SM 5

Agricultural Row Crop Pest Control

by Fred Fishel
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SM 5 Agricultural Row Crop Pest Control
3rd Edition
Fred Fishel, PhD

A training manual for persons preparing for a Restricted Use Pesticide Applicator License in the Agricultural Row Crop 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 agricultural row crop pesticide applicators who want to become certified as applicators of restricted-use pesticides for controlling pests of agricultural row crops under the provisions of the Florida Pesticide Law (Chapter 487 Florida Statutes) and its rules (Chapters 5E-2 and 5E-9 of the Florida Administrative Code). It is intended to accompany the 'Core' training manual, *Applying Pesticides Correctly—A Guide for Private and Commercial Applicators, SM-1*.

The material presented in this manual offers agricultural row crop applicators the detailed knowledge that they must have to be fully prepared for the agricultural row crop pest control certification exam.

In addition, an agricultural row crop pest control 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 eight chapters:

Ch. 1 Licensing of Agricultural Row Crop Pest Control Applicators in Florida

Ch. 2 Understanding the Label

Ch. 3 Agricultural Row Crop Pest Identification

Ch. 4 Integrated Pest Management

Ch. 5 Pesticide Use

Ch. 6 The Worker Protection Standard and Commercial Pesticide Handler Employers

Ch. 7 Application Equipment

Ch. 8 Equipment Calibration and Calculating Site Sizes

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 and conversion factors used in making calculations related to making pesticide applications.

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 Agricultural Row Crop Pest Control Applicators in Florida

In this Chapter

Learning Objectives

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

- Define the term "agricultural row crop pest control applicator."
- Explain the standards for certification of agricultural row crop pest control applicators.
- Know the cost of the agricultural row crop pest control applicator license for:
  - Commercial applicators.
  - Public applicators.
- Understand the exam process for agricultural row crop pest control applicators.
- Understand the process of recertification to keep your license valid.
- Define the term "restricted use pesticide."

Terms to Know

Continuing education unit (CEU): Approximately one hour of study credit used to make up the total of 12 CEUs required for agricultural row crop pest control applicator recertification.

Florida Department of Agriculture and Consumer Services (FDACS): The agency that administers the Florida Pesticide Law (Chapter 487).

Florida Pesticide Law: The law that governs the use of pesticides in Florida, which is administered by the Florida Department of Agricultural and Consumer Services (FDACS).

Agricultural row crop pest control applicator: An individual who is licensed to use, purchase, or supervise the use of restricted use pesticides, or other pesticides requiring licensure, in the production of agricultural crops other than tree crops, including but not limited to tobacco, peanuts, cotton, feed grains, soybeans, forage crops, vegetables, small fruits not produced on trees, grasslands, or non-crop agricultural lands, but not including the use or supervision of restricted use fumigant pesticides.

Recertification: The process by which licensed pesticide applicators accumulate continuing education units in order to keep the license valid.

Restricted use pesticides (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.

The Agricultural Row Crop Pesticide Applicator Agricultural License

The licensing and regulation of persons who supervise the use or apply ground application of restricted use pesticides to agricultural row crop commodities in Florida (Figure 1.1) is controlled by the Florida Pesticide Law (Chapter 487) which is administered by the Florida Department of Agriculture and Consumer Services (FDACS). The licensing program is managed by the FDACS Bureau of Licensing and Enforcement. An agricultural row crop pest control applicator must be at least the age of majority (18) to be licensed.

How do I know if I need a license to purchase, use, and supervise the use of restricted use pesticides for pest control in agricultural row crop commodity production in Florida? This license is for all persons who apply or supervise the application of restricted use pesticides to agricultural row crops.

Does the agricultural row crop pest control applicator license allow for supervision of unlicensed employees? Yes; a license holder may directly supervise up to 15 employees. Licensed applicators are responsible for the pesticide use activities and actions of individuals under their direct supervision and must be in a location from which they can physically arrive on site before or during pesticide use, if and when their presence is needed. The licensed applicator must be immediately available for verbal communication with persons under his or her immediate supervision to provide direction and instructions during all times pesticides are being used.

Figure 1.1: Pesticide application to a peanut crop. Credit: Doug Mayo, UF/IFAS Extension, Jackson County.

Information on how to obtain this licenses can be obtained from FDACS Bureau of Licensing and Enforcement at (850) 617-7997 or at **https://www.freshfromflorida.com/Business-Services/Pesticide-Licensing/Pesticide-Applicator-Licenses**.

Restricted Use Pesticides (RUP)

Restricted use pesticides are 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. 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 statement describing the reason for the restricted classification (Figures 1.2 and 1.3).

There are various reasons which are determined by the U.S. Environmental Protection Agency (EPA) why a particular pesticide is classified as restricted. These criteria involve the EPA's determination that the pesticide may be hazardous to human health or to the environment even when used according to the label.

Figures 1.2 and 1.3: There are various reasons why EPA classifies pesticides as "restricted use." Credit: CDMS.

Category Certification Standards

Applicators seeking a license in this category must demonstrate practical knowledge of:

- agricultural row crops and associated pests;
- the chemical control measures that pertain to the prevention or control of such pests;
- the equipment or methodologies used to safely and effectively implement such measures;
- the potential for pesticide residues on such crops;
- preharvest application intervals;
- post-application reentry interval restrictions;
- phytotoxicity;
- pesticide-related soil or water problems;
- potential for pesticide-induced environmental contamination;
- non-target injury and community problems that may result from the improper use of pesticides in agricultural row crop production;
- the procedures and equipment used to apply pesticides with irrigation water through an irrigation system;
- calibration of equipment for applying pesticides with irrigation water;
- proper design, use, and maintenance of anti-siphon devices and check valves to prevent pesticide contamination of water supplies;
- proper interpretation of pesticide labels or labeling requirements for products registered for chemigation; and
- appropriate use of personal protective equipment associated with this type of application.

License Classification

Certified agricultural row crop pest control applicators may be licensed as either public applicators or commercial applicators. These are the major differences:

- A public applicator is a licensed applicator employed by a public or governmental agency. The license is only valid when performing work for the public or governmental agency. The public applicator fee for a four-year license is $100.
- A commercial applicator is a licensed applicator who is licensed to apply restricted-use pesticides on any property provided they are certified in the category for which the applications are made. A commercial applicator is usually a contract applicator. The commercial applicator fee for a four-year license is $250.

Qualifications and Examinations

There are no special qualifications or training required to apply for the certification exams and license other than the person must be 18 years of age. Persons must successfully complete two examinations before they can apply to the FDACS for a license. These examinations are a Core examination and the Agricultural Row Crop Pest Control Applicator category examination.

The Core examination and the Agricultural Row Crop Pest Control Applicator category examination may be taken at any University of Florida IFAS County Extension Office (Figure 1.4). Exams are available in paper format at all extension offices and online at select offices. Regardless of exam format, apply online through the FDACS licensing portal located at: **https://aesecomm.freshfromflorida.com/** to schedule examinations at an office convenient to your location. There are no fees to take the examinations.

Exam scores are immediately available upon completion of online exams. The Bureau of Licensing and Enforcement grades the paper exams and sends exam results to examinees by U.S. Postal Service. Exam scores for paper exams should reach individuals in two to three weeks after

Figure 1.4: Aspiring applicators must pass the examinations to apply for a license. Credit: UF/IFAS Pesticide Information Office.

testing. To obtain scores for paper exams online, go to **http://aessearch.freshfromflorida.com/**. Scores for paper exams are available online approximately two to three weeks following the test date.

Study Materials

Exam preparation materials for the Core exam are available in two formats: written manuals or interactive DVDs. Each format contains the same content. Exam preparation materials for the category exam are available only in written format. All materials may be purchased from the UF/IFAS Extension Bookstore by calling (800) 226-1764 or online at **https://ifasbooks.ifas.ufl.edu/**. See Table 1.1 for information.

License Application

Upon successful completion (70%) of the exams, FDACS sends the individual an Agricultural Row Crop Pesticide Applicator license application. The license application and license fee can be submitted online via the FDACS licensing website **https://aesecomm.freshfromflorida.com/** or the individual may mail in payment with the completed application. Licenses processed online will be issued electronically next-day.

Table 1.1. Study materials for the Agricultural Row Crop Pest Control Applicator exams.

Exam	Publication	Publication number	Price ($)
Core	Applying Pesticides Correctly written manual	SM-1	24.00
	Applying Pesticides Correctly interactive DVD	SM-69	30.00
Category	Agricultural Row Crop Pest Control written manual	SM-5	30.00

Procedures for Recertification and License Renewal

What is recertification? Recertification is a demonstration of continued competency in the safe and proper use of pesticides, which is required before a license can be renewed. Recertification may be accomplished by either retaking the certification examinations or accumulating 12 continuing education units (CEUs) during the license period. The exams required for recertification are the same exams required for initial certification. Recertification exams should be scheduled following the same procedures used for initial certification. The agricultural row crop pest control license requires four core and eight category CEUs (12 total) for a four-year renewal. Applicators may choose to renew by a combination of exams and CEUs. However, reexamination is required if the license has been revoked or suspended for six months or longer or it is deemed by the FDACS that new information concerning pesticide use, application techniques, or impact on health or the environment makes reexamination essential for continued certification.

How do I earn CEUs to renew my certification and license? Training classes approved by the FDACS to issue CEUs are given statewide and in some out-of-state locations. The majority of the CEU programs are sponsored by the local Cooperative Extension Service offices in each county. To find out where and when approved training classes will be held, and the number of CEUs approved, applicators should check the online CEU Class Search at **http://ceupublicsearch.freshfromflorida.com/** (click Available CEU Classes). Online approved CEU courses are also available and may be accessed from this site or by going directly to **https://pested.ifas.ufl.edu/ceu/**. Applicators may also check with local Cooperative Extension Service offices or with the Bureau of Licensing and Enforcement in Tallahassee at (850) 617-7870. A directory of Cooperative Extension Service offices is available in Appendix B of this publication or online at **http://directory.ifas.ufl.edu/Dir/searchdir?pageID=3&pl=05**. An expired license can be renewed for up to one year after expiration using either exams or CEUs.

How do I renew my license following meeting the recertification requirements? Licenses should be renewed on or before the license expiration date. Applicators renewing after the expiration date must not purchase or use restricted use pesticides while the license is expired. Applicators will be required to affirm on the renewal notice that restricted use pesticides have not been purchased or used since the license expired.

Licenses can be renewed up to 60 days after the expiration date without incurring any late fees. However, a $50 late fee is required if a license is renewed more than 60 days after it has expired. If a license has been expired for one year or longer, the license may not be renewed. The individual must retake the certification examinations and get a new license.

FDACS sends renewal notices to all licensees approximately 60 days before a license expiration date. It is the applicator's responsibility to notify FDACS in writing of any change in mailing address or other personal information on file. To change mailing addresses or personal information, go online to **http://forms.freshfromflorida.com/13359.pdf** for the form to complete.

Recordkeeping Requirements

The Florida Pesticide Law and Rules require licensed pesticide applicators to maintain records relating to the application of all restricted use pesticides. The records must contain the following elements:

- Name and license number of the licensee responsible for the pesticide application.
- Name of the person who actually applied the pesticide.
- Date, start time, and end time of treatment.
- Location of treatment site, which may be recorded using any of the following designations:
  - County, range, township, and section.

- An identification system utilizing maps and/or written descriptions which accurately identify the location and distinguish the treatment site from other sites.
- The identification system established by the United States Department of Agriculture found at 7 CFR § 110 (1994) which utilizes maps and a numbering system to identify field locations.
- The legal property description.
- Global Positioning System (GPS) coordinates or longitude/latitude points that delineate the treated area.

- Crop, commodity, or type of target site treated.
- Total size (in acres, square feet, acre-feet, or other appropriate units) of the treatment site.
- Brand name and EPA registration number of the pesticide product applied.
- Total amount (pounds, gallons, etc.) of formulated product applied.
- Application method.
- Name of the person requesting or authorizing the application, or a statement of authority to make such application, if the application was made to property not owned or leased by the licensee.

The required information must be recorded no later than two working days after the date of application and may be incorporated into other business transaction records. All records must be retained for a period of two years and maintained in a manner that is accessible to authorized representatives. A suggested recordkeeping form developed by FDACS is available online at **https://www.freshfromflorida.com/content/download/81151/2340985/Suggested_Pesticide_Recordkeeping_Form.pdf**. Although this specific form is not required, it does contain spaces for providing the required data to be recorded.

Organo-Auxin Herbicide Rule

Sublethal doses of organo-auxin herbicides, such as the phenoxy herbicides 2,4-D and triclopyr, cause very visual effects to sensitive plant species, indicative of plant growth hormonal action (Figure 1.5). Due largely to phenoxy herbicide applications in south Florida on sugarcane and drift or volatilization to nearby tomato crops and their subsequent destruction, FDACS enacted the Organo-Auxin Herbicide Rule (Table 1.2).

Figure 1.5: Organo-auxin herbicide injury to cotton seedlings, a sensitive species. Credit: UF/IFAS Pesticide Information Office.

A suggested recordkeeping form developed by FDACS is available online at **http://forms.freshfromflorida.com/13328.pdf**. Although this specific form is not required, it does contain spaces for providing the required data to be recorded.

Table 1.2. Florida Organo-auxin Herbicide Rule.

Restrictions and Prohibitions			
1.	Synthetic organo-auxin herbicides: the Synthetic organo-auxin herbicides are defined as herbicides which produce hormonal auxin type effects on plants similar to the effects of 2,4-D. These herbicides include:		
	2,4-D	2,4-Dichlorophenoxyacetic acid, in all forms;	
	2,4,5-T	2,4,5-Trichlorophenoxyacetic acid, in all forms;	
	Silvex	2-(2,4,5-Trichlorophenoxy)propionic acid, in all forms;	
	MCPA	4-chloro-2-methylphenoxyacetic acid, in all forms;	
	2,4-DP	2-(2,4-Dichlorophenoxy)propionic acid, in all forms;	
	MCPP	2-(2-methyl-4-chlorophenoxy)propionic acid, in all forms;	
	MCPB	4-(2-methyl-4-chlorophenoxy)butyric acid, in all forms;	
	Dicamba	2-Methoxy-3, 6-dichlorobenzoic acid, in all forms;	
	Triclopyr	(3,5,6,-Trichloro-2-pyridinyl)oxyacetic acid, in all forms;	
2.	Sale and use of highly volatile forms of organo-auxin herbicides in the state is prohibited except for those products labeled for use as plant growth regulators on citrus. Highly volatile organo-auxin herbicides include the methyl, ethyl, propyl, isopropyl, and butyl esters of 2,4-D, etc.		
3.	Based upon the wind speed and direction at the time of application, the distance which must separate the closest edge of the area to be sprayed from susceptible crops is listed below. Susceptible crops are defined as commercially produced plants or crops that may be damaged when exposed to low concentrations of organo-auxin herbicides. Users of organo-auxin products on citrus as plant growth regulators are exempt from the wind speed restrictions below provided they adhere to the restrictions appearing on the product label.		
	Wind Speed	**Aerial Equipment**	**Ground Equipment**
	0 - 3 mph	½ mile downwind	1/8 mile downwind
		½ mile crosswind	1/8 mile crosswind
		50 feet upwind	20 feet upwind
	3 - 6 mph	1 mile downwind	1/4 mile downwind
		½ mile crosswind	1/8 mile crosswind
		50 feet upwind	5 feet upwind
	6 - 10 mph	2 miles downwind	½ mile downwind
		½ mile crosswind	1/4 mile crosswind
		50 feet upwind	5 feet upwind
	Above 10 mph	Prohibited	Prohibited
Note: “Crosswind” means wind from a direction 90 degrees (+/-10 degrees) to a line drawn between the proposed treatment site and a susceptible commercial crop site.			

4.	Wind speed will be measured at the crop site or up to two miles away. Wind speed measurements will be taken at spray boom height for ground application and at least six feet above the ground for aerial application. The measurement site will be located so that structures, plants, or terrain features do not interfere with the accuracy of the reading. Wind direction will be estimated as accurately as possible by the person taking the wind speed readings. THE APPLICATOR OR HIS REPRESENTATIVE SHALL TAKE AND RECORD WIND SPEED AND DIRECTION READINGS BEFORE SPRAYING STARTS AND ONCE EVERY HOUR OF THE SPRAYING OPERATION. A reading shall consist of an average of three measurements taken within a five-minute interval. These measurements shall be taken by rotating and positioning the anemometer into the wind in such a manner as to obtain the maximum wind velocity measurements which will be used to calculate the average reading. An anemometer accurate to within +/-10% shall be used to take the wind speed measurements.	
5.	Applicators should minimize the production of droplets with mean volume diameter less than 200 microns in diameter regardless of spray equipment utilized. When utilizing boom application equipment on the ground, flat fan nozzles or their equivalent should be used and application pressures should not exceed 35 pounds per square inch. Applications of organo-auxin herbicides on citrus as a plant growth regulator utilizing air blast sprayers are exempt from the requirements of this section.	
6.	Persons making spray applications of organo-auxin herbicides to cumulative land or water surface areas exceeding five acres per 24-hour period, shall maintain the following records for two years:	
	a.	Name and address of the owner, lessee or tenant person(s) in control of the land (owner, lessee or tenant), and the name and address of the applicator.
	b.	Location of the site to be treated, location of the herbicide mixing and loading area and description of application equipment used.
	c.	Date and time of application.
	d.	Trade name, manufacturer, formulation, total amount of product to be applied per acre and the amount of active ingredient of the product applied per acre.
	e.	Total acreage and crop or site treated.
	f.	Average hourly wind speed and direction.
	g.	Nozzle type including gallons per minute rating at specified pressure (usually 40 psi) and angle of spray emission if applicable.
7.	AERIAL APPLICATION OF ORGANO-AUXIN HERBICIDES BY FIXED WING AIRCRAFT FROM JANUARY 1 UNTIL MAY 1 OF EACH YEAR IN HENDRY, PALM BEACH, GLADES, OR MARTIN COUNTIES IS PROHIBITED. The use of rotary wing aircraft using Microfoil spray booms or their equivalent for right-of-way and aquatic spray applications is allowed provided the terms of subsections 2, 3, 4, 5 and 6 are met.	
8.	Applicators who apply organo-auxin herbicides to ditches, canals, or the banks of similar waterways will assure that they are not treating water that will be directly used for irrigation of sensitive crops.	
9.	The ground application of low volatility 2,4-D products registered in the State of Florida for use as a growth regulator on red potatoes in small dosages substantially less than for herbicidal use is not subject to the use regulations and restrictions set forth in subsections (3) and (4) of this rule provided the product is not applied within 50 feet of susceptible crops, the spray boom height does not exceed 18 inches above the crop canopy and label instructions are followed.	
	SPECIFIC AUTHORITY: 487.051(4); 487.154, 570.07(23) F.S. LAW IMPLEMENTED: 487.031(10), (13)(e) FS. 487.031(8); 487.051(2)(d), (4) F.S. HISTORY: New 2/4/86; Amended 7/10/89, 7/29/04.	

Test Your Knowledge

Q: An agricultural row crop pest control applicator is a person who applies:

A. Any type of pesticide
B. Pesticides that are toxic to honeybees
C. Restricted use pesticides
D. Pesticides that are not EPA-registered

A: C

Q: The practical knowledge that agricultural row crop pest control applicators must demonstrate for certification is based upon the:

A. Knowledge obtained while pursuing a secondary education degree
B. Category certification standards
C. EPA-approved training courses for this category
D. 1960's novel, "Silent Spring"

A: B

Q: Match the license category with the cost of a four-year license.

1. Commercial	A. $100
2. Public	B. $250

A: 1-B; 2-A

Q: The location to take restricted use pesticide certification exams is at:

A. The FDACS main office in Tallahassee
B. EPA headquarters in Washington D.C.
C. Local public libraries
D. County extension offices that offer the service

A: D

Q: The number of continuing education units (CEUs) that an agricultural row crop pest control applicator must obtain to keep the license valid:

A. Four core and eight category
B. Four core and four category
C. Two core and two category
D. One core and one category

A: A

Q: A "restricted use pesticide" is one that is:

A. Only approved for purchase and use by certified applicators and those under their direct supervision
B. Only approved for purchase and use by members of Local Union UAW 486
C. Only approved for purchase and use by government employees performing regulatory pest control
D. Only approved for purchase and use by public applicators conducting mosquito control programs

A: A

Additional Information

Florida Department of Agriculture and Consumer Services Bureau of Licensing and Enforcement, Pesticide Licensing Section, 3125 Conner Drive, Bldg. 8, Tallahassee, FL 32399-1650. Telephone (850) 617-7870; Fax (850) 617-7895. **https://www.freshfromflorida.com/Business-Services/Pesticide-Licensing/Pesticide-Applicator-Licenses/Pesticide-Applicator-Certification-and-Licensing**.

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

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 or Chemical Hazards
  - Limited Warranty and Disclaimer
  - Directions for Use
  - Storage and Disposal

Terms to Know

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

Acute effect: An illness that becomes apparent soon, usually within 24 hours, after exposure to a pesticide occurs.

Application rate: The amount of pesticide 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. A few of the least toxic pesticides don't have a signal word.

Certified applicator: A person who has demonstrated, through an examination process, the knowledge 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 U.S. 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 items such as coveralls, eye protection, gloves, boots, respirators, aprons, and hats.

Registration number: Numbers assigned to a pesticide product to identify that the product has been registered by the U.S. 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: Highly hazardous pesticides that can only be possessed or used by applicators who are certified and licensed.

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 on treating people exposed to the pesticide. This includes emergency first aid information.

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

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

Introduction

Whenever a pesticide is part of a pest management plan, understanding the contents of the pesticide label is essential for the safe and effective use of the product.

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 U.S. 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 (Figure 2.1). 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 as the main source of information on how to use the product correctly, legally, and safely.

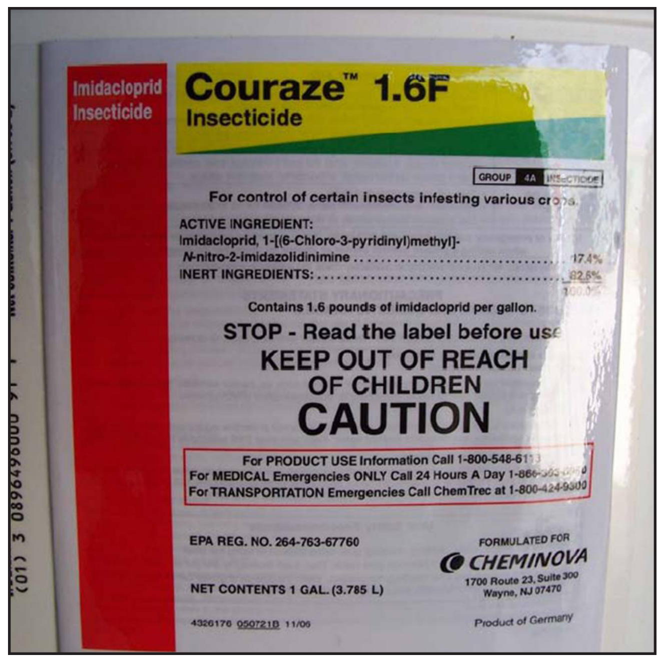


Figure 2.1: The label is the information on or attached to the product container. Credit: FDACS.

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. 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 that 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 labels of products they will be using on a regular basis.

You should carefully read the entire label so you know how to properly mix, apply, and store the pesticide.

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.

Safety Information

[1]Child Hazard Warning

The front panel of every pesticide label must bear the statement, "KEEP OUT OF REACH OF CHILDREN." Poisoning is a major cause of injuries to children. 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.

Research workers test pesticides on mice, rats, rabbits, and dogs. They divide laboratory animals into several groups and test different routes of exposure (skin, mouth, eyes, lungs). They rate a pesticide's toxicity by determining the amount, or lethal dose (LD_{50}), that kills 50% of a test population as shown in Table 2.1.

Table 2.1. Acute toxicity label signal words.

Signal word	Category	Oral lethal dose (LD_{50})[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 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).

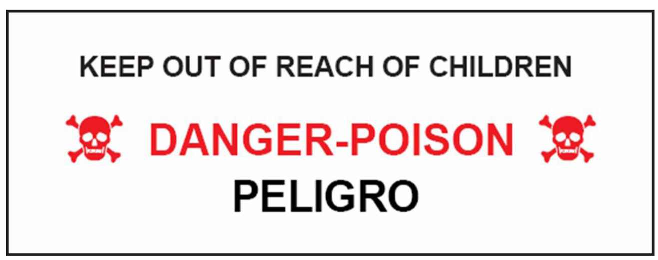


Figure 2.2: Example of a "Danger-Poison" pesticide label signal word. Credit: CDMS.

[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.”

In this section 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) must particularly be protected and what specific action is needed 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 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 of the materials that are chemical-resistant to this product are listed below. If you want more options, follow the instructions for category A on an EPA chemical-resistance category chart.

Applicators and other handlers must wear: long sleeved shirt and long pants, shoes plus socks, and chemical resistant gloves made of any waterproof material such as polyethylene or polyvinyl chloride.

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

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."

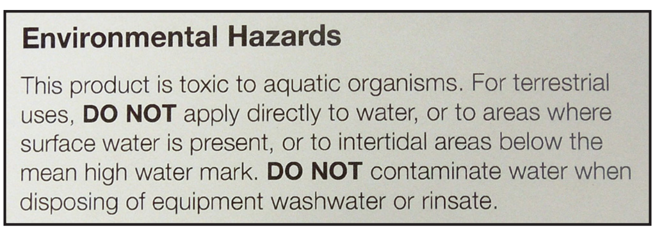


Figure 2.4: Practically all labels carry concerns about water contamination. Credit: CDMS.

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, apply, and/or supervise someone handling restricted use pesticides, a person must be certified and licensed in the state of Florida.

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

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 or work under the direct supervision of a certified and licensed individual 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, PROVOST, is displayed prominently. Credit: UF/IFAS Pesticide Information Office.

[9] Ingredients 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 Ingredient:	
spinetoram (a mixture of spinetoram-J and spinetoram-L)	25.0%
Other Ingredients	75.0%
Total	100.0%
Contains 25% active ingredient on a weight basis (250 g ai/kg)	

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

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

Some manufacturers will describe the product formulation on the front panel folowing the brand name; others may state this information elsewhere, such as in the product information section. 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 agricultural 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 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 Requirements 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 (WPS) applies to the product. When the Worker Protection Standard applies, a statement regarding information on employee notification of restricted entry intervals and personal protective equipment for early entry is stated here. This notice also lets you know that when the product is used you must now follow the WPS as well as the label. 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.

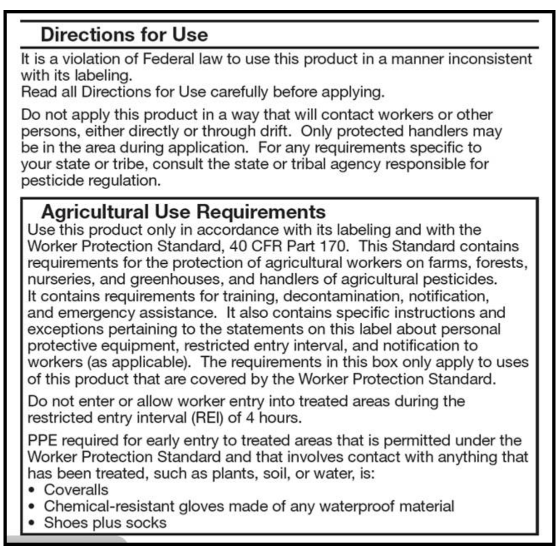
- A description of how the product should be applied and by which type of application equipment it is most effectively applied.

