pressure increases (up to 300 bugs per leaflet have been observed), leaves develop brownish streaks and wilt (Figure 17.30). Damaged leaves eventually become gray and tattered. Royal palms produce a new leaf monthly. During the period of royal palm bug activity, about four leaves are damaged. Royal palm bugs rarely, if ever, kill palms, but their damage is unsightly and deleterious to the palm's health. Palms less than ten feet tall are seldom attacked.

Control and treatment: Other than some general predation by miscellaneous arthropods, such as spiders, insecticidal control is the only known reliable method for controlling the royal palm bug in Florida. Chemical control with a contact insecticide can, however, be a challenge due to the height of infested palms and problems with insecticide drift. Root drenches with soil-applied neonicotinoid systemic insecticides are a viable management option because their application does not require special equipment to reach palm leaves. Soil application is preferred in urban landscapes over foliar treatments as this eliminates drift and avoids environmental concerns. To fully protect the aesthetic appearance of the palms, apply the soil drench at first symptoms of an infestation. Before drenching, scrape away mulch or grass near the base of the palm and pour the mixture **very slowly** around the base of the trunk in a band a few inches wide. If the soil is dry, wet it first with five gallons of water before applying the drench.

Figure 17.29: Royal palm bug adult (center). Credit: L.J. Buss, UF/IFAS Entomology and Nematology.

Figure 17.30: Royal palm bug damage to royal palm. Credit: Tim Broschat, Symptoms of Palm Diseases and Disorders, USDA APHIS ITP, Bugwood.org.

Source: Weissling, T.J., F.W. Howard, and A.W. Meerow. 2015. *Royal Palm Bug, Xylastodoris luteolus Barber (Insecta: Hemiptera: Thaumastocoridae.* UF/IFAS publication EENY-097, **http://edis.ifas.ufl.edu/in254**.

Red date scale (Phoenicococcus marlatti)

Description/biology:

- The red date scale is one of the most important insect pests of date palm species.
- Adult females are small, spherical-shaped insects, with a body length size of approximately 0.04 to 0.06 inches, and reduced or absent legs. Adult females are a red to reddish-brown color and may be found embedded in a mass of white cottony wax on plant tissue (Figure 17.31).
- Males and first instars of both sexes have well-developed eyes, antennae, and legs. Wax is denser on second instar males, but present in enough quantity to completely cover the body for all instars of males and females.
- Prior to emergence as adults, small, wingless, elongated white cocoons of males may be visible.
- Females have three instars or developmental stages. Males have five instars, with the final development stage appearing as a white cocoon.
- Typically, four generations per year occur.

Damage: Red date scale usually establish at the base of fronds near the trunk or leaf midribs and fruit stalks. Host plant leaves, stems, trunk, fruits, as well as exposed and underground roots may also be infested. Extensive damage may occur and not be detected until pruning occurs. Premature leaf aging, drying of the fruit, disruption of normal plant metabolic functions, and even plant death may result from heavy infestations.

Control and treatment: Scale insects are commonly attacked by predators, parasites, and diseases that can help manage scale populations, particularly for long-term control. Contact insecticides commonly provide quick knockdown of the pest but require good coverage and repeat applications. The stage most susceptible to contact insecticides is the crawler stage. Horticultural oil and insecticidal soaps can also provide good control, but must be treated like contact insecticides, which require thorough coverage and repeat applications. Systemic insecticides can provide excellent options for scale control and can provide some flexibility in application timing and methods.

Figure 17.31: Red date scale adult female. Credit: L.J. Buss, UF/IFAS Entomology and Nematology.

Source: Espinosa, A., A. Hodges, G. Hodges, and C. Mannion. 2016. *Red Date Scale, Phoenicococcus marlatti (Cockerell) (Insecta: Hemiptera: Phoenicoccidae).* UF/IFAS publication EENY-454, **http://edis.ifas.ufl.edu/in816**.

Insects with Chewing Mouthparts

*Palmetto weevil (*Rhynchophorus cruentatus*)*

Description/biology:

- The largest weevil in North America is the palmetto weevil; they can be quite variable in size.
- The adults of this species display various color variations (Figure 17.32).
- The Florida palmetto weevil is native to Florida and is present throughout the state.
- The larvae, or grubs, are legless and creamy to yellowish in color (Figure 17.33). Their prominent head is dark brown and very hard. They have large mandibles.
- The palmetto weevil has a complete life cycle, with an egg, several larval instars, prepupal, pupal, and adult stages.
- Adult activity is usually more noticeable in the late spring and early summer months and least noticeable in the cool and dry winter months.

Damage: Two non-native palm species, Canary Island date palm and Bismarck palm, are most severely affected by this weevil, but they will infest other palms, including the native cabbage palm if severely stressed. The symptoms of a weevil infestation vary, but commonly involve a general, often irreversible decline of younger leaves. In palm species with upright leaves, such as the Canary Island date palm, the older leaves begin to droop during the early stages of infestation but quickly collapse thereafter. As the infestation progresses, the larval feeding damage and associated rot is so severe that the integrity of the crown is compromised and the top of the palm falls over. This condition is termed "popped neck." If the palm is pulled apart at this stage, larvae, cocoons, and even adults may be found within the crown region. Early detection of weevil infestation is difficult, and treatment even in the early stages of infestation may be too late to save the tree, depending upon the amount of damage to the apical meristem.

Control and treatment: Insecticidal treatment of trees infested with the palmetto weevil is difficult owing to problems with detecting a weevil infestation before lethal damage is done to the crown. The best recourse is to cut down infested palms and destroy them before adults emerge from the tree. Prophylactic treatment of recently transplanted palms with insecticides is an option, but the costs can quickly become prohibitive unless only a few trees are to be protected. Curative and preventative treatments with systemic neonicotinoid insecticides are possible, but require vigilance and persistence.

Figure 17.32: Adult color variations of the palmetto weevil. Credit: L.J. Buss, UF/IFAS Entomology and Nematology.

Figure 17.33: Palmetto weevil larvae. Credit: L.J. Buss, UF/IFAS Entomology and Nematology.

Source: Weissling, T.J. and R.M. Giblin-Davis. 2013. *Palmetto Weevil, Rhynchophorus cruentatus Fabricius (Insecta: Coleoptera: Curculionidae)* UF/IFAS publication EENY-013, **http://edis.ifas.ufl.edu/in139**.

*Palm leaf skeletonizer (*Homaledra sabalella*)*

Description/biology:

- The palm-leaf skeletonizer is a moth (Figure 17.34), the larvae of which feed on many species of palms.
- The caterpillars form dark tube-like structures on the underside of the leaf and eat leaf sections between veins (Figure 17.35).
- Larvae and the adult moth wingspan reach a length of 5/8 inch.
- The palm leaf skeletonizer is detected by tiny brown fecal pellets incorporated in a silk web on the palm fronds. These pellets look like fine sawdust and are found on the underside of leaves or where they have been woven together.

Damage: Larval feeding cause damage that looks much like a leaf "skeleton" (Figure 17.36). Larvae will also feed on the leaf stems, disrupting the vascular tissue and causing the death of the entire leaf.

Control and treatment: Removal and burning of affected fronds may be helpful if infestations are noticed early and the infestation has not spread in the area. Washing off the larvae and their frass with a wet sponge or blasting with a spray of water may be helpful, especially if the palm species has stiff fronds. Some parasitoids and parasites of this pest are known to attack the larva, including a predacious beetle and a tachinid fly. They are not known to be available commercially. Chemical control is not a practical option for widespread use because it would be costly and potentially disruptive of natural enemies. Also, spraying of tall palms could result in environmental contamination from insecticide drift.

Figure 17.34: Adult palm leaf skeletonizer moth. Credit: L.J. Buss, UF/IFAS Entomology and Nematology.

Figure 17.35: Frass tubes of palm leaf skeletonizer. Credit: Tim Broschat, Symptoms of Palm Diseases and Disorders, USDA APHIS ITP, Bugwood.org.

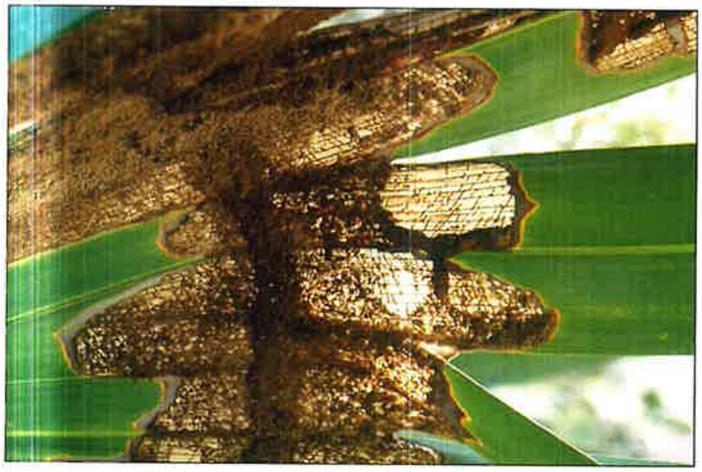


Figure 17.36: Adult palm leaf skeletonizer damage. Credit: J.L. Castner, retired UF/IFAS Entomology and Nematology.

Source: Howard, F.W and E. Abreu. 2007. *The palm leaf skeletonizer, Homaledra sabalella (Lepidoptera: Coleophoridae): Status and Potential Pest Management Options.* Proc. Fla. State Hort. Soc. 120:356-359.

Test Your Knowledge

Q: True or False:
For confirmation purposes, a laboratory analysis should always be used in conjunction with the field diagnosis of the problem.

A: True

Q: What is the primary reason why a laboratory analysis may result in a "false positive" or "false negative?"

A. The wrong tissue is sampled.
B. A sample of poor quality is submitted to the laboratory.
C. The diagnostician lacks the proper training and experience.
D. Both A and B are primary reasons.

A: D

Q: Why is soil nutrient analysis of limited value when employed in the diagnosis of palm problems?

A. Because a report may show a nutrient to be "deficient" but the palm is able to extract sufficient amounts of that element from the soil.
B. Soil analysis isn't useful for diagnosing a common problem such as high soluble salts.
C. Soil analysis isn't reliable in providing useful information regarding soil pH.
D. Because the time and expense of taking samples, submitting them to the lab for analysis, and waiting for results outweigh the benefits.

A: A

Q: Which palm tissue would be most appropriate for sampling to determine a nutrient deficiency?

A. A core from the trunk
B. A cross section from the trunk
C. The youngest, fully expanded leaf
D. The leaf petiole

A: C

Q: Match the deficient nutrient with its descriptive photo.

1. Potassium (K)
2. Magnesium (Mg)
3. Manganese (Mn)
4. Boron (B)

A.

B.

C.

D.

A: 1-B; 2-C; 3-D; 4-A

Q: Which palm disease do the following symptoms best describe for a Canary Island date palm? The leaflets on only one side of the rachis are desiccated or dead, a reddish-brown or dark-brown streak on the petiole and rachis on the same side as the desiccated or dead leaflets, internal discoloration can be observed in cross section.

A. Texas Phoenix palm decline
B. Fusarium wilt of Canary Island date palm
C. Thielaviopsis trunk rot
D. Ganoderma butt rot

A: B

Q: Which palm disease is associated with conks on the trunk?

A. Petiole (rachis) blight
B. Fusarium wilt of Canary Island date palm
C. Thielaviopsis trunk rot
D. Ganoderma butt rot

A: D

Q: What is the first obvious symptom of lethal yellowing and Texas Phoenix palm decline?

A. Darkened vascular tissue in a cross section of the trunk
B. Leaf wilt
C. Premature drop of most or all fruits at one time
D. Chlorotic leaf tissue

A: C

Q: Match the insect with its descriptive photo.

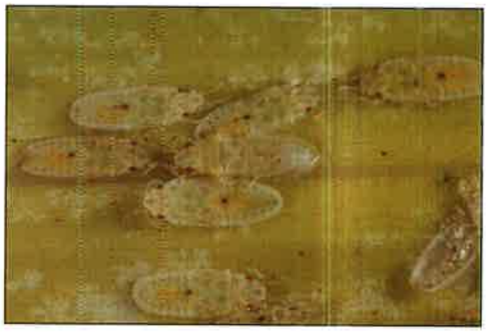
1. Palm aphid
2. Royal palm bug
3. Red date scale
4. Palmetto weevil
5. Palm leaf skeletonizer

A.

B.

C.

D.



E.

A: 1-C; 2-D; 3-E; 4-A; 5-B

CHAPTER 18

APPLICATION EQUIPMENT

IN THIS CHAPTER

Learning Objectives

After you complete your study of this chapter, you should be able to:

- Name three types of compressed air sprayers.
- Describe the advantages and disadvantages of compressed air sprayers.
- Describe the basic components of power sprayers.
- Describe desirable features of spray guns used in power sprayers.
- Describe the advantages and disadvantages of drenching and injection types of application.
- Name three types of granular applicators.
- Describe the advantages and disadvantages of drop spreaders.
- Describe the advantages and disadvantages of rotary spreaders.
- Understand the importance of regular maintenance of fleet vehicles.
- Understand the importance of keeping the owner's manual of your application equipment.

Terms to Know

gpm (gallons per minute): Standard unit used for a pesticide sprayer's flow rate.

PPE (personal protective equipment): Garments designed to be worn while handling pesticides to protect the handler from exposure.

psi (pounds per square inch): Standard unit used for a pesticide's sprayer's application pressure.

Introduction

Equipment used for application of pesticides to landscaped sites can vary from simple to complex. The type of equipment used will depend on variables such as the type of pesticide product to be applied, the size of the application site, and type of plants being treated. For example, some situations will require nothing more than simple handheld, low-volume equipment, such as compressed air sprayers, to apply pesticides. Other sites, such as lawns, may require much larger high-volume spray equipment, such as power-driven spray guns and boom sprayers. Many landscape professionals also use some form of spreader to apply dry materials such as granular formulations to lawns and plant beds. This chapter will discuss the types of equipment used by professional applicators for application of pesticides to landscape sites.

Compressed Air Sprayers

Three common types of compressed air sprayers for landscape pesticide applications are backpack sprayers, hand-held tank sprayers, and spray bottles. All are extremely useful for small jobs where only a few gallons or less of material are needed. Generally, these sprayers hold a pint to three gallons of water. Compressed air sprayers are effective and commonly used for directed, selective applications.

All of these types work on the same principal. The user rapidly pushes and pulls a plunger on the top or side of the tank, much like the plunger on a bicycle tire pump. The force of the plunger pumps air into the empty space inside the tank and compresses it. When the space is full of air, it becomes nearly impossible to push the plunger into the tank. At this point, the tank is pressurized.

As the air pressure inside the tank drops, the amount of liquid being expelled through the nozzle also decreases. Therefore, it is important to maintain a constant pressure inside the sprayer by pumping it regularly during application.

NOTE: Sprayers used for applying herbicides must be clearly labeled and used **only for that purpose.** Never use more than one type of pesticide in a sprayer; that is, use one for herbicides and a separate one for fungicides and insecticides. Label each sprayer for its intended type of pesticide. The cost of an extra sprayer is nominal compared to the replacement cost of valuable landscape plants, and cost is not the only inconvenience. It may take years for replacement plants to reach maturity.

A flat-fan, even-distribution tip, or adjustable cone nozzle can be used on a compressed air sprayer. Even distribution tips minimize drift by eliminating smaller droplets on the outside of the spray pattern. An adjustable cone nozzle provides the advantage of going from a broad coverage to a stream for increasing reach. Flat fan tips vary in their spray angle and rate of output and can be chosen based on the area of coverage desired. A tip with a spray angle of 15 to 40 degrees that delivers 0.3 to 0.5 gallons per minute (gpm) rated at 40 pounds per square inch (psi) is a good choice for most applications. Spray product catalogs will explain their coding for determining angle and output. For example, Spraying Systems TP 1502 and TP 1503 have a spray angle of 15 degrees and deliver 0.2 and 0.3 gpm, respectively; TP 2502 and 2503 have a spray angle of 25 degrees and deliver 0.2 and 0.3 gpm, respectively, at 40 psi. Spray tips may be installed in the spray wand that comes with the backpack sprayer, or a spray gun may be attached. A spray gun with both a flat fan tip and cone nozzle can be used to add versatility, but this adds weight and required maintenance to the unit. The spray gun can immediately be switched from one spray tip to the other by rotating the spray head. All compressed air sprayers should have chemical resistant seals (such as Viton® seals) for the pesticides being used.

Backpack Sprayers

Backpack sprayers are carried on the user's back, held by adjustable shoulder straps that allow the weight of the tank to be distributed evenly (Figure 18.1). A hose extends from the bottom of the tank around one side of the user. Attached to the hose is a spray wand with a trigger mechanism that the user squeezes to expel the tank mixture. Many backpack sprayers are equipped with a pump lever that extends from the bottom of the equipment around one side of the user. This permits the applicator to pump the sprayer regularly, with one hand, while moving the spray wand with the other hand. This maintains the pressure inside the tank and keeps the flow rate uniform.

The nozzle tip on backpack sprayers can usually be adjusted to create various spray patterns. This important feature allows the user to select the pattern most appropriate for uniform coverage of the target weed, plant, etc. A hollow cone tip which expels spray in a circular pattern is often the best choice for spraying shrubs or other plants.

Hand-held Tank Sprayers

The only real difference between a hand-held tank sprayer and a backpack sprayer is how it is carried by the user (Figure 18.2). A hand-held tank sprayer typically holds one to three gallons of liquid and is carried in one hand while operating the spray wand with the other. When the pressure inside the sprayer begins to decrease, the user must set the sprayer down and pump it. As with backpack sprayers, hand-held sprayers come with adjustable nozzles.

Figure 18.1: Applying a spot treatment with a backpack sprayer.

Figure 18.2: Applying a spot treatment with a hand-held tank sprayer.

Spray Bottles

When only a small amount of pesticide is needed, such as for spot treating a few weeds in a lawn, you might prefer a small bottle sprayer similar to those in which window cleaning products are sold (Figure 18.3). Empty spray bottles are available at discount and department stores as well as garden centers. Purchase one that has an adjustable nozzle that will allow you to select the setting most appropriate for the job at hand. Label the sprayer in LARGE LETTERS for the product used, and always store it in a locked facility with other pesticide products and equipment. Do not use a bottle that has previously held, or is labeled for, any other product!

Figure 18.3: Spray bottles are ideal for small jobs.

When dealing with very small quantities of pesticide, there is no room for error. It is important to carefully measure the amount of pesticide that you put into a bottle sprayer. Too little or too much pesticide concentrate can render your application useless—or disastrous.

Since it's usually not practical to calibrate a bottle sprayer, you must estimate the total amount of product needed for a job, and it is important to use the entire quantity mixed. Never save and store pesticide products that have been mixed with water—they lose their potency over time.

Pressure is created in a bottle sprayer based on its design. In one type, pressure is created by squeezing a trigger on the lid. A similar model has a lid with a small pump and handle with a trigger. On each model, each time the trigger is squeezed, pressure forces a small amount of liquid through the nozzle.

There are advantages and disadvantages with compressed air sprayers.

Advantages:

- Compressed air sprayers are portable. Backpack and hand-held compressed air sprayers allow the user to move about freely.
- They're efficient. Compressed air sprayers allow more precision than larger equipment in treating individual or small groups of plants.
- Their flexibility is a plus. Adjustable nozzles and interchangeable nozzle tips allow the applicator to select the spray pattern most appropriate for the job.
- They're easy to use and affordable. Most tank sprayers are moderately priced: $20 and up. Factors that affect price are the material they're made of (plastic, brass, or stainless steel); features such as adjustable nozzle tips and pressure gauges; size; and overall quality.
- Compressed air sprayers allow precise direction of the spray. A predictable spray pattern permits the user to accurately place the product where it is needed, such as along sidewalks or around flower beds.
- They're durable. When maintained according to the manufacturer's instructions, compressed air sprayers will last for many years. Individual parts usually can be obtained, permitting repair rather than replacement when the sprayer malfunctions.

Disadvantages:

- Usefulness of compressed air sprayers is limited. Due to their small tank capacity, they are inefficient for treating large areas or large groups of plants.
- Experience governs effectiveness. The user has to develop a feel for the amount of pressure that must be maintained to ensure uniform and complete coverage.
- Backpack and hand-held compressed air sprayers generally require maintenance. Proper maintenance is essential.
- Compressed air sprayers are cumbersome. Lifting and carrying a full, compressed air sprayer—especially a backpack sprayer—can result in muscle strain and fatigue.

Power Sprayers

Power sprayers are one of the staple pieces of equipment used by the "green industries" to make fertilizer and pesticide applications. Typically, these sprayers are skid-mounted on trucks, utility vehicles, or trailers. Hose and reel sprayers are the most commonly-used type of equipment by choice. They may be quite simple in design, ranging from single to multiple tanks, hoses, and reels mounted on a single piece of transport equipment (Figure 18.4). Standard hose and reel sprayer components include a tank, small engine, pump, pressure gauge, hose, reel, and spray gun.

Figure 18.4: Trailer-mounted sprayer with multiple tanks, hoses, and reels.

Tanks vary in capacity from 50 gallons or less to more than 500 gallons and are commonly constructed of corrosion-resistant polyethylene. Some of the larger tanks may be equipped with either a mechanical or hydraulic type agitation system. Good agitation is important for maintaining a uniform spray mixture. Other useful tank features include graduations on the side that indicate the volume of spray mixture and a large opening for easy filling and cleaning.

On sizeable service vehicles having large capacity fiberglass tanks, you should have baffles installed in the tanks, as liquid loads will shift during transport, especially when tanks are partially loaded. If a tank does not have baffles, the fluid will move to the front of the tank, which can push the truck forward and make it more difficult to stop. The sloshing liquid also places tremendous pressure on the tank walls.

Engines are the pump's power source. Depending on the pressure needed and the distance the liquid must travel from the equipment, common capacities are either 5.5 or 6.5 horsepower for gasoline-powered engines and 12-volt for electric motors.

The pump is the "heart" of the power sprayer. There are several types available, but those used in the green industries are usually either diaphragm or roller pumps. Each type has certain capabilities and limitations that determine when it should be chosen. Benefits of diaphragm pumps include relatively low cost, low maintenance, and small size compared with other pumps with similar flow and pressure ratings. Diaphragm pumps withstand abrasion from wettable powders much better than roller pumps because the spray mixture does not contact any moving metal parts except the valves. They are self-priming pumps commonly powered by a 12-volt electric motor with an output rate of 1.0 to 3.8 gpm, although higher capacities are available in larger and more costly units. Roller pumps are often made of nylon or rubber; therefore, wear is a concern as fluid can leak back past the rollers. For this reason, roller pumps are not a good choice for sprays made from wettable powders.

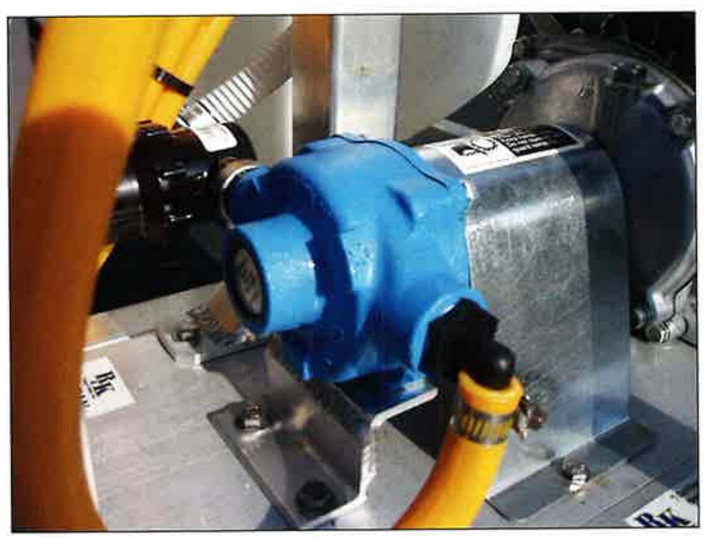


Figure 18.5: Roller pump.

The pressure gauge should be located where the sprayer operator can easily check the system pressure. A gauge should be easy to read, and the pressure range should be appropriate for the pressures being used. A high-pressure gauge will not give an accurate reading of a low-pressure sprayer. A gauge that sticks or will not zero should be replaced. Pressure in the system is controlled by the pressure regulator. This protects sprayer parts from damage due to excess pressure. The pressure range and flow capacity of the regulator must match the pressure range you plan to use and the pump capacity. The bypass line from the pressure regulator must be kept fully open and should be large enough to carry the total pump output with excess pressure buildup. Spring-loaded pressure relief valves are used with diaphragm and roller pumps (Figure 18.6).

Figure 18.6: Spring-loaded bypass valve

Sprayer component hoses are often overlooked, but their function is vital for successful application. All hoses have two pressure ratings: a working pressure rating and a bursting pressure rating.

The working pressure rating represents common pressures a hose experiences each time the equipment is operated. Hoses that operate within their working pressure ratings will move just as much fluid at the end of the day as they did at the beginning.

Bursting pressure ratings are normally four times higher than working pressure ratings, though these safety margins may vary depending on the manufacturer. The difference between the working and bursting pressure ratings is a built-in safety margin. When operators keep the hose within the working pressure range, the hose should not fail as a result of pressure alone.

Hose size is important, because the pressure loss in the hose depends on the hose inside diameter (ID), length, and the flow rate. Pressure loss in relatively short hoses is not very important, but it is important to choose the proper hose size when extremely long hoses are used, such as in some handgun lawn spraying work. For pump outputs less than 12 gpm, a ¾ inch suction side and 5/8 inch pressure side hose is recommended. For pump outputs of 12 to 25 gpm, a one inch suction side and ¾ inch pressure side hose is recommended.

Most professional lawn and landscape care operations roll their hoses on reels. Hoses used on reels in lawn care work are typically 300 to 400 feet in length with a working pressure of 600 psi. To help prevent spills in populated areas, there are a few tips specifically for hoses used on reels:

- Select hoses with burst strengths no less than double the pump's maximum pressure.
- Replace all hoses (regardless of use) at least every three years.
- Each year, unroll every hose from the reel, disconnect it from the reel, and reverse the hose. If you have reusable couplers, cut off about two feet of hose from each end. Hoses experience the most wear at the shut-off valve. Reversing and trimming hoses helps avoid hose memory problems.
- Install a hose guide on the reel.
- Spray and wipe off a little lubricating oil on the hose during reeling or unreeling. This keeps the hose clean and helps it roll neatly on the reel.

Reels are necessary for long hoses and commercial models available have holding capacities that will accommodate hose lengths of 100 to 400 feet. Some models are manually hand-cranked while others are electrically driven to provide a much faster and easier rewinding of the hose.

Spray guns are a standard piece of equipment used by the green industries for making pesticide applications to the appropriate target site. Desirable features of spray guns include:

- Interchangeable nozzle tips to allow various spray rates. Spray rates for guns used in lawn pest management typically range from approximately 1.5 to 6.5 gpm.
- Nozzle tips that provide a 45° full cone "showerhead" spray pattern containing large droplets to reduce drift potential.
- A trigger lock to provide continuous spraying.

- An adapter for allowing replacement of the showerhead nozzles with an extension wand for spot spraying.
- A maximum operating pressure of 200 psi.
- Chemical resistant seals (such as Viton® seals) for the pesticides being used.

High-performance spray guns are commercially available that allow for high-pressure spraying of distant targets, such as trees. They typically have barrels that range in length from 15 to 24 inches.

Some models are available that operate by rotating the handle 360° from shutoff to maximum flow position. As the handle is turned, the spray pattern changes from an initial cone spray through intermediate cone spray to straight stream. Spray tips are interchangeable orifice discs made of corrosion- and erosion-resistant stainless steel. Operated at high pressures, these spray guns can have a maximum vertical throw height upwards of 40 feet, depending on the orifice disc.