- 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.”

- 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.



Directions for Use

It is a violation of Federal law to use this product in 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 state or tribal 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 requirements for the protection of agricultural workers on farms, forests, nurseries, and greenhouses, and handlers of agricultural pesticides. It contains requirements for training, decontamination, notification, and emergency assistance. It also contains specific instructions and exceptions pertaining to the statements on this label about personal protective equipment, restricted entry interval, and notification to workers (as applicable). 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 4 hours.

PPE required for early entry to treated areas that is permitted under the Worker Protection Standard and that involves contact with anything that has been treated, such as plants, soil, or water, is:
- Coveralls
- Chemical-resistant gloves made of any waterproof material
- Shoes plus socks

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

[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: Super Fly Away Insecticide

Q: Who is the manufacturer of this pesticide?

A: Bugsby, Inc.

Q: What does this pesticide control?

A: Insects

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 control of corn earworm?

A: Two ounces product per acre

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: 901-358

Sample Label

[7]Restricted Use Pesticide
(GROUND AND SURFACE WATER CONCERNS)
For sale to 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]Super Fly Away Insecticide
3.5 EC[14]

[9]Active Ingredient
Killzdamine (2,4 butyl-ptoluidine)..........24.5%
Inert Ingredients............................75.5%
1 gal contains 3.5 lb killzdamine
[10]NET CONTENTS 2.5 GALS (9.46 L)
[11]EPA REG. #901-358
[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.

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

AGRICULTURAL USE REQUIREMENTS
Use this product only in accordance with its labeling and with the Worker Protection Standard, 40 CFR part 170. Do not allow worker entry into treated areas during the restricted entry interval of 4 hours. PPE required for early entry to treated areas—that is permitted under the Worker Protection Standard and that involves contact with anything that has been treated; such as plants, soil, or water—is •coveralls •waterproof gloves •shoes plus socks.

Cucurbit vegetables: Armyworms and corn earworms: apply 2 ounces product per acre. Allow at least 10 days before making a second application.

[1]KEEP OUT OF REACH OF CHILDREN
[2]CAUTION
[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
Bugsby Inc. warrants that this insecticide conforms to the chemical description on its label. When used in accordance with label directions under normal conditions, this insecticide 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]Bugsby, Inc.
2738 Washington Hwy.
PO BOX 4603
Pensacola, FL 64208-0603

Chapter 3

Agricultural Row Crop Pest Identification

In this Chapter

Learning Objectives

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

- Explain the importance of correctly identifying pests.
- Explain the importance of knowing the life cycles and habits of pests.
- Name two physical characteristics that all insects have in common.
- List four types of insect mouthparts and give examples of insects that have each type.
- Define "plant disease."
- List the main types of pathogens that cause plant diseases.
- Describe some ways plants respond to diseases.
- Explain how symptoms and signs can help you diagnose a plant disease.
- Name and describe the four developmental stages of weeds.
- Distinguish between annual, biennial, and perennial weeds.
- Distinguish between the three types of weeds.
- Describe nematodes in general.
- Explain how nematodes damage agricultural row crops.
- Describe the only positive method for detecting the presence of nematodes.
- Give two examples of vertebrate pests and the types of damage they cause.

Terms to Know

Abiotic: Nonliving factor affecting plant health, such as nutrient deficiency, drought stress, or temperature extremes.

Annual weed: Weed that lives one year or less.

Arthropod: Organism with an external skeleton and jointed body parts.

Biennial weed: Weed with a two year life cycle.

Biotic: Living pathogenic microorganisms that cause plant disease, including bacteria, fungi, viruses, and viroids.

Complete metamorphosis: Insect life cycle in which the insect passes through four stages of development: egg, larva, pupa, and adult.

Gradual metamorphosis: Insect life cycle in which the insect passes through three different stages of development: egg, nymph, and adult.

Host: The living plant or animal a pest depends on for survival.

Hyphae: In a fungus, one of the threadlike elements of the mycelium.

Life cycle: The series of stages an organism passes through during its lifetime.

Mycelium: The vegetative part of a fungus, consisting of a mass of branching, thread-like hyphae.

Nematode: Small, usually microscopic, roundworms; some are parasites of plants.

Parasite: An organism that lives and feeds on or in an organism of another species.

Pathogen: Any disease-producing organism.

Perennial weed: Plant that normally lives more than two years.

Plant disease: Any harmful condition that makes a plant different from a normal plant in its appearance or function.

Saprophyte: An organism, especially a fungus or bacterium, that derives its nourishment from 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.

Vertebrate: Any animal that has a jointed backbone; examples include snakes, fish, lizards, frogs, birds, rats, bears, and humans.

Pest Identification

Correct identification of pests and a working knowledge of their development and behavior are key to effective pest control. In this chapter, pests are grouped into five broad categories:

1. arthropods,
2. weeds,
3. plant diseases,
4. nematodes, and
5. vertebrates.

When you find a pest or pest problem you cannot identify, ask an expert to help you. When having pests identified, always collect several specimens. There is professional assistance available, such as through the University of Florida Plant Diagnostic Network. UF/IFAS county Extension agents, specializing in agricultural plant production, have expertise in pest identification and are in close contact with other UF/IFAS specialists. Additionally, many private crop care firms have experts on their staff who can provide assistance.

- UF/IFAS Plant Diagnostic Center–Gainesville
  (352) 273-4638
  http://plantpath.ifas.ufl.edu/extension/plant-diagnostic-center/

- North Florida Research and Education Center–Quincy
  (850) 875-7140
  http://nfrec.ifas.ufl.edu/plant-disease-diagnostic-clinic/#d.en.215206

- Gulf Coast Research and Education Center–Wimauma
  (813) 419-6670
  http://gcrec.ifas.ufl.edu/plant-clinic/

- Tropical Research and Education Center–Homestead
  (305) 246-7001
  http://fpdn.ifas.ufl.edu/trec.shtml

- Southwest Florida Research and Education Center–Immokalee
  (239) 658-3432
  http://fpdn.ifas.ufl.edu/swfrec.shtml

- Insect Identification Service–Gainesville
  (352) 392-1901
  http://fpdn.ifas.ufl.edu/ufmain-insect-lab.shtml

- UF Nematode Assay Lab–Gainesville
  (352) 392-1994
  http://nematology.ifas.ufl.edu/assaylab/

The difficulty in identifying certain pests in the field is their small size. Accurate identification requires the use of a hand lens or microscope, laboratory tests, or careful analysis of damage (Figure 3.1). Often the pest's host association and location are important to making positive identifications. Information on the environmental conditions where you collect the specimens and the time of year can provide valuable identification evidence.

Figure 3.1: The University of Florida offers assistance with plant pest diagnosis. Credit: UF/IFAS Pesticide Information Office.

Pest species may have vastly diverse physical forms depending on their life cycles (Figure 3.2). For example, many insect species, especially those with a complete metamorphosis, undergo extreme changes in appearance as they develop from egg through the adult stage.

Figure 3.2: Fall armyworm larva and adult. Credit: Lyle Buss, UF/IFAS Department of Entomology and Nematology.

Pests may leave signs of their presence that help you determine their identity (Figure 3.3). The type of feeding damage helps you identify many insects. Fungi and other pathogens sometimes cause specific types of damage, deformation, or color changes to host tissues.

Figure 3.3: Leaf galls on grape caused by the grape phylloxera. Credit: Lyle Buss, UF/IFAS Department of Entomology and Nematology.

After you have identified a pest, and confirmed that it is causing damage, become familiar with its life cycle, growth, and reproductive habits. Then use this information to decide how you must manage it. Remember that even though a pest is present, it is not necessarily harmful—it may even be beneficial (as a food for natural enemies, for example). Consider whether the cost of control would be more than the economic loss from the pest's damage. Then, choose the methods that will do a cost-effective job of managing the pest while causing the least possible harm to people and the environment.

Pesticides are valuable integrated pest management (IPM) tools, but like other IPM tools, you should use them only when they are needed. Consider using chemical control:

- when pests are causing unacceptable levels of damage and other IPM practices are not providing the level of control needed, or
- when your knowledge indicates that you need to use a pesticide preventively. For example, you may know that the temperature and humidity forecast makes it very likely that a particular plant disease will rapidly develop.

Remember, never try to control any pest until you know what it is. Misidentification and lack of information about a pest could cause you to choose the wrong control method or apply the control at the wrong time. These are frequent causes of pest control failure.

Arthropods

Arthropods are one of the largest groups in the animal kingdom. The word "arthropod" means "jointed foot" and refers to organisms with an external skeleton and jointed body parts. Important arthropod pests of agricultural crops in Florida include insects and mites.

Insects

Insects (bugs, beetles, flies, wasps, etc.) are the most diverse group of animals on the planet. There are more species of insects on earth than all other kinds of living animals combined. In general, insects can be divided into three categories according to their importance to people:

- **Insects of ecological importance**–About 99 percent of all insects are in this category. They are food for birds, fish, mammals, reptiles, amphibians, aquatic life, and other insects. Some remove animal wastes and dead plants and animals, returning nutrients to the environment.

- **Beneficial insects**–In this important group are the predators and parasites that feed on harmful insects, mites, and weeds. Examples are minute pirate bugs (Figure 3.4), praying mantids, lady beetles, and many tiny parasitic wasps. Also in this category are the pollinating insects such as bumblebees, honeybees, and butterflies. Without pollinators, many kinds of plants will not produce fruit or seed.

- **Destructive insects**–Although this is the category that usually comes to mind when insects are mentioned, it includes the fewest species. These are the insects that feed on, cause injury to, or transmit disease to people, animals, plants, food, fiber, and structures. This category includes aphids, stinkbugs (Figure 3.5), whiteflies, caterpillars, scale insects, psyllids, and fire ants.

Figure 3.4: Minute pirate bug—an example of a beneficial insect—feeding on thrips larva. Credit: Lyle Buss, UF/IFAS Department of Entomology and Nematology.

Figure 3.5: Southern green stink bug—a common insect pest of agricultural crops. Credit: Lyle Buss, UF/IFAS Department of Entomology and Nematology.

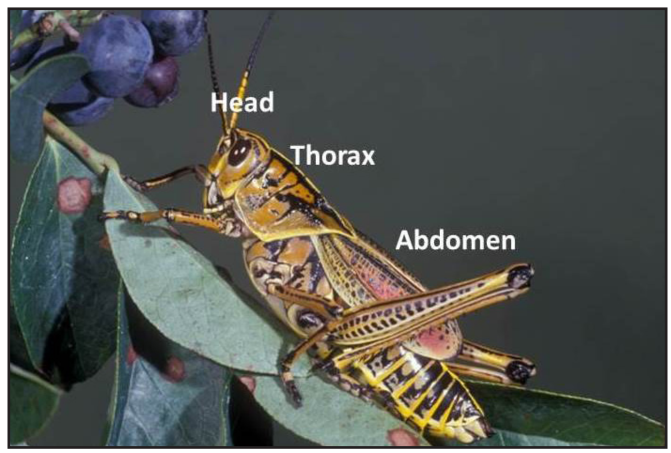


Figure 3.6: The three body regions of an insect. Credit: Lyle Buss, UF/IFAS Department of Entomology and Nematology.

The body of an adult insect has three distinct parts–the head, thorax, and abdomen (Figure 3.6). The head has antennae, eyes, and mouthparts. Antennae vary in size and shape and can be a help in identifying some pest insects. Insects have compound eyes made up of many individual eyes. Compound eyes enable insects to detect motion. The head has four types of mouthparts:

1. chewing,
2. piercing-sucking,
3. sponging, and
4. siphoning.

Chewing mouthparts contain toothed jaws that bite and tear (Figure 3.7). Ants, beetles, caterpillars, and grasshoppers have chewing mouthparts.

Figure 3.7: Close-up of the head of the banded sphinx moth caterpillar, showing the mandibles. Credit: Lyle Buss, UF/IFAS Department of Entomology and Nematology.

Piercing-sucking mouthparts form a long needle-like tube that is forced into plant or animal tissue to extract fluids or blood. Insects with piercing-sucking mouthparts include stable flies, sucking lice, mosquitoes, true bugs, and whiteflies (Figure 3.8).

Figure 3.8: Citrus whitefly–a piercing-sucking insect of citrus. Credit: Lesley Ingram, Bugwood.org.

Sponging mouthparts are tubular tongue-like structures with a spongy tip to suck up liquids or soluble food. This type of mouthpart is found in flesh flies (Figure 3.9), blow flies, and horse flies.

Figure 3.9: Flesh fly–an insect with sponging mouthparts. Credit: Lyle Buss, UF/IFAS Department of Entomology and Nematology.

Siphoning mouthparts form a flexible tube, like a flexible drinking straw, for extracting nectar from flowers. Butterflies (Figure 3.10) and moths have siphoning mouthparts.

Figure 3.10: Zebra longwing butterfly–an insect with siphoning mouthparts. Credit: Lyle Buss, UF/IFAS Department of Entomology and Nematology.

The thorax bears the legs and wings (whenever present). The size, shape, or texture of the wings is sometimes used to identify an insect species. The forewings take many forms. In beetles, they are hard and shell-like; in grasshoppers, they are leathery. The forewings of flies are membranous; those of true bugs are part membranous and part hardened. Most insects' hindwings are membranous. The wings of moths and butterflies are covered with scales.

The insect abdomen is composed of distinct sections (segments). A careful inspection of each side of most segments will reveal the tiny, valved holes, called spiracles, through which the insect breathes. In some insects, the last couple of segments of the abdomen have protruding tail-like, sometimes pincherlike, appendages.

Life Cycles of Insects

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 3.11): 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.

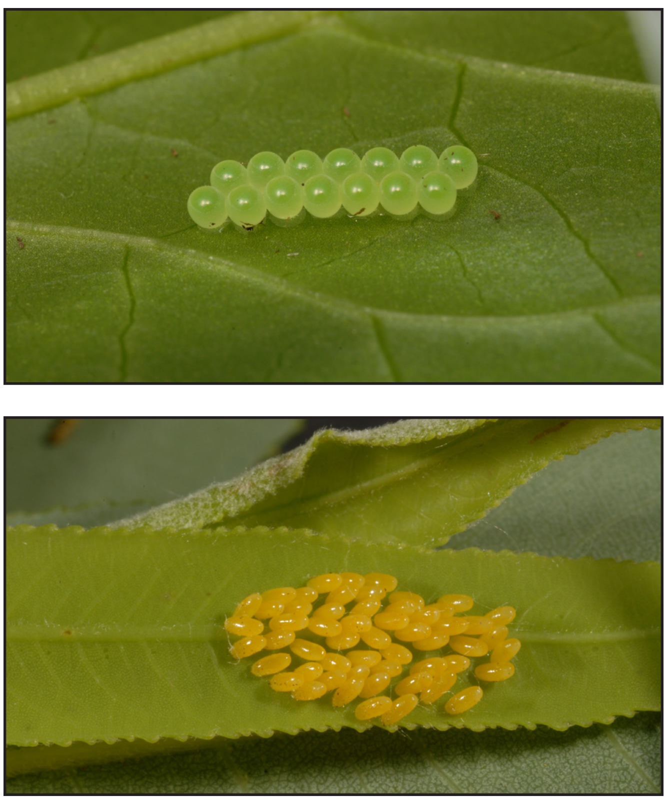


Figure 3.11: Insect eggs vary in shape and size. Credit: Lyle Buss, UF/IFAS Department of Entomology and Nematology.

The change through which an insect passes in its growth from egg to adult is called *metamorphosis*. When a young insect 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 larva. 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. In some cases, 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 3.12). The nymphs look like small versions of the adult form. 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 grasshoppers, stinkbugs, lice, termites, aphids, and scales.

Figure 3.12: Example of gradual metamorphosis. Credit: J.L. Castner, UF/IFAS Department of Entomology and Nematology.

Insects undergoing *complete metamorphosis* pass through four stages of development: egg, larva, pupa, and adult (Figure 3.13). 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 also known as 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 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.

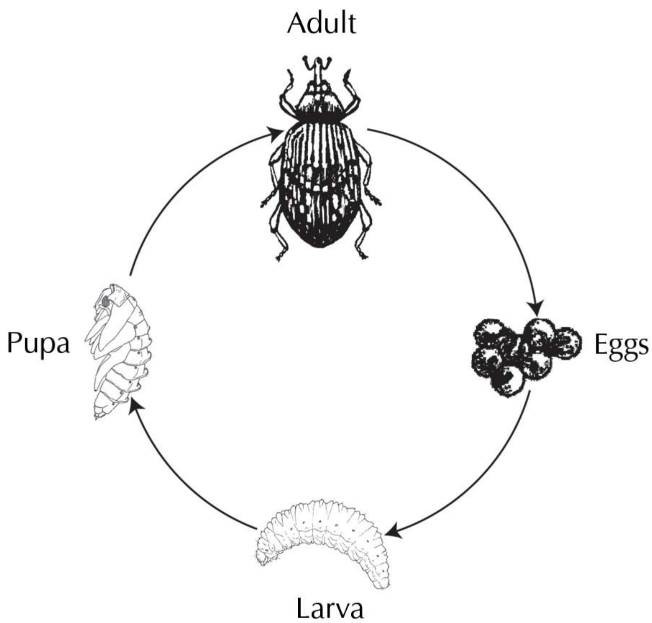


Figure 3.13: Example of complete metamorphosis. Credit: Invasive.org/The Bugwood Network.

Mites

Mites are among the most diverse and successful of all arthropods. They are adaptable to an incredible array of habitats, and because of their small size (most are microscopic), go largely unnoticed. Many live freely in the soil or water, but there are also a large number of species that live as parasites on plants and animals.

Like insects, mites occupy a wide range of ecological niches. For example, some mites are important decomposers and occur in many habitats. They eat a wide variety of material, including living and dead plant and fungal material; some are even predatory.

Mites have their abdomen broadly joined to the head and thorax. Adults usually have four pairs of legs, while immature mites most often have three or fewer pairs. Some species of mites produce fine webbing from silk glands located near their mouth. Most mites are very small and difficult to see without the aid of a hand lens or microscope (Figure 3.14).

Mites have a gradual metamorphosis life cycle, hatching from eggs and developing quickly passing through several immature stages before becoming adults. The length of time from egg to adult varies depending on temperature. The immature stage resembles the adult stage.

Figure 3.14: A mite shown under a microscope. Credit: Lyle Buss, UF/IFAS Department of Entomology and Nematology.

Damage Caused by Arthropod Pests

Arthropods can cause damage in many ways. The damage often provides clues to the identity of the pest. Even when pests are present, the level of damage may not be enough to warrant a control measure. Also, the potential for harm is greater at some times, and under certain conditions, than at others. For example, pink citrus rust mite populations begin to increase in April to early May on new foliage, reaching a peak in mid-June to mid-July. They are also more abundant in drier weather conditions. Mite densities in the fall rarely approach those early in the summer.

Leaf eaters. Some pests feed on plant leaves. For many plants, the loss of a few leaves will not cause reduced yield. But when pests remove most or all of the leaves from a plant, the plant is killed or is left stunted and unproductive. The larval stage of certain butterflies and moths can cause this type of costly damage. An example is the leaf feeding damage caused by the Colorado potato beetle (Figure 3.15).

Figure 3.15: Colorado potato beetle feeding on foliage. Credit: Lyle Buss, UF/IFAS Department of Entomology and Nematology.

Internal feeders. Some pests feed inside fruit, seed, or other plant parts (Figure 3.16). Usually, the larval stage causes the damage during feeding. Because they are inside the plant, these pests often cause significant damage before they are detected. They are also more difficult to control. Examples of internal feeders of agricultural crops include the European corn borer, and pickelworm.

Figure 3.16: Pickelworm boring into squash fruit. Credit: Lyle Buss, UF/IFAS Department of Entomology and Nematology.

Plant-sucking pests. Some pests have sucking mouthparts that allow them to extract juices from plants. These pests cause curling and stunting of leaves and stems, plant wilting or dead areas caused by toxins injected during feeding (Figure 3.17).

As they feed, plant-sucking pests may also spread plant disease organisms. Some plant diseases are best managed by controlling the insect pests that cause their spread. Aphids and similar insects excrete honeydew that drips onto the lower parts of the plant. A fungus that causes a black sooty mold, that is unsightly and blocks sunlight, often grows on this sticky material. Other examples of plant-sucking pests include whiteflies and mealybugs.

Figure 3.17: Sweetpotato whitefly adult and tomato yellow leaf curl damage by a virus they vector. Credit: Lyle Buss, UF/IFAS Department of Entomology and Nematology and UF/IFAS Pesticide Information Office.

Underground feeders. Some pests cause damage by feeding on plant roots (Figure 3.18). Root-feeding pests interfere with the plant's water and nutrient uptake. They can cause poor color, stunting, or loss of vigor in a wide range of crops. Some underground feeders are the larval stage of insects. These include several species of weevils and moths, such as the diaprepes root weevil. Underground pests often cannot be seen without uprooting the plants.

Figure 3.18: The larval stage of sugarcane grub feeds on roots. Credit: Lyle Buss, UF/IFAS Department of Entomology and Nematology.

Weeds

Any plant can be considered a weed when it is growing where it is not wanted. Weeds reduce crop yields, increase production costs, and reduce crop quality. Some weeds cause allergies, such as hay fever; others are poisonous if eaten or touched.

Weeds harm desirable plants by:

- competing for water, nutrients, light, and space;
- contaminating the product at harvest;
- harboring pest insects, mites, vertebrates, or plant disease agents; or
- releasing toxins that inhibit growth of desirable plants.

A simple way to identify common weeds is to compare specimens with color photographs and/or drawings. Key characteristics to look for when identifying weeds include the physical features, consisting of flowers, leaves, stems, and roots. Fruits, seeds, and special structures, such as tubers or rhizomes, are also useful identification characteristics, as are the plant's growth habits. UF/IFAS EDIS has many publications addressing weed identification, most with color photographs and written descriptions (**https://edis.ifas.ufl.edu/**).

Stages of Plant Development

Most weeds pass through several stages of development, beginning with the seed. Sprouted seeds, known as *seedlings*, are usually tender. This is the growth stage when annual weeds are most susceptible to herbicides. Because of this, it is important to learn to recognize seedlings (Figure 3.19), which differ in appearance from mature plants and so may be difficult to identify.

From seedlings, weeds continue their *vegetative growth* stage marked by rapid foliage development as they attain their maximum size. Plants then enter a *reproductive* period in which they divert most of their energy to flowering and seed production. Once they form seeds, weeds reach maturity–a *post-reproductive* period. Perennial plants continue to repeat vegetative growth and reproductive cycles each year.

For identification, learn to recognize the different growth stages of weeds. Understanding the growth stages is also important when selecting herbicides or other methods of weed control.

Figure 3.19: Prickly sida seedling. Credit: Ohio State Weed Lab, The Ohio State University, Bugwood.org.

Life Cycles of Weeds

Weed life cycles are classified as either *annual*, *biennial*, or *perennial*. Occasionally, some weed species with one type of life cycle may behave as if they have a different life cycle. This may be due to favorable weather or abnormal or unusual changes in environmental influences. Milder temperatures, for example, promote longer life cycles. Once you are familiar with the life cycle of a weed, you can properly time herbicide applications.

Annual weeds grow from seed, mature, and produce seed for the next generation in 12 months or less. Annual weeds can be either grasslike, such as crabgrasses (Figure 3.20) and goosegrass; or broadleaved, such as Florida pusley, (Figure 3.21), common ragweed and pigweed. There are two types of annual life cycles. Summer annuals grow from seeds that sprout in the spring. They grow, mature, produce seed, and die before winter. Examples of summer annuals include crabgrass, broadleaf signalgrass, and pigweed. Winter annuals grow from seeds that sprout in the fall. They grow, mature, produce seed, and die before summer. Examples of winter annuals include chickweed, Carolina geranium, and wild mustard.

Figure 3.20: Crabgrass–a common summer annual grass. Credit: UF/IFAS Pesticide Information Office.

Figure 3.21: Florida pusley–a common summer annual broadleaf. Credit: UF/IFAS Pesticide Information Office.

Plants with a two-year life cycle are called *biennials*. They grow from seed and develop a heavy root and compact cluster of leaves, called a *rosette*, in the first year (Figure 3.22). In the second year, they mature, produce seed, and die. Examples of biennials include cutleaf evening primrose and Carolina false dandelion.

Figure 3.22: Cutleaf evening primrose rosette. Credit: John D. Byrd, Mississippi State University, Bugwood.org.

Plants that normally live more than two years are referred to as perennials. Some perennial plants mature and reproduce in the first year and then repeat the vegetative, seed production, and maturity stages for several more years. In other perennials, the seed production and maturity stages may be delayed for several years.

Some perennial plants die back each winter; others, such as trees, lose their leaves but do not die back to the ground. Most perennials grow from seeds; many species also produce tubers, bulbs, rhizomes (belowground root-like stems), or stolons (aboveground stems that produce roots). Examples of perennials include Johnsongrass, purple nutsedge, dandelion, curly dock, and skunk vine. *Simple perennials* normally reproduce by seeds; however, root pieces left by cultivation can produce new plants. Examples of simple perennials include dandelions, plantain, trees, and shrubs. *Bulbous perennials* reproduce by seeds, bulblets, or bulbs. An example of a bulbous perennial is wild garlic, which produces seeds and bulblets above ground and bulbs below ground. *Creeping perennials* produce seeds but also produce rhizomes, or stolons. Examples of creeping perennials include Johnsongrass, cogongrass, vaseygrass, and Bermudagrass (Figure 3.23).

Figure 3.23: Bermudagrass—a creeping perennial weed. Credit: UF/IFAS Pesticide Information Office.

Weed Classification

Grass seedlings have only one leaf as they emerge from the seed. Their leaves are generally narrow and upright with parallel veins (Figure 3.24). Grass stems are generally round and may be either hollow or solid. Most grasses have fibrous root systems. The growing point on seedling grasses is sheathed and located below the soil surface. Some grass species are annuals; others are perennials.

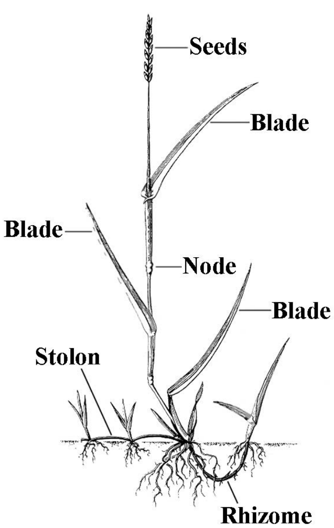


Figure 3.24: Important plant parts of grassy weeds. Credit: Jim Converse, The Scotts Company, Maryville, Ohio.

Sedges are similar to grasses except that they have triangular stems and their leaves are arranged in groups of three (Figure 3.25). Although they are similar in appearance to grasses, sedges are not true grasses and herbicides specifically for grass control generally do not control sedges. Most sedges grow in wet places, but principal pest species grow in fertile, well-drained soils. Many sedge species are perennial in habit, including two of the more common species, yellow and purple nutsedge, which produce rhizomes and tubers.