Other models are available that have an added handle near the end of the barrel for easier control of accurately hitting distant targets. They, too, should have seals to prolong a productive life.

Pesticide Injection and Drenching

Injection application may be made directly into the trunk of the tree or the soil underneath it near the roots. Drenching is similar to soil injection, except the pesticide mixture is poured to the soil surrounding the tree. A wide variety of pesticides, including plant growth regulators, are available for use with this technology. These methods can offer several advantages:

- Little, if any, pesticide applied is wasted to drift or runoff, because it can be applied precisely to where it is needed in the tree.
- Applications may be made during windy and rainy weather because there is no drift or runoff.
- There is little non-target organism exposure, therefore it can be done in environmentally-sensitive areas.
- Injection methods for treating some of Florida's troublesome piercing-sucking insects of trees, such as whiteflies and aphids, can be particularly useful.
- At least with soil injection/drenching, trees are not wounded.
- The soil drench method requires almost no tools.

Disadvantages of these methods include:

- Trunk injections cause wounding and can cause subsequent injury.
- Coverage with trunk injections can be spotty throughout the crown.
- With drenching, somewhat higher amounts of chemicals must be used than with injection.
- Trunk injection equipment can be costly.

Drenching and Soil Injection

Soil injection or drench methods involve placing chemicals in liquid form near the roots in the soil for root uptake. As with the other injection methods, the chemicals must be water soluble. Chemicals should be applied to moist but not saturated soil.

With the soil drench method you simply pour chemical mixed in water on the soil near the tree's root crown. Mulch or other surface organic matter is pulled back and the chemical is poured directly on the soil. Then the mulch is replaced. The amount of chemical used is based on inches of trunk diameter and will be stated on the label.

Soil injection methods vary somewhat, but typical recommendations are to inject chemicals two to four inches deep with a high pressure injector either within 18 inches of the trunk or on a grid. Amounts to be applied depend on trunk diameter, and diameters are added if multiple trees are being treated in an area.

Injection Equipment

One of the best known low-pressure systems is the Mauget system (**www.mauget.com**), which uses plastic capsules that are pressurized by depressing a plunger that locks in place

(Figure 18.7). The capsule then is pressed onto a tube that is already inserted into the tree, breaking a seal in the capsule and releasing the pressurized chemical. Other systems that use pressurized capsules with a similar array of chemicals include Tree Tech Microinjection Systems (**www.treetech.net**), and Rainbow Treecare (**www.treecarescience.com**). These systems require fairly small drilled holes (1/8 inch to 3/16 inch), are fairly simple to use, and are slower than high pressure systems.

Figure 18.7: Tree injection using the Mauget system. Credit: David Cappaert, Bugwood.org.

Higher pressure systems are available that inject chemicals using either a syringe or tubing, tees, and a chemical reservoir designed to be under pressure. These include Arborjet's Tree I.V. system, which uses tees and tubing and delivers high volumes of chemicals from a pressurized reservoir; and their Quik-Jet system, which applies small chemical volumes with a syringe (**www.arborjet.com**). Rainbow Treecare also has pressurized tubing and reservoir systems. ArborSystem's (**www.arborsystems.com**) Wedgle injection system doesn't use drilled holes but relies on injection through a seal with a syringe and specially designed needle. It is fairly fast because of the pressure created by the syringe.

Granular Applicators

Granular applicators are another one of the staple pieces of equipment used by the green industries to make fertilizer and pesticide applications. There are several types of granular applicators: drop spreaders and rotary (cyclone) spreaders. For larger jobs, higher holding capacity, and faster work, automated blower-type granular applicators are also commercially available.

Drop Spreaders

With drop spreaders, the product is poured into a hopper mounted between two wheels. At the bottom of the hopper is a rotating agitator bar, driven by the movement of the wheels, which stirs the product and keeps it flowing freely and uniformly.

Drop spreaders are aptly named because the granules drop straight down between the wheels through a set of adjustable openings, collectively called the gate, in the bottom of the hopper. The amount of product that falls through the gate is governed by adjusting the openings according to the settings or numbers on the hopper's scale. Higher numerical settings correspond to larger openings and will result in more of the product being dropped.

The size of individual granules affects the rate at which they can fall through the gate openings. Switching to a new product that contains smaller or larger granules, without changing gate openings set previously for another product, can result in significantly more or less of the new product being applied.

Advantages of drop spreaders:

- Drop spreaders are accurate and easy to use. The applicator usually can see the wheel tracks from the previous pass across the area and use them as a guide, overlapping slightly to ensure uniform coverage. Sometimes it is also possible to see the product on the ground after it is dropped.
- Precise placement is easy to achieve. The product drops down between the wheels, preventing granules from moving off-target or falling onto an area such as a sidewalk, driveway, dog kennel, pond, flower bed, street, storm sewer, pool, sand box, etc., where it isn't intended.
- Drop spreaders are efficient in small areas. They are easy to operate and very accurate on small lawns and narrow strips of grass in a side yard or between the street and sidewalk.

Disadvantages of drop spreaders:

- Drop spreaders leave little room for error. There is no forgiveness when passes are not overlapped correctly. Failure to ensure that the wheel tracks overlap slightly means that some turf will remain untreated. Too much overlap is even worse. Overlapping too far can burn or kill grass plants because twice the required amount of product is applied.

- A drop spreader must be recalibrated each time a different product is used in it because granules differ in size, weight, and shape. Carrier materials in granules also can affect their flow through the spreader.

- Corrosion can occur. Drop spreaders must be thoroughly cleaned with water and dried properly after each use, especially when a fertilizer is used, as fertilizer products can rust metal hoppers. Be sure to lubricate any metal parts with a light oil, after cleaning.

- There is no automatic shutoff. Granules continue to drop after the spreader stops moving. The gate openings must be closed manually—and quickly—each time the spreader is stopped.

- Clogging can occur. The gate openings can become clogged with product when the bottom of the hopper brushes against tall wet grass.

Rotary Spreaders

With push-type rotary spreaders, gravity causes granules to drop through an adjustable gate opening (or openings) in the bottom of the hopper onto a spinning plate activated by the turning wheel axle as the spreader is pushed across the treatment area (Figure 18.8). The spinning plate slings the granules 8 to 12 feet out in front of the equipment in a semicircular arc.

Figure 18.8: Rotary spreader for applying granular products.

Smaller, hand held rotary spreaders are available for use in smaller areas; they have a crank that is turned by hand to throw the granules outward.

As with the drop spreader, the openings on rotary equipment can be set by selecting the appropriate number (or letter). Read the product label or your equipment manual to determine the initial settings to use in calibrating the spreader.

Rotary spreaders do not distribute granules uniformly because of the tapered, fan-shaped pattern created by the spinning plate. More of the product is distributed in the center of the arc than on either side. This uneven distribution requires that you overlap each pass by 30 to 50 percent as you move back and forth across the site, thus throwing additional granules onto the outer edge of the previous pass.

It is important to read the product label, or the spreader instruction manual, for instructions on how to determine the amount of overlap required. If that information is not provided, space the passes far enough apart so that the outside edge of the distribution arc just touches the wheel tracks made during the previous pass. Overlapping each pass in this manner will ensure uniform, complete coverage.

Advantages of rotary spreaders:

- Rotary spreaders save time. They dispense the product over a wider swath per pass than drop spreaders, allowing quicker treatment of the total area.

- Low maintenance is required. Most rotary spreaders are manufactured primarily from plastic parts, which eliminate rust problems. They are easy to clean with a hose after each use. Be sure to lubricate any metal parts with a light oil, after cleaning.

- Rotary spreaders are compatible with many products. They permit the use of many different products, including some that have large granules.

Disadvantages of rotary spreaders:

- Uneven distribution is a problem with combination products. Small, light particles tend to fall to the ground close to the spreader, while larger, heavier ones are thrown farther out. Products that contain a mixture of large fertilizer granules and small pesticide granules, for instance, may be difficult to disperse evenly.

- Uniform coverage may be more difficult to achieve than with drop spreaders. Proper overlap is essential. It is important to overlap the right amount on each pass, and to do so consistently.

- Off-target placement can be a problem. When operating a rotary spreader, you must prevent the product from being thrown onto areas where it should not be applied: sidewalks, driveways, patios, play areas, sensitive landscape plants, gardens, etc. In addition to managing the swath pattern, you must be aware of cross winds that could possibly blow granules off-target.

Blower-type Granular Applicators

Automated blower-type granular applicators eliminate most hand application of granular product, utilizing positive airflow to propel granular material to the desired area (Figure 18.9). The blower on the spreader can be detached in order to remove excess granular product from driveways, sidewalks, and leaf surfaces of ornamental plants. Some of these models are portable small-capacity units, while others have large capacity and are designed to be mounted on vehicles.

Figure 18.9: Blower-type granular applicator.

Fleet Vehicles and Maintenance

The fleet vehicles of commercial pesticide applicators serving residential and industrial clientele fulfill multiple functions, notably for transportation of equipment and materials to the work site, mobile office facilities, and company advertisement. The proper maintenance of the vehicles and articles stored on board promotes applicator safety, reduces risk of accidental environmental contamination by transported pesticides, and serves as an indicator of the degree of professional responsibility assumed by the company.

Fleet vehicles can be an important tool in terms of acquiring and keeping customers. Rigs that are stained with pesticides, have granules and dirt in the bed, carry old and poorly serviced application equipment, or simply present an unkempt appearance do nothing to secure customer confidence in your business. Fleet vehicles can say quite a lot about the capabilities of their owner. Along those same lines, your rigs represent a sizeable investment. The simple act of a regular inspection can increase their useful life and their value to you.

Demonstrate your commitment to personal safety and environmental quality: Advertise your company proudly. Recognize the value of regular vehicle inspections. Use the listing in Table 18.1 as your checklist to developing your regular fleet vehicle inspection.

Table 18.1. Suggested fleet vehicle checklist.

Cab interior	**Tires**
□ Clean cab – no trash	□ Pressure
□ Coveralls for routine inspections	□ Tread wear
□ Extra change of clothes	□ Cuts and cracks
□ Pest identification information	□ Spare tire
□ Emergency numbers	**Lights – front**
□ Record of on-board pesticide	□ High beam headlights
□ Product labels and SDS	□ Low beam headlights

□ First aid kit	□ Turn signals
□ Fire extinguisher	□ Running lights
□ No pesticides in cab	□ Emergency flashers
□ No application equipment in cab	**Lights – rear**
On-board pesticide containers	□ Taillights
□ Containers properly sealed and secured	□ Brake lights
□ Legible labels on all containers	□ Turn signals
□ Granules in proper containers	□ Running lights
□ No oversupply of pesticides	□ Emergency flashers
□ Empty containers rinsed and ready for removal	□ Reverse lights
Spill control	□ License plate lights
□ Absorbent materials and rags on-board	**Windshield wipers**
□ Shovel, broom, plastic bags on-board	□ Blades in good condition
Equipment check	□ Fluid dispenser filled
□ Sprayers not pressurized	□ Fluid pump in working order
□ Supplies in moisture-proof containers	**Under the hood**
□ Lids fit securely on pesticide tanks	□ Belts
□ Spray hoses in good condition	□ Hoses
□ Pressure gauges operable	□ Oil
□ All sprayers cleaned and secured	□ Radiator fluid
□ Water containers labeled	□ Automatic transmission fluid
PPE on-board	**Other**
□ Respiratory gear	□ Horn in working order
□ Hard hat	□ Seat belts in working order
□ Goggles	□ Brakes in working order
□ Gloves	□ Windshield free of obstructions
□ Boots	□ No spills on truck exterior
□ Apron	□ No spills in truck bed
□ Coveralls	□ Truck bed free of debris
Inspected by________________________________	**Date**_____________
Notes	

Owner's Manual and Instructions

New pesticide application equipment comes with the manufacturer's instructions on how to use it properly. The instructions may be found in an owner's manual, on loose-leaf papers, or printed on the equipment itself. Instructions accompanying most new application equipment will provide:

- a product registration card;
- the model number of the equipment, or a place to write down this important number;
- a phone number for the manufacturer's customer relations department;
- address where a new set of instructions or an owner's manual can be obtained;
- a diagram and corresponding numbered parts list; instructions on how to set up and use the equipment;
- routine maintenance procedures needed to extend the life of the equipment;
- the manufacturer's warranty and related disclaimers;
- charts with proper equipment settings.

Equipment instructions are sometimes misplaced or thrown away, which is unfortunate because you may not remember all there is to know about equipment that you use infrequently. Instructions should be kept for reference when cleaning, maintaining, and calibrating the equipment.

Keep instructions in a safe place where they can be accessed easily and quickly. An example would be to maintain a reference file box for these and other home appliance and tool manuals. If instructions are printed directly on the equipment, copy them onto a piece of paper and store it in the box. These references are just as important for refreshing the memory of an experienced user as they are in getting the beginner started.

Test Your Knowledge

Q: Which class of pesticide should be applied with a designated sprayer for only that purpose?
A. Fungicide
B. Herbicide
C. Insecticide
D. Plant growth regulator
A: B

Q: Which feature should all compressed air sprayers possess?
A. A solar-powered diaphragm pump
B. Chemical-resistant seals for the pesticides being used
C. Nozzle spray tips constructed of hardened stainless steel
D. Teflon hoses reinforced with stainless steel wire braid
A: B

Q: What is a disadvantage of using a rotary spreader for applying granular products?
A. Achieving even distribution and uniform coverage
B. Rotary spreaders are not compatible with many products
C. They require high maintenance
D. They don't allow quick treatment of an area
A: A

Chapter 19

Site Measurements and Equipment Calibration

In this Chapter

Learning Objectives

After you complete your study of th s chapter, you should be able to:

- Describe the method for determining the area of the following:
  - Rectangular sites,
  - Triangular sites,
  - Circular sites, and
  - Irregular sites.
- List three times when you should calibrate equipment.
- Know how to calibrate equipment by the area to be treated or by the amount of pesticide in the sprayer or spreader.
- Know how to achieve uniform coverage using a spray gun attached to a hose and reel sprayer.
- Determine the amount of product to be added to a hose and reel sprayer's tank based on sprayer output and tank capacity.
- Determine the amount of product to be added to a compressed air backpack sprayer based on a percentage solution.
- Determine the effective swath width a rotary and blower-type granular spreader covers.