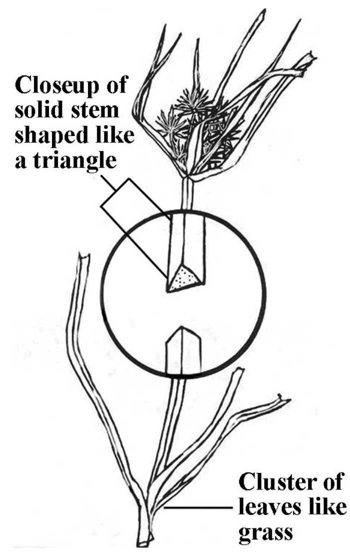


Figure 3.25: Sedge weed. Credit: Oklahoma Cooperative Extension Service.

The seedlings of broadleaf weeds emerge from the seed with two leaves (Figure 3.26). The leaves of these plants are generally broad with netlike veins (Figure 3.27). Broadleaf weeds usually have a strong central taproot and a fairly coarse root system. Broadleaf weed species may have either annual, biennial, or perennial life cycles. Most actively growing broadleaf plants have exposed growing points at the end of each stem and in each leaf axil. Perennial broadleaf plants may also have growing points on roots and stems above and below the surface of the soil.

Figure 3.26: First emerging leaves of black nightshade. Credit: Doug Doohan, Ohio State University/OARDC, Bugwood.org.

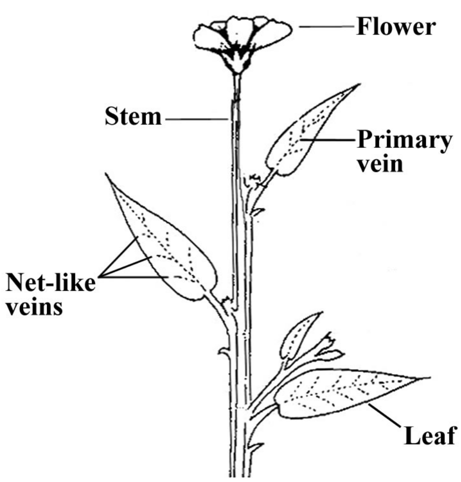


Figure 3.27: Important plant parts of broadleaf weeds. Credit: Oklahoma Cooperative Extension Service.

Plant Diseases

Another important group of pests includes plant disease-causing agents. Nonliving (*abiotic*) factors and living (*biotic*) pathogenic microorganisms cause diseases in plants. Biotic and abiotic factors alter or interfere with the chemical processes that take place within an organism's cells. This produces disease symptoms or disorders. Sometimes both pathogens and disorders can cause symptoms that have an identical appearance. Symptoms are a reaction of the host plant that indicates disease (Figure 3.28).

Figure 3.28: Peanut plant showing symptoms of root rot. Credit: William M. Brown Jr., Bugwood.org.

Examples of plant disease symptoms include spots, blight, galls, wilts, rots, and slow growth. Sometimes you can see signs of the pathogen causing the disease. A sign is an indication of disease from direct observation of a pathogen or its parts. Examples of plant disease signs include rust spores on a leaf, mushrooms on a tree trunk, and bacterial ooze from a plant. It's important to recognize the difference between abiotic and biotic factors in order to avoid unnecessary pest management practices.

An agricultural plant's susceptibility often depends on a combination of factors including its genetic makeup, nutritional state, and climatic conditions. Plants exhibit symptoms resembling diseases as a result of physical factors. These include:

- extreme temperatures,
- too much or too little soil moisture,
- too little or too much fertilizer,
- mechanical or physical damage,
- pesticide or chemical injury, and
- improper cultural practices.

Disorders caused by abiotic factors are a result of the plant's response to the conditions in its environment. These cannot be transmitted from one plant to another. Pesticides do not correct or prevent abiotic disorders.

Biotic disease-causing factors are pathogens capable of spreading from one host to another and producing disease symptoms. Pathogens include:

- fungi,
- bacteria, and
- viruses and viroids.

Pathogens that cause plant disease live and feed on plant debris or host plants. Many can be passed from one plant to another. Three factors are required before a pathogenic disease can develop: (1) a susceptible host plant, (2) a pathogenic agent, and (3) an environment favorable for development of the pathogen. Together, these factors are known as the "plant disease triangle" (Figure 3.29). The disease process starts when the parasite arrives at a part of a plant where infection can occur. If environmental conditions are favorable, the parasite enters the plant and infection starts. The plant is diseased when it responds to the parasite.

The three main ways a plant responds are:

1. overdevelopment of tissue, such as galls, swellings, and leaf curls;
2. underdevelopment of tissue, such as stunting, lack of green color, and incomplete development of organs; and
3. death of tissue, such as blights, leaf spots, wilting, and cankers.

The parasites that cause plant diseases may be spread by wind, rain, insects, birds, snails, slugs, earthworms, transplant soil, nursery grafts, vegetative propagation, contaminated equipment and tools, pollen, dust storms, irrigation water, and people.

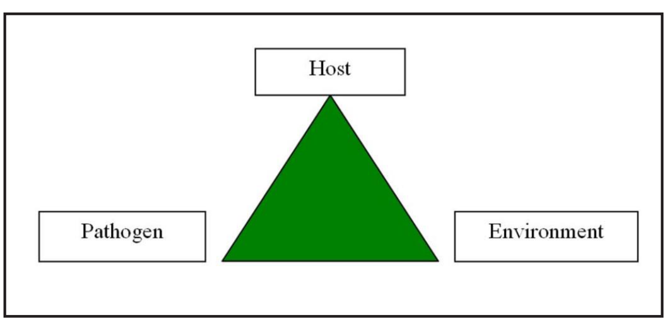


Figure 3.29: The plant disease triangle. Credit: Phil Harmon, UF/IFAS Department of Plant Pathology.

Fungi

Fungi are a diverse group of microscopic primitive plants. They must obtain their nutrients from some organic source such as living or dead plant material. Most fungi live off dead organic matter. These fungi are called *saprophytes*. They are generally beneficial because they help break down organic materials and build up soil fertility. However, some fungi invade agricultural commodities causing diseases (Figure 3.30). These fungi require living host plants to grow and reproduce; because they require a living host, they are parasites. This group includes the major plant pest species.

Figure 3.30: Leaf spot of peanut is a common fungal disease. Credit: Dan Anco, Clemson University, Bugwood.org.

Most pest fungi have a vegetative body (mycelium) that consists of tiny filamentous strands (hyphae). The mycelium grows through the tissues of an infected host. You can usually see this structure without magnification. Reproduction in fungi is primarily by means of spores. Many species of fungi produce more than one type of spore. One of these types of spores acts as a resting structure to carry the fungus through adverse conditions. Other spore types are responsible for the ongoing secondary spread of the organism.

Fungal identification usually depends on characteristics of the mycelium and structures known as fruiting bodies. Diagnosis of a fungal infection involves looking for these structures on or in plant tissues or infected wood. Symptoms of fungal infections include soft rot of fruits, plant stunting, smuts, rusts, leaf spots, wilting, and thickening or curling of leaves. Leaf spots, scab, blights, root and fruit rots are examples of fungus-caused agricultural crop diseases (Figure 3.31).

Figure 3.31: Peanut plant showing symptoms of infection with collar rot due to Aspergillus sp. Credit: William M. Brown Jr., Bugwood.org.

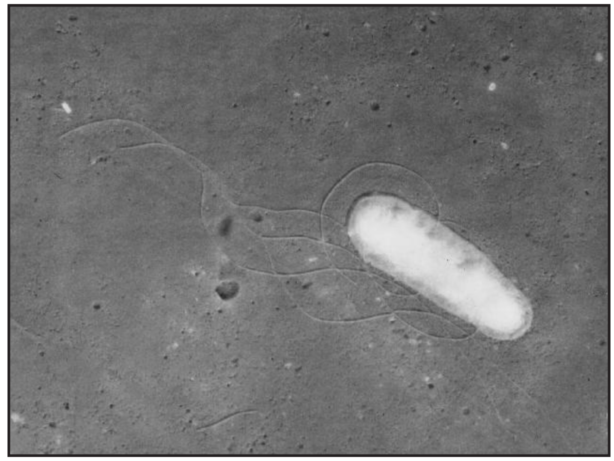


Figure 3.32: Bacterial cell. Credit: Ken Pernezny and Tim Momol, UF/IFAS Department of Plant Pathology.

Spores of fungi spread by wind, rain, irrigation water, insects, and cultural practices. Any practice that moves infected plant material from one location to another can also spread fungal spores. Roots of non-infected plants may grow into areas where fungal organisms are present and become infected in this manner.

Fungi enter plant tissues through wounds and natural openings and by penetrating the outer surface of the host. Usually certain environmental conditions promote or accelerate fungal organism growth and infection. These include high humidity or presence of water and warm temperatures.

Bacteria

Plant-disease-causing bacteria are microscopic single-celled organisms. Plant-infecting bacteria are rod-shaped and most have threadlike structures called flagella that propel them through liquids (Figure 3.32). Most bacteria require warmth and moisture to multiply. Some bacteria can cause serious diseases of agricultural crops, such as bacterial spot (Figure 3.33).

Figure 3.33: Bacterial spot of tomato. Credit: Howard F. Schwartz, Colorado State University, Bugwood.org.

Most bacteria are spread by contact. Means of spread include wind-driven rain and storm events such as tropical storms and tornadoes, overhead irrigation, human movement of infected plant material, human and equipment movement within fields and groves, insects, birds, and other animals.

Bacteria invade plant tissues above or below the soil surface through natural openings and through wounds. They must enter tissues to infect the plant. Bacterial diseases show up as galls, leaf spots, wilts, blights, chlorotic tissue, and rots.

Viruses

Viruses should not be considered organisms. They are simply molecules made of a nucleic acid (DNA or RNA) with a "wrapping" of protein and have no cellular structures. They multiply in living cells to produce disease symptoms in plants. Viruses are much smaller than bacteria and require the use of an electron microscope to be seen. Often, it is difficult to distinguish between plant diseases caused by viruses and those caused by fungi or bacteria. In the field, comparing symptoms with pictures and descriptions of diseased plants might suggest a plant disease caused by a virus, but a more positive diagnosis of virus diseases requires laboratory tests.

Structurally, viruses are very simple compared with other living organisms; they have different shapes depending on the type. Most viruses can survive for only short periods of time outside host plant cells, and depend on other living organisms for their materials and for their reproduction. Viruses are commonly spread from plant to plant by mites or by aphids, leafhoppers, whiteflies, or other plant-feeding insects (Figure 3.34). They may be carried by nematodes, fungus spores, or pollen and may be spread by people through cultivation practices, such as pruning and grafting.

Viruses invade cells of plants and, using their own genetic information, alter these cells. Infected cells produce more viruses rather than the usual proteins or nucleic acid. Viruses can induce a wide variety of responses in host plants. Most often, they stunt plant growth or alter the plant's natural color. Viruses can cause abnormal formation of many parts of an infected plant, including the roots, stems, leaves, and fruit (Figure 3.35).

Figure 3.34: The virus that causes tomato spotted wilt of peanut is vectored by thrips. Credit: Steve L. Brown, University of Georgia, Bugwood.org.

Figure 3.35: Tomato yellow leaf curl virus causes distorted plant growth. Credit: Don Ferrin, Louisiana State University Agricultural Center, Bugwood.org.

Phytoplasmas

A phytoplasma is an unculturable bacterium that has no cell wall. Phytoplasmas are mostly dependent on insect transmission or grafting for their spread and survival. The phytoplasma life cycle involves replication in insects and plants. They infect the insect but are phloem-limited in plants. Phytoplasma diseases can be recognized by one or more characteristic symptoms, such as stunting, and yellowing. Molecular techniques are necessary for detection and identification of phytoplasmas.

Nematodes

Nematodes are small, usually microscopic, roundworms (Figure 3.36). Those that feed on plants have a needle-like mouthpart called a *stylet*. They use the stylet to puncture plant cells and feed on the contents. Nematodes may develop and feed either inside or outside of a plant. They move with an eel-like motion in water, even water as thin as the film of moisture around plant cells or soil particles. Because most plant pest nematodes are not visible to the naked eye, it is easy for people to unknowingly spread them. Nematodes can be carried on footwear, tools, and equipment.

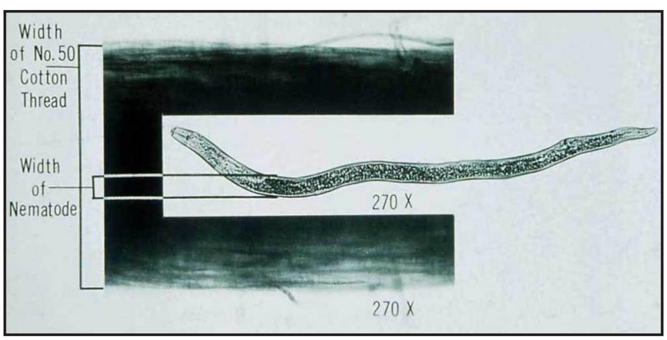


Figure 3.36: Relative size of a plant parasitic nematode. Credit: W.T. Crow and R.A. Dunn, UF/IFAS Department of Entomology and Nematology.

The life cycle of a nematode includes an egg, several larval stages, and an adult. Larvae look like adults, but are much smaller. The females of some nematodes form an inactive, resistant form called a *cyst*. The cyst is the hard, leathery, egg-filled body of the dead female. A nematode cyst is very difficult to penetrate with pesticides. A cyst may provide protection for several hundred eggs for as long as ten years.

Many different genera and species of nematodes can be important to crop production in Florida. In many cases a mixed community of plant parasitic nematodes is present in a field, rather than having a single species occurring alone. In general, the most widespread and economically important nematode species include the root-knot nematode and sting nematode (Figure 3.37). The host range of these nematodes, as with others, includes many different weeds and most if not all of the commercially grown vegetables within the state. Yield reductions can be extensive but vary significantly between plant and nematode species. In addition to the direct crop damage caused by nematodes, many of these species have also been shown to predispose plants to infection by fungal or bacterial pathogens or to transmit virus diseases, which contribute to additional yield reductions.

Figure 3.37: Roots of pepper infested with root-knot nematode. Credit: Scott Bauer, USDA Agricultural Research Service, Bugwood.org.

The only effective way of determining the presence or distribution of nematodes within a field is by soil and root tissue sampling. A representative sample for most nematode species consists of soil and roots, using a shovel or soil sampling tube. Once soil and root samples have been collected, they should not be subjected to overheating, freezing, drying, or to prolonged periods of exposure to direct sunlight. Samples should be submitted immediately to a commercial laboratory or to the University of Florida Nematode Assay Laboratory for analysis and recommendations.

Vertebrates

Vertebrates are animals that have a jointed backbone. They include mammals, birds, reptiles, amphibians, and fish. Some vertebrates, such as birds, rodents, raccoons, feral hogs, and deer, injure agricultural crops. When natural foods are scarce or inaccessible, hogs will readily forage on almost any agricultural crop, leading to significant losses (Figure 3.38). Wild hogs will also feed on tree seeds and seedlings, causing significant damage in forests, groves, and plantations.
In addition to the effects of consuming, knocking down, rubbing, and trampling large amounts of native vegetation and crops, the rooting behavior of hogs also causes significant damage. Rooting destabilizes the soil surface, which can lead to erosion and exotic plant establishment; uproot or weaken native vegetation; and damage lawns, dikes, roads, trails, and recreation areas. Hogs have also been known to damage fences and other structures. Finally, hogs' wallowing behavior destroys small ponds and stream banks and can lead to declines in water quality.

Amphibians occasionally clog filters, pipes, and other equipment associated with irrigation systems.

Figure 3.38: Feral hog foraging in a Florida citrus grove. Credit: UF/IFAS Pesticide Information Office.

Test Your Knowledge

Q: Why is accurate pest identification so critical in managing a particular pest?

A. Because it is key to effective control
B. Because it will determine the pest's management strategy
C. Because identification may reveal that the pest does not require control
D. All of the above are valid reasons

A: D

Q: Which of the following comprise the largest group of insects?

A. Insects of ecological importance
B. Beneficial insects
C. Destructive insects

A: A

Q: Ants, beetles, caterpillars, and grasshoppers have ___________ mouthparts.

A. piercing-sucking
B. chewing
C. siphoning
D. sponging

A: B

Q: Which type of metamorphosis do stink bugs and scales undergo?

A. Complete
B. Incomplete
C. Gradual
D. Complex

A: C

Q: Which of the following statements is false regarding mites?

A. Mites occupy a wide range of ecological niches
B. Some species of mites produce fine webbing from silk glands located near their mouth
C. Mites have a gradual metamorphosis life cycle
D. Adult mites have three pairs of jointed legs

A: D

Q: Match the weed species with its life cycle:

1. Crabgrasses and pigweeds	A. Perennial
2. Cutleaf evening primrose	B. Biennial
3. Johnsongrass and purple nutsedge	C. Annual

A: 1 – C; 2 – B; 3 – A

Q: Match the categories of weeds with their correct description:

1. Grasses	A. Wide leaves with netlike veins; seedlings have two leaves
2. Sedges	B. Narrow, upright leaves with parallel veins; round stems
3. Broadleaf weeds	C. Triangular stems; leaves in groups of threes.

A: 1 – B; 2 – C; 3 – A

Q: Which of the following statements is false regarding plant disease?

A. Abiotic factors and biotic pathogenic microorganisms cause diseases in plants
B. Sometimes both pathogens and disorders can cause symptoms that have an identical appearance
C. Symptoms are an indication of disease by reaction of the host plant
D. Spots, blight, galls, wilts, rots, and slow growth are examples of disease signs

A: D

Q: Which factors are required before a pathogenic disease can develop? (Select all that apply)

A. A susceptible host plant
B. A pathogenic agent
C. An environment favorable for development of the pathogen

A: A, B, and C

Q: Match the categories of plant pathogens with their correct description:

1. Fungus — A. Very small organisms that multiply in living cells to produce disease

2. Bacterium — B. Identification usually depends on mycelium characteristics and fruiting bodies

3. Virus — C. Those that infect plants are rod-shaped and have flagella for locomotion

A: 1 – B; 2 – C; 3 – A

Q: Which of the following statements is false regarding nematodes?

A. Nematodes are small, usually microscopic, roundworms
B. It is easy for people to unknowingly spread them
C. There are relatively few genera and species important to agricultural crop production
D. The only effective way of determining the presence or distribution of nematodes is by soil and root tissue sampling

A: C

Q: True or False

Mammals, birds, reptiles, and fish are vertebrates since they have a jointed backbone.

A: True

Chapter 4

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 action threshold concept.
- Describe monitoring (scouting) and explain why it is important.
- Describe the following IPM practices as they pertain to the control of plant diseases, insects and mites, and weeds:
  - Cultural control
  - Biological control
  - Mechanical controls
  - Chemical control

Terms to Know

Action threshold: Action thresholds refer to the number of pests or level of pest damage before requiring action. This is done to prevent damage from exceeding tolerable levels.

Allelopathic compound: Biochemical produced by an organism that influences the germination, growth, survival, and reproduction of other organisms.

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

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.

Inoculum: The pathogen propagule that can cause infection in crops.

Integrated pest management (IPM): The coordinated use of pest and environmental information and available pest control methods to prevent unacceptable levels of damage by the most economical means with the least possible hazard to people, property and the environment.

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

Parasitoid: An organism that lives in close association with its host and at the host's expense, and which sooner or later kills it.

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 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, 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)

Figure 4.1: Scouting a potato field. Credit: Howard F. Schwartz, Colorado State University, Bugwood.org.

IPM is commonly used in agricultural crop production, where the economic thresholds for key pests have been determined. IPM programs are dependent upon periodic monitoring (scouting) to ascertain pest densities and upon establishment of densities when treatment is warranted, i.e., thresholds (Figure 4.1). Although thresholds based upon the economics of the crop and upon the cost of treatment have been developed for some pests of crops, these "economic" thresholds generally have not been used because of the variability and unpredictability of the ultimate market value of commodities. Therefore, action thresholds have been utilized. Action thresholds refer to the number of pests or level of pest damage before requiring action. This is done to prevent damage from exceeding tolerable levels.

The Scouting Plan

Scouting relies upon a sampling plan, the procedure for obtaining a sample to estimate the population of one or more pests or the degree of crop injury in a field. Scouting methods should not only take into account the relative density and distribution of pests, but also the stage of growth of the plant. The plan includes the timing of sampling and the directions for:

- Spatial distribution of survey stops.
- The number of survey stops.
- The size or composition of the sampling unit at each survey stop.

The magnitude or composition of subsamples from a single inspection or survey stop is called the "sampling unit." A "survey stop" is the area of the field in which a single sampling unit is inspected, counted, or collected. The total number of observations from all survey stops is referred to as the "sample." For example, if the sampling unit consisted of 20 sweeps with a sweep net, 10 survey stops would require 10 sets of 20 sweeps each, or a sample size of 200 sweeps in the field.

The sampling pattern will dictate where each of the survey stops will occur. Because sampling is performed in order to estimate the degree of pest infestation or the amount of crop injury, it may seem appropriate to use a completely randomized scheme in which each subdivision in the field would have an equal chance of selection, enabling to obtain an unbiased estimate of the pest population or crop injury. Several forms of zigzag-shaped patterns are commonly used, because it is simple, convenient, and ensures all regions of the field are visited (Figure 4.2).

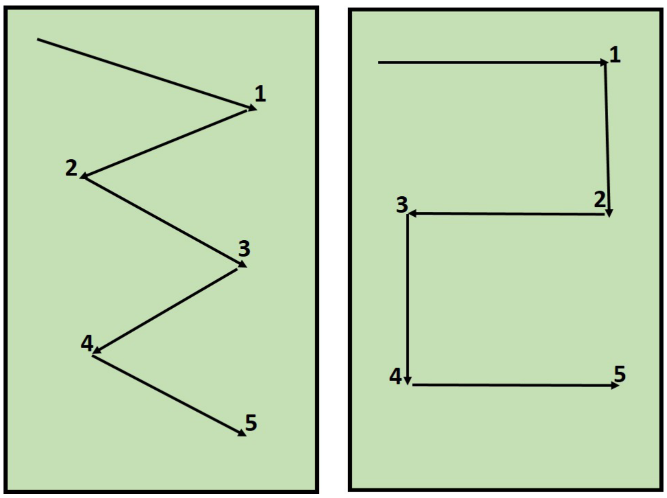


Figure 4.2: Common sampling patterns through a field. Credit: UF/IFAS Pesticide Information Office.

Each survey stop should represent approximately five to seven acres in agronomic row crops. Use this relationship to determine the number of survey stops. For example, a 50-acre field would require seven to ten survey stops. Higher value crops, such as tomato and strawberry, would justify more intensive sampling, such as two acres per survey stop. The exact number of survey stops and sampling units inspected, counted, or collected at each survey stop may be influenced by the pest, its spatial dispersion, the type of crop injury, and other factors. Detailed sampling protocols for some key crops and their specific pests can be found on the UF/IFAS EDIS website at **https://edis.ifas.ufl.edu/** and at IPM Florida **http://ipm.ifas.ufl.edu/index.shtml**.

Disease Management

The health of agricultural row crops is best maintained through management practices that integrate different techniques. When making management decisions it is important to consider the economics of the crop, cost of the management practice, history of the production area, weather and climatic conditions, and potential risk for a disease to develop. Integrated management strategies are more likely to successfully control diseases than non-integrated strategies because they reduce disease risk through multiple techniques and often before infection begins. Non-integrated strategies can also adequately manage a disease; however, producers must limit expectations about the probability that they will see significant economic return from a crop. Ultimately, integrated management strategies provide a means for producers to reduce the risk that they will have significant economic losses from a disease.

Economics

Often the top priority of any producer is the economic benefit they will see from the application of a specific management strategy. These benefits will depend upon the market price of the crop as well as the cost of the specific management strategy. Typical costs include the price of a cultivar, labor, machinery, fuel and various materials (e.g. fungicides) used in an integrated disease management strategy. All of these costs are variable, and it is up to a producer to assess the inputs required for managing specific diseases so they can calculate the economic returns from their decisions, if any.

Disease Identification

Proper management of any plant disease starts with an accurate identification of the pathogen or pest causing the problem. There are many different types of pathogens (i.e. fungi, bacteria, viruses and nematodes) involved in diseases of agricultural row crops, which can require very different management strategies. To assess which management strategy is most appropriate, there needs to be information about the pathogen present in a field. This information can be gained by assessing the crop yourself and/or with the aid of a professional. There are many guides and applications available for disease identification; however, proper identification often requires the use of a microscope to identify key structures or through a more complex test (e.g. DNA/RNA-based and serological). There are many printed and electronic (e.g. EDIS; University of Florida) resources available for disease identification, but if a professional applicator or producer is unsure about how to identify a disease they should contact their local extension office or nearest University of Florida Plant Disease Clinic for help.

Once a pathogen has been identified, monitoring of the disease is critical to collecting the information needed to make a beneficial management decision. The distribution of a disease within a field can inform a producer about where and when the disease may be a problem. Monitoring is also critical to determining the risk a producer's crop has to experiencing significant economic impacts from a disease. For example, if a disease is affecting only 5% of a production area, it is likely that the combination of multiple low-cost strategies may effectively manage a disease. However, if a disease is causing a problem in 50% or more of a field then it is likely different management strategies will be needed to adequately reduce its impact.

There are many integrated management methods available for disease control, and many of these methods are often chosen even before the crop is planted. Three important pre-plant tools are site determination and preparation, crop rotation, and cultivar selection. Site determination and crop rotation are two excellent methods for reducing a pathogen population within a specific site. For example, fields with a history of a disease are more likely to have that disease again, especially if it has been continually planted with susceptible host plants. Removal of debris through tillage or the planting of a non-host plant can limit the pathogens present and thus reduce a disease's overall impact. Cultivar selection is also critical to determining how likely a disease is to continue developing and spread within a field. Resistant cultivars will most likely require less inputs than susceptible cultivars after disease establishment (Figure 4.3).

Figure 4.3: Susceptible peanut cultivar to tomato spotted wilt virus. Credit: Steve L. Brown, University of Georgia, Bugwood.org.

Multiple post-plant management options are also available to producers. These include, but are not limited to, weed control, irrigation management, nutrient management, soil amendments, sanitation practices, and canopy regulations (e.g. staked tomatoes). These management options are aimed at reducing plant stresses and limiting mechanical movement of the pathogen within a field site. For instance, weeds can serve as alternate hosts for a pathogen and can stress plants by competing for essential nutrients such as calcium. Stressed plants are more prone to pathogen infections and alternate weed hosts create local inoculum sources that can cause problems under the right environmental conditions. All of these management strategies provide better results when used as prevention methods and are even more useful when combined with pre-plant methods.

Figure 4.4: Volunteer cucumber seedlings following the spring crop provide inoculum for fall crop. Credit: Charles Averre, North Carolina State University, Bugwood.org.

Inoculum is the pathogen propagule that can cause infection in crops (Figure 4.4). The amount of inoculum present is critical to the development and spread of disease.

Monitoring provides producers with an initial assessment of the pathogens' inoculum; however, the production of further inoculum is highly dependent on the environment. Environmental conditions that are conducive for pathogen development varies, but with proper identification it is possible to assess the risk of continued inoculum production. There are many disease models and decision support systems (e.g. strawberry) available to evaluate disease risk based on environmental conditions. When determining the risk of further disease development it is important to consider the environment and the likelihood that disease will continue to develop.

Biological and chemical products are an important component of many disease management programs. These products provide post infection management options; however, they should be integrated with all other techniques mentioned in this chapter. The efficacy of these products will vary depending on timing of the application and the physical mode of action of the product. Often these products will be more efficacious when applied early in a disease epidemic, before the pathogen has produced significant amounts of inoculum. All of these products should be used following recommended rates and application frequencies, and within all labeled requirements. It is important to consider the cost of these products and what average yield savings will equal with a product application. In general, the most costly application is when there is no disease present or a product does not affect the disease afflicting the crop. However, preventive applications can be beneficial particularly when the disease risk is high, thus proper disease assessment is critical for any management strategy.

Insect Management

The management and control of insects and mites can be challenging, even under optimum conditions. IPM is a useful approach for producing agricultural row crops. It involves integration of cultural, physical, biological, and chemical methods to maximize productivity in a way that is ecologically sound and safe. Often, but not always, it means limiting the use of broad-spectrum insecticides and miticides. IPM implies management of all crop pests, including insects, mites, diseases, nematodes, and weeds; however, only insects and mites will be considered in this section of Chapter 4. Where possible, the effects of measures to control diseases and weeds should enhance or, at least, not interfere with the management of insects and mites.

Many of the general IPM principles and tactics that apply to the control of plant diseases apply to the management of insects and mites. These include regular scouting or monitoring for problems, identifying pests and their life stages, keeping good records of pest management practices, using exclusion techniques, practicing good sanitation, testing soil or plants for nutrients, using biological controls when possible, and using selective pesticides, properly timed and applied.

Crop Scouting and Monitoring

To detect pests and the damage they cause before a problem becomes serious, growers must visually inspect plants once or twice a week. As a first step, growers should observe the overall plant, looking for speckling or bronzing on leaves, holes and other damage caused by chewing insects, distorted growth, and fruit damage (Figure 4.5). The next step is to carefully inspect all plant parts from ground or stem level up to the growing tip. Some insects will feed on roots, others on stems, leaves, flower blossoms, and fruit. The grower must become proficient at quickly examining these plant parts and recognizing the presence of pests and the damage they cause. Workers engaged in cultural practices should be trained to recognize insects and the damage they cause.

Figure 4.5: Fall armyworm feeding leaves a ragged appearance to corn. Credit: John C. French Sr., Retired, Universities: Auburn, GA, Clemson and U of MO, Bugwood.org.

Both the upper and lower leaf surfaces must be thoroughly inspected. Many insects, as well as some diseases, begin their infestation or infection from the lower side of the leaf. Many insects and mites only feed on the underside of the leaf and may never move to the upper leaf surface or other plant parts until populations become so great that overcrowding forces movement. Attention should be given to the midrib area under the leaf and along large, lateral, lower leaf veins. The leaf axils, growing tips, and terminal buds should be carefully inspected. Often weeds serve as hosts for insects, mites, and diseases that can move to vegetable crops and should be removed (see section on sanitation).

Some insects, particularly thrips, will be found within the blossoms, so these should be included in the inspection. Tap the blossoms over a white pan or card to see these tiny insects. The area under the calyx or stem end of tomatoes and cucumbers can also be an attractive hiding place for insects. Generally speaking, insects inhabit secluded areas of the plant that provide protection.

Yellow sticky traps are useful for monitoring the adult (flying) stages of many insects. Blue is more attractive to thrips, but yellow works well also. Traps are usually placed vertically at or just above the plant canopy. Some insects, such as thrips and leafminers, can be caught just above the surface of the growing medium. One recommendation is to use one to three cards per 1,000 sq ft. Traps should be inspected weekly and replaced regularly. A system of numbered traps can facilitate sampling and simplify record keeping. Yellow sticky tape can be used on a larger scale to reduce insect populations by trapping. Yellow sticky traps and tape are available from many online distributors.

Many of the arthropod pests that infest agricultural row crops are very small. Mites are 1/50–1/60 of an inch long. Thrips, aphids, whitefly crawlers, and the eggs of other harmful insects are not much larger. Growers and professional applicators should have at least a 10x hand lens (jewelers' hand lens), but a 16x–20x is preferred. With a hand lens, a person can quickly identify many of the arthropod pests that are otherwise difficult to see. If at all possible, growers and professional applicators should buy and learn to use a common dissecting microscope. These microscopes can be purchased either as a monocular (one barrel) or binocular (two barrel) type. They have approximately 10x–200x magnification. With a microscope, a person can see small mites, such as broad mites, and disease lesions clearly. This tool can be very helpful in detecting and diagnosing problems early.

Identification of Insects and Mites

Proper identification of insects and mites and the damage they cause is absolutely critical. If the manager knows exactly which pests are present, proper chemical or biological controls can be selected and steps taken to exclude or limit further introductions. In Florida, Cooperative Extension Service offices in each county are able to help with pest identification (to find an office near you, visit **http://solutionsforyourlife.ufl.edu/map/**). Workshops may be offered on pest scouting and identification, and there are many publications and online resources available (see **http://ipm.ifas.ufl.edu**).

Recordkeeping

Good records can help to see trends in pest infestations, keep track of the success or failure of control efforts, and determine how the environment affected the crop. Of course, pesticide application records are essential and should include the time and date of application, product name, EPA registration number, active ingredient, amount used, the target pest, and effectiveness. Some things that general records should include are daily minimum and maximum temperatures, measurements of plant growth and development, the pH of the growing medium, soluble salts, general root health, and other specific crop observations. Insect counts from monitored plants and sticky cards are also useful for identifying trends over time and for determining the effectiveness of control efforts. Over several seasons, it may be possible to see that certain problems occur at the same time each year. Details of releases of beneficial insects and mites should be recorded.

Management Strategies and Tactics

Exclusion. Growers need to make every effort from the beginning of a crop until the final harvest to prevent the introduction of insect and mite pests into the crop. Highly reflective or metalized plastic mulches have been used in agriculture for many purposes, but the primary use has been to repel certain insects. Metalized mulches are effectively used in field production by covering the narrow raised beds in a full-bed polyethylene mulch production system.

Sanitation. Sanitation is closely related to exclusion and should be practiced to manage insects and mites as well as diseases. The following practices are strongly recommended:

- Burning, burying, or hauling away all leftover roots and other plant parts so that there is no chance that insects in the egg, larval, nymphal, pupal, or adult stages could remain. Crop residues must be removed immediately after the final harvest.

- Sanitation must be practiced not only during preplant times but also throughout the growing period. Workers should immediately dispose of plant parts generated by pruning, such as leaves and stems. Culls (undesirable) or overripe fruit should be removed from the surrounding areas. Insects are often attracted to and can live for long periods on these plant materials.

- A clean transplant program will aid in keeping pests out. Plants coming from other locations should be carefully inspected for insects, mites, and diseases and temporarily quarantined until it is clear that the plants are free of pests. Workers should avoid wearing yellow clothing because it is highly attractive to insects.

Biological control. Biological control means providing or releasing insect or mite predators, parasitoids (specialized parasites that ultimately kill their hosts), nematodes, or disease-causing organisms (fungi, bacteria, and viruses) that attack insect pests (Figure 4.6). Some biological controls cannot be used with most insecticides. Reducing or eliminating chemical pesticides leads to a safer working environment, can reduce production costs, and, in the case of organic production, can result in premium prices for the crop. Biological control, however, is much more management intensive than using conventional insecticides and miticides and requires a greater knowledge of pest biology and pest

Figure 4.6: Predatory stink bug feeding on a pest larva. Credit: J.L. Castner, former UF/IFAS Department of Entomology and Nematology.

numbers. Many factors contribute to success or failure of biological control: type and quality of the natural enemy selected, release rates, timing, placement, temperature and humidity, and the previous use of insecticides and miticides.

Suppliers can provide technical advice on the optimum use of their products. Some have detailed websites. In general, releases must be made when or before the pest population is first detected. High pest populations will be difficult to control biologically. Some predators and parasitoids are better adapted to particular temperature and humidity conditions than others, and some do better on some crops than others. The life span of the parasitoid or predator will determine how often it has to be reintroduced. It is important to note that if all the pests are eliminated, the natural enemies will also be eliminated. Providing nectar sources (flowering plants) may prolong the life of parasitoid wasps. Yellow sticky cards may have to be temporarily removed to avoid trapping predators and parasitoids.

Insecticides and miticides. Even when a good biological control program has been established, there may be times when a conventional insecticide or miticide is needed. Biorational insecticides, such as insecticidal soaps, oils, neem products, and Bacillus thuringiensis (Bt) can be much less harmful to beneficial insects, although active against pest species. Systemic insecticides, insect growth regulators, and pheromones used for mating disruption also fall into this category. Some products are harmful to some stages of some beneficial insects and not others. Oils, for example, are toxic to lacewing eggs and adult parasitoid wasps, but have relatively little effect on adult lady beetles and lacewings. Soaps are toxic to young lady beetle larvae. Neem and Bt products are generally safe for use with natural enemies. Other advantages of biorational insecticides are shorter reentry intervals and safety for workers.

Conventional insecticides and miticides also have a place in IPM, if it is not feasible to use biological controls and if biorational insecticides do not offer sufficient control. These options are limited, however, to only a few registered pesticides. The development of resistance to insecticides is more likely if a product is used repeatedly. Therefore, pesticides with different modes of action should be used in a sequence that will help prevent resistance.

The following steps are suggested when using any pesticide:

1. Choose the right insecticide or miticide. Only after properly identifying the pest can the best insecticide or miticide be selected. Insecticides and miticides are

sometimes effective against one pest but useless against other closely related pests. Also, one pesticide may be effective against a specific developmental stage, while others may be effective against a different stage, or even against all developmental stages. Properly identifying the pest and understanding its biology and life cycle allow the grower to make wiser decisions when choosing an insecticide or miticide. Growers should consult their Cooperative Extension Service, pesticide manufacturers and dealers, published literature, and, ultimately, the pesticide label, for helpful information.

2. Use the correct amount of pesticide. After choosing the pesticide, carefully read the label to determine the correct amount to use. Sometimes this decision will be based on the size or stage of the pest and whether the population is high or low. For example, small caterpillars may require the lowest recommended label rate, while large ones may require the highest.

   It is critical that the quantity of pesticide be accurate; buy a set of graduated cylinders that are marked in ounces (oz) and milliliters (cc or ml), as well as a set of good-quality measuring cups. Plastic syringes (minus the needles) are very useful for measuring thick liquids, such as suspension concentrate (SC) formulations. These are available in several sizes from suppliers of animal feed. A scale is essential for weighing dry flowables, wettable granules, and other dry formulations. Measuring devices, such as graduated cylinders, should have pouring lips and graduated markings that enable accurate measurements. Plastic is generally safer than glass. Accurate measurement is essential for efficacy against the target pest, a safe range of pesticide residues on the crop, efficient use of chemicals and money, and the reduction or elimination of phytotoxicity (burning).

   Proper measuring devices also play an important role in the overall safety and handling of pesticides. They aid in preventing spills of concentrated materials. Pesticide concentrates are usually handled when the sprayer is loaded and diluted sprays are being prepared. Special handling precautions are necessary at this time. The applicator must be particularly careful in handling finished sprays but even more so in dealing with the more dangerous concentrated material. Workers must be mindful, cautious, and use all pesticides according to the label.

   If applicators use too much pesticide, the following problems can result:

   - The crop can have more residue than the law allows, which can pose health hazards to consumers and could prevent the crop from entering the market until it has undergone special cleaning. Reentry by workers into overdosed areas could be dangerous and lead to illnesses, medical costs, and liability to the grower.

   - Production costs could increase without the benefit of added profits.

   - Phytotoxicity is more likely to occur.

   It is important not to exceed the label rates. If the maximum labeled rate is not achieving the desired results, look for other reasons for failure, such as poor coverage or resistance to the insecticide in the target insect population.

3. Apply pesticides at the right time. The chosen pesticide should be applied at the correct time. This is one of the most difficult tasks any grower faces. Determining the best time to apply chemical control is a very dynamic undertaking. Failure to treat at or near the correct time is one of the major reasons for unsuccessful pest management.

   - Growers should regularly and thoroughly inspect the crop so that they are aware of the presence of insects and mites as well as any increase in numbers.

   - Growers and professional applicators should know the pest, its behavior, and its ability to damage the crop.

   - Growers and professional applicators should be aware of the number of insects or mites that constitute an economic or action threshold. Thresholds for each pest where information is available are discussed later in this document.

   - Growers and professional applicators should know the biology of the pest so that insecticide or miticide application can be aimed at the weakest, most vulnerable stage or size. Some stages of insects and mites, such as the egg stage, can seldom be controlled. Young larval or nymphal stages are more easily controlled and require less insecticide or miticide than older stages. Pesticides generally do not affect pupae (large larvae nearing this stage are also difficult to control).

It is generally best to apply pesticides in the late afternoon or evening hours when temperatures start to decrease. This also allows for maximum exposure before "airing" out the sprayed area for employees. Also, many insects are most active at night. The risk of phytotoxicity is greater when applications are made during the middle of the day when temperatures are high. However, it has been reported that better mite control can be achieved by spraying early in the morning hours. As a rule, insecticide or miticide applications should be made while temperatures are low. Pesticides should not be applied when plants are water stressed.

4. Apply pesticides correctly. Proper application, like proper timing, is one of the most important steps in pest control efforts. It does little good to complete the first three steps properly and then fail to deliver the material to the target area. There are many factors and components of spray methods that add up to proper application of pesticides.

   Spray equipment must be properly calibrated. A calibration mistake can result in applying too little pesticide and not achieving control, or applying too much, which is wasteful and illegal. Equipment calibration is presented in detail in Chapter 8.

Weed Management

Weeds compete with agricultural row crops for light, water, and nutrients (Figure 4.7). This competition decreases plant vigor, yield, and crop quality. They also interfere with hand harvest and can complicate or prevent machine harvest. Weeds also serve as alternative hosts for diseases, viruses, and nematodes. There are a range of EDIS documents that can help you identify weeds in Florida, including a document with lists of weed hosts for virus diseases of crops. See "Common Weed Hosts of Insect-Transmitted Viruses of Florida Vegetable Crops" at **http://edis.ifas.ufl.edu/pdffiles/IN/IN93100.pdf**. Other helpful weed identification publications are available from the Southern Weed Science Society for online purchase at **http://www.swss.ws/store/**.

Figure 4.7: Cotton crop overrun with a common cocklebur infestation. Credit: John D. Byrd, Mississippi State University, Bugwood.org.

The first step in weed management is frequent and proper scouting. Fields should be scouted frequently early in the production year when the crop is more susceptible to competition. Keep in mind that weed populations tend to be patchy, are greater along the edges of fields, and will vary within and between fields due to small changes in site characteristics such as increased soil moisture or changes in soil type Scouting should be completed in a zig zag pattern that covers the entire field area. Be sure to include areas with known differences that might lead to increased weed incidence such as low-lying areas and areas with a history of weeds. All observations should be recorded in a field manual for future reference.

Weed management practices can be separated into five categories: prevention, cultural, mechanical, biological, and chemical. The most successful weed management programs will incorporate more than one type of weed control.

Preventative Control

The first step is site selection. Select a field with low weed populations and treat problem areas such as poor drainage prior to crop establishment. Control or mow the weeds at the edges of fields or irrigation furrows to prevent seed formation. Seeds can move on equipment, wind, animals, and in water and may spread throughout the field. Weed seed can also move between fields on tractors, blades of cultivators, heads of harvest equipment, and other methods. All equipment should be cleaned after completing a task in a field with a high weed population. In addition, when possible limit travel in the field to periods when weed seeds are not mature and when possible work your cleanest fields first and move towards the ones with the greatest weed populations. Purchase crop and cover crop seed from reputable sources to limit the amount of weed seed contamination. Prevention of weed seed production when possible will help reduce weed seedbanks over time and reduce future problems. Keep in mind that seeds can mature on a weed in some situations after it has been hand pulled.

Cultural Control

As a professional applicator, instill into your customer base that a healthy crop is a better competitor with weeds. Use healthy transplants or seeds with excellent germination to ensure quick canopy closure when possible. Plants stressed by improper watering (too wet or two dry) or diseases/nematodes are less competitive. Proper nutrition is important; minimize fertilizer in the row middles where crops won't benefit but weeds will. Select the proper row spacing that will allow for quicker canopy closure.

Crop and variety selection has an impact on weed growth. Crops that are tall or have large leaves shade the soil surface and prevent weed seed germination. Crops such as cabbage, bean, and corn are very competitive crops. Onions and carrots allow more light to the soil surface and are less competitive. The same principal of light penetration to the soil surface can be applied to crop varieties, a variety that is compact or smaller in growth is less competitive compared to other varieties.

Multiple vegetable crops are grown with polyethylene mulch as part of the cultural practices. The horticultural benefits of plasticulture are reduced water loss, improved nutrient management, and increased fumigant retention. Plastic mulches also prevent light penetration to the soil surface and inhibits weed seed germination. Weeds can germinate under clear or white plastic which allows light to reach the soil surface. If white mulch is desired select one that has a black underside to prevent light penetration. When plastic mulches are used, grass and broadleaf weed emergence is limited to the crop hole and row middle. Minimizing the size of the planting hole can reduce the number of weeds that emerge. Yellow and purple nutsedge are the only species that pierce the plastic mulch and can rapidly spread within a mulched bed (Figure 4.8).

Figure 4.8: Yellow and purple nutsedges can pierce through plastic mulch. Credit: UF/IFAS Pesticide Information Office.

Crop rotation is an effective weed management tool. Growing the same crop repeatedly with the same weed management practices can select for difficult-to-control weed species as well as other pests and diseases. Properly designed rotations typically include a range of: (1) crop types preferably with a mix of row and agronomic crops, (2) planting dates, (3) agrochemical inputs, and (4) weed management tools. Choose a rotation based on crop competitiveness, use of mulch or cultivation, and different herbicide modes of action. The inclusion of cover crops can be an effective weed management tool. Take care to observe herbicide plant back restrictions or injury may occur in subsequent crops.

Cover crops should be included in any crop rotation. Cover crops shade the soil surface and prevent weed germination. Some cover crops such as rye have allelopathic compounds, which are plant chemicals that prevent seed germination. Additional information can be found in the EDIS document, "Cover Crops Benefits for South Florida Vegetable Producers," at **http://edis.ifas.ufl.edu/pdffiles/SS/SS46100.pdf**.

Mechanical Control

Mechanical weed control includes plows, cultivators, mowers, hoes, and hand-weeding. Chisel and moldboard plows are used at the beginning of the season and cultivate deep into the soil profile. This process buries weed seeds below the germination zone. Light cultivation with a field cultivator controls small weeds by cutting the weeds and is shallow to prevent weed seeds from being brought to the soil surface. A single cultivation provides excellent control of annual weeds; however, cultivation may break apart pieces of perennial weeds and cause the weed to spread. Repeat cultivation is important for perennial weed control as it encourages repeated growth and can reduce the carbohydrates in the storage structure of the weed which can reduce the population over time.

Basket, tine, or finger cultivators lightly disturb the soil surface and control small weeds by breaking roots or foliage. Basket cultivars will provide control in the row middles, however, weed control in the crop row will be minimal. Tine or finger cultivators may provide better weed control in the crop row.

Use mechanical weed control only when it will be most effective because mechanical weed control degrades soil structure, dries the soil surface, and prunes crop roots.

Biological Control

Biological control relies on a biological agent to damage a weed species. This method uses insects, plant pathogens, or animals. Several control agents are host specific controlling certain weed species (i.e. tropical soda apple leaf beetle and tropical soda apple). Because of the narrow feeding habits, this method is typically used in natural and aquatic areas for a single invasive species. Biological control is not used in vegetable production due to the multiple weed species in the field, however, research is being conducted and new techniques may emerge in the future.

Chemical Control

Proper herbicide selection can be an effective weed control tool. Herbicides are classified by their mode of action, which is how they affect plant growth. Herbicides are separated by application placement, selectivity, and translocation.

Application placement includes foliar-applied or soil applied herbicides. Foliar-applied herbicides control the weeds after emergence above the soil surface (post emergence). Proper coverage of the foliage is important for foliar applied herbicides and a surfactant is often required for proper absorption of the herbicide. Soil-applied herbicides control the weeds before emergence above the soil surface (preemergence). Soil-applied herbicides are applied to the soil surface or require incorporation into the soil surface. Incorporation reduces vaporization of certain herbicides or places the herbicide closer to the weed seed. Incorporation includes irrigation, rainfall, or light cultivation. Poor incorporation will result in reduced efficacy.

Herbicide selectivity results in control of a specific type of weed, such as broadleaf or grass weeds only. Auxin herbicides (2,4-D, dicamba) control broadleaf weeds only and are common in grass crops, such as corn. Carfentrazone and certain sulfonylureas have excellent control of broadleaf weeds and low to no injury to grass crops. Grass only herbicides (clethodim, sethoxydim, fluaziflop) control only grass weeds and can be applied over the top of broadleaf crops.

Herbicides can be grouped as translocating or contact herbicides. Translocating, or systemic, herbicides (glyphosate, halosulfuron) move from the contact point to another part of the plant. This is important when controlling perennial weeds, which require root death for complete control. Contact herbicides (carfentrazone, paraquat) kill the area around the contact point; complete coverage is important for these herbicides.

Herbicide resistant weed species have become more problematic. Paraquat-resistant American black nightshade and goosegrass, and glyphosate-resistant Palmer amaranth have been documented or observed in Florida agricultural row crops. To prevent resistance, growers should incorporate nonchemical methods, rotate modes of action, use products with multiple modes of action, use correct rates, and constant monitoring.

Test Your Knowledge

Q: Which of the following principles are combined to create an IPM program? (Select all that apply)

A. Eliminating all insects present in an area
B. Identifying the pest accurately
C. Preventing pest problems
D. Using guidelines to determine the best control techniques
E. Removing vegetation completely at a location
F. Monitoring for pests and pest damage
G. Combining pest management tools

A: B, C, D, F, G

Q: True or False

IPM is the coordinated use of pest and environmental information and available pest control methods to eliminate damage by the most economical means with the least possible hazard to people, property, and the environment.

A: False

Q: Match the pest management method with its example.

1. Exclusion	A. Releasing insect predators
2. Biological control	B. Destroying diseased plant material
3. Chemical control	C. Highly reflective or metalized plastic mulches
4. Sanitation	D. Applying an insecticide

A: 1-C; 2-A; 3-D; 4-B

Q: What is the first step in weed management?

A. Selecting an appropriate herbicide
B. Frequent and proper scouting
C. Taking soil samples
D. Running a field cultivator through the crop rows

A: B

Q: As a professional applicator, what should you recommend to your clients to minimize or prevent pesticide resistance? (Select all that apply)

A. Incorporate nonchemical methods
B. Rotate modes of action
C. Use products with multiple modes of action
D. Use the highest labeled rates
E. Constantly monitor pest populations

A: A, B, C, E

Chapter 5

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 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 reducing the impact of pesticide use on pollinator health.

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.

CERCLA: The Comprehensive Environmental Response, Compensation, and Liability Act, commonly known as Superfund, created a tax on the chemical and petroleum industries and provided broad Federal authority to respond directly to releases or threatened releases of hazardous substances.

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, with 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 steroids that are an important class of organic molecules occurring naturally in plants, animals, and fungi.

Systemic (translocated): 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 be 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 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.

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:

- **IPM** - 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 and 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 long-sleeved 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 5.1).

Figure 5.1: There are many factors to consider when selecting a pesticide. Credit: UF/IFAS Pesticide Information Office.

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 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 ground water 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 of 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 professional row crop applicators are insecticides, fungicides, and herbicides.

Insecticides. Insecticides are toxins that kill insects. Insecticides 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. They are 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 5.2). 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 5.2: Grass-infested okra crop. Credit: Edward Sikora, Auburn University, Bugwood.org.

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. Most fungicides need to be applied before disease occurs or at the first appearance of symptoms to be effective. 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, thus they 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

Insecticides usually are most effective on nymphs or larvae, and in some situations, adults (Figure 5.3). 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 5.3: The more immature stages of pest insects are usually easier to control. Credit: Frank Peairs, Colorado State University, Bugwood.org.

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 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 the pest,
- formulation of the pesticide, and
- 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.

Some pesticides enter pests by both 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 resulting in 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 5.4 – 5.5). 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 5.4 – 5.5: Due to their small size, it can be difficult to distinguish aphids from mites. Credit: J.L. Castner, formerly of the UF Entomology & Nematology Department.

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 and 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 5.6).

Target Pests		Lorsban-4E (pint/acre)
aphids (including brown citrus aphid) glassywinged sharpshooter grasshoppers (1) katydids lepidopterous larvae, such as: avocado leafroller cutworms fruit tree leafroller orange dogs orange tortrix western tussock moth mealybugs (see below for California and Arizona)	scale insects, such as: black scale brown soft scale California red scale (see below for California and Arizona) chaff scale Florida red scale long scale purple scale snow scale thrips (see below for California and Arizona)	2 - 7
citrus rust mites (2) (3)		4 - 7
citrus psylla (4)		5
thrips suppression and mealybugs (California and Arizona, see restrictions)		6 - 12
California red scale (California and Arizona, see restrictions)		8 -12

Numbers in parentheses (-) refer to Pest-Specific Use Directions.

Figure 5.6: Rates often vary depending upon target species. Credit: CDMS.

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 5.7).

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 5.8). 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.

Figure 5.8: Pink bollworms emerging from a damaged cotton boll. Credit: Peggy Greb, USDA Agricultural Research Service, Bugwood.org.

Weed Type and Stage	Rate Per Acre (fl oz)	Weed Type and Stage	Rate Per Acre (fl oz
Annual[1] Small, actively growing Established weed growth	 8 - 16 16 - 24	**Perennial** Top growth suppression Top growth control and root suppression Noted perennials (footnote 1 in **Table 1**) Other perennials[3]	 8 - 16 16 - 32 32 32
Biennial Rosette diameter 1 - 3" Rosette diameter 3" or more Bolting	 8 - 16 16 - 32 32	**Woody Brush & Vines** Top growth suppression Top growth control [2,3] Stems and stem suppression[3]	 16 - 32 32 32

[1] Rates below 8 fluid ounces per acre may provide control or suppression but should typically be applied with other herbicides that a effective on the same species and biotype.
[2] Species noted in **Table 2** will require tank mixes for adequate control.
[3] **DO NOT** broadcast apply more than 32 fluid ounces per acre for single application. Use the higher level of listed rate ranges whe treating dense vegetative growth or perennial weeds with well established root growth. "Other perennials" are defined as those list ed in **Table 1. General Weed List, Including ALS- and Triazine-Resistant Biotypes** without footnote 1. The use on other perennials and on Woody Brush and Vine stems and for stem suppression is not registered in California.
Rates higher than 32 fluid ounces per acre are for spot treatment only. **DO NOT** exceed 64 fluid ounces per acre per year.

Figure 5.7: Rates often vary depending upon growth stage or size. Credit: CDMS.

Unfavorable environmental conditions. Aside from the examples previously mentioned, 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. Wind or conditions conducive to volatility can cause pesticides to drift from their intended sites and can also result in damage to desirable plants. (Figure 5.9). Injuries of this sort are subject to legal penalties.

Figure 5.9: Herbicide vapor drift from a cotton field caused damage to this residential tree. Credit: UF/IFAS Pesticide Information Office.