Terms to Know

Calibration: The process of measuring and adjusting pesticide application equipment performance.

dbh: Stem diameter at breast height (referred to in inches on pesticide labels).

Diameter: The straight line segment that passes through the center of a circle.

gpm: Gallons per minute.

psi: Pounds per square inch. A measurement of pressure.

Radius: The distance from the center of a circle to a point on the circle.

Introduction

To use pesticides successfully, you must apply the correct amount over the target plant or area uniformly. Mistakes in the amount of pesticide or uneven application may:

- waste money;
- fail to control pests;
- damage the environment;
- harm plants; and
- result in fines for illegal application.

In every situation, you should know—rather than guess—whether or not you are applying the correct amount of pesticide.

Site Measurements

To apply pesticides at the proper rate, you need to measure the area you want to treat. Most lawn and ornamental sites are measured in square feet. Larger areas are measured in acres. A helpful conversion to know is that an acre equa s 43,560 square feet (see Appendix Table D). Measurements of an area are very important when you treat turf or large beds of ornamental plants. Mistakes in measuring the area can result in expensive errors, such as applying too much or too little pesticide.

There are property-mapping apps commercially available that will calculate site areas for you. Maps are made online and available for downloading on your cell phone or computer. Some programs will also produce property corner coordinates that can be sent to your portable GPS unit. The advantages and disadvantages of using this approach should be carefully considered because such apps are not perfect or error-free.

Many landscape professionals will continue to measure sites using tools such as a measuring wheel or tape. The purpose of the following section is to review the basics of site calculations for various geometric shapes.

Rectangular Sites

To calculate the area of a rectangular site, you must know two dimensions:

- the length of the rectangle
- width of the rectangle

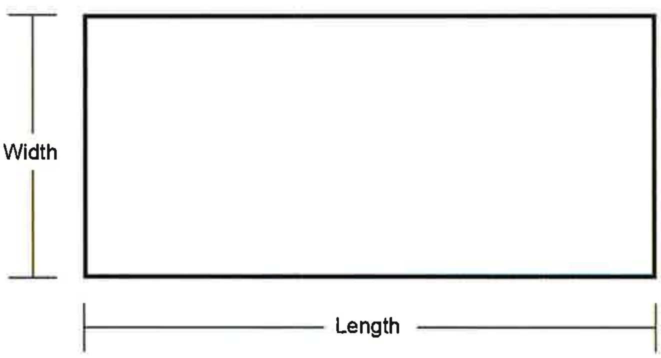


Figure 19.1: Area of a rectangular site.

Before any calculation, make sure that both dimensions are stated in the same units (for example, both length and width are known in feet). To find the area in square feet, multiply the length by the width. Most lawn and landscape product labels will provide rates based on square footage such as amount of product to apply per 1,000 square feet. Most manufacturers will also list on their product labels, or provide a conversion table, with rates provided per acre.

Example: A rectangular area is 60 feet wide and 90 feet long. Since most landscape professionals will use square footage as a standard unit of site measurement, calculate the area in square feet. What is the area in acres?

Solution: 60 ft × 90 ft = 5,400 ft^2

Convert to acres: 5,400 ft^2 ÷ 43,560 ft^2/acre = 0.124 acres

Triangular Sites

To calculate the area of a triangular site, you must know two dimensions:

- the length of the triangle's longest side
- the width of the triangle at its widest point

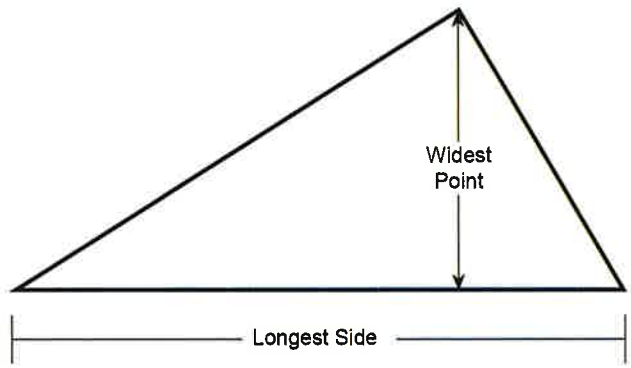


Figure 19.2: Area of a triangular site.

Before making a calculation, make sure that both dimensions are stated in the same units (for example, both the length and the width are known in feet). To find the area in square feet, multiply the length of the triangle's longest side by the width of its widest point, and then divide by two.

Example: A triangular site is measured and found to be 40 feet wide at its widest point and 60 feet long along its longest side. How many square feet does this triangular site contain?

Solution: (60 ft × 40 ft) ÷ 2 = 1,200 ft^2

Circular Sites

To calculate the area of a circular site, you must know two values:

- the radius of the circle
- the value of *pi* (π)

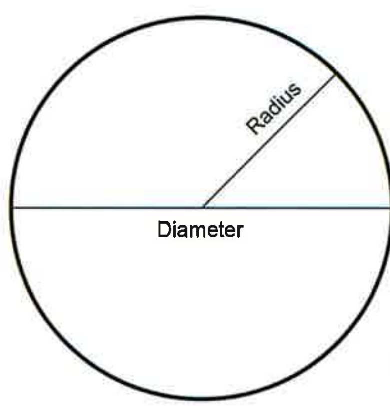


Figure 19.3: Area of a circular site.

The radius of a circle is the length of the straight-line distance from the center of a circle to any given place on the circle's edge. The radius is equal to one-half of the diameter of the circle. The diameter of a circle is the length of the longest possible straight-line distance across a circle. Any such straight line must pass through the center of the circle.

Pi (π) is an unchanging value that was discovered by ancient mathematicians. It is used to calculate areas or volumes that involve circles, spheres, and other curved objects. For basic calculations, the value for π is 3.14.

The area of any circle is determined by multiplying π by the square of the radius of the circle, where the square of the radius means the length of the radius multiplied by the length of the radius. Before the calculation, make sure the length of the radius (or the diameter) is known in feet.

Then, to calculate the area of the circle in square feet, multiply the length of the radius times the length of the radius by π. In mathematical format, it appears as $\pi(r^2)$.

Example: Measurement of a circular plant bed shows the site has a diameter of 40 feet. What is the area of the plant bed in square feet?

Solution: Find the radius of the circle. To do this, divide the length of the diameter in half:

40 ft ÷ 2 = 20 ft

Calculate the area of the circle by multiplying the length of the radius, times itself, by the value for pi: $3.14(20^2) = 1{,}256$ ft^2

Irregular Sites

Usually it is simple to measure the area of squares or rectangles such as in regularly-shaped sites. However, you may have to take several steps to measure the area of irregular sites such as some clients' lawns. One way to do this is to match each part of the irregular site to the closest geometric shape, such as squares, circles, and triangles. Then calculate the area of each shape and add them to get the sum total area to be treated (Figure 19.4).

Many lawn application sites contain objects that occupy space and do not require treatment: the house, flowers, shrubs, trees, patios, fountains, pools, sidewalks, driveways, etc. The total space occupied by all such objects must be subtracted

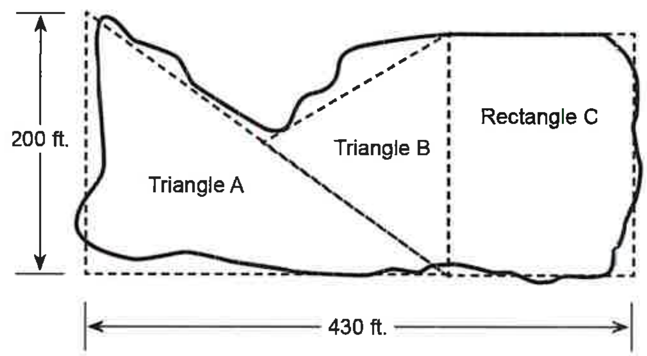


Figure 19.4: Area of an irregularly-shaped site.

from the total area of the property to determine the area that actually will be treated.

Example: A property has dimensions of 100 ft by 70 ft (Figure 19.5). How much square footage of lawn does the property actually occupy should only the lawn be treated taking the following into account?

- The house and garage occupy 1,700 ft^2.
- The driveway and sidewalk occupy 500 ft^2.
- The two plant beds occupy 600 ft^2.

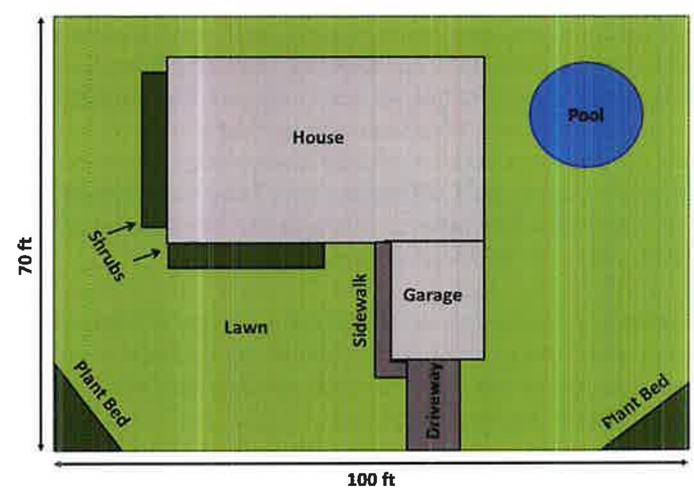


Figure 19.5: Diagram of a property that is not completely composed of turfgrass.

Solution: Determine the property's total area: 100 ft × 70 ft = 7,000 ft^2

Determine the space the other objects, other than lawn, are taking up on the property:

1,700 ft^2 + 500 ft^2 + 600 ft^2 + 160 ft^2 + 700 ft^2 = 3,660 ft^2

Subtract the objects' space from the total area to determine the amount of lawn present on the property: 7,000 ft^2 – 3,660 ft^2 = 3,340 ft^2

Conclusion: Less than half of the property is actually composed of lawn. Should a treatment need to be made to the lawn, consider only the amount of area that will require treatment.

Equipment Calibration

Calibration means 1) How you measure pesticide and fertilizer output; and 2) How you adjust your equipment so it applies the right amount to the target area.

There is no substitute for having properly calibrated equipment. Whether you want to control a pest better, have a healthy landscape, save money, prevent off-site damage, or reduce customer complaints, investing time in calibrating equipment always pays significant dividends. Precise applications of pesticides and fertilizers allows the product to function as intended.

If you apply too little or too much product, it can seriously affect performance and have consequences that customers readily see. An improperly calibrated herbicide applicator can result in poor weed control. Not applying enough fertilizer can lead to turf that is off-color, streaked, uneven in color, and unhealthy. At the other end of the spectrum, you can injure turf if you apply more herbicide or fertilizer than the product label allows. In such cases, improper calibration means you could be violating the pesticide label.

Customers are not the only ones who see the results of poor applications. Every trip your employees make to deal with an application complaint (callback) is a trip and application that is not billable. The costs of labor, equipment, and fuel make such complimentary applications expensive. The loss in dollars might seem insignificant on one lawn, but multiply that by the number of lawns you service and the number of rounds you make to each one, and you're talking about a significant sum of money. Profits increase when there are fewer callbacks.

It might be a subtle point, but improperly calibrated equipment leads to quality issues which customers, clients, or supervisors will notice. When pests are not controlled or turf looks unhealthy, customers question the value of the service. Your truck and the application posting notice you leave behind advertise the quality of your work.

When to Calibrate

The methods described here are practical, easy to learn and require only basic tools. Before you begin, check to see that all equipment parts are clean and in proper working order. Every time you calibrate a piece of equipment, write down the settings, rates and operating conditions. Frequent calibration is extremely important with liquid pesticides, because the flow rate can change.

Some companies may require calibration at the beginning of each work day; however, if daily calibration is impractical, do a check each day for a week to check for variation in the amount of water delivered. If it doesn't, then checking once a week should suffice. Some companies require applicators to keep a daily chemical worksheet, showing calculations of the actual amount of spray mixture used and the square footage treated. Numbers that don't calculate correctly indicate the need to recalibrate.

Don't assume that calibration of new equipment in the factory is correct. Remember to calibrate application equipment:

- Before you use it for the first time
- When you change the type of pesticide
- When you change the rate and speed at which you apply the pesticide

Safety

Following an application, equipment will have pesticide residues. Because of the residue, you should wear protective gear as required by the product label. If you will be mixing the pesticide with water, you can calibrate with water. What if the pesticide is granular or is mixed with something other than water, such as fertilizer? Use the actual pesticide or mixture for testing the calibration. Always wear the recommended protective equipment when you work with pesticides.

Calibrating the Hose-and-Reel Sprayer

Application Volume

The first thing you must do is to choose the volume of water you want your sprayer to apply. As an example, we'll choose to apply a rate of two gallons per minute (gpm). Several spray gun tips are commercially available that vary in their spray rates. In some cases, the nozzle manufacturer indicates the flow rate on the plastic nozzle, and/or it may be color-coded. In this example, we'll choose the nozzle that produces a flow rate of two gpm.

Now, run the sprayer. Spray water out of the tank and into a container for one minute (Figure 19.6). If you collect more than your two gallon target rate, reduce the operating pressure. If you collect less, increase the pressure. Continue to measure and adjust the output of the sprayer until you achieve your target rate. Because of practical limitations, you may actually have to change the nozzle first, and then adjust the pressure as needed.

Figure 19.6: Performing a catch test with a spray gun.

Be sure to note the reading on the pressure gauge. Always set the throttle so that the pump runs at this pressure. As long as you don't change spray tips, change the hose diameter or length, or make any other modifications to your equipment, the sprayer should remain calibrated for the desired rate.

Walking Speed and Arm Motion

Applying the correct amount of spray mixture using a vehicle-mounted hose-and-reel sprayer is likely as much an art as the science involved. The art involves the applicator calibrating his or her walking speed and a proper back and forth arm motion to achieve uniform coverage. It requires practice and experience to attain consistency.