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 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, managers must do all they can to extend the useful life of the products currently available.

Agricultural managers in Florida have become more aware of pesticide resistance development in key crop commodity pests. Insect resistance to insecticides is a serious problem in whitefly management with a number of products no longer highly effective for killing adult whiteflies. Palmer amaranth resistant to several herbicide chemistries is an especially serious problem and was documented in Florida during 2013.

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 5.10). 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.

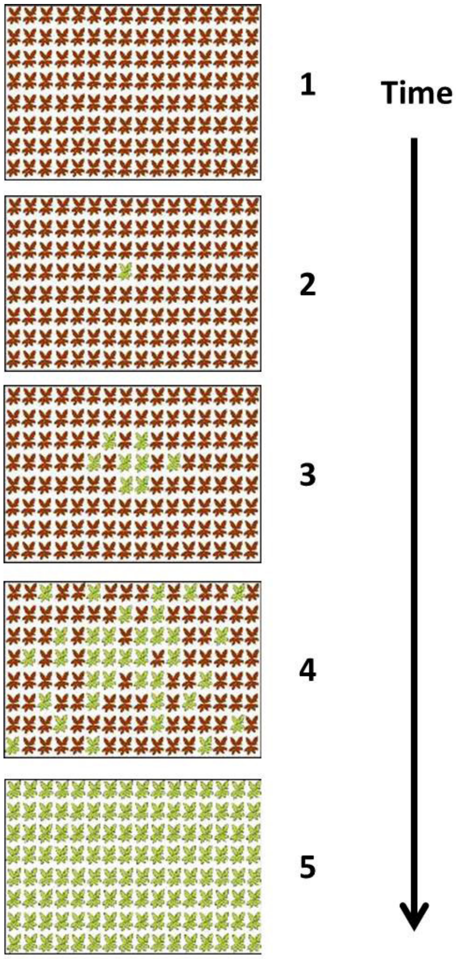


Figure 5.10: Population shift progression from susceptible to resistant individuals. Credit: UF/IFAS Pesticide Information Office.

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 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 pesticide 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 5.11). For example, Figure 5.11 shows a product label displaying its Group 6 mechanism of action. According to the Insecticide Resistance Action Committee, this means that this insecticide active ingredient is a member of the avermectin family with glutamate-gated chloride channel allosteric modulation as its mode of action (affects the insect nervous system). 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 5.1). 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.

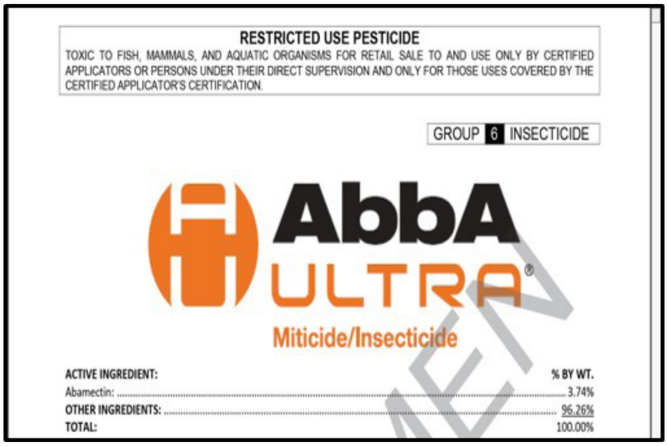


Figure 5.11: Mechanism of action group number displayed in the upper right corner of a product label. Credit: CDMS.

Table 5.1. Resistance Action Committee websites.

Pesticide class	**Website**
Fungicide	http://www.frac.info/
Herbicide	http://www.hracglobal.com/
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 agricultural 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 5.12).
- 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 5.12: Locked metal pesticide storage facility. Credit: UF/IFAS Pesticide Information Office.

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 5.13). 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 5.13: 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. 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.

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 Midwest Plan Service and the UF/IFAS Extension Bookstore. 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 **https://floridadep.gov/waste/permitting-compliance-assistance/content/operation-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 5.14). For more information, go to **https://floridadep.gov/waste/permitting-compliance-assistance/content/operation-cleansweep-pesticides**.

Figure 5.14: Operation Cleansweep unused pesticide collection event. Credit: FDEP.

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 5.15).** This can lead to the costly contamination of a water supply.

Figure 5.15: Never do this; always leave an air gap—it's the law! Credit: UF/IFAS Pesticide Information Office.

Use extreme caution when handling concentrated chemicals (Figure 5.16). 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 5.16: Use extreme caution when handling concentrates—always wear the appropriate PPE. Credit: Gerald Holmes, California Polytechnic State University at San Luis Obispo, Bugwood.org.

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 5.17). 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.

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 5.17: Be ready for spills—large or small. Credit: Mongi Zekri, UF/IFAS Extension.

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. Relatively few of the pesticides routinely used in production agriculture 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 **https://www.epa.gov/sites/production/files/2015-03/documents/list_of_lists.pdf**. It is your responsibility to determine if a pesticide you use has a reportable quantity.

Wash Water. Wash water from pesticide application equipment must be managed properly, since it could contain pesticide residues. Wash the application equipment in a designated wash area (Figure 5.18). 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. Avoid conducting such washing in the vicinity of wells or surface waterbodies.

Figure 5.18: Washing a spray rig on a concrete containment pad. Credit: UF/IFAS Pesticide Information Office.

For large 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 5.19). Otherwise it must be treated as a (potentially hazardous) waste.

Figure 5.19: Agricultural facility with separate rinsate tanks designated for different pesticide classes. Credit: UF/IFAS Pesticide Information Office.

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 which 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 5.20). 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 5.20: 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 site 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 ten 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. Become familiar with Florida's Organo-Auxin Rule as records are required when these herbicides are applied. More information may be accessed at **https://edis.ifas.ufl.edu/wg051** or refer to Chapter 1 of this publication. 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. The western honey bee is conceivably the most important pollinator in Florida and American agriculture. The honey bee is credited with approximately 85 percent of the pollinating activity necessary to supply about a quarter to a third of the nation's food supply. There are also over 4,500 registered beekeepers in Florida, managing a total of more than 400,000 honey bee colonies and producing between 10 - 20 million pounds of honey annually (Figure 5.21).

Figure 5.21: There are over 4,500 registered beekeepers in Florida. Credit: UF/IFAS Pesticide Information Office.

Protecting honey bees and other pollinators from pesticide impacts is important to the sustainability of agriculture, but can be challenging. Pesticide applicators must determine

Figure 5.22: Varroa mite parasitizing a honey bee. Credit: J.L. Castner, former UF Entomology & Nematology Dept.

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.

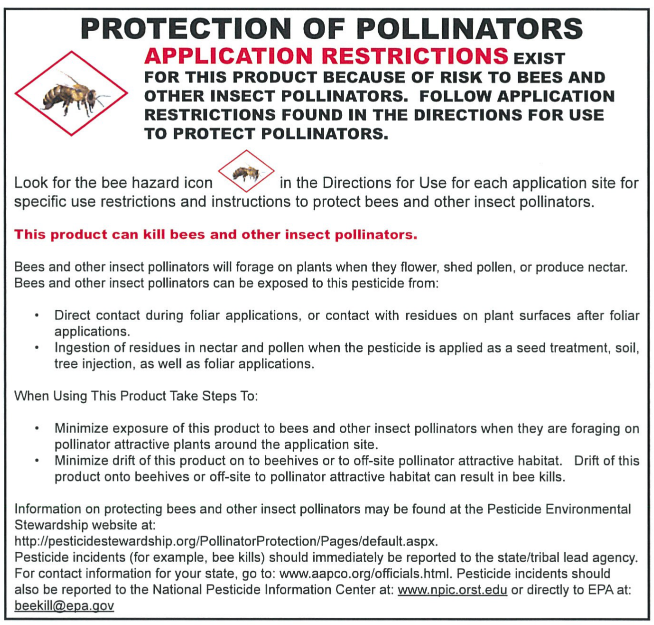
Native bees, butterflies, and other pollinators are wildlife, deserving of protection in the same way birds such as raptors and songbirds are protected. Unfortunately, honey bee health is in decline and some native bees and butterflies are threatened. Honey bees are well studied because of their economic 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 percent to be acceptable, and losses greater than this make it difficult or impossible to remain profitable.

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. 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 (Figure 5.22). Other parasites and pathogens may become a more serious problem in hives weakened by Varroa mites.

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 range 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 habitats, they may be exposed to a complex mixture of many different chemicals.

One group of insecticides, the neonicotinoids (neonics), has 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 5.23). 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.


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 5.23: Product label with pollinator protection directions for use. Credit: CDMS.

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.

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 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 agricultural production has an impact on pollinators. The following section will explain the best ways to minimize pollinator exposure to pesticides.

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 site 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 "Ag-Apiary Mapping Service."

- **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.

- **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, 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. Third, honey bees fly when the air temperature is above 55°F - 60°F. Finally, always check 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 prior to flowering 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 ten ppb (parts 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 (one to six 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 insecticides, 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 more toxic to bees than acetamaprid by itself.

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

2. Resistance

A. The acquired ability of a pest to survive and reproduce following exposure to a dose of pesticide normally lethal to the wild type

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 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: 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

Chapter 6

The Worker Protection Standard and Commercial Pesticide Handler Employers

In this Chapter

Learning Objectives

After you complete your study of this chapter, you should be able to describe the basic elements of the Worker Protection Standard as they pertain to commercial pesticide handler employers, including:

- General responsibilities for commercial pesticide handler employers
- Responsibilities of employers to instruct supervisors of handlers
- Emergency assistance
- Training pesticide handlers
- Employer information exchange
- Decontamination supplies for handlers
- Retaliation against employees
- Employer responsibilities for WPS violations

Terms to Know

Agricultural employer: Any person who is an owner of, or is responsible for the management or condition of, an agricultural establishment, and who employs any worker or handler.

Agricultural establishment: Any farm, forest operation, or nursery engaged in the outdoor or enclosed space production of agricultural plants. An establishment that is not primarily agricultural is an agricultural establishment if it produces agricultural plants for transplant or use (in part or their entirety) in another location instead of purchasing the agricultural plants.

Agricultural plant: Any plant, or part thereof, grown, maintained, or otherwise produced for commercial purposes, including growing, maintaining or otherwise producing plants for sale, trade, for research or experimental purposes, or for use in part or their entirety in another location. Agricultural plant includes, but is not limited to, grains, fruits and vegetables; wood fiber or timber products; flowering and foliage plants and trees; seedlings and transplants; and turf grass produced for sod. Agricultural plant does not include pasture or rangeland used for grazing.

Application exclusion zone (AEZ): The area surrounding the application equipment that must be free of all persons other than appropriately trained and equipped handlers during pesticide applications.

Chemigation: The application of pesticides through irrigation systems.

Closed system: An engineering control used to protect handlers from pesticide exposure hazards when mixing and loading pesticides.

Commercial pesticide handler employer (CPHE): Any person, other than an agricultural employer, who employs any handler to perform handler activities on an agricultural establishment. A labor contractor who does not provide pesticide application services or supervise the performance of handler activities, but merely employs laborers who perform handler activities at the direction of an agricultural or handler employer, is not a commercial pesticide handler employer.

Commercial pesticide handling establishment: Any enterprise, other than an agricultural establishment, that provides pesticide handler or crop advising services to agricultural establishments.

Crop advisor: Any person who is assessing pest numbers or damage, pesticide distribution, or the status or requirements of agricultural plants.

Employ: To obtain, directly or through a labor contractor, the services of a person in exchange for a salary or wages, including piece-rate wages, without regard to who may pay or who may receive the salary or wages. It includes obtaining the services of a self-employed person, an independent contractor, or a person compensated by a third party, except that it does not include an agricultural employer obtaining the services of a handler through a commercial pesticide handler employer or a commercial pesticide handling establishment.

Enclosed space production: Production of an agricultural plant indoors or in a structure or space that is covered in whole or in part by any nonporous covering and that is large enough to permit a person to enter.

Fumigant: Any pesticide that is a vapor or gas, or forms a vapor or gas upon application, and whose pesticidal action is achieved through the gaseous or vapor state.

Handler: Any person, including a self-employed person, who is employed by an agricultural employer or commercial pesticide handler employer and performs any of the following activities:

- Mixing, loading or applying pesticides,
- Disposing of a pesticide,
- Handling opened containers of pesticides, emptying, triple-rinsing, or cleaning pesticide containers according to pesticide product labeling instructions or disposing of pesticide containers that have not been cleaned,
- Acting as a flagger,
- Cleaning, adjusting, handling, or repairing the parts of mixing, loading or application equipment that may contain pesticide residues,
- Assisting with the application of pesticides,
- Entering an enclosed space after the application of a pesticide and before the inhalation exposure level listed in the labeling has been reached or one of the ventilation criteria established by WPS or the labeling has been met to operate ventilation equipment, monitor air levels, or adjust or remove coverings used in fumigation,
- Entering a treated area outdoors after application of any soil fumigant during the labeling-specified entry-restricted period to adjust or remove coverings used in fumigation, and
- Performing tasks as a crop advisor during any pesticide application or restricted-entry interval, or before the inhalation exposure level listed in the pesticide product labeling has been reached or one of the ventilation criteria established by WPS or the pesticide product labeling has been met.

Handler employer: Any person who is self-employed as a handler or who employs any handler.

Immediate family: Is limited to the spouse, parents, stepparents, foster parents, father-in-law, mother-in-law, children, stepchildren, foster children, sons-in-law, daughters-in-law, grandparents, grandchildren, brothers, sisters, brothers-in-law, sisters-in-law, aunts, uncles, nieces, nephews, and first cousins. “First cousin” means the child of a parent’s sibling, i.e., the child of an aunt or uncle.

Labor contractor: A person, other than a commercial pesticide handler, who employs workers or handlers to perform tasks on an agricultural establishment for an agricultural employer or a commercial pesticide handler employer.

Owner: Any person who has a present possessory interest (fee, leasehold, rental, or other) in an agricultural establishment. A person who has both leased such agricultural establishment to another person and granted that same person the right and full authority to manage and govern the use of such agricultural establishment is not an owner for purposes of this part.

Personal protective equipment (PPE): Devices and apparel that are worn to protect the body from contact with pesticides or pesticide residues, including, but not limited to, coveralls, chemical-resistant suits, chemical-resistant gloves, chemical-resistant footwear, respirators, chemical-resistant aprons, chemical-resistant headgear, and protective eyewear.

Restricted-entry interval (REI): The time after the end of a pesticide application during which entry into the treated area is restricted.

Treated area: Any area to which a pesticide is being directed or has been directed.

Use: As in “to use a pesticide” means any of the following:

- Pre-application activities, including, but not limited to:
  - Arranging for the application of the pesticide,
  - Mixing and loading the pesticide,
  - Making necessary preparations for the application of the pesticide, including responsibilities related to worker notification, training of workers or handlers, providing decontamination supplies, providing pesticide safety information and pesticide application and hazard information, use and care of personal protective equipment, providing emergency assistance, and heat stress management.
  - Application of the pesticide.

- Post-application activities intended to reduce the risks of illness and injury resulting from handlers' and workers' occupational exposures to pesticide residues during and after the restricted-entry interval, including responsibilities related to worker notification, training of workers or early-entry workers, providing decontamination supplies, providing pesticide safety information and pesticide application and hazard information, use and care of personal protective equipment, providing emergency assistance, and heat stress management.
    - Other pesticide-related activities, including, but not limited to, transporting or storing pesticides that have been opened, cleaning equipment, and disposing of excess pesticides, spray mix, equipment wash waters, pesticide containers, and other pesticide containing materials.

Worker: Any person, including a self-employed person, who is employed and performs activities directly relating to the production of agricultural plants on an agricultural establishment.

Figure 6.1: Harvest operations are considered worker activities. Credit: UF/IFAS Pesticide Information Office.

Figure 6.2: Pesticide application is a handler activity. Credit: UF/IFAS Pesticide Information Office.

What is the Worker Protection Standard?

The Worker Protection Standard (WPS) is a regulation originally issued by the U.S. Environmental Protection Agency (EPA) in 1992 and most recently revised in 2015. This regulation is primarily intended to reduce the risks of illness or injury to workers and handlers resulting from occupational exposures to pesticides used in the production of agricultural plants on agricultural establishments (i.e., farms, forests, nurseries, and enclosed space production facilities, such as greenhouses). Workers are generally those who perform hand-labor tasks in pesticide-treated crops, such as harvesting, thinning, and pruning (Figure 6.1). Handlers are usually those that are in direct contact with pesticides such as mixing, loading, or applying pesticides (Figure 6.2).

The WPS requires agricultural employers and commercial pesticide handler employers to provide specific information and protections to workers, handlers, and other persons when WPS-labeled pesticide products are used on agricultural establishments in the production of agricultural plants. It also requires owners of agricultural establishments to provide certain protections for themselves and their immediate family, to require handlers to wear the labeling-specified clothing and personal protective equipment when performing handler activities, and to take measures to protect workers and other persons during pesticide applications.

This chapter describes some of the WPS protections commercial pesticide handler employers must provide to their handlers. Commercial pesticide handling establishments and their employees are included in WPS when they apply WPS-labeled pesticide products on agricultural establishments, even if some of the pesticide handling tasks (mixing, loading, disposal, etc.) take place somewhere other than the agricultural establishment that is the treatment site. Owners and managers of commercial pesticide handling establishments have WPS responsibilities as commercial pesticide handler employers.

The WPS applies to you if you use a WPS-labeled pesticide product (that contains an AGRICULTURAL USE REQUIREMENTS box under DIRECTIONS FOR USE) on an "agricultural establishment" directly related to the production of an "agricultural plant" (Figure 6.3). If you also employ workers or handlers, directly or through a labor contractor, you will have additional WPS responsibilities. In the WPS, employers of workers or handlers are referred to as "agricultural employers" or "commercial pesticide handler employers" depending on the situation.

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 requirements for the protection of agricultural workers on farms, forests, nurseries, and greenhouses, and handlers of agricultural pesticides. It contains requirements for training, decontamination, notification, and emergency assistance. It also contains specific instructions and exceptions pertaining to the statement on this label about personal protective equipmen (PPE), and restricted-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 24 hours.

PPE required for early entry to treated areas that is permitted under the Worker Protection Standard and that involves contact with anything that has been treated, such as plants, soil, or water, is:

- Coveralls worn over long-sleeved shirt and long pants
- Chemical-resistant gloves such as barrier laminate or butyl rubber gloves
- Chemical-resistant footwear plus socks
- Protective eyewear

Figure 6.3: The presence of an Agricultural Use Requirements box on a label. Credit: CDMS.

Employers are responsible for making sure that workers and handlers receive the protections required by the pesticide labeling and the WPS. The terms "employ" and "agricultural employer" have special meanings in the WPS—you are an employer even though you are self-employed or use only members of your own family to do the work on your establishment. You are also considered the employer when you hire workers or handlers through a labor contractor. However, an owner or agricultural employer who hires handlers through a commercial pesticide handler employer is not considered the handler employer for those handlers.

A complete reference for the WPS is provided by the US Environmental Protection Agency publication: *How to Comply with the 2015 Revised Worker Protection Standard for Agricultural Pesticides: What Employers Need to Know*, available online at: **http://www.pesticideresources.org/wps/htc/htcmanual.pdf.**

NOTE: In all cases, pesticide labeling supersedes the WPS requirements.

General Responsibilities for Commercial Pesticide Handler Employers

A commercial pesticide handling establishment is defined as an enterprise, other than an agricultural establishment, that provides pesticide handler or crop advising services to agricultural establishments. In other words, this is usually a custom pesticide application business that is hired by a farm, forest, nursery, or enclosed space agricultural production facility to apply pesticides or to provide crop-consulting services.

The commercial pesticide handler employer (CPHE) is defined as any person, other than an agricultural employer, who employs any handler to perform handler activities on an agricultural establishment. The CPHE must ensure that:

- All pesticides are used consistent with the pesticide product label at all times, including following the WPS requirements when applicable.
- Each worker and handler receives the protections required by the WPS.
- Each handler, or worker that conducts early-entry tasks, is at least 18 years of age.
- Employees do not clean, repair, or adjust pesticide application equipment without completing WPS handler training.
- Other persons (not employed by the agricultural establishment) do not clean, repair, or adjust pesticide application equipment until they are told:
  - That the equipment may be contaminated with pesticides.
  - About the potentially harmful effects of pesticide exposure.
  - How they are to handle the equipment to limit exposure to pesticides.
  - How to wash themselves and/or their clothes to prevent or remove pesticide residues.

- Handlers are given instruction in the safe operation of equipment used to mix, load, transfer, or apply pesticides.

- Before any equipment is used to mix, load, transfer, or apply pesticides, it must be inspected for leaks, clogged nozzles, worn or damaged parts. Any faulty equipment must be repaired or replaced before use.

- Handlers that apply pesticides on an agricultural establishment are informed about, or are aware of, the location and description of any treated areas on the agricultural establishment where a REI is in effect, and the restrictions on entering those areas.

- Records or other information required by WPS are provided for inspection to an employee of EPA or any duly authorized representative of the Federal, State, or Tribal agency responsible for pesticide enforcement.

Responsibilities of Employers to Instruct Supervisors of Handlers

If a CPHE employs anyone to supervise handlers, or hires handlers through a labor contractor, the CPHE must provide sufficient instructions to the supervisors and/or labor contractors to ensure that handlers receive all required WPS protections. The instructions must specify which tasks the labor contractor and/or supervisors are responsible for in order to comply with the WPS.

The CPHE must also require labor contractors and anyone who supervises handlers to provide sufficient information and directions to each handler to ensure that they can comply with the WPS provisions applicable to their duties and tasks as a handler.

The CPHE and their supervisors must clearly understand each of the responsibilities for complying with the WPS and ensure that they are implemented.

Emergency Assistance

If there is reason to believe that a handler employed by a CPHE has experienced a potential pesticide exposure during or within 72 hours after his or her employment, and needs emergency medical treatment, the CPHE must do all of the following promptly after learning of the possible poisoning or injury:

- Provide emergency transportation. Promptly make emergency transportation available to take the handler from the commercial pesticide handling establishment, or any agricultural establishment on which the handler may be working on behalf of the CPHE, to a medical care facility capable of providing emergency medical treatment to a person exposed to pesticides.

- Provide emergency information. The CPHE must provide all of the following information to the treating medical personnel:

  - Copies of the applicable safety data sheet(s) and the product name(s), EPA registration number(s) and active ingredient(s) for each pesticide product to which the person may have been exposed.

  - The circumstances of application or use of the pesticide on the agricultural establishment.

  - The circumstances that could have resulted in exposure to the pesticide.

Training Pesticide Handlers

The following section provides an overview of the key requirements for training handlers in accordance with the WPS.

There is no grace period for WPS handler training! Handlers must be trained before performing any handling task. All handlers must be trained every 12 months. Employees are only exempt from WPS handler training if the handler is currently:

- Certified as an applicator of restricted-use pesticides.

- Certified or licensed as a crop advisor by a program acknowledged as appropriate in writing by EPA or the State or Tribal agency responsible for pesticide enforcement and that includes all the topics required.

Only qualified trainers may provide training and they must be present during the entire training program to respond to questions. The person who conducts handler training must:

- Currently be a certified applicator of restricted-use pesticides (in any category of certification), or
- Currently be designated as a trainer of certified pesticide applicators or handlers by a Federal, State, or Tribal agency having jurisdiction, or
- Have completed an EPA-approved pesticide safety train-the-trainer program for trainers of handlers.

Training must be given orally from written materials or audio-visually using only EPA approved training materials. Training must be presented in a manner employees can understand using a translator if necessary. Records of handler training must be kept for two years. Training records must be provided to employees upon request.

WPS training materials produced by EPA will bear the official EPA logo and have an EPA publication number. WPS training materials that have been developed by others and approved by EPA will bear an EPA approval number and an EPA statement of approval for use for WPS training. WPS training materials for handlers must include at least the following information:

- Format and meaning of information on pesticide labels and in labeling, including safety information such as precautionary statements about human health hazards.
- Hazards of pesticides resulting from toxicity and exposure, including acute effects, chronic effects, delayed effects, and sensitization.
- Routes through which pesticides can enter the body.
- Signs and symptoms of common types of pesticide poisoning.
- Emergency first aid for pesticide injuries or poisonings.
- How to obtain emergency medical care.
- Routine and emergency decontamination procedures, including emergency eye flushing techniques.
- Need for and appropriate use of personal protective equipment.
- Prevention, recognition, and first aid treatment of heat-related illness.
- Safety requirements for handling, transporting, storing, and disposing of pesticides, including general procedures for spill cleanup.
- Environmental concerns such as drift, runoff, and wildlife hazards.
- Warnings about taking pesticides or pesticide containers home.
- An explanation of WPS requirements that handler employers must follow for the protection of handlers and others, including the prohibition against applying pesticides in a manner that will cause contact with workers or other persons, the requirement to use personal protective equipment, the provisions for training and decontamination, and the protection against retaliatory acts.
- The responsibility of agricultural employers to provide workers and handlers with information and protections designed to reduce work-related pesticide exposures and illnesses. This includes:
  - Ensuring workers and handlers have been trained on pesticide safety,
  - Providing pesticide safety and application and hazard information,
  - Providing decontamination supplies and emergency medical assistance,
  - Notifying workers of restrictions during applications and on entering pesticide treated areas, and
  - Informing workers or handlers that they may designate, in writing, a representative to request access to pesticide application and hazard information.
- How to recognize and understand the meaning of the posted warning signs used for notifying workers of restrictions on entering pesticide treated areas on the establishment.
- How to follow directions and/or signs about keeping out of pesticide treated areas subject to a REI and application exclusion zones (AEZ).

- Where and in what forms pesticides may be encountered during work activities, and potential sources of pesticide exposure on the agricultural establishment. This includes exposure to pesticide residues that may be on or in plants, soil, tractors, application and chemigation equipment, or used PPE, and that pesticides may drift through the air from nearby applications or be in irrigation water.

- Potential hazards from toxicity and exposure that pesticides present to workers, handlers and their families, including acute and chronic effects, delayed effects, and sensitization.

- Routes through which pesticides can enter the body.

- Signs and symptoms of common types of pesticide poisoning.

- Emergency first aid for pesticide injuries or poisonings.

- Routine and emergency decontamination procedures, including emergency eye flushing techniques, and if pesticides are spilled or sprayed on the body to use decontamination supplies to wash immediately or rinse off in the nearest clean water, including springs, streams, lakes, or other sources, if more readily available than decontamination supplies, and as soon as possible, wash or shower with soap and water, shampoo hair, and change into clean clothes.

- How and when to obtain emergency medical care.

- When working in pesticide treated areas, wear work clothing that protects the body from pesticide residues and wash hands before eating, drinking, using chewing gum or tobacco, or using the toilet.

- Wash or shower with soap and water, shampoo hair, and change into clean clothes as soon as possible after working in pesticide treated areas.

- Potential hazards from pesticide residues on clothing.

- Wash work clothes before wearing them again and wash them separately from other clothes.

- Do not take pesticides or pesticide containers used at work to your home.

- Safety data sheets provide hazard, emergency medical treatment, and other information about the pesticides used on the establishment they may come in contact with. It is the responsibility of agricultural employers to do all of the following:

  – Display safety data sheets (SDS) for all pesticides used on the establishment.

  – Provide workers and handlers information about the location of the SDS on the establishment.

  – Provide workers and handlers unimpeded access to SDS during normal work hours.

- The rule prohibits agricultural employers from allowing or directing any worker to mix, load or apply pesticides or assist in the application of pesticides unless the worker has been trained as a handler.

- The responsibility of agricultural employers to provide specific information to workers before directing them to perform early-entry activities. Workers must be 18 years old to perform early-entry activities.

- Potential hazards to children and pregnant women from pesticide exposure.

- Keep children and nonworking family members away from pesticide treated areas.

- After working in pesticide treated areas, remove work boots or shoes before entering your home, and remove work clothes and wash or shower before physical contact with children or family members.

- How to report suspected pesticide use violations to the State or Tribal agency responsible for pesticide enforcement.

- The rule prohibits agricultural employers from intimidating, threatening, coercing, or discriminating against any worker or handler for complying with or attempting to comply with the requirements of this rule, or because the worker or handler provided, caused to be provided or is about to provide information to the employer or the EPA or its agents regarding conduct that the employee reasonably believes violates this part, and/or made a complaint, testified, assisted, or participated in any manner in an investigation, proceeding, or hearing concerning compliance with this rule.

- Information on proper application and use of pesticides.

- Handlers must follow the portions of the labeling applicable to the safe use of the pesticide.
- Format and meaning of information contained on pesticide labels and in labeling applicable to the safe use of the pesticide.
- Need for and appropriate use and removal of all PPE.
- How to recognize, prevent, and provide first aid treatment for heat-related illness.
- Safety requirements for handling, transporting, storing, and disposing of pesticides, including general procedures for spill cleanup.
- Environmental concerns, such as drift, runoff, and wildlife hazards.
- Handlers must not apply pesticides in a manner that results in contact with workers or other persons.
- The responsibility of handler employers to provide handlers with information and protections designed to reduce work-related pesticide exposures and illnesses. This includes:
  - Providing, cleaning, maintaining, storing, and ensuring proper use of all required PPE,
  - Providing decontamination supplies, and
  - Providing specific information about pesticide use and labeling information.
- Handlers must suspend a pesticide application if workers or other persons are in the application exclusion zone (AEZ).
- Handlers must be at least 18 years old.
- The responsibility of handler employers to ensure handlers have received respirator fit-testing, training and medical evaluation if they are required to wear a respirator by the product labeling.
- The responsibility of agricultural employers to post treated areas as required by this rule.

Training records for each handler must be kept on the establishment for two years from the date of training. The training record must include:

- The handler's printed name and signature,
- The date of training,
- Trainer's name,
- Evidence of the trainer's qualification to train,
- Employer's name, and
- Information to identify which EPA-approved training materials were used for the training. (i.e., the EPA document number or EPA approval number for the materials.)

A copy of the training record is not required to be provided to each handler trained. However, the CPHE must provide a copy of the training record to the trained handler if requested by the employee. Individual training record forms or other methods of maintaining the required training information may be developed and used to meet this requirement.

How often must handlers be trained? Once every 12 months (annually), counting from the end of the month in which the previous training was completed.

Employer Information Exchange

Whenever a commercial pesticide handler, including crop advisors, will perform pesticide handling tasks on an agricultural establishment, the CPHE must provide the agricultural employer with certain information concerning pesticide applications being conducted on the agricultural establishment.

The purpose of this exchange of information is to allow the agricultural employer the opportunity to inform workers or handlers of pesticide applications made, restricted areas, and to record and display the appropriate information.

In addition, the agricultural employer must provide certain information to the CPHE about treated areas on the agricultural establishment. The purpose of this exchange of information, and the requirement for the CHPE to pass it along to the handler, is to ensure that a commercial pesticide handler is aware of areas under REIs on an agricultural establishment close to where he/she will be working.

What information should an agricultural employer provide to the CPHE? Before a commercial pesticide handler enters an agricultural establishment, the agricultural employer must inform the CPHE about treated areas and any restrictions on the establishment and the CPHE must provide that information to the commercial pesticide handler. While it is the agricultural employer's responsibility to inform the CPHE, the CPHE must obtain this information so it can be communicated to their handler employees. The agricultural employer must provide to the CPHE:

- The specific location and description of any treated areas on the agricultural establishment under a restricted-entry interval that the commercial pesticide handler may be in (or walk within 1/4 mile of), and
- Any restrictions on entering those areas.

The CPHE must inform their handler of the information provided by the agricultural employer.

What information should a CPHE provide to the agricultural employer? To allow an agricultural employer to inform workers on the establishment about a pesticide application that is, or will be performed, the CPHE must inform the agricultural employer of the following:

- The specific location and description of the area(s) on the agricultural establishment that are to be treated with a pesticide product,
- Date, start time, and estimated end time of the pesticide application,
- Pesticide product name, EPA registration number, and active ingredient(s),
- REI for the pesticide product,
- Whether the pesticide product labeling requires posting, oral notification, or both to be conducted by the agricultural employer, and
- Any other specific requirements on the pesticide product labeling concerning protection of workers and other persons during or after application.

What if the information changes? The CPHE must provide the agricultural employer with updated information PRIOR to the application when there are any changes to:

- The location to be treated,
- REI,
- Method of notification,
- Labeling requirements to protect workers/other persons, or
- The start time which will cause it to be earlier than estimated.

If the product information changes or there are other changes to the date, start, and end time, the CPHE must provide the updated information to the agricultural employer within two hours after completing the application. Changes to the estimated application end time of less than one hour do not need to be reported to the agricultural employer.

Decontamination Supplies for Handlers

To prevent, or mitigate pesticide exposures, the commercial pesticide handler employer is required to provide supplies to each handler for routine washing to remove pesticide residues, emergency decontamination, and immediate eye flushing in certain situations (Figure 6.4).

What supplies must be provided?

- Water. The water must be of a quality and temperature that will not cause illness or injury when it contacts the skin or eyes or if swallowed. If a water source is used for mixing pesticides, it cannot be used for decontamination without additional precautions taken to prevent contamination of the water with pesticides (e.g., back-flow prevention device, air gap, etc.).

- Soap and single use towels. Enough for handlers' needs. Hand sanitizers or wet towelettes do not meet the requirement for soap or towels.

- Clean change of clothes. Such as one-size-fits-all coveralls, to put on if the handlers' clothes are contaminated and need to be removed right away.

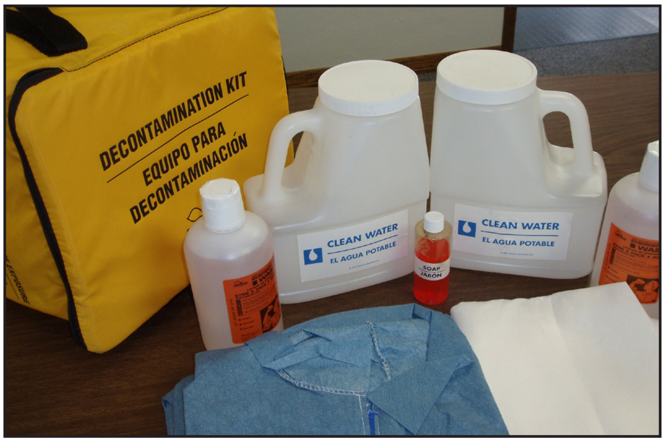


Figure 6.4: Commercially-available portable decontamination supply kit. Credit: UF/IFAS Pesticide Information Office.

For handlers, three gallons or more per handler of water is required at the start of the work period. Emergency eye flushing supplies must be provided at any site where handlers are mixing or loading a pesticide that requires protective eyewear or are mixing or loading any pesticide using a closed system operating under pressure. The supplies that must be available are:

- A system capable of delivering gently running water at a rate of at least 0.4 gallons per minute for at least 15 minutes, or

- At least six gallons of water in containers suitable for providing gently running water for eye flushing for 15 minutes. The container(s) must be able to dispense a gentle steady flow of water.

Additionally, when applying a pesticide that requires protective eyewear, one pint of water must be immediately available to each handler in a portable container (on the applicator's person or in the application equipment being used).

Where must routine decontamination supplies be located?
The water for routine cleaning, soap, single use towels and change of clothes must be located together and must be:

- Reasonably accessible to handlers (within 1/4 mile or at the nearest vehicular access),

- Outside of any treated area or an area under an REI unless supplies (soap, single-use towels, clean change of clothing and routine decontamination water) are all contained within a pesticide protected closed container (except if running water is available, it does not have to be in the container),

- At any mixing or loading site, and

- At the site where PPE is removed.

For a pilot who is applying pesticides aerially, the decontamination supplies must be at the aircraft's loading site or in the aircraft.

Retaliation Against Employees is Prohibited

The commercial pesticide handler employer, their supervisors or others cannot intimidate, threaten, coerce or discriminate against, prevent, discourage, or fire any handler for complying or attempting to comply with the WPS. Additionally, the commercial pesticide handler employer cannot retaliate in any manner if:

- Any handler refuses to participate in any activity that the handler reasonably believes to be in violation of the WPS,

- Any handler has, or is about to report WPS noncompliance to appropriate authorities for enforcement of WPS provisions, or

- Any handler agrees to provide information to the EPA or any duly authorized representative of a Federal, State or Tribal government about WPS compliance, or assists or participates in any manner in an investigation, proceeding, or hearing concerning WPS compliance.

Employer Responsibilities for WPS Violations

Commercial pesticide handler employers can be subject to civil and criminal penalties if they do not comply with the federal WPS including all revisions to this rule. Failure to comply is a pesticide misuse violation since the WPS is referenced on applicable pesticide product labeling. Failure to comply with distinct requirements of the WPS can result in independently assessable charges, even if the violative acts occurred during one pesticide application.

The Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) includes provisions that hold commercial pesticide handler employers liable for a WPS penalty if another person employed by or acting for them, including supervisors, fails to comply with any WPS requirements. The term "acting for" includes both employment and contractual relationships.

Test Your Knowledge

Q: Match the person with their activities.

1. Worker
2. Handler
3. Commercial pesticide handler employer

A. Mixing, loading, and applying pesticides
B. Harvesting, pruning, and transplanting
C. Person who employs handlers to perform handler activities on an agricultural establishment

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

Q: Which of the following commercial establishments are considered to fall under the requirements of the WPS? (Select all that apply)

A. Strawberry farm
B. Anheuser Busch in Jacksonville
C. Port of Miami
D. Longleaf pine nursery
E. Ornamental plant nursery
F. Landscaped grounds at the Ritz-Carlton
G. Greenhouse producing tomato transplants

A: A, D, E, G

Q: How would you know if a pesticide product falls under the requirements of the WPS?

A. It will have a RESTRICTED USE classification box on its label
B. It will be a product manufactured only in the U.S.
C. Its labeling will contain an Agricultural Use Requirements box
D. Its labeling will have a skull and crossbones symbol on the front panel

A: C

Q: How often are commercial pesticide handler employers required to provide safety training for their pesticide handlers?

A. Once trained, the handler does not need to repeat training for that employer
B. Every 12 months
C. Every two years
D. Every five years

A: B

Q: How long must commercial pesticide handler employers keep records of their employees' handler training?

A. Records are not required to be kept
B. One year
C. Two years
D. Five years

A: C

Q: Which of the following materials are approved for commercial pesticide handler employers to use for training handler employees?

A. Those that are purchased from the UF/IFAS Extension Bookstore
B. Those that are purchased from retail suppliers, such as Gemplers
C. Those that are purchased only directly from the EPA
D. Those that bear an EPA approval number

A: D

Q: True or False

Commercial pesticide handler employers are required to provide the agricultural employer with certain information concerning pesticide applications being conducted on the agricultural establishment.

A: True

Q: Which decontamination supplies is the commercial pesticide handler employer required to supply his handler employees? (Select all that apply)

A. Syrup of ipecac
B. Soap
C. Rubbing alcohol
D. Water
E. Shampoo
F. Clean change of clothes
G. Single use towels
H. After-shave lotion

A: B, D, F, G

Q: True or False

Commercial pesticide handler employers cannot retaliate in any manner if any handler refuses to participate in any activity that the handler reasonably believes to be in violation of the WPS.

A: True

Q: True or False

A commercial pesticide handler employer's failure to comply with the WPS is a pesticide misuse violation since the WPS is referenced on applicable pesticide product labeling.

A: True

Chapter 7

Application Equipment

In this Chapter

Learning Objectives

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

- Recall the main advantages and disadvantages associated with various types of pesticide application equipment.
- List four types of sprayer pumps and indicate their main features and suitabilities.
- Give at least two benefits that are likely if you follow the “extra 20 percent rule” when you buy a new pump.
- Explain the purpose of strainers in a sprayer system.
- Identify desirable features of tanks, hoses, pressure gauges and regulators, and valves.
- Name two types of agitation used in sprayers and identify the formulations best suited to each type.
- Name the four principal parts of a nozzle and describe the main function of each part.
- List the five principal factors that determine any nozzle’s performance.
- Recall basic nozzle patterns and give an example of a specific nozzle tip for each pattern.
- Recall five materials that nozzle tips are made of and describe the wear characteristics of each.
- Describe the kinds of equipment used to apply granules.
- Identify the basic system components associated with a chemigation system.
- State the procedural steps for preparing a sprayer for storage and flushing chemigation equipment.

Terms to Know

Abrasion: The process of being worn away by physical action (such as grinding or rubbing).

Agitation: The physical motion used to produce mixing (such as stirring or shaking).

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

Concentrate: Pesticide formulation containing a high percentage of active ingredient; occasionally applied full-strength, but usually diluted before application.

Corrosion: The process of being worn away by chemical action (such as rusting).

Diluent: Anything used to dilute a pesticide.

Dilute pesticide: A pesticide that is not concentrated; one that has a low percentage of active ingredient.

Drift: Pesticide unintentionally carried away from the target site.

Emulsifiable concentrate: A liquid formulation that contains an active ingredient, one or more petroleum-based solvents, and an agent that allows the formulation to be mixed with water to form an emulsion (droplets of one liquid dispersed in another liquid).

Foliage: Primarily the leaves; may include stems of a plant.

Formulation: Pesticide product as sold; usually a mixture of active and inert ingredients.

gpa: Gallons per acre; the standard unit of measure for spray volume in calibration calculations.

gpm: Gallons per minute; the standard unit of measure for nozzle output in calibration calculations.

Hydraulic agitation: Stirring or mixing provided by high-pressure flow from a pump.

Independently powered: A mechanism whose rotational speed (rpm) is not determined or influenced by the travel speed (fpm) of the application equipment.

Mechanical agitation: Stirring or mixing done by the motion of paddles or propellers.

Personal Protective Equipment (PPE): Devices and clothing worn to protect the human body from contact with pesticides.

psi: Pounds per square inch; a measurement of pressure.

Soluble powder: A pesticide formulation marketed in a dry form but designated for use as a spray after being mixed with water. The powder dissolves in water to form a true solution. Solutions require little or no agitation and are not abrasive to sprayer parts.

Target: The site or pest toward which control measures are being directed.

Volatile: Evaporating rapidly; turning easily into a gas or vapor.

Wettable powder: A pesticide formulation that is marketed in a dry form but designed for use as a spray after being mixed with water. The powder does not dissolve in water, instead it forms a suspension. Sprays made from wettable powders generally require constant agitation; the fine particles are abrasive to sprayer parts.

Introduction

The equipment you use may determine the success of your pesticide application. For this reason alone, it is important to select the right kind of application equipment, use it correctly, and maintain it. This chapter provides an overview of what you need to know to choose, use, and properly care for pesticide application equipment. Knowing the information in this chapter can help you in understanding other equipment literature (such as an equipment manual, or nozzle selection chart). Always study the equipment manufacturer's directions carefully.

Liquid Application Equipment

Sprayers are the most common kind of pesticide application equipment. Sprayers range in size and complexity from simple handheld devices to self-propelled machines that weigh tons. This section briefly describes the kinds of sprayers that agricultural row crop applicators are most likely to use.

Large power driven sprayers (low-pressure) are widely used in row crop agriculture and are designed to apply dilute sprays to large areas (Figure 7.1). Some models are mounted on trailers; others are fitted on tractors or trucks. They deliver a low to moderate volume of spray, usually 10 to 60 gallons per acre, at working pressures ranging from 10 to 80 psi.

Figure 7.1: Large low-pressure sprayers are commonly used in row crop agriculture. Credit: UF/IFAS Pesticide Information Office.

Roller pumps or centrifugal pumps are most often used and typically provide outputs from 5 to 20 gallons per acre. Spray tank sizes range from 50 to 1,000 gallons and are generally fitted with either a hydraulic or mechanical agitator.

These sprayers may be configured as either boom or boomless sprayers. Advantages of these sprayers are that the tank size allows a large area to be treated per fill, and versatility. However, a limitation is that low pressure may limit spray penetration and reach.

Boom sprayers are low pressure sprayers that have their nozzles mounted along a horizontal spray boom (Figure 7.2). The spray boom may be 10 to 90 feet long. The height of the boom can be adjusted to the needs of the job. By changing the nozzle arrangement along the boom, one can set up a boom sprayer for either broadcast, band, or directed spraying.

Figure 7.2: Large row crop sprayer. Credit: Gerald Holmes, California Polytechnic State University at San Luis Obispo, Bugwood.org.

Hand spray guns apply pesticide to a targeted area, such as applying herbicides along fence rows and spot treatments for weed control (Figure 7.3). Applicators also use them to apply insecticides to livestock for control of external parasites.

You can attach hand spray guns to many different types of spraying equipment. Many row crop sprayers have connections for attaching a hand spray gun for specialized spraying.

Figure 7.3: Boom sprayer equipped with a hand spray gun attachment. Credit: UF/IFAS Pesticide Information Office.

Components of Liquid Application Equipment

Before considering liquid pesticide application as a whole, look at all the individual components. Make sure they meet your application needs by assessing the application site and customizing the sprayer to best target the pest, accommodate plant structures and sizes, and apply pesticides uniformly. Some components, such as nozzles, are easy to replace when worn or damaged or if your application requires a change. Other parts, such as tanks, are expensive to replace and may be difficult to repair if they become damaged. Select these with care to be sure they are compatible with the pesticides you plan to use.

Pesticide tanks. Manufacturers produce tanks for mixing and holding liquid pesticides from metal, fiberglass, and thermoplastic materials such as polyethylene and polypropylene. Choose a nonabsorptive material so you can easily clean the tank of pesticide residues. Tanks must be resistant to corrosion and rust to protect them from reacting with corrosive pesticides. They should have a large opening for easy filling and cleaning (Figure 7.4). Table 7.1 is a guide for selecting tanks based on your pesticide application needs.

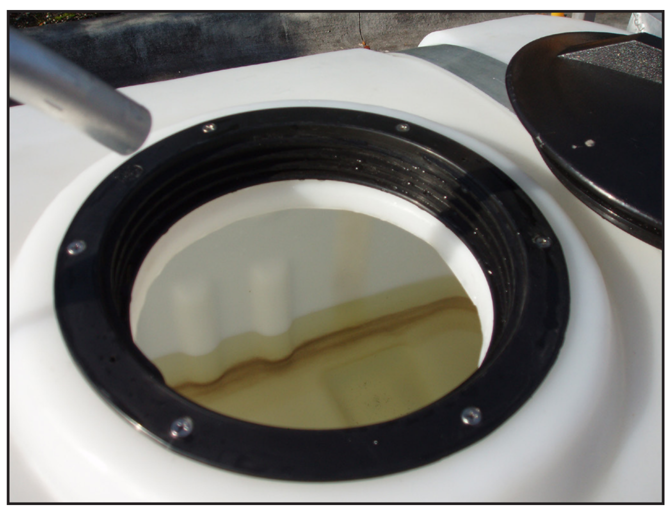


Figure 7.4: Tanks should have a large opening for ease in filling. Credit: UF/IFAS Pesticide Information Office.

The tank opening should have a cover. A tight-fitting cover prevents pesticides from spilling or splashing. A lockable cover may be a worthwhile safety feature. It prevents unauthorized or accidental exposure to the tank contents.

Table 7.1. Pesticide tank selection guide[1].

Characteristics	Tank type				
	Coated metal	**Stainless steel**	**Fiberglass**	**Polypropylene**	**Polyethylene**
Acid resistance	Fair to good	Depends on grade	Fair to good	Good	Good
Alkali resistance	Excellent	Excellent	Fair	Good	Good
Organic solvent resistance	Excellent	Excellent	Poor to fair	Good	Fair
Rust and corrosion resistance	Fair to good	Excellent	Excellent	Excellent	Excellent
Absorbs pesticides	If scratched	No	If scratched	No	No
Easily cleaned	Good	Excellent	Fair	Excellent	Excellent
Easily repaired	Yes	Yes	Yes	No	No
Strength and durability	Good to excellent	Excellent	Good	Good	Good
Weight	Heavy	Heavy	Medium	Light	Light
Requires external reinforcement	No	No	No	Yes	Yes
Cost	Moderate	High	Moderate	Low	Low
[1]From Publication 3324, UC Statewide Integrated Pest Management Program.					

Larger tanks need a bottom drain so that they can be completely drained. The inside of large tanks should allow mechanical or hydraulic agitation devices to be installed. All tanks with a 50-gallon capacity or larger should have a sight gauge, tube, or other accurate means to determine the amount of liquid in the tank. Equip external sight gauges with shut-off valves to prevent leaking if they become damaged.

Agitators. Spraying equipment needs an agitator for initial mixing of pesticides and to keep insoluble mixtures from settling inside spray tanks. Use a sprayer with agitation whenever wettable powders, water-dispersible granules, flowables, or emulsions will be mixed and sprayed. There are two primary types of agitation system: hydraulic and mechanical (Figure 7.5).

Hydraulic agitators circulate spray material through jets located in the bottom of the spray tank. In most designs, this fluid comes from a bypass line on the pressure (outlet) side of the pump. Other sprayers have a separate pump to circulate fluid for tank agitation. Jets located in the bottom of the tank must be at least one foot from tank walls. This prevents the spray from weakening or making holes in the tank. The main disadvantage with hydraulic agitation is that they are not able to break up settled spray material when you shut the pump down for a while. Severe settling requires mechanical agitation to re-suspend insoluble particles.

Mechanical agitators are propellers or paddles mounted on one or more rotating shafts near the bottom of a spray tank. The shaft passes through the tank wall and connects to the drive line by belts or chains. Mechanical agitators can provide constant mixing in the tank even if the sprayer pump is not running. They are usually effective

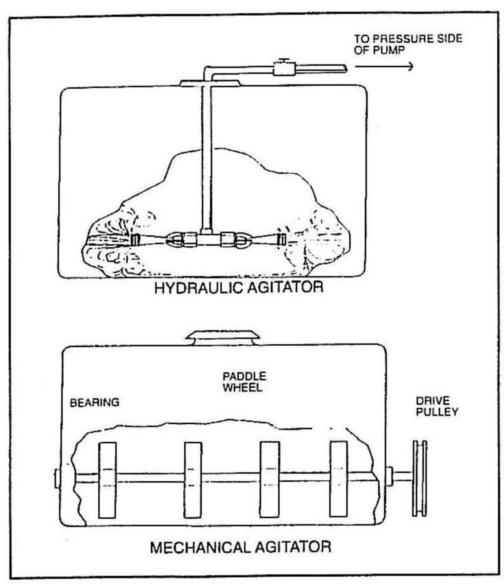


Figure 7.5: Illustration of two primary types of agitation. Credit: UF/IFAS Communication Services.

in suspending settled formulations. Mechanical agitators require some maintenance, especially where shafts pass through tank walls. Packings and grease fittings prevent leaks but need periodic tightening and servicing. Be sure to use a marine-grade grease on bearings and seals exposed to liquids. Also, periodically tighten and service belts or chains.

Pumps. The type and size of pump required is determined by a number of factors, including the pesticide formulation, the spray pressure needed, and the nozzle delivery rate desired (Figure 7.6). Regardless of pump type, the pump must have enough capacity to both operate the agitation system and supply the needed volume to the nozzles. This can be accomplished if the pump's capacity is at least 20 percent greater than the largest volume required by the nozzles—the extra 20 percent will allow for agitation, desired nozzle output, and loss of pump capacity due to normal wear.

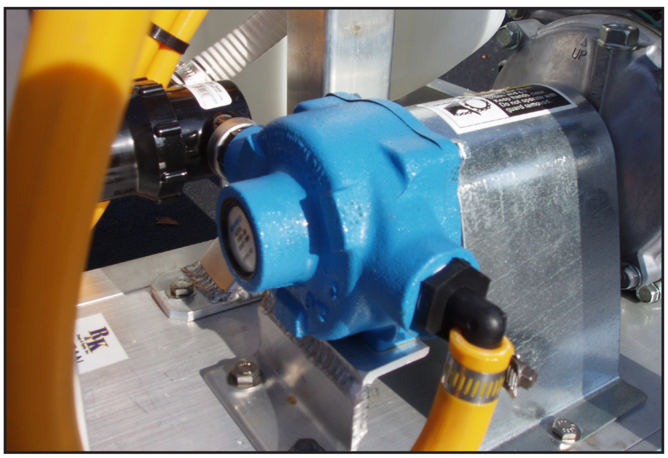


Figure 7.6: Roller pumps are commonly used sprayer pumps. Credit: UF/IFAS Pesticide Information Office.

Pump parts should resist corrosion and be abrasion-resistant if abrasive materials, such as wettable powders, will be used. Select gaskets, plunger caps, and impellers that resist the swelling and chemical breakdown caused by many liquid pesticides. Dealers will have available options. Never operate a pump at speeds or pressures above those recommended by the manufacturer. Any pump will be damaged if operated dry or with restricted flow at the inlet or outlet. Most pumps depend on spray mix for lubrication and cooling.

Table 7.2 is a guide for selecting common pump designs. Other types of pumps not included in this table may also be available and suitable for certain applications.

Strainers. Three types of strainers are commonly used on agricultural sprayers:

1. tank-filler strainers,
2. line strainers, and
3. nozzle tip strainers.

The primary purposes of strainers are to keep foreign matter from plugging the sprayer nozzles and minimizing pump

Table 7.2. Pesticide sprayer pump selection guide[1].

Pump type	Pressure range (psi)	Output volume (gpm)	Operating speed (rpm)	Suitable pesticide formulations	Comments
Centrifugal	5-200	>200	1,000-5,000	All	Used on large, heavy-duty sprayers. Common on air-blast sprayers. Best for high-volume uses.
Diaphragm	20-700	5-40	500-800	All (organic solvents may deteriorate some parts)	Often used on low-volume herbicide sprayers. Also used with some high-pressure equipment.
Gear	20-100	5-65	500-2,000	Nonabrasive	Limited uses. Good for low-volume and low-pressure applications.
Piston	20-1,000	2-60	500-800	Nonabrasive unless equipped with wear-resistant cups	Excellent for high-pressure applications. Very versatile.
Roller	10-300	8-40	300-2,000	Nonabrasive only; may be damaged by organic solvents	Limited low-volume uses. Can produce moderate pressure.
[1]From Publication 3324, UC Statewide Integrated Pest Management Program.					

wear. The main types are the slit and the wire mesh (Figure 7.7). Strainer numbers (20-mesh, 50-mesh, etc.) indicate the number of openings per linear inch of wire mesh. Thus, strainers with low numbers only filter out large particles; strainers with high numbers will filter out small particles. Probably the most widely used wire mesh strainer has a 50-mesh screen. This strainer will filter out most trouble-making particles while still allowing wettable powders to pass through.