Therefore, the next step is to train or "calibrate" your technician to cover 1,000 square feet in approximately one minute. Since the equipment was just calibrated to spray two gpm, the technician will be putting out two gpm on each 1,000 square feet. Mark a 1,000-square-foot area, preferably a 50 feet by 20 feet area of pavement. Start by having the technician pull the hose to the farthest point of that area. Then have him make parallel passes (often the most efficient way to make an application), working his way back to the sprayer while you time him. Remember—the goal is to cover the 1,000-square-foot course in a timely manner, but walking slowly enough to achieve even coverage.

Uniform coverage using a spray gun with a hose reel is almost totally dependent on the person at the end of the hose. Test on a dry pavement so it will be easy to see the pattern as it dries (Figure 19.7). Watch as the pavement dries. Areas that dry more quickly than others indicate that too little water was applied; areas that remain wet longer indicate over-application. Repeat the process until uniform coverage is obtained, evidenced by even drying of the pavement.

Begin spraying the lawn by holding the spray gun perpendicular to your body and focusing on a point in the distance. This will help you walk a straight line and not veer off-course. Keep the arms up and out, and make sure to use a brisk, back-and-forth arm motion. Your goal is to swing the arm—not the wrist—fast enough to spray the target in the lawn three times as you walk by: once with the front end of the spray, once with the middle, and once with the trailing edge. At the end of the first pass, turn off the spray gun. Walk over about two steps to get a fifty percent overlap of the previous pass. The edges of the eight-foot swath of spray are feathered; therefore, the overlap is necessary to ensure that the entire lawn gets the full application rate. It is important that a full rate be applied

Figure 19.7: Dry pavement, such as a parking lot, works well to test spray coverage.

to the edges that were parallel to the application because they only received a half rate since they were not overlapped. Go over the edges very quickly (approximately twice the normal application speed) so that another half rate is applied.

If a different application volume will be used, be certain to make adjustments in walking speed and back and forth arm motion.

Adding Product to the Tank

Read the product label and you'll see the manufacturer's recommended dosage normally is expressed in ounces per 1,000 square feet. **NOTE: Liquid and dry ounces are not created equal.** A liquid ounce is a volume measurement, while a dry ounce is a measure of weight. This is a significant distinction that directly influences the accuracy of a measurement. Be certain that you use a measuring device specific for the formulation you are using. If you use a device to measure liquid volume when you should be using a device to measure dry formulations, you will change the intended application rate drastically.

When you pour a liquid ounce into a measuring container, it always represents 1/128 of a gallon. This is called a volumetric measurement because one ounce of any liquid always fills the same volume—it takes up the same amount of space.

A dry ounce is equal to 1/16 of a pound. The amount of a material it takes to get one dry ounce depends on the density of the material. Water dispersible granule (WDG, WG, and DG) formulations are an example of a commonly-used dry product by professionals in the green industries. Many of these products are used at extremely low rates, thus placing a premium on accurate measurement.

Example: The product label says to apply two fluid ounces of product per 1,000 square feet. Assume the following:

- You have a truck with a 500-gallon tank.
- The output has been measured to be two gallons per 1,000 square feet.

Solution:

1. Determine the number of square feet a full tank will cover: (500 gal ÷ 2 gal) × 1,000 ft^2 = 250,000 ft^2.
2. Next, since the product rate is 2 oz per 1,000 ft^2, divide the total amount a full tank can cover into 1,000 ft^2 units: 250,000 ft^2 ÷ 1,000 ft^2 = 250 ft^2 units.
3. Next, determine total product to add to a full tank: 250 ft^2 units × 2 oz = 500 oz of product.
4. Finally, for ease of measuring, determine the number of gallons of product needed: Since there are 128 fluid ounces in one gallon: 500 oz ÷ 128 oz = 3.9 gal product.

Example: Assume the same variables as in the previous example, except in this example a dry formulation of a product will be used at a rate of 0.20 ounces per 1,000 square feet.

Solution:

1. Determine the number of square feet a full tank will cover: (500 gal ÷ 2 gal) × 1,000 ft^2 = 250,000 ft^2.
2. Next, since the product rate is 0.2 ounces per 1,000 square feet, divide the total amount a full tank can cover into 1,000-square-foot units: 250,000 ft^2 ÷ 1,000 ft^2 = 250 ft^2 units.

3. Next, determine total product to add to a full tank: 250 ft^2 units × 0.2 oz = 50.0 oz of product.

4. Finally, for ease of measuring, determine the number of pounds of product needed: Since there are 16 ounces in one pound: 50 oz ÷ 16 oz = 3.1 lb product.

Calibrating Compressed Air Sprayers

Compressed air sprayers range in capacity from small hand-held bottles to backpacks, generally holding a volume of two to three gallons. Applying the correct amount using compressed air sprayers works through several principles:

- calibrating by area;
- calibrating by volume; and
- determining percent solutions

Depending upon the application objective, any one of these may be suitable.

Calibrating by Area

This can work for treating small areas, but is not recommended for large areas because of application volume and coverage variability. Here are the basic steps of an example to treat an area of 250 square feet at a labeled rate of five ounces product per 1,000 square feet:

1. Pour one gallon of plain water into the tank and pump the sprayer to capacity.
2. While standing still on dry pavement, hold your arm extended while moving the spray wand back and forth just as you would while spraying the target site. Measure the width of the area that received the spray. The width of the sprayed area on the pavement is four feet.
3. Spray the pavement, moving in a straight line and maintaining the four-foot-swath width, for 15 seconds. Measure the length of the strip covered in 15 seconds. The length of the covered strip is 25 feet.
4. Determine the total area covered by multiplying the width of the strip by the length (4 ft × 25 ft = 100 ft^2).
5. Spray plain water into a bucket for 15 seconds, then measure the volume of water collected (64 oz or 0.5 gal).
6. Determine the volume of water required to treat the area by first dividing the total area needing treatment by the square footage calculated in step four (250 ft^2 ÷ 100 ft^2 = 2.5).
7. Determine the total amount of water required by multiplying the number from step six by the amount of water collected in step five (2.5 × 0.5 gal = 1.25 gal water required).
8. Determine the amount of product needed to treat the area by first dividing the area to be treated by 1,000 square feet, since the labeled rate is stated per 1,000 square feet (250 ft^2 ÷ 1,000 ft^2 = 0.25).
9. Finally, multiply the labeled rate of product required per 1,000 square feet times the number determined in step eight (5 oz × 0.25 = 1.25 oz product to treat 250 ft^2).

Calibrating by Volume

A similar method works for calibrating the sprayer to treat particular plants or small groups of plants. In this situation, however, you calculate how much water to use to treat an average plant. If the label states "spray to wet," spray as if you were painting the plant with spray paint. Try to avoid applying too much spray to limit the pesticide from dripping off the plant.

Add water without any pesticide to the tank. Pressurize the tank. Then record the number of seconds it takes to spray the plant completely. Now spray water into a container for that length of time. Use this number to determine the amount of water and product needed.

Example: You have a plant bed containing 18 azalea shrubs to treat. The labeled rate of insecticide is three ounces per gallon of water.

Solution:

1. Select a single representative plant or group of plants (one azalea).

2. Add plain water to the tank and pump it to capacity. Do not add the pesticide product at this time. Adjust a hollow cone nozzle to deliver a fine spray (small droplets are less apt to roll off the leaf surface).

3. Apply the water so that all parts of the azalea are covered uniformly. Be sure to treat the underside of the leaves as well as the upper side. Record the amount of time required to achieve adequate coverage (12 seconds).

4. Spray plain water into a bucket for the amount of time recorded in the previous step. Measure and record the amount of water in the bucket (10 ounces water).

5. Determine the amount of product needed to treat the group of azaleas. If 10 ounces will treat a single azalea, then 180 ounces of spray mix will treat all 18 azaleas.

   - Convert to gallons: 180 oz ÷ 128 oz/gal = 1.4 gal total spray mix
   - Label rate is three ounces product per gal of water
   - 1.4 gal × 3 oz = 4.2 oz product needed

Determining Percent Solutions

In some situations, such as spot spraying, calibration may not be necessary. Many turfgrass and ornamental pesticides applied as spot treatments are mixed with water at a particular percent solution as directed by the product label. Some product labels will contain tables listing the amount of product to mix with various volumes of water to achieve desired percentage solutions. If the label does not list this information, to make this solution, convert the pesticide's percentage of concentrate into a decimal before you calculate the amount of concentrate to mix with water. Do this by dividing the percentage number by 100 to get the decimal. This is the same as moving the decimal point two places to the left and adding zeroes as needed (Table 19.1).

Table 19.1. Decimal equivalencies.

% Solution	Decimal equivalency
100	1.00
50	0.50
10	0.10
5	0.05
1	0.01
0.5	0.005
0.1	0.001

Example: You want to spot treat a patch of bermudagrass using a nonselective herbicide. The product label calls for a 2% solution. You wish to fill a three gallon backpack to capacity. How much herbicide should be added to accomplish this?

Solution:

1. Convert 2% to a decimal: 2 ÷ 100 = 0.02
2. Determine the number of ounces of herbicide needed per gallon of water: 0.02 × 128 oz/gal water = 2.6 oz
3. Determine the total amount needed to mix with three gallons of water: 2.6 oz × 3 gal = 7.8 oz
4. Mix a little less than eight ounces of herbicide with slightly less than threee gallons of water.

There are some situations, such as spot treating very small areas or individual plants, where a small hand-held bottle is convenient and useful. There is less potential for wasting material due to the need for mixing only a very small volume, such as 16 ounces. The same principles regarding percent solutions using decimal equivalencies apply whether mixing three gallons or 16 ounces. When mixing such small volumes, a useful conversion factor to know is that one fluid ounce is equal to 29.6 milliliters (ml). For precise measurement of such minute volumes when mixing, a small graduated cylinder marked in milliliter increments is useful. Other helpful conversions are found in Appendix D of this publication.

Injection and Soil Drench

Some tree injection techniques use products that are premixed and applied through a closed system; therefore, no mixing or calibration is required. Others require direct injection into holes drilled into the bark of the tree. The dose and number of holes to drill are based on the size of the tree. The size of the tree is the diameter measured at breast height, known as "dbh," a measurement taken at 54 inches from the ground. To determine the application/dose rate per tree:

1. Measure the tree circumference in inches for determining the dbh.
2. Divide the circumference by three to obtain the dbh in inches.
3. Calculate the number of injection sites by dividing the dbh in inches by two.
4. Multiply the tree dbh by the dosage rate to calculate the total dose in milliliters per tree.
5. Divide the total dose by the number of injection sites to determine required dosage per injection site.

Example: You are hired to inject palm trees with an insecticide for control of whiteflies. The product label states to apply four milliliters per inch of trunk diameter at dbh.

Solution:

1. You measure the trunk's circumference to be 36 inches.
2. Determine dbh: 36 in ÷ 3 = 12 in dbh.
3. Determine the number of injection sites: 12 in ÷ 2 = 6 injection sites.
4. Determine total dose: 12 in × 4 ml = 48 ml total dose per tree.
5. Determine amount to deliver into each injection site: 48 ml ÷ 6 injection sites = 8 ml per injection site to deliver the required dosage.

With soil injection around trees and shrubs, the dbh principle is also used to determine product dosage. Injection holes around the base of the tree are based on a grid, circle, or basal system. The grid system recommends to space holes on 2.5-foot centers, in a grid pattern, extending to the drip line of the tree. With the circle system, pesticide is injected into holes spaced evenly beneath the drip line of the tree extending in from that line. Depending on the size of the tree, more than a single circle of holes may be necessary. The basal system spaces injection holes evenly around the base of the tree trunk no more than 6 to 12 inches out from the base. The required dosage is mixed in sufficient water to inject an equal amount of solution into each hole. At least four holes per tree or shrub should be used.

The goal of soil drenching is to deliver the product uniformly in at least 10 gallons of water per 1,000 square feet around the base of the tree, directed to the root zone. A misconception is that if higher volumes of water are used, then the product will be diluted, or that putting on less water will result in a very concentrated product. However, whether two ounces of product are applied per thousand square feet mixed in 10 gallons or 100 gallons, there is no difference. When the application is over, two ounces of product are left behind.

Calibrating Granular Spreaders

Drop Spreaders

Drop spreaders may be calibrated by either a multiple or single pass method.

Example: You want to apply a granular product to a lawn measuring 6,300 square feet. The directions on the granular product's label states that a 20-pound bag will treat 5,000 square feet when the spreader's gate is set at 5¾.

Solution (multiple pass method):

1. Determine the number of bags of product needed: 6,300 ft^2 ÷ 5,000 ft^2 = 1.26 bags, about 1¼ bags will be needed.
2. Set the spreader gate lower than the 5¾ recommended setting. Set the gate at 2½.
3. Place about half a bag of product into the hopper.
4. Push the drop spreader back and forth across the lawn until the product is gone. Make sure that the wheel tracks of each pass slightly overlap the tracks from the previous pass.
5. Fill the hopper with another half bag and repeat the treatment at right angles to the first application. Continue until 1¼ bags are completely used.

Solution (single pass method):

1. Set the gate openings on the spreader using the product label directions: 5¾.
2. Measure the width of the bottom of the hopper between the wheels: two feet.
3. Measure and mark a convenient distance on clean pavement such as a driveway; 50 feet is suggested. Ten passes back and forth along this distance will result in the release of enough product to calibrate the equipment accurately. 50 feet × 10 passes = 500 ft^2
4. Compute the area covered by multiplying the length of the hopper by the length of the area covered: 2 ft × 500 ft = 1,000 ft^2.
5. Weigh five pounds of product and place in the hopper. Turn the spreader on and push it over the test strip ten times, using a consistent walking speed. Be sure to turn the spreader off immediately when you reach the end of the test strip.
6. Weigh the amount of product that is left in the hopper: 1 lb.
7. Compute the amount of product that was used to cover the test area by subtracting the leftover amount from the amount put into the hopper. The result represents the amount of product applied to the 1,000-square-foot test area: 5 lb - 1 lb = 4 lb/1,000 ft^2.
8. If the amount of the product used in the previous step is within 10 percent (high or low) of the label-recommended rate (20 lb/1,000 ft^2), the spreader is calibrated correctly. If the amount of product is not between 90 and 110 percent of the labeled rate, (that is, if it is not within ±10 percent), reset the gate openings and repeat the process. In this case 4 lb/1,000 ft^2 is the equivalent of the label rate of 20 lb/5,000 ft^2. Therefore, the spreader is applying the correct amount and no additional adjustments are necessary.
9. Apply the product according to label directions, using the gate setting determined in calibrating the spreader: 6,300 ft^2 ÷ 5,000 ft^2/bag = 1.26 bags product.