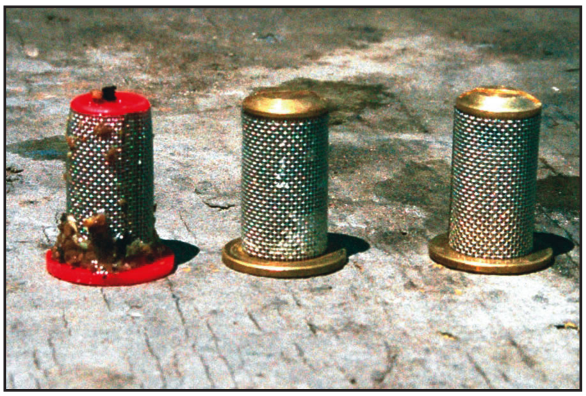


Figure 7.7: Left to right: strainer with debris; strainer with leftover pesticide, and clean strainer. Credit: UF/IFAS Pesticide Information Office.

Hoses. Select neoprene, rubber, or plastic hoses that resist collapse and:

- have a burst strength that is greater than the pump's peak operating pressure,
- have a working pressure that is at least equal to the sprayer's maximum operating pressure,
- resist oil and solvents present in pesticides, and
- are resistant to sunlight.

Inspect all hoses regularly and replace any that show signs of chemically-caused deterioration (cracking, swelling, softening, or hardening).

For fittings and couplings, select noncorrosive materials that can withstand the solvents used in pesticide formulations. Brass, stainless steel, and high-density plastic are common materials for these fittings. Use quick disconnect couplings and fittings in case you need to make repairs to the system. Be sure couplings or fittings do not reduce the internal diameter of the hoses they connect. This could cause a pressure drop at the nozzles and additional pressure on the pump.

If you need to attach or disconnect certain hoses during operation, use dry break couplings. These prevent pesticide leaks when you disconnect the hoses. Dry break couplings have a spring-loaded check valve that automatically plugs the disconnected hoses and fittings.

Flow control valves. Use control valves to turn on and shut off liquid being pumped to the nozzles. These may be trigger-type valves on hand spray guns or lever valves controlling spray to nozzles on a boom. A sprayer may be set up so that electric solenoids control each nozzle individually.

Field and row crop spray booms often have two or three controllable sections and special valves for these sections (Figure 7.8). In one case, a control valve for a three-section boom is divided into left, center, and right sections; and the valve supplies spray to the:

- right section only,
- left section only,
- center section only,
- right and left sections,
- right and center sections,
- left and center sections, and
- all three sections.

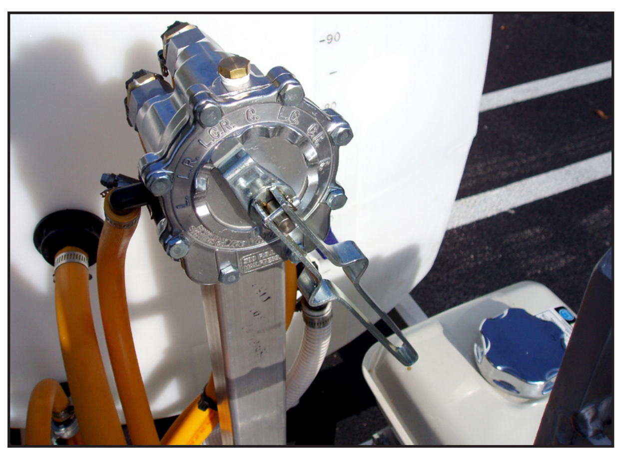


Figure 7.8: Control valve used to turn on or shut off sections of the boom. Credit: UF/IFAS Pesticide Information Office.

Electronic sprayer controllers allow very accurate metering of pesticide sprays. They use microcomputers to monitor and regulate spray output and/or pressure at each nozzle. Some units warn the operator of malfunctions of nozzles or pumps. These controllers allow consistent and precise amounts of pesticide even if the travel speed of the equipment varies. Some controllers use sensing devices to regulate the spray according to target plant size or type. Other controllers use GPS navigation to automatically shut off nozzles and prevent respraying of areas in the field.

Pressure regulators. A pressure regulator is a spring-loaded valve that controls the pressure of liquid. In sprayers, pressure regulators are used between the pump and the nozzle, spray boom, or manifold (Figure 7.9). To change the pressure, adjust the amount of compression on the valve by turning the pressure-regulating screw or handle. Increasing the spring tension (turning the screw clockwise) increases the pressure going to the nozzles. When the pressure in the system exceeds the pressure of the spring-loaded valve, the valve opens. This allows some spray material to flow back into the tank and prevents pressure in the system from going any higher. Should the pump output pressure drop, the regulator reduces or stops the flow of liquid into the tank.

For an accurate reading, adjust pressure regulators while the system is operating, and nozzles are spraying. When you shut off the nozzles, pressure in the system increases slightly and the pressure regulator sends all the liquid through the bypass.

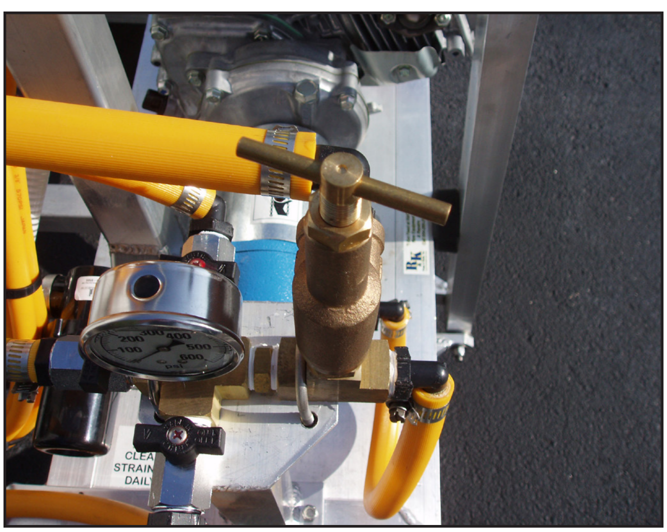


Figure 7.9: Spring-loaded pressure relief valve. Credit: UF/IFAS Pesticide Information Office.

Unloaders. An unloader senses pressure changes that occur when turning on or shutting off the flow of liquid to the nozzles. When you shut off all the nozzles, the unloader returns all the pumped liquid into the spray tank. Once the flow to the nozzles starts, the unloader redirects the liquid at the pressure set by the pressure regulator. Unloaders are an important part of high-pressure systems because they protect pumps, valves, hoses, and other components from excessive, sudden pressure surges. They also reduce the power load on the sprayer engine.

Pressure gauges. The purpose of the pressure gauge is to allow the operator to monitor the fluid pressure in the system (Figure 7.10). A change in pressure also warns of potential malfunctions such as leaks or clogged nozzles. Usually, install the pressure gauge between the pressure regulator and as close to the boom as possible to minimize pressure losses through tubing. In this position, it monitors pressure in the system while spray is being emitted through the nozzles.

Proper equipment calibration depends on an accurate pressure gauge. A damaged pressure gauge, such as one with a bent indicator needle, one that sticks, or will not zero should be replaced immediately.

Figure 7.10: Pressure gauge with a 300 psi maximum reading capacity. Credit: UF/IFAS Pesticide Information Office.

You have a choice of gauges to measure different ranges of pressures. For example, some measure from 1 to 20 psi, while others measure from 1 to 200 psi, 1 to 500 psi, or 1 to 1,000 psi. Be sure the gauge you use is compatible with your sprayer pressure range. If your sprayer produces a maximum of 50 psi, a gauge with a range of 1 to 500 psi will be difficult to read and will have reduced accuracy. Use a gauge with a range of 1 to 100 for greater accuracy. The 1 to 500 psi gauge works best on sprayers that operate at maximum pressures of 300 or 400 psi. Gauges should operate at about 50% of their maximum pressure. This protects them against damage in the case of unexpected pressure surges. When possible, use glycerin-filled gauges on spray equipment. These last longer and can absorb the shock of rapid pressure changes and the vibrations from the equipment. You can recognize these gauges by the clear liquid visible inside the face of the dial.

Nozzles. Nozzles are one of the most important parts of the sprayer because they control a pesticide's application rate, droplet size, and spray pattern. Your choice of nozzle impacts the amount of potential drift that may occur as well as the effectiveness and efficiency of the application. If you do not carefully select and maintain nozzles, you may have a less than desirable to a disasterous outcome.

Several different nozzle designs and construction materials are available, depending on the type of application. Base your nozzle selection on several criteria, including the

- material the nozzle is made of,
- type of nozzle design,
- nozzle orifice size,
- pesticide formulation,
- droplet size, pattern, or distribution, and
- drift risk.

Most nozzles used for spraying row crops have four major parts (Figure 7.11):

1. body
2. strainer (screen)
3. tip
4. cap

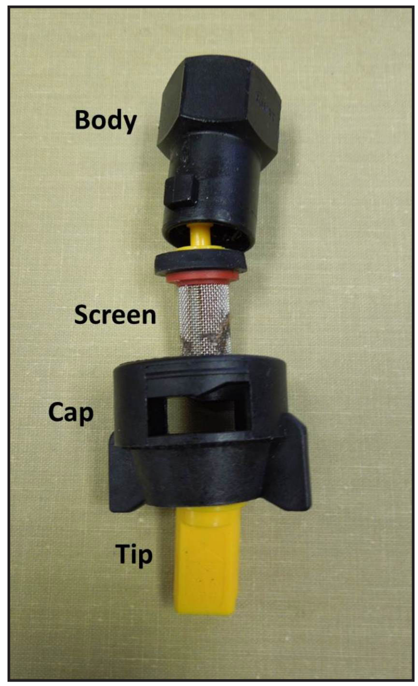


Figure 7.11: The four major parts of a nozzle. Credit: UF/IFAS Pesticide Information Office.

The nozzle body holds the strainer and tip in proper position. Tips that produce different spray patterns may be interchanged on a nozzle body. The nozzle strainer is placed in the nozzle body to screen out debris that may clog the nozzle opening. The size and type of strainer to use depends on the size of the tip and the chemical being sprayed. Nozzle screens equipped with a check valve help prevent nozzle dripping. Check valve screens (dripless nozzles) are especially useful when a sprayer must be stopped and started frequently. The cap secures the strainer and the tip to the body. The cap should not be overtightened. Nozzle tips break the liquid spray mix into droplets and distribute the spray in a predetermined pattern. Nozzle tips influence application rate, spray coverage and spray penetration.

Table 7.3. Nozzle materials.

Material	Comments
Aluminum	• Useful life much shorter than brass • Not damaged by solvents and oils • Easily corroded by most fertilizers • Very quickly abraded by wettable powders and flowables
Plastic	• Easily broken or damaged (mechanically weak) • Swells when exposed to some solvents • Will not corrode • Resists abrasion better than brass
Brass	• Very good for low-pressure spraying of non-abrasive formulations • Not damaged by solvents and oils • Corroded by some liquid fertilizers, but not corroded by most pesticides • Quickly abraded by wettable powders and flowables
Stainless steel	• Lasts longer than brass • Will work with high pressure and wettable powders • Good corrosion resistance • Resists abrasion, especially if hardened
Tungsten carbide and ceramic	• Lasts longer than stainless steel • Best materials for high pressures and wettable powders • Very good corrosion resistance • Better abrasion resistance than any other material

Table 7.4. Nozzle selection guide[1].

Nozzle style	Suggested uses	Recommended pressure (psi)	Spray pattern
Flat-fan	Preemergent and postemergent herbicides, insecticides, and fungicides. Used on a boom.	20-60	Fan-shaped pattern with fewer droplets at sides than in center of fan pattern. Suitable for overlapping with other nozzles to produce wide spray swath.
Off-center flat-fan	Used on ends of spray booms to extend reach of spray pattern.	20-60	Fan-shaped with angle to one side.
Even flat-fan	Preemergent and postemergent herbicides, insecticides, and fungicides. Do not overlap spray pattern.	20-40	Fan-shaped pattern with even distribution of spray across width of fan.
Cone	Insecticides and fungicides applied to foliage. Often used with airblast sprayers.	40-120	Hollow or solid cone pattern. Fine spray droplets, good penetration.
Solid stream	All types of pesticides. Used on booms and handguns.	5-200	Low- or high-pressure solid stream. High pressure breaks spray into fine to medium droplets.
Flood	Herbicides and fertilizers. High volume and low pressure reduce drift. Used on booms.	5-20	Wide, fan-shaped pattern of coarse droplets.
Broadcast	Weed and brush control in pastures. Nozzles are clustered without boom.	10-30	Wide, fan-shaped pattern ranging from fine to coarse droplets.
[1]From Publication 3324, UC Statewide Integrated Pest Management Program.			

Most nozzle parts are available in several materials that differ widely in cost, durability, or both. The principal materials are aluminum, plastic, brass, stainless steel, tungsten carbide, and ceramic. The main features of each material are shown in table 7.3.

Different applications require nozzles adapted to specific requirements. Nozzles used to apply herbicides in a field may be unsuitable for applying fungicides or insecticides to foliage. Airblast sprayers have different nozzle requirements than those used in row crops. Table 7.4 is a guide for selecting nozzles based on your pesticide application needs.

Most manufacturers have a method of coding nozzle tips, and they print identification numbers on the face of the nozzle (Figure 7.12). For example, for flat spray nozzles, a common nozzle number is 8004. The first two digits indicate that the nozzle produces an 80-degree fan spray angle when set at the proper height over the target surface. The last two numbers indicate the volume of spray (0.4 gpm) output at 40 psi. Nozzle number 6515 is a 65-degree fan spray producing a volume of 1.5 gpm at 40 psi. Check the manufacturer's catalog to determine the rated operating pressure for the nozzle you use. Some nozzle styles operate at higher or lower pressures. For example, manufacturers commonly rate flood nozzles at 10 psi.

When selecting nozzles, read the manufacturer's catalog. Learn about the nozzle sizing, its proper application, and the optimal pressure range. Manufacturers have charts for selecting spray volume or determining nozzle size.

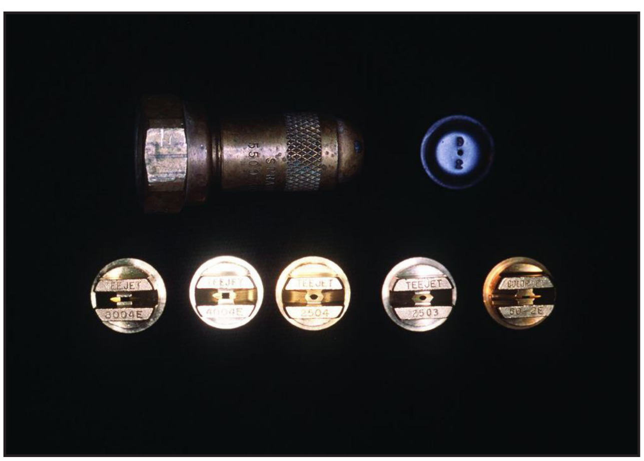


Figure 7.12: Various nozzle types. Credit: UF/IFAS CAIP.

Spray shields. When necessary, install spray shields on your boom sprayer to confine pesticide droplets and minimize drift (Figure 7.13). The shields consist of boxes constructed of metal, plastic, or fabric shrouds. These surround the nozzles and confine the spray to a small area of ground or specific plants. Attach these to the spray boom so they move with the tractor as a unit. Damaged spray shields should be replaced so that the crop is not harmed.

Figure 7.13: Sprayer with shields. Credit: Charles T. Bryson, USDA Agricultural Research Service, Bugwood.org.

Chemigation

Injection pumps allow application of pesticides through irrigation systems, a practice known as chemigation (Figure 7.14). Depending on the type of irrigation system, chemicals may be applied to the root zone, the aerial part of the plant, or both. Applying pesticides using irrigation systems is an effective and efficient means to deliver them, since these systems are already optimized to thoroughly cover a target area. Chemigation is not a perfect solution, however, and chemigation systems, per Federal and Florida law, must have devices in place to prevent possible contamination of the water supply by backflow of irrigation water. For instance, regulations require automatic shut-off devices on injection pumps that can stop pesticides from being injected into the system when the irrigation water flow stops.

Chemigation should be used only when water and pesticides can be distributed uniformly by the irrigation system. At best, uneven delivery of pesticides via irrigation systems may result in unsuccessful control of the target organism; at worst, it can result in environmental contamination, crop injury, and can waste money and natural resources.

Parts of a chemigation system. In addition to the existing water delivery system, a chemigation setup contains the following components:

- A chemical supply tank (with agitator), with sufficient secondary containment, to hold concentrated pesticide.
- A platform to support the tank, pump, and piping.
- A series of specially designed valves (many are packaged as a unit) to prevent water and backflow contamination, control chemical dispersion through the system, and drain the system after use.
- An injection system to deliver pesticide from the tank in controlled amounts.
- A metering pump that functions both with required safety equipment and the pesticide formulation.
- A low-pressure switch that will stop the water pump motor when water pressure falls below levels effective for proper pesticide distribution.
- Interlocking electrical or hydraulic controls that will automatically shut down the pesticide injection pump in response to the low-pressure switch.
- A calibration setup, such as a tube, to help properly calibrate the injection system.

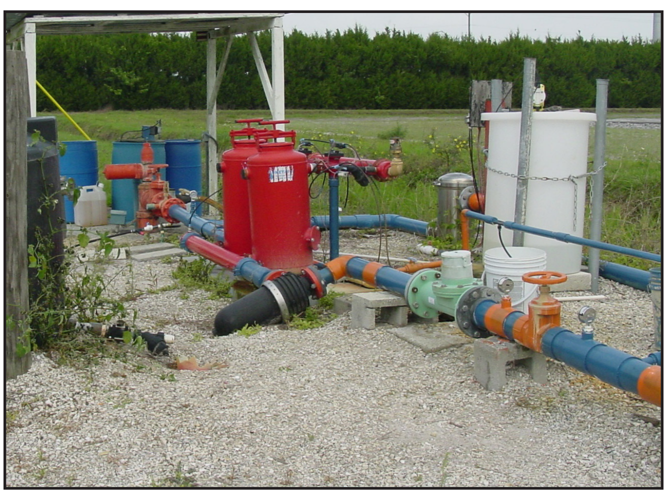


Figure 7.14: Chemigation system setup. Credit: Mongi Zekri, UF/IFAS Multi-County Citrus Agent.

Granule Applicators

There may be times when agricultural row crop applicators receive requests to apply a granular pesticide product. Because many agricultural pesticide product dealerships also offer custom lime and fertilizer services, the same spreader equipment may be used for pesticides formulated as granules. The material hopper may be mounted on a large truck or towed as a trailer. The spreading of material is facilitated by spinning blades, which sling the granules in swaths, generally ranging from 40 to 70 feet.

Because granules are of varying sizes and shapes, equipment must accommodate size differences. Pellet formulations are granules of identical size and shape. When applied through specially designed applicators, pellets allow for accurate calibration. This provides more uniform application rates than are possible with irregularly shaped granules.

Application Equipment Maintenance

Regular equipment maintenance is a must for pesticide applicators. There are three good reasons for this:

- Pesticide misapplication is very likely if a treatment is made with faulty equipment.
- In Florida, it's against the law for a pesticide applicator to operate faulty or unsafe equipment.
- WPS also has a provision requiring that application equipment be maintained.

Put simply, your application equipment will only work as well as you maintain it. The best thing to do is check every part of your equipment on a regular basis—and train your employees to do likewise.

Liquid application equipment—preventing problems. Take the following preventive steps to reduce problems of sprayer malfunction or breakdown and to maintain uniform and accurate application.

- Use clean water. Water that contains sand or silt causes rapid pump wear and can clog screens and nozzles.

- Keep screens in place. Filter screens remove foreign particles from the spray liquid. It is a nuisance to remove collected debris from the screens, but debris accumulation indicates that screens are doing the job for which they were intended.

- Use chemicals that are compatible with the sprayer and pump. Spray chemicals are corrosive to some metals and deteriorate rubber and plastic components. Avoid problems by modifying the equipment to accommodate the corrosive pesticides. Otherwise, use the equipment only for chemicals that are not corrosive. Sometimes it is possible to replace parts of a sprayer with corrosion-resistant materials.

- Flush sprayers before use. Use clean water to flush new sprayers and sprayers coming out of storage. Flushing removes foreign particles, dirt, and other debris. The manufacturing process may leave metallic chips, dirt, or other residue in the tank or pump.

- Clean sprayer after use. Clean your sprayer according to the instructions on the label of the last pesticide used. Following the label's directions will ensure that your efforts will remove most residues that can contaminate future tank mixes or damage crops (Figure 7.15). Cleaning agents should be selected based on the herbicide and formulation to be cleaned. Cleaning agents should penetrate and dissolve pesticide residues and allow them to be removed when the rinsate is removed from the sprayer. The functions of cleaning agents are dilution, solubilization, and deactivation. Commercial tank-cleaning agents and detergents help remove both water- and oil-soluble herbicides. The commercial tank-cleaning agents usually perform better than household detergents and can deactivate some herbicides in addition to solubilizing them. Some tank-cleaning agents and ammonia solutions also raise the pH of the rinsate solution, making some products such as sulfonylurea herbicides more water soluble and thus easier to remove from internal sprayer parts. Chlorine bleach solutions will accelerate decomposition of sulfonylurea and some other herbicides into inactive compounds. However, chlorine is less effective at dissolving and removing sulfonylurea herbicide residues from spray tanks than ammonia solutions. Chlorine bleach should never be added to ammonia or liquid fertilizers containing ammonia because the two materials react to form toxic chlorine gas, which can cause eye, nose, throat, and lung irritation.

Figure 7.15: A spraying system contaminated with dicamba caused injury to these peanut plants. Credit: UF/IFAS Pesticide Information Office.

Liquid application equipment–inspection and maintenance. Perform regular inspections and periodic maintenance on spraying equipment. This keeps it in good operating condition and ready for use. Always check for the following problems:

- Weakened hoses
- Leaking fittings
- Damage to the tank or tank protective coating
- Broken regulators or gauges
- Worn nozzles
- Worn bearings
- Damaged tires (if equipped)
- Other mechanical defects or wear

Liquid application equipment–storage. Before storing a sprayer, decontaminate and clean it thoroughly. Wear the appropriate PPE to avoid contact with pesticide residues. Remove, clean, and reinstall all filters. Partially fill the tank with clean water and add a commercial neutralizing cleaner, or ½ pound of detergent to 30 gallons of water. Circulate this solution through the system for at least 30 minutes and flush it out through the nozzles. Refill the sprayer about half full. Add more commercial cleaner according to directions or add one quart of household ammonia to each 25 gallons of water.

Circulate this solution for about five minutes and flush a small amount through the nozzles. Shut off the sprayer and let the solution remain in the tank for 12 to 24 hours.

While the cleaning solution is soaking in the tank, thoroughly wash all external parts of the sprayer. Use a detergent or ammonia solution or a commercial cleaner. Scrub residue off all surfaces using a bristle brush.

Remove and clean nozzles and nozzle strainers. Store in a clean plastic bag to keep them free of dirt.

After the tank has finished soaking, flush the solution out and rinse with clean water. Seal nozzle outlets with corks or plastic bags to prevent insects or dirt from getting into the lines. Remove and clean all remaining filter screens and store them in a clean plastic bag. Remove o rings from filters and strainers and store them in a plastic bag to prevent them from becoming brittle. Cover the tank loosely to prevent dirt, insects, and rodents from entering during storage. Do not close the tank cover tightly, as this may permanently distort its rubber seal. You can remove small pumps and store them in a can of new, lightweight motor oil to prevent rusting. However, if pumps have rubber or neoprene parts, do not expose them to oil.

Release the tension from the pressure regulator and remove the o ring seal. Lubricate the internal cylinder of the regulator and reassemble without the o ring. Place the o ring in a plastic bag and tie it to the regulator.

Before using spray equipment again after it has been in storage, be sure to flush the system thoroughly with clean water.

Granule application equipment–inspection and maintenance. Before using granule applicators, inspect them for wear and to make sure there are no pesticide residues left in the hopper or anywhere else on the machine. Remove and replace worn or damaged parts and check to be sure there are no blockages before loading the equipment. Check to make sure the gear cover is in place on applicators that have one; this helps protect moving parts that are easily damaged by dirt or pesticide residue.

Empty and thoroughly wash granule applicators after every use. Normally, cold water is all that you will need to remove pesticide residue from the equipment; however, some pesticides will require scrubbing or the use of hot water to loosen built-up residues. It may be useful to close the spreader, so the hopper can be filled with water and then drained.

Lubricate granule applicators only if the manufacturer recommends it. Be careful of too much lubrication, because grease can increase the buildup of pesticide residues and dirt that can damage an applicator's moving parts. Read the manufacturer's recommendations carefully to find out if your equipment requires lubrication before taking this step.

Granule application equipment–storage. Granule applicators should be housed inside. Store equipment only after it is clean and completely dry. Any pesticide remaining in or on the equipment can cause corrosion, as can moisture and heat, especially in combination.

Chemigation equipment–inspection and maintenance. Periodic monitoring of chemigation systems can help you ensure that they are operating safely and effectively. The following items should be inspected thoroughly before you begin chemigation activities:

- Main pipeline check valve
- Vacuum relief valve
- Low-pressure drain
- Chemical injection line check valve
- Main control panel for the irrigation system and pumping plant
- Chemical injection pump safety interlock
- Injection system (inline strainer, manual valve, and chemical storage tank)
- Irrigation pump
- Injection pump
- Power source

Repair or replace any parts you find that are damaged or worn. Be sure to recalibrate the system any time maintenance has been performed and parts have been replaced.

Chemigation equipment must be thoroughly flushed after each use to ensure safe operation during the next application. After completing an application, run the irrigation system for at least 10 minutes to flush out any chemicals that may remain. You may have to run the system for more than 10 minutes if you are using drip irrigation, as water takes longer to run through low-volume systems. For any irrigation type that shuts down automatically at the end of an application, be sure to flush it as soon as possible after shutdown is complete. You must also flush systems that have been shut down because of a malfunction or loss of water pressure. Do this as soon as you can after discovering the shutdown. In both these situations, it is best to flush the system for at least 30 minutes, to be sure all traces of the pesticide have been run out of the system.

Use clean water to flush the injection system after each use to prevent pesticides from accumulating. It is best to flush the injection system as you are irrigating, so that whatever pesticides you flush out are applied to the same site.

Test Your Knowledge

Q: What is a major disadvantage of polypropylene and polyethylene materials for constructing pesticide tanks?

A. The pesticide mixture easily corrodes this material
B. They aren't easily repaired if damaged
C. They readily absorb pesticides
D. They have no acid resistance

A: B

Q: Which type of pump is an excellent choice for a high volume, high pressure application?

A. Piston
B. Roller
C. Gear
D. Diaphragm

A: A

Q: Which type of agitation system is the best choice for keeping wettable powder pesticide formulations evenly dispersed after mixing into the tank?

A. Turbo
B. Hydraulic
C. Jet
D. Mechanical

A: D

Q: True or False

Strainers with low numbers, such as 20-mesh, only filter out large particles; strainers with high numbers will filter out small particles.

A: True

Q: What is meant by the "20% rule" when selecting a pump for pesticide applications?

A. Always spend less than 20% of the asking price of a used pump
B. Capacity allowance for agitation, desired nozzle output, and loss of pump capacity
C. Keeping 20% less oil of pump capacity for lubricating purposes
D. A factor that is used in relation to sprayer ground speed for setting the pump speed

A: B

Q: Which of the following statements is false regarding pressure gauges for pesticide application equipment?

A. The needle should not stick or be bent
B. The purpose of the pressure gauge is to allow the operator to monitor the fluid pressure in the system
C. If your sprayer produces a maximum of 50 psi, a gauge with a range to 500 psi is a good choice
D. Always replace the pressure gauge if it will zero out

A: C

Q: Which of the following nozzle materials would be expected to best resist abrasion?

A. Brass
B. Aluminum
C. Stainless steel
D. Ceramic

A: D

Q: What does a nozzle code of 8002 designate?

A. 8-degree spray angle with an output of 2.0 gpm
B. 8-degree spray angle with an output of 0.2 gpm
C. 80-degree spray angle with an output of 0.02 gpm
D. 80-degree spray angle with an output of 0.2 gpm

A: D

Q: What is a legal requirement of chemigation systems?

A. A solar-powered injection pump
B. Device to prevent backflow
C. Pump that operates on the Venturi principle
D. A chemical holding tank constructed of polypropylene

A: B

Q: True or False

In Florida, it's against the law for a pesticide applicator to operate faulty or unsafe pesticide application equipment.

A: True

Chapter 8

Equipment Calibration and Calculating Site Sizes

In this Chapter

Learning Objectives

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

- Define calibration and explain why calibration is essential to safe, effective pest control.
- List the tools needed for calibration.
- Describe how to calibrate liquid sprayers and be able to calculate speed, gallons per minute for low- and high-pressure sprayers, and nozzle output using formulas.
- Describe how to determine the correct amount of pesticide for a particular application.
- Describe methods used to determine how much pesticide to put into the hopper or tank for a specific application rate over the total area of the application site.
- Describe the best way to change the output of various types of pesticide application equipment and the consequences of each change.
- Calculate the amount of liquid pesticide product needed to prepare a spray mix containing a desired percentage of pesticide product (dilutions).
- Describe how to determine granule output and distribution from a spreader.
- Describe how to calibrate micro-sprinkler and drip and center pivot irrigation systems for delivering pesticides to the treatment site, also referred to as chemigation.
- Explain how system controllers can impact the calibration of equipment and calculations necessary to apply pesticides effectively.
- Explain the importance of properly calibrating sensors that are part of a system controller.
- Know how to calculate the area of a rectangle, circle, and triangle and how these regular-shaped units can be used to calculate the area of an irregular-shaped site.

Terms to Know

Band application: Applying a pesticide in narrow lengthwise strips (such as along a crop row) with untreated portions lying between adjacent treated areas.

Band width: Usually measured in inches; the distance across any individual lengthwise strip actually being treated with pesticide by a band application device.

Broadcast application: Applying a pesticide uniformly to an entire target site.

Calibration: The process of measuring and adjusting equipment performance.

Directed spraying: Applying a pesticide spray at a specific portion of a plant or other target site.

Effective swath width: Usually measured in feet; the width of the treatment path made by any application device that does not require overlap from a subsequent pass in order to be suitably treated.

fpm: Feet per minute; for most calibration arithmetic, fpm is the best form to express actual travel speed.

gpa: Gallons per acre; the standard unit of measure for spray volume in calibration calculations.

gpm: Gallons per minute; the standard unit of measure for nozzle output in calibration calculations.

GPS: The Global Positioning System is a space-based navigation system that provides location and time information in all weather conditions, anywhere on or near the Earth where there is an unobstructed line of sight to four or more GPS satellites.

mph: Miles per hour; an alternative measure of travel speed, sometimes used in nozzle selection charts, but usually not very useful for calibration arithmetic.

rpm: Revolutions per minute is a measure of the frequency of rotation, specifically the number of rotations around a fixed axis in one minute. It is used as a measure of rotational speed of a mechanical component.

Introduction

Calibration refers to all the adjustments you make to be sure you apply the correct amount of pesticide to the treatment area. This chapter discusses the steps you need to take to calibrate pesticide application equipment commonly used by agricultural row crop applicators. Examples of calculations are provided along with step-by-step instructions. There are shortcuts, but first, principles of calibration will be presented.

To calibrate your equipment, you must first determine the amount of pesticide to apply—the rate. Check the product label's Directions for Use to verify that the crop/site to treat is approved. The rate is most often given as the appropriate unit amount of product per area—most often acres, square feet, or a percentage dilution. You may need to adjust ground speed and equipment output or modify application patterns to achieve the desired rate. Once you have calibrated your equipment, check and test it periodically to be sure calibration remains accurate. Your equipment will very likely need adjustments to continue applying the desired rate.

Appendix C contains a list of helpful conversion factors to use when calibrating pesticide application equipment.

Why Calibration is Essential

The main reason for calibrating application equipment is to determine how much product to put into the tank or hopper. Without calibration, you can't ensure that you will apply the correct amount. Calibration is necessary for:

- Effective pest control
- Protecting human health, domestic animals, and the environment
- Preventing waste of resources
- Controlling the volume of water applied to an area (liquid applications)
- Complying with the law

Effective pest control. Registration of a single pesticide active ingredient costs manufacturers millions of dollars due to all of tests required along with research and development costs. A portion of the research is determining the correct amount of formulated product to effectively and safely control target pests. Using less than the labeled rate may result in inadequate control, wasting time and money. Using too much product has adverse effects on natural enemies, target surfaces, and the environment. Applying higher than label rates also wastes product, but more importantly, it is illegal.

Human health concerns. If you apply pesticides at higher than label rates, you could endanger the health of people in the area from the increased concentration. In addition, illegal residues may result if a pesticide is overapplied (Figure 8.1). If residues are above allowable tolerances on the crop, regulators may confiscate the entire crop to protect consumers. Poorly calibrated equipment may also expose application equipment operators and fieldworkers to concentrations of pesticide for which they are not adequately protected.

Figure 8.1: Label rates help to safeguard produce from illegal residues, protecting consumers. Credit: UF/IFAS Pesticide Information Office.

Environmental concerns. Improper pesticide concentrations may cause environmental problems. Calibrating equipment to maintain application rates within label requirements helps protect beneficial insects and wildlife. It also reduces the potential for contaminating surface and groundwater and the air.

Preventing waste of resources. Using the improper amount of pesticide wastes time and adds unnecessary costs to the application. Not only are pesticides expensive, but the fuel, labor, and equipment wear and tear required to make additional applications are costly as well.

Legal aspects. Applicators who use pesticides improperly are subject to criminal and civil charges, resulting in fines, imprisonment, and lawsuits. Applicators are liable for injuries or damage caused by pesticide application.

Equipment Calibration Methods—Tools

There are some simple tools needed for calibration. Keep these separately and use only for calibration purposes (Figure 8.2). These tools should be kept clean and in good working condition; make equipment calibration a professional operation. Liquid and granular application equipment require different calibration techniques.

Figure 8.2: Some of the simple tools needed for calibration. Credit: UF/IFAS Pesticide Information Office.

The basic tools needed for calibration include:

- Stopwatch–for timing travel speed and flow rates. Never rely on a wristwatch unless it has a stopwatch function.
- Measuring tape–use a 100-foot moisture- and stretch-resistant tape for marking off the distance to be traveled and measuring spray swath or distance between nozzles.
- Graduated container–use a 1- or 2-quart container, calibrated for liquid ounces, for measuring spray nozzle output.
- Scale–use a small scale capable of measuring pounds and ounces for weighing granules collected from a granule applicator. The most accurate weight measurements come from scales that have maximum capacities from five to 10 pounds.
- Pocket calculator–for making calculations in the field.
- Pressure gauge–use an accurate, calibrated pressure gauge that has fittings compatible with spray nozzle fittings for checking boom pressure and for calibrating the sprayer pressure gauge.
- Flowmeter–use a flowmeter attached to a flexible hose or filling pipe for measuring the amount of water put into a tank. If not available, a five-gallon bucket can be used.
- Flagging tape–use colored plastic flagging tape for marking off measured distances when determining applicator speed.

Calibrating Liquid Sprayers

To monitor pump and nozzle wear, you must calibrate liquid spraying equipment on a regular basis. Abrasive pesticides, such as wettable powders, dry flowables, and water dispersible granules, increase the rate of wear. Pump wear decreases the amount and pressure of fluid output. This usually lowers the output pressure and may produce a poor spray pattern.

The goal is to determine how much area each full tank of spray mix covers when the equipment moves at a known speed and operates at a known pressure. You need to measure these four factors:

- Tank capacity
- Travel speed
- Flow rate
- Spray swath width

Tank capacity. Physically measure the capacity of the spray tank, or tanks, if the equipment has more than one. Never rely on the manufacturer's tank size ratings. They may be approximate or may not consider fittings installed inside the tank. Also, the capacity of spray lines, pump, and filters influence tank volume.

Situate the sprayer on a perfectly level surface. Be sure the tank is completely empty, then close all valves to prevent water leaks. Add measured volumes of clean water until you completely fill the tank. Use a flowmeter attached to a hose, or a bucket, or other container of known volume. A five-gallon bucket works well for smaller sprayers. Be sure to calibrate and mark the bucket before using it to fill the tank. If you are not using a flowmeter, use smaller-volume calibrated containers to top off the tank. After recording the total volume of water, paint or engrave this figure onto the outside of the tank for permanent reference.

While filling the tank, calibrate the tank's sight gauge. Make marks on the tank or gauge as you add measured volumes of water. If the tank does not have a sight gauge, mark volume increments on a dipstick. Then, always keep this dipstick with the tank. Use increments of five or 10 gallons for tanks having a total capacity of 50 gallons or less. On larger tanks, use increments of 10 to 20 gallons (Figure 8.3).

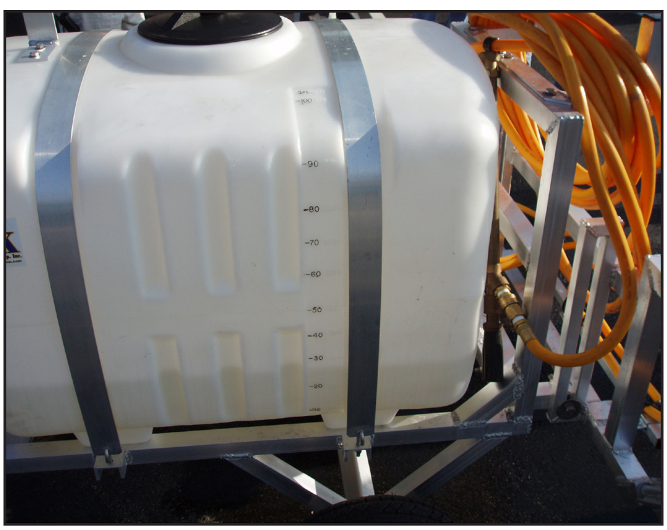


Figure 8.3: 100-gallon tank marked in 10-gallon increments. Credit: UF/IFAS Pesticide Information Office.

Travel speed. Always measure travel speed under actual working conditions. For instance, if you are calibrating a boom sprayer for use in a strawberry field, take the full sprayer to the field. Equipment travels faster on paved or smooth surfaces than on soft sand or clods. Never rely on

Example 8.1. Calculating travel speed.

Step 1. Convert minutes and seconds into minutes by dividing the seconds (and any fraction of a second) by 60.

Example

Your trip took 1 min and 47.5 sec

47.5 sec ÷ 60 sec/min = 0.79 min

Add these amounts together:

1 min + 0.79 min = 1.79 min

Step 2. Determine the average of the run time by adding the converted minutes from each run and dividing by the number of runs.

Example

Three runs were made.

Run One = 1 min, 47.5 sec = 1.79 min
Run Two = 1 min, 39.8 sec = 1.66 min
Run Three = 1 min, 52.0 sec = 1.87 min
Total = 5.32 min

5.32 min ÷ 3 runs = 1.77 min/run average time

Step 3. Divide the measured distance by the average time. This will tell you how many feet were traveled per minute.

Example

The measured distance is 227 feet.

227 ft ÷ 1.77 min = 128.25 ft/min

Step 4. If you wish to determine the speed in miles per hour, divide the feet per minute figure by 88 (the number of feet traveled in one minute at one mile per hour).

Example

128.25 ft/min ÷ 88 ft/min/hr = 1.46 mi/hr speedometers for mile-per-hour measurements. Wheel slippage and variation in tire size due to wear produce as much as a 30% difference in actual versus indicated speed.

Using a 100-foot tape, measure off any convenient distance. It can be less than 100 feet; however, accuracy increases with longer distances. Sometimes multiples of 88 feet are chosen because 88 feet is the distance covered in one minute while traveling one mile per hour. Indicate the beginning and end of the measured distance with colored flagging tape.

Have someone drive through the measured distance. Maintain the speed desired for an actual application. Choose a speed within a range appropriate for the application equipment. When using a tractor, note the throttle setting, gear, and rpm of the engine. Be sure to bring the equipment up to the actual speed before crossing the first marker. Use a stopwatch to determine the time, in minutes and seconds, required to traverse the measured distance. For best results, repeat this process two or three times and take an average. Follow the procedure in Example 8.1 to calculate the actual speed of the equipment. You can also use a GPS unit to check the measurements you take using the flagging tape and stopwatch to ensure your accuracy.

Flow rate. Measure the actual output of the sprayer when nozzles are new, then periodically thereafter to accommodate for nozzle wear. Manufacturers provide charts showing output of given nozzle sizes at specified sprayer pressures. However, you should check output under actual conditions of operation. Manufacturers' charts are most accurate when using new nozzles; however, used nozzles may have different output rates because of wear. Even new nozzles may have slight variations in actual output—It's always best to check first. Sprayer pressure gauges may not be accurate, which further adds error to the output estimate determined from charts.

Measure liquid sprayer output in gallons per minute (gpm). For low-pressure boom sprayers that have more than one nozzle, collect water from each separately, which allows you to compare each nozzle's output and points out any malfunction or wear. You need a stopwatch and calibrated container for making measurements. Wear chemical-resistant gloves to avoid skin contact with water that may contain pesticide residues.

For low-pressure boom sprayers, fill the tank at least half full of water. Start the sprayer and bring the system up to normal operating pressure. Operate the hydraulic agitation system, if so equipped, and if used during the application. This is important because hydraulic agitators divert some liquid from the nozzles and often lower the pressure in the system. Most power sprayers have a limited operating pressure range depending on the type of pump and type of power unit. Never attempt to operate equipment beyond its normal working range, because this may damage the pump. If you are calibrating a power take-off (PTO) driven sprayer, be sure that the tractor engine speed (rpm) is the same as that used in the speed calibration. If this is not the same, the pump output pressure will be different. Adjust the pressure to the requirements of the spray situation and nozzle manufacturer's recommendations. Check the pressure by attaching a calibrated pressure gauge at either end of the boom, replacing one of the nozzles. Open the valves to all nozzles and note the pressure, adjust as necessary; then remove the gauge.

While all nozzles are operating at the proper pressure, collect about 15 to 30 fluid ounces of liquid from each nozzle (Figure 8.4). Use a stopwatch to determine the time in seconds required to collect each volume.

Figure 8.4: Checking nozzle output. Credit: UF/IFAS Pesticide Information Office.

Record the volume of liquid collected from each nozzle or orifice and the time in seconds required to collect each amount. Use a format like the form in Example 8.2.

Determine the output in fluid ounces per second for each nozzle by dividing the volume by the number of seconds required to collect it. Convert ounces per second into gallons per minute by multiplying the result by the constant 0.4688. This constant represents 60 seconds per minute by dividing by 128 fluid ounces per gallon.

Output among nozzles will usually vary. In Example 8.3, the output ranges from 0.250 gallons per minute to 0.328 gallons per minute. Assume that the rated capacity (as given by the manufacturer) for these

Example 8.2. Record of nozzle output.

Nozzle	Volume (fl oz)	Time (sec)
1	12.5	23.2
2	12.0	22.5
3	15.5	24.8
4	14.5	26.1
5	19.0	27.2
6	13.0	23.9

Example 8.3. Calculating gallons per minute output for low-pressure sprayers.

Step 1. Determine the gallons per minute (gpm) output of each nozzle (from Example 8.2) by dividing the fluid ounces by the time (in seconds) and multiplying the result by 0.4688.

Example

Nozzle	Output (fl oz)	÷	Time (sec)	=	Output per sec	x	0.4688	=	gpm
1	12.5	÷	23.2	=	0.539	x	0.4688	=	0.253
2	12.0	÷	22.5	=	0.533	x	0.4688	=	0.250
3	15.5	÷	24.8	=	0.625	x	0.4688	=	0.293
4	14.5	÷	26.1	=	0.556	x	0.4688	=	0.261
5	19.0	÷	27.2	=	0.699	x	0.4688	=	0.328
6	13.0	÷	23.9	=	0.544	x	0.4688	=	0.255
							Total output = 1.640		

Step 2. Compute the percentage of variation from the rated nozzle output. Divide the actual gallons per minute output by the rated output. Subtract one from this number and multiply by 100.

Example

Nozzle	gpm	÷	Rated gpm	=		-	1.00	=		x	100	=	Percent variation
1	0.253	÷	0.250	=	1.012	-	1.00	=	0.012	x	100	=	1.2
2	0.250	÷	0.250	=	1.000	-	1.00	=	0.000	x	100	=	0.0
3	0.293	÷	0.250	=	1.172	-	1.00	=	0.172	x	100	=	17.2
4	0.261	÷	0.250	=	1.044	-	1.00	=	0.044	x	100	=	4.4
5	0.328	÷	0.250	=	1.312	-	1.00	=	0.312	x	100	=	31.2
6	0.255	÷	0.250	=	1.020	-	1.00	=	0.020	x	100	=	2.0

Example 8.4. Calculating output after replacing worn nozzles.

Step 1. Replace worn nozzles (numbers three and five in this example) and re-measure the output of all nozzles on the boom. Recalculate the gallons per minute for each nozzle. Add these rates together to determine the total output of the sprayer.

Example

Nozzle	Output (fl oz)	÷	Time (sec)	=	Output per sec	x	0.4688	=	gpm
1	12.5	÷	23.2	=	0.539	x	0.4688	=	0.253
2	12.0	÷	22.5	=	0.533	x	0.4688	=	0.250
3	13.3	÷	24.5	=	0.543	x	0.4688	=	0.255
4	14.5	÷	26.1	=	0.556	x	0.4688	=	0.261
5	15.2	÷	28.3	=	0.537	x	0.4688	=	0.252
6	13.0	÷	23.9	=	0.544	x	0.4688	=	0.255
							Total output = 1.525		

Step 2. Check to see that all nozzles are within 10% of the rated capacity of these nozzles.

Example

Nozzle	Actual gpm	÷	Rated gpm	=		-	1.00	=		x	100	=	Percent variation
1	0.253	÷	0.250	=	1.012	-	1.00	=	0.012	x	100	=	1.2
2	0.250	÷	0.250	=	1.000	-	1.00	=	0.000	x	100	=	0.0
3	0.254	÷	0.250	=	1.016	-	1.00	=	0.016	x	100	=	1.6
4	0.261	÷	0.250	=	1.044	-	1.00	=	0.044	x	100	=	4.4
5	0.252	÷	0.250	=	1.008	-	1.00	=	0.008	x	100	=	0.8
6	0.255	÷	0.250	=	1.020	-	1.00	=	0.020	x	100	=	2.0

nozzles at the recommended operating pressures is 0.250 gallons per minute. The variation among nozzles and the manufacturer's rated output should not be greater than 10%. Determine the percentage of variation as shown in step two of Example 8.3. Divide the actual output by the rated output. Subtract 1.00 from this figure, then multiply by 100 to obtain the percentage of variation. Nozzles three and five in this example exceed these amounts and therefore must be replaced. However, whenever you replace any nozzles, recheck the flow rate of all the nozzles. Changing one nozzle may affect the pressure in the whole system. After changing the nozzles, readjust the pressure regulator to maintain the desired pressure. Step one of Example 8.4 shows how to recalculate the output in gallons per minute after replacing worn nozzles.

Spray check devices are calibration aids that provide a digital reading of the spray output (Figure 8.5). Place this portable device under the boom and collect output from several nozzles. There are several commercially-available brands of these devices available.

Swath width. The final measurement needed to complete calibration is the width of the spray swath being applied by the sprayer. The type of application situation dictates how swath width is determined. For multiple-nozzle boom sprayers, the swath is the width of the boom plus the distance between each pair of nozzles. An accurate measurement of swath width must consider the actual spacing between the nozzles on the boom, so measure these distances carefully. You can also calculate swath width by multiplying the number of nozzles by the nozzle spacing. When making an application with a boom sprayer, overlap the spray by the same amount as the overlap of the nozzles on the boom. Adjust the boom height so that there is approximately a 30% overlap of spray from adjacent nozzles on the boom (Figure 8.6).

When applying spray as separate bands or strips, the swath width is equal to the combined width of each band. It does not include the unsprayed spaces between bands.

Some applications use a boom configured so that nozzles direct spray to the tops and both sides of plants in a row. Sometimes these booms cover a row on each side of the tractor. The swath width for this type of equipment is equal to the distance between opposing nozzles (Figure 8.7).

Determining the amount of pesticide to use. Use tank volume, travel speed, flow rate, and swath width to calculate the total area covered with each tank of material. Knowing this value allows you to determine how much pesticide to put into the tank. One common calculation that agricultural row crop applicators use is to determine the amount of product to apply by the acre. Example 8.5 shows a step-by-step process for making this calculation.

Changing sprayer output. Once you calibrate a sprayer, you have determined its output rate for a specific speed. There may be times when you need alter speeds, thus changing the output rate. You can make several adjustments, either alone or in combination, to effectively increase or decrease sprayer output within a limited range.

The simplest way to adjust the volume of spray being applied is to change the travel speed of the sprayer. A slower speed results in more liquid being applied, while a faster speed reduces the application rate. You may need these adjustments when swath width changes slightly. Changing the travel speed eliminates the need to altering the concentration of chemical in the spray tank. However, there are limits to the amount of speed change you can make. Operating application equipment too quickly is a common error and results in poor coverage. Operating it too slowly results in runoff, waste, and an increase in application time and cost. To determine the effect of travel speed on sprayer output, plug in the new travel speed and rework the calculations shown in Example 8.5.

The most effective way to change the output volume of a sprayer is to install nozzles of a different size. Larger nozzles increase, while smaller ones reduce volume. Changing

Figure 8.5: Handheld device for checking nozzle output. Credit: UF/IFAS Pesticide Information Office.

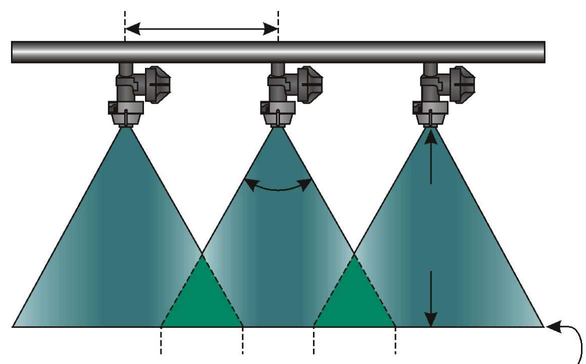


Figure 8.6: Flat-fan nozzles should be spaced to produce a 30% overlap. Credit: UF/IFAS Pesticide Information Office.

Figure 8.7: Directed spray application to a tomato crop. Credit: UF/IFAS Pesticide Information Office.

Example 8.5. Calculating how much pesticide to put into the tank on a per-acre basis.

Step 1. Determine the area that can be treated in one minute. Divide the spray swath width by 43,560 (the number of square feet in one acre) and multiply the result by the travel speed in feet per minute. In Example 8.1, the travel speed was calculated to be 128.25 feet per minute.

Example

Assuming that the swath width is 12 feet, the calculation would be

(12 ft ÷ 43,560 sq ft/ac) x 128.25 ft/min = 0.0353 ac/min

In this example, when a swath width 12 feet wide is being sprayed, 0.0353 acre is covered in one minute.

Step 2. Determine the gallons of liquid being applied per acre. Divide the gallons per minute (1.52 gal/min from Example 8.4) figure by the acres per minute.

Example

1.52 gal/min ÷ 0.0353 ac/min = 43.2 gal/ac

Step 3. Determine the number of acres that can be treated with a full tank. Divide the actual measured volume of the spray tank (or tanks) by the number of gallons per acre being applied. Assume that the tank holds 252.5 gallons when filled.

Example

252.5 gal/tank ÷ 43.2 gal/ac = 5.84 ac/tank

Step 4. Determine how much pesticide to put in the tank. Multiply the number of acres by the label rate per acre of product.

Example

Recommended rate per acre	x	Acres per tank	=	Amount of pesticide to put in tank
1.5 lb	x	5.84	=	8.76 lb
3 qt	x	5.84	=	17.52 qt
2 gal	x	5.84	=	11.68 gal
1 pt	x	5.84	=	5.84 pt

nozzles usually alters the pressure of the system and requires an adjustment of the pressure regulator. Whenever you change any nozzles, recalibrate the sprayer and recalculate its new total output.

As nozzles begin to wear, the spray volume increases. When a pump begins to wear, it becomes less efficient and nozzle output drops off. Adjusting the pressure regulator to increase or decrease output pressure changes the spray volume slightly: increasing pressure increases the output, while decreasing pressure lowers it. However, to double the output volume you must increase the pressure by a factor of four. This is usually beyond the capabilities of a spraying system, as the working pressure range of the sprayer pump limits this adjustment. Whenever pressure in the system changes, measure the nozzle output again—see Example 8.2. Then rework the calibration calculations. Increasing pressure breaks the spray up into finer droplets, increasing the likelihood of spray drift. Lowering pressure too much reduces the effectiveness of nozzles by reducing their ability to form appropriately sized droplets.

Preparing spray mixes as percentage solutions (dilutions). Some pesticide labels will give rate directions to prepare a spray solution based on a percentage volume. Particularly in situations where small handheld sprayers such as backpacks will be used to make treatments, the label, for example, may state to prepare a 0.5 to 5% by volume solution. When determining a percentage solution, the calculation involves using a decimal equivalency. Examples of decimal equivalencies are listed in Table 8.1. The procedure is described in Example 8.6.

Table 8.1. Decimal equivalencies.

% Solution	Decimal equivalency
0.25	0.0025
0.5	0.005
1.0	0.01
5.0	0.05
10.0	0.10
50.0	0.50
100.0	1.00

Example 8.6. Calculating a percentage solution.

If you are making a spot treatment application using a three-gallon backpack sprayer and the product label directs for a 2% spray solution:

Step 1. Determine the amount of product needed for filling the three-gallon backpack.

Tank capacity x % solution

Example

3 gal x .02 = 0.06 gal

Step 2. For ease of mixing, convert gallons to ounces

0.06 gal x 128 oz/gal = 7.7 oz product

Therefore mix 7.7 ounces of product with slightly less than three gallons of water to completely fill the backpack sprayer.

Using System Monitors and Controllers

Even though the use of system monitors and controllers has become popular, they do not eliminate the need for sprayer inspection and calibration. Monitors measure the operating conditions such as travel speed, pressure, and/or flow rate and can alert you to unexpected changes in the application rates.

Rate (or spray) controllers are monitors with the added capability of automatic rate control. The controller receives the actual application rate from the monitors and compares with the desired rate. If an error exists, the pressure is regulated to adjust the spray volume. However, nozzles