Rotary Spreaders

Because rotary spreaders seldom spread granules evenly, it is recommended to make two passes over a treatment area. Make the passes over the area at right angles to each other. A single-pass method may be used if the effective swath width has been determined. If this single-pass method is used, make parallel passes spread apart at half the swath width.

Some spreaders come with a calibration gauge. The gauge has stepped increments of 1/32 inch to allow the applicator to accurately measure the size of the opening. Use the gauge (not the numbers on the operating lever) to accurately document the opening size. After you obtain the desired spread pattern, document the step number and the product information for future reference.

Another technique, not quite as accurate, is to use a manufacturer's calibration plate specific to the granular product, if available for the product (Figure 19.8). Because each product has its own specific size, density, and weight, don't interchange plates with other products.

Figure 19.8: Manufacturer's calibration plate.

The swath width and distribution pattern from a rotary spreader should be checked frequently because some types of granules travel farther and make a different pattern than other granules. A good way to check the distribution pattern is to use a row of shallow boxes, trays, or pans set in a straight line. Use boxes that are the same size—one to two inches deep with an area of at least one square foot. You need an odd number of boxes, such as seven or nine. Number each box with a permanent marker. Put cloth or paper towels in the bottom of each box to keep the granules from bouncing out.

1. Place one box in the center. Space the remaining boxes on two-feet centers on both sides. The boxes should cover a total width 1½ to two times the expected swath width.

2. Pour some of the granular product into the spreader, and set the spreader's gate to the setting recommendation on the label. Make three passes over the boxes always from the same direction (Figure 19.9).

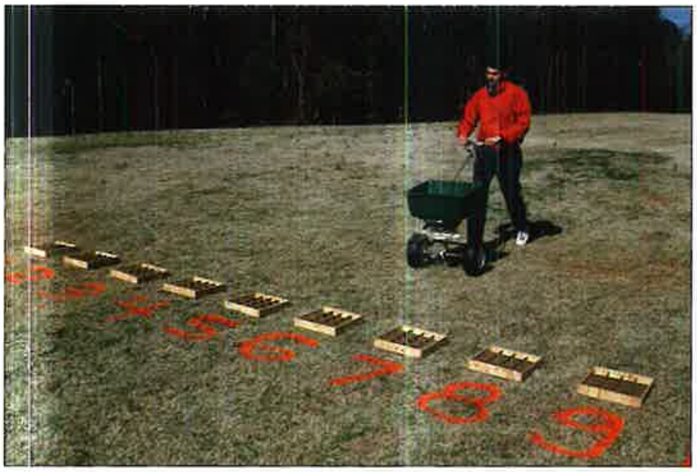


Figure 19.9: Checking the rotary spreader output. Credit: Wayne Buhler, N.C. State University.

3. Record the weight of the granules collected from each box. You may also pour granules into a jar on which you have written the box number. When you line up the jars in the same order as the collection boxes, you will see the distribution pattern (Figure 19.10). The center jar should have the most product in it, with amounts in the other jars tapering off evenly to each side. If the pattern is not even on each side, follow the spreader's guide for adjusting the spreader. Then repeat steps two and three until the spreader applies the product in the most uniform pattern possible.

Figure 19.10: Rotary spreader's distribution pattern. Credit: Wayne Buhler, N.C. State University.

4. Determine which jars to each side of the center jar have half the amount of granules that the center jar contains. The distance between the boxes represented by these jars is the effective swath width (Figure 19.11).

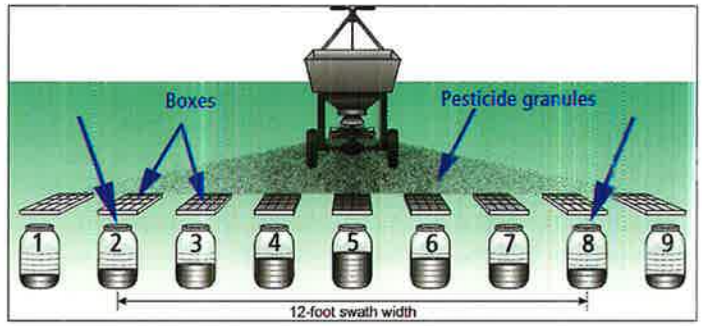


Figure 19.11: Rotary spreader's distribution pattern swath measurement. Blue arrows indicate jars #2 and #8 on each side have half the amount of granules as the center jar. Credit: Grace Jenkins, Design and Production, Raleigh, N.C.

Example: The jars in Figure 19.11 hold the collected granules from the nine boxes set up on a test course. What is the effective swath width?

Solution:

Because the boxes are spaced two feet apart and jars #2 and #8 contain half the amount of that collected in the center box (jar #5), the effective swath width is 12 feet (six feet to each side of center).

Example: Suppose that you are using a rotary spreader to apply a granular product to a 6,300-square-foot lawn. The label indicates that one 20-pound bag will cover 3,500 square feet of turf when the gate for the rotary spreader is set at five.

Solution (2-pass method):

1. Determine how many bags of product will be needed to treat the entire area: 6,300 ft^2 ÷ 3,500 ft^2 = 1.8 (about 1¾ bags).

2. Use a gate setting that is smaller than that recommended: set the gate at three.

3. Place half a bag of product into the hopper: 20 lb ÷ 2 = 10 lb.

4. Push the rotary spreader back and forth across the lawn until the spreader is empty. Fill the hopper with another half bag and repeat the treatment at right angles to the

first application. Repeat the process until 1¾ bags are completely used.

Solution (single-pass method):

1. The effective swath width has been determined to be 10 feet.

2. Measure and mark a convenient distance on clean pavement for a test strip. Suggestion: Use 100 feet or another distance that can be divided easily into 1,000 square feet.

3. Multiply the swath width (step one) by the length of the test strip (step two) to determine the area that will be covered in the test run: 10 ft × 100 ft = 1,000 ft^2.

4. Weigh the amount of product that you put in the hopper: 8 lb.

5. Turn the spreader on and push it down the test strip, using a consistent walking speed. Be sure to turn the spreader off immediately at the end of the test strip.

6. Weigh the amount of product left in the hopper after treating the test area: 2 lb.

7. Subtract the amount left in the hopper (step 6) from the amount put into the hopper (step 4) to determine the amount used over the test area: 8 lb – 2 lb = 6 lb/1,000 ft^2.

8. If the amount of the product that is used (step 7) is within 10 percent (plus or minus) of the recommended rate on the product's label, the spreader is calibrated correctly. If the amount of product varies by more than 10 percent of the recommended rate, repeat the steps above to recalibrate the spreader. In this case 5¾ pounds per 1,000 square feet would equal the label rate of 20 pounds per 3,500 square feet. Six pounds of product was applied per 1,000 square feet in the test run. This is within 10 percent of the recommended rate. No additional adjustments are necessary.

9. Using the rate on the label, determine the square footage that one bag of the product will cover. 20 lb ÷ 6 lb = 3.33. 3.33 × 1,000 ft^2 = 3,333 ft^2 per bag.

10. Determine the number of bags needed for the entire lawn: 6,300 ft^2 ÷ 3,333 ft^2 per bag = 1.89 (between 1¾ and two bags).

11. Sweep up the granules from the pavement and place them in the hopper.

12. Apply the product according to label directions, using the gate setting determined in calibrating the spreader.

Blower-type Granular Applicators

Delivery rates for powered blower-type granular applicators can be varied by adjusting the unit's valve. They typically have maximum delivery rates of 12 to 15 pounds per minute. Some models also have extension tubes that may be attached to the material-delivery hose for increasing delivery distance. The diameter of the extension tube is smaller than that of the hose, and although it does allow for longer delivery distance, flow rate is reduced. The larger diameter extension tube will allow for more volume of material, but with less delivery distance. Regardless of delivery tube diameter, the effective swath width should be measured (Figure 19.12).

Figure 19.12: Measuring a blower's effective swath width.

Example: Determine the application rate of a powered blower-type granular applicator. You will use a dry parking lot to conduct the test run. This can be achieved using two methods.

Solution (1):

1. Determine how much product to apply per 1,000 square feet. The product label states to apply at a rate of 2.3 pounds per 1,000 square feet.

2. Determine the blower's effective swath width while walking a steady, but comfortable, pace over the parking lot. In

this example the effective swath width is measured to be 12 feet.

3. Set the length of the calibration course. In this example, you want the calibration course to measure 1,000 square feet: 1,000 ft^2 ÷ 12 ft = 83 ft.

4. Place a known quantity of granules into the hopper: 10 lb.

5. Set the adjustable valve on the blower and operate the blower over the 83-foot test course.

6. Determine the weight of the granules remaining in the hopper following the test run. A shop vacuum will help you remove the granules that were left in the hopper. Subtract what's left from the amount you started with to calculate how much fertilizer you applied to the calibration course: 10 lb – 7.9 lb = 2.1 lb/1,000 ft^2.

7. Since 2.1 pounds is within 10 percent of the desired application rate of 2.3 pounds, the blower is set correctly. If the amount varied by more than 10 percent of the desired rate, the valve should be adjusted and the test repeated.

Solution (2):

1. Assume the following from the previous example: Effective swath width is 12 feet and the test course is 83 feet.

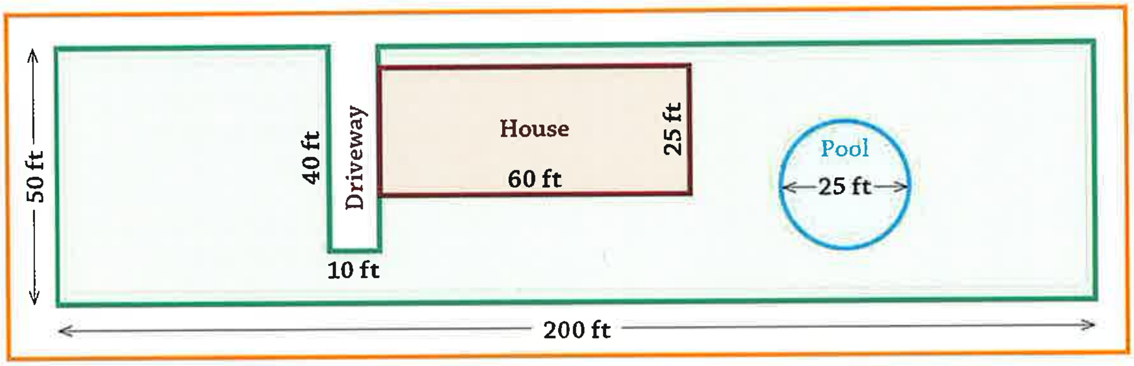
2. Determine the time that it takes to operate the blower across the 83-foot test course while walking at a comfortable pace. Using a stopwatch, you determine that it takes 30 seconds to walk the course.

3. Line the bottom of a five-gallon bucket with cloth or paper towels to prevent granules from bouncing out while operating the blower.

4. Operate the blower and catch the granules in the bucket for 30 seconds.

5. Weigh the granules caught in the bucket. This will be the application rate per 1,000 square feet.

Test Your Knowledge



Q: Based on the diagram above, how many ounces of fungicide will be needed to treat only the lawn area of the property if the label rate is three ounces of fungicide per 1,000 square feet?
A. 12 oz
B. 23 oz
C. 39 oz
D. 48 oz

A: B

Q: When should you calibrate your application equipment?
A. Before you use the equipment for the first time
B. When you change the type of pesticide
C. When you change the rate and speed at which you apply the pesticide
D. All of the above

A: D

Q: The product label says to apply six fluid ounces of product per 1,000 square feet. How much product should be mixed to make up a full 100-gallon tank if the sprayer's output has been measured to be four gallons per 1,000 square feet?
A. 1.2 gal
B. 1.8 gal
C. 2.2 gal
D. 2.4 gal

A: A

Q: The product label says to apply 0.4 ounces of a WDG product per 1,000 square feet. How much product should be mixed to make up a full 100-gallon tank if the sprayer's output has been measured to be four gallons per 1,000 square feet?
A. 5 oz
B. 10 oz
C. 15 oz
D. 20 oz

A: B

Q: You have a plant bed containing 12 camellias to treat for scale infestation. The labeled rate of insecticide is two fluid ounces per gallon of water applied as "spray to wet." You determine that it requires 15 seconds to spray an average size plant and collect 21 ounces of water when sprayed into a bucket for 15 seconds. How much insecticide will be needed for this entire job?
A. 1 oz
B. 2 oz
C. 3 oz
D. 4 oz

A: D

Q: You want to spot treat an area of a lawn to be renovated using a nonselective herbicide. The product label calls for a one percent solution. You wish to fill a two-gallon compressed air backpack sprayer to capacity. How much herbicide should be added to accomplish this?
A. 1.2 oz
B. 2.5 oz
C. 5.0 oz
D. 6.5 oz

A: B

Q: You are hired by a homeowners' association to inject residential trees with an insecticide for control of aphids. The product label states to apply two millileters per inch of trunk diameter at dbh. For a tree with a circumference of 48 inches, how many injection sites should be made to the tree?

A. 16
B. 12
C. 8
D. 4

A: C

Q: In the previous question, determine the amount of insecticide to deliver into each injection site.

A. 16 ml
B. 12 ml
C. 8 ml
D. 4 ml

A: C

Q: If the label of a granular insecticide indicates that one 40-pound bag will cover 5,000 square feet of turf, how many bags are needed to treat an 8,000-square-foot lawn?

A. 0.6
B. 1.0
C. 1.2
D. 1.6

A: D

Q: In a 1,000 square feet calibration test of a rotary granular spreader, 6¼ lb of granules were caught. Is the spreader applying at a rate equal to the label rate of 40 pounds per 5,000 sqaure feet?

A. Yes, the spreader is correctly calibrated
B. No, the spreader is over-applying
C. No, the spreader is under-applying

A: C

APPENDIX A

IMPORTANT TELEPHONE NUMBERS

Emergency Reporting Telephone Numbers

For Ambulance, Fire, or Police
Dial 911

State Warning Point
24 hours Toll-Free 1 (800) 320-0519

Department of Community Affairs, Division of Emergency Management
(850) 413-9911

National Response Center
24 hours Toll-Free 1 (800) 424-8802
(Federal law requires that anyone who releases into the environment a reportable quantity of a hazardous substance [including oil when water is or may be affected], or a material identified as a marine pollutant, must immediately notify the NRC).

FDEP Emergency Response
Jacksonville (904) 807-3246
Orlando (407) 893-3337
Ft. Lauderdale (954) 958-5575
Ft. Myers (239) 332-6975
Tampa (813) 744-6462
Panama City (850) 872-7650
Pensacola (850) 595-8300
Tallahassee (850) 245-2010

Non-emergency Telephone Numbers

State Emergency Response Commission
(NOT a 24-hour number) 1 (800) 635-7179
(This telephone number is for follow-up reporting under state spill reporting requirements. In an emergency, call the State Warning Point [see Emergency Reporting Telephone Numbers]. If federal reporting is required, also call the National Response Center [see Emergency Reporting Telephone Numbers)

Florida Friendly Landscapes Program
University of Florida (352) 273-4520

Florida Department of Agriculture and Consumer Services
Bureau of Licensing and Enforcement (850) 617-7997

Florida Department of Environmental Protection
Stormwater/Nonpoint Source Management Section (Tallahassee) (850) 245-7508
Hazardous Waste Management Section (850) 245-8707
Mangrove Trimming Section (850) 245-8482

Florida Department of Environmental Protection District Offices
Northwest (Pensacola) (850) 595-8300
Northeast (Jacksonville) (904) 807-3300
Central (Orlando) (407) 894-7555
Southeast (West Palm Beach) (561) 681-6600
Southwest (Tampa) (813) 632-7600
South (Ft. Myers) (239) 332-6975

Water Management Districts
Northwest Florida (Tallahassee) (850) 539-5999
Suwannee River (Live Oak) (386) 362-1001 or 1-800-226-1066
St. Johns River (Palatka) (386) 329-4500 or 1-800-451-7106
Southwest Florida (Brooksville) (352) 796-7211 or 1-800-423-1476
South Florida (West Palm Beach) (561) 686-8800 or 1-800-432-2045

Sunshine State One Call (locator service)
811 or 800-432-4770 or **www.callsunshine.com**

Appendix B

Florida Cooperative Extension Service Telephone Numbers

County	City	Phone	County	City	Phone
Alachua	Gainesville	(352) 955-2402	Lake	Tavares	(352) 343-4101
Baker	Macclenny	(904) 259-3520	Lee	Ft. Myers	(239) 533-4327
Bay	Panama City	(850) 784-6105	Leon	Tallahassee	(850) 606-5200
Bradford	Starke	(904) 966-6224	Levy	Bronson	(352) 486-5131
Brevard	Cocoa	(321) 633-1702	Liberty	Bristol	(850) 643-2229
Broward	Davie	(954) 370-3725	Madison	Madison	(850) 973-4138
Calhoun	Blountstown	(850) 674-8323	Manatee	Palmetto	(941) 722-4524
Charlotte	Punta Gorda	(941) 764-4340	Marion	Ocala	(352) 671-8400
Citrus	Inverness	(352) 527-5700	Martin	Stuart	(772) 288-5654
Clay	Green Cove Springs	(904) 284-6355	Monroe	Key West	(305) 292-4501
Collier	Naples	(239) 353-4244	Nassau	Callahan	(904) 530-6353
Columbia	Lake City	(386) 752-5384		Yulee	(904) 530-6350
Dade	Homestead	(305) 248-3311	Okaloosa	Crestview	(850) 689-5850
Desoto	Arcadia	(863) 993-4846	Okeechobee	Okeechobee	(863) 763-6469
Dixie	Cross City	(352) 498-1237	Orange	Orlando	(407) 254-9200
Duval	Jacksonville	(904) 387-8850	Osceola	Kissimmee	(321) 697-3000
Escambia	Cantonment	(850) 475-5230	Palm Beach	West Palm Beach	(561) 233-1700
Flagler	Bunnell	(386) 437-7464		Belle Glade	(561) 996-1655
Franklin	Apalachicola	(850) 653-9447	Pasco	Dade City	(352) 518-0470

Gadsden	Quincy	(850) 875-7255	Polk	Bartow	(863) 519-8677
Gilchrist	Trenton	(352) 463-3174	Putnam	East Palatka	(386) 329-0318
Glades	Moore Haven	(863) 946-0244	St. Johns	St. Augustine	(904) 209-0430
Gulf	Wewahitchka	(850) 639-3200	St. Lucie	Ft. Pierce	(772) 462-1660
Hamilton	Jasper	(386) 792-1276	Santa Rosa	Milton	(850) 623-3868
Hardee	Wauchula	(863) 773-2164	Sarasota	Sarasota	(941) 861-5000
Hendry	LaBelle	(863) 674-4092	Seminole	Sanford	(407) 665-0311
Hernando	Brooksville	(352) 754-4433	Sumter	Bushnell	(352) 569-6862
Highlands	Sebring	(863) 386-6540	Suwannee	Live Oak	(386) 362-2771
Hillsborough	Seffner	(813) 744-5519	Taylor	Perry	(850) 838-3508
Holmes	Bonifay	(850) 547-1108	Union	Lake Butler	(386) 496-2321
Indian River	Vero Beach	(772) 770-5030	Volusia	DeLand	(386) 822-5778
Jackson	Marianna	(850) 482-9620	Wakulla	Crawfordville	(850) 926-3931
Jefferson	Monticello	(850) 342-0187	Walton	DeFuniak Springs	(850) 892-8172
Lafayette	Mayo	(386) 294-1279	Washington	Chipley	(850) 638-6180
Pinellas	Largo	(727) 582-2100			

APPENDIX C

FERTILIZER LABEL REQUIREMENTS FOR URBAN TURF, SPORTS TURF, OR LAWNS (RULE 5E-1.003)

a) Definitions:

1. "Urban Turf" or "Lawns" means non-agricultural land planted in closely mowed, managed grasses except golf courses, parks and athletic fields.

2. "Sports Turf" means non-agricultural land planted exclusively for golf courses, parks and athletic fields.

3. "No Phosphate Fertilizer" means fertilizer products with phosphate levels below 0.5% intended for established urban turf or lawns.

4. "Low Phosphate Fertilizer" means fertilizer products intended for new or established urban turf or lawns, with phosphate levels equal to or above 0.5% or as provided in paragraph (2)(b).

5. "Starter Fertilizer" means a fertilizer formulated for a one-time application at planting or near that time to encourage root growth and enhance the initial establishment.

6. "Established Urban Turf" means urban turf older than 12 months.

7. "New Urban Turf" means urban turf established less than 12 months.

b) Fertilizer products labeled for use on sports turf, urban turf or lawns shall be no phosphate or low phosphate and have labeling that meets the restrictions set forth in this rule for the application of nitrogen.

1. No phosphate fertilizers shall not contain more than 0.5% of available phosphate expressed as P_2O_5. The "grade" shall indicate a zero guarantee.

2. Fertilizers labeled as Low phosphate shall have use directions that do not exceed an application rate of 0.25 lbs P_2O_5/1,000 ft^2 per application and not to exceed 0.50 lbs P_2O_5/1,000 ft^2 per year. Label use directions may be included that allow higher rates if an annual soil sample representative for the site shows the need for a higher application rate.

3. Fertilizers labeled as, or formulated for use as, starter fertilizer shall have use directions that do not exceed an application rate of 1.0 lb of P_2O_5/1,000 ft^2 and that subsequent applications shall be made with products meeting the definition of Low or No Phosphate fertilizers. The term "Starter Fertilizer" shall be part of the brand name.

4. Fertilizers labeled as urban turf, sports turf, or lawn fertilizer shall have directions for use for nitrogen that:

   a. Are consistent with the recommendations in the following table:

Appendix Table C.1. Fertilization guidelines for established turfgrass lawns in three regions of Florida.[1]

	Nitrogen recommendations (lbs N/1,000 ft^2/year)		
Species	**North**	**Central**	**South**
Bahiagrass	2-3	2-4	2-4
Bermudagrass	3-5	4-6	5-7
Centipedegrass	1-2	2-3	2-3
St. Augustinegrass	2-4	2-5	4-6
Zoysiagrass	3-5	3-6	4-6

[1]North Florida is north of Ocala. Central Florida is defined as south of Ocala to a line extending from Vero Beach to Tampa. South Florida includes the remaining southern portion of the state.

b. Nitrogen shall not be applied at an application rate greater than 0.7 lbs of readily available nitrogen per 1,000 ft^2 at any one time based on the soluble fraction of formulated fertilizer, with no more than 1 lb total N per 1,000 ft^2 to be applied at any one time and not to exceed the annual nitrogen recommendations in the Fertilization Guidelines for Established Turfgrass Lawns in Three Regions of Florida, set forth herein. Use directions for nitrogen may be included that allow higher rates if an annual tissue sample representative of the site shows the need for a higher application rate.

5. The following language shall appear conspicuously on bags of fertilizer sold at retail: "Do not apply near water, storm drains or drainage ditches. Do not apply if heavy rain is expected. Apply this product only to your lawn/ garden, and sweep any product that lands on the driveway, sidewalk, or street, back onto your lawn/garden."

c) Specialty fertilizers labeled for urban turf or lawns shall have directions for use that include:

1. Application rates for phosphorous shall not exceed 0.25 lbs. P_2O_5/1,000 ft^2 per application and not exceed 0.50 lbs. P_2O_5/1,000 ft^2 per year. Label use directions may be included that allow higher rates if an annual soil sample representative for the site shows the need for a higher application rate.

2. Application rates for nitrogen shall not exceed 0.7 lbs of readily available nitrogen per 1,000 ft^2 at any one time based on the soluble fraction of formulated fertilizer, with no more that 1 lb total N per 1,000 ft^2 to be applied at any one time and not to exceed the annual nitrogen recommendations in the Fertilization Guidelines for Established Turfgrass Lawns in Three Regions of Florida. Use directions for nitrogen may be included that allow higher rates if an annual tissue sample representative of the site shows the need for a higher application rate.

3. Rates shall be expressed in units of weight or volume per unit of area coverage (where application rates are given in volume, the label shall provide sufficient information to calculate the application rates by weight).

4. Rates shall be expressed per 1,000 square feet.

5. Maximum coverage area per container or bag shall be displayed prominently on the front of the container or bag. (i.e. This product covers 5,000 square feet; This bag feeds 4,000 square feet).

d) Fertilizers labeled for sports turf at golf courses, parks and athletic fields shall:

1. Have directions for use not to exceed rates recommended in the document titled SL191 "Recommendations for N, P, K and Mg for Golf Course and Athletic Field Fertilization Based on Mehlich I Extractant", dated March 2007, which is hereby adopted and incorporated by reference into this rule. Copies may be obtained from the Soil and Water Science Department, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida, Gainesville, FL 32611 or the following website: **http://edis.ifas.ufl.edu/SS404**.

2. Have directions for use in accordance with the recommendations in "BMP's for the Enhancement of Environmental Quality on Florida Golf Courses", published by the Florida Department of Environmental Protection, dated January 2007. Copies may be downloaded from **http://www.dep.state.fl.us/water/nonpoint/docs/nonpoint/glfbmp07.pdf**.

e) Fertilizers other than specialty fertilizers labeled for urban turf shall:

1. Have directions for use not to exceed rates recommended in the document titled Best Management Practices for Protection of Water Resources in Florida, June 2002, Florida Green Industries., which is hereby adopted and incorporated by reference into this rule. Copies may be obtained from **http://fyn.ifas.ufl.edu/professionals/GI-BMP_publications.htm**.

f) Existing Stock - Licensees are permitted to sell or distribute products that do not meet the label requirements of the rule for one and one-half years after the effective date of the rule. Products at the retail level on or after the effective date of the rule are permitted to be offered for sale.

Appendix D

Standard Measures and Metric Conversions

Standard measures	Metric conversions
Length	
1 foot (ft) = 12 inches (in)	1 in = 2.54 centimeters (cm)
1 yard (yd) = 3 ft	1 ft = 30.48 cm
1 mile (mi) = 5,280 ft	1 yd = 914.4 millimeters (mm) = 91.44 cm = 0.914 meters (m)
1 mile per hour (mph) = 88 ft/1 minute (min)	1 mi = 1,609 m = 1.61 kilometers (km)
	1 mm = 0.03937 in
	1 cm = 0.394 in = 0.0328 ft
	1 m = 39.37 in = 3.28 ft
	1 km = 3,281 ft = 0.621 mi
Area	
1 square inch (sq in) = 0.007 sq ft	1 sq in = 6.45 square centimeters (sq cm)
1 square foot (sq ft) = 144 sq in	1 sq ft = 929 sq cm
1 square yard (sq yd) = 1,296 sq in = 9 sq ft	1 sq yd = 8,361 sq cm = 0.8361 sq m
1 acre (ac) = 43,560 sq ft = 4,480 sq yd	1 ac = 4,050 sq m = 0.405 hectares (h)
	1 sq cm = 0.155 sq in
	1 sq m = 1,550 sq in = 10.76 sq ft
	1 h = 107,600 sq ft = 2.47 ac
Volume	
1 teaspoon (tsp) = 0.17 fluid ounces (fl oz)	1 fl oz = 29.6 milliliters (ml) = 0.0295 liters (L)
1 tablespoon (tbsp.) = 3 tsp	1 pint (pt) = 473 ml = 0.437 L
1 fl oz = 2 tbsp = 6 tsp	1 quart (qt) = 946 ml = 0.945 L
1 cup = 8 fl oz = 16 tbsp	1 gallon (gal) = 3,785 ml = 3.785 L
1 pt = 2 cups = 16 fl oz	1 ml = 0.033 fl oz
1 qt = 2 pt = 32 fl oz	1 L = 33.8 fl oz = 2.112 pt = 1.057 qt = 0.264 gal
1 gal = 4 qt = 8 pt = 128 fl oz (Note: To convert fl oz to gal, divide by 128)	
Weight	
1 oz = 0.0625 pound (lb)	1 oz = 28.35 grams (g)
1 lb = 16 oz	1 lb = 454 g = 0.4536 kilograms (kg)
1 ton = 2,000 lb	1 ton = 3,907 kg
1 gal of water = 8.34 lb	1 gal of water = 3.786 kg
	1 g = 0.035 oz
	1 kg = 35.27 oz = 2.205 lb

Appendix E

References

Unless otherwise mentioned, references are available from the Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida, Gainesville, FL 32611, or your county UF/IFAS Extension agent.

General Information

Buss, L.J. 2013. *Insect Identification Form*. UF/IFAS Publication RFSR022. **https://edis.ifas.ufl.edu/sr022**.

Florida Board of Professional Engineers. Regulation of Professional Engineering. **http://www.fbpe.org/**.

Florida Department of Business and Professional Regulation. Regulation of Landscape Architecture. **http://www.myfloridalicense.com/dbpr/pro/larch/**.

Florida Department of Environmental Protection. 2007. *Best Management Practices for Enhancement of Environmental Quality on Florida Golf Courses*. **http://www.dep.state.fl.us/water/nonpoint/docs/nonpoint/glfbmp07.pdf**.

Florida Department of Environmental Protection. 2015. Best Management Practices, Public Information, and Environmental Education Resources. **http://www.dep.state.fl.us/water/nonpoint/pubs.htm**.

Florida Fish and Wildlife Conservation Commission Invasive Plant Management Section. Aquatic Plant Removal Permits. **https://public.myfwc.com/CrossDOI/PermitSystem/loginForm.aspx?ReturnUrl=%2fCrossDOI%2fPermitSystem%2fDefault.aspx**.

Harmon, C.L., P.F. Harmon, A.J. Palmateer, M. Paret, and N. Peres. 2013. *Sample Submission Guide for Plant Diagnostic Clinics of the Florida Plant Diagnostic Network*. UF/IFAS Publication RFSR007. **http://edis.ifas.ufl.edu/SR007**.

Mekete, T. and W.T. Crow. 2015. *Nematode Assay Form*. UF/IFAS Publication RFSR023. **https://edis.ifas.ufl.edu/pdffiles/SR/SR02300.pdf**.

Trenholm, L.E. and J.B. Unruh. 2005. *Florida Lawn Handbook*. UF/IFAS publication SP 45 Third Edition. **http://ifasbooks.ufl.edu/**.

UF/IFAS Rapid Turfgrass Diagnostic Service. **http://turfpath.ifas.ufl.edu/rapiddiag.shtml**.

Design and Installation References (Preparation)

Gilman, E.F. 2002. *Specifications for Planting Trees and Shrubs in the Southeastern U.S.* UF/IFAS Publication ENH 856. **http://edis.ifas.ufl.edu/EP112**.

Hansen, G. 2010. *Basic Principles of Landscape Design*. UF/IFAS Circular 536. **http://edis.ifas.ufl.edu/MG086**.

Trenholm, L.E. 2014. *Preparing To Plant a Florida Lawn*. UF/IFAS Publication ENH-02. **http://edis.ifas.ufl.edu/LH012**.

Trenholm, L.E. 2015. *Establishing Your Florida Lawn*. UF/IFAS Publication ENH-03. **http://edis.ifas.ufl.edu/LH013**.

Design and Installation References (Selection)

Trenholm, L.E., J.L. Cisar, and J. B. Unruh. 2014. *St. Augustinegrass for Florida Lawns*. UF/IFAS Publication ENH-5. **http://edis.ifas.ufl.edu/LH010**.

UF/IFAS Landscape Plants. 2015. **http://hort.ifas.ufl.edu/woody/**.

Wunderlin, R.P. 1998. *Guide to the Vascular Plants of Florida*. Gainesville, Florida: University Press of Florida.

Wunderlin, R.P. and B.F. Hansen. 2000. *Atlas of Florida Vascular Plants*. (S.M. Landry and K.N. Campbell [application development], Florida Center for Community Design and

Research). Tampa, Florida: Institute for Systematic Botany, University of South Florida. **http://www.plantatlas.usf.edu/default.asp**.

Environmental Stresses

Trenholm, L.E. 2016. *Environmental Stresses and Your Florida Lawn.* UF/IFAS Publication ENH-153. **http://edis.ifas.ufl.edu/EP070**.

Trenholm, L.E. 2016. *Growing Turfgrass in the Shade.* IFAS Publication ENH-151. **http://edis.ifas.ufl.edu/EP072**.

Trenholm, L.E. and J.B. Unruh. 2015. *Minimizing Traffic Damage to Your Florida Lawn.* UF/IFAS Publication ENH-152. **http://edis.ifas.ufl.edu/EP071**.

Irrigation References

Dukes, M.D. and D.Z. Haman. 2009. *Operation of Residential Irrigation System Controllers.* UF/IFAS Circular 1421. **https://edis.ifas.ufl.edu/ae220**.

Florida Automated Weather Network **http://fawn.ifas.ufl.edu**.

Florida Department of Environmental Protection. 2006. *Landscape Irrigation and Florida-Friendly Design Standards.* **http://www.dep.state.fl.us/water/waterpolicy/docs/LandscapeIrrigationFloridaFriendlyDesign.pdf**

Gilman, E.F. 2002. *Irrigating Landscape Plants During Establishment.* UF/IFAS Publication ENH 857. **http://edis.ifas.ufl.edu/EP113**.

The Irrigation Association. 2005.*Turf and Landscape Irrigation Best Management Practices.* (703) 536-7080, 6540 Arlington Blvd., Falls Church, VA 22042-6638. **http://www.irrigation.org**.

Smajstrla, A.G., B.J. Boman, D.Z. Haman, D.J. Pitts, and F.S. Zazueta. 1997. *Field Evaluation of Microirrigation Water Application Uniformity.* UF/IFAS Publication AE094. **http://edis.ifas.ufl.edu/AE094**.

Smajstrla, A.G., F.S. Zazueta, and D.Z. Haman. 2011. *Potential Impacts of Improper Irrigation System Design.* UF/IFAS Publication SS-AGE-807. **http://edis.ifas.ufl.edu/AE027**.

Trenholm,L.E., J.B. Unruh, and J.L. Cisar. 2013. *Watering Your Florida Lawn.* UF/IFAS Publication ENH 9. **http://edis.ifas.ufl.edu/LH025**.

U.S. Department of Agriculture, Natural Resources and Conservation Service. 2004. *Florida Mobile Irrigation Labs.* **http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs141p2_014930.pdf**.

Zazueta, F.S., A. Brockway, L. Landrum, and B. McCarty. 2014. *Turf Irrigation for the Home.* UF/IFAS Circular 829. **http://edis.ifas.ufl.edu/AE144**.

Mulching, Mowing and Pruning References

Duryea, M.L. 2000. *Landscape Mulches: What are the Choices in Florida?* UF/IFAS Fact Sheet FOR80. **http://edis.ifas.ufl.edu/fr079**.

Florida Department of Environmental Protection. Mangrove Coordination. **http://www.dep.state.fl.us/water/wetlands/mangroves/**.

Trenholm, L.E., J.B. Unruh, and J.L. Cisar. 2015. *Mowing Your Florida Lawn.* UF/IFAS Fact Sheet ENH10. **http://edis.ifas.ufl.edu/LH028**.

UF/IFAS Landscape Plants. Pruning Shade Trees in Landscapes. **http://hort.ifas.ufl.edu/woody/pruning.shtml**.

Fertilization References

Broschat, T.K. 2014. *Fertilization of Field-grown and Landscape Palms.* UF/IFAS Publication ENH 1009. **http://edis.ifas.ufl.edu/EP261**.

Broschat, T.K. 2014. *Nutrient Deficiencies of Landscape and Field-grown Palms in Florida.* UF/IFAS Publication ENH 1018. **http://edis.ifas.ufl.edu/EP273**.

Harper, H.H. and D.M. Baker. 2007. *Evaluation of Current Stormwater Design Criteria within the State of Florida.* Florida Department of Environmental Protection. Contract SO108. **http://www.dep.state.fl.us/water/nonpoint/docs/nonpoint/SW_TreatmentReportFinal_71907.pdf.**

Sartain, J.B. 2015. *General Recommendations for Fertilization of Turfgrasses on Florida Soils.* UF/IFAS Publication SL-21. **http://edis.ifas.ufl.edu/LH014**.

Sartain, J.B. 2015. *Soil and Tissue Testing and Interpretation for Florida Turfgrasses.* UF/IFAS Publication SL-181. **http://edis.ifas.ufl.edu/SS317**.

Sartain, J.B. and W.R. Cox. 2015. *The Florida Fertilizer Label.* UF/IFAS Publication SL-3. **http://edis.ifas.ufl.edu/SS170**.

Weather Terminology: **http://www.wrh.noaa.gov/sew/MediaGuide/TermsOutlooks_Watches_Warnings.pdf**.

Pesticide References

Many documents are available on the Florida Department of Environmental Protection's Nonpoint Source Management Publications web page at **http://www.dep.state.fl.us/water/nonpoint/pubs.htm**.

FDACS Bureau of Licensing and Enforcement, Pesticide Certification and Licensing Section, 3125 Conner Blvd., Bldg. 8, L-29, Tallahassee, FL 32399-1650, Phone: 850-617-7997, **http://www.freshfromflorida.com/Divisions-Offices/Agricultural-Environmental-Services/Bureaus-and-Sections2/Bureau-of-Licensing-and-Enforcement**

UF/IFAS Pesticide Information Office, P.O. Box 110710, Bldg. 164, Gainesville, FL 32611-0710, Phone: 352-392-4721, **http://pested.ifas.ufl.edu/**

Operation Cleansweep: **http://www.dep.state.fl.us/waste/categories/cleansweep-pesticides/**

In-depth profiles of insects, nematodes, arachnids and other organisms that are of interest: *Featured Creatures* at **http://entomology.ifas.ufl.edu/creatures/**.

Information on lawn, landscape, and ornamental pests: **http://edis.ifas.ufl.edu/TOPIC_Ornamental_Pests**.

Designing Facilities for Pesticide and Fertilizer Containment. MWPS-37. 1995. Midwest Plan Service, 4306D Elings Hall, Iowa State University, Ames, IA 50011. Telephone (515) 294-4337. **http://www.mwps.org/**.

Agrichemical Handling Facility, Code 309. 2008. U.S. Department of Agriculture, Natural Resources Conservation Service, P. O. Box 141510, Gainesville, FL 32605. Telephone (352) 338-9555. **http://efotg.nrcs.usda.gov/references/public/FL/fl309_March_2008.pdf**.

Buss, E.A. and A.G. Dale. 2016. *Landscape Integrated Pest Management.* UF/IFAS Publication ENY-298. **http://edis.ifas.ufl.edu/in109**.

Buss, E.A. 2014. *Commercial Applications of Insecticides and Miticides in the Green Industry.* UF/IFAS Publication ENY-337. **http://edis.ifas.ufl.edu/IG145**.

Buss, E.A. and A.G. Dale. 2016. *Insect Pest Management on Turfgrass.* UF/IFAS Publication ENY-300. **http://edis.ifas.ufl.edu/IG001**.

Crow, W.T. 2014. *Nematode Management in Residential Lawns.* UF/IFAS Publication ENY-006. **http://edis.ifas.ufl.edu/NG039**.

Crow, W.T. 2014. *Nematode Management for Perennial Landscape Plants in Florida.* UF/IFAS Publication ENY-051. **http://edis.ifas.ufl.edu/IN469**.

Dean, T.W., O.N. Nesheim, and F.M. Fishel. 2014. *Pesticide Container Rinsing.* UF/IFAS Publication PI-3. **http://edis.ifas.ufl.edu/PI003**.

Elliott, M.L. and P.F. Harmon. 2014. *Turfgrass Disease Management.* UF/IFAS Publication SSPLP14. **http://edis.ifas.ufl.edu/LH040**.

Fishel, F.M. 2013. *Spray Gun Calibration.* UF/IFAS Publication PI-225. **http://edis.ifas.ufl.edu/pi225**.

Harmon, P.F. and S.D. Bledsoe. 2012. *Professional Disease Management Guide for Ornamental Plants.* UF/IFAS Publication PP-202. **https://edis.ifas.ufl.edu/pp123**.

Harmon, P.F. and M.L. Elliott. 2014. *Key for Identification of Landscape Turfgrass Diseases.* UF/IFAS Publication SS-PLP-1. **http://edis.ifas.ufl.edu/LH064**.

Marble, C. and A. Koeser. 2015. *Improving Weed Control in Landscape Planting Beds.* UF/IFAS Publication ENH1262. **https://edis.ifas.ufl.edu/ep523**.

Mizell, R.F. and D.E. Short. 2009. *Integrated Pest Management in the Commercial Ornamental Nursery.* UF/IFAS Publication ENY-336. **http://edis.ifas.ufl.edu/IG144**.

Sellers, B.A., J.A. Ferrell, G.E. MacDonald, and D.C. Odero. 2016. *Single-Nozzle Backpack or ATV Sprayer Calibration.* UF/IFAS Publication SS-AGR-108. **http://edis.ifas.ufl.edu/wg217**.

Unruh,B., R.G. Leon, B.J. Brecke, and L.E. Trenholm. 2015. *Weed Management Guide for Florida Lawns*. UF/IFAS Publication ENH884. **https://edis.ifas.ufl.edu/ep141**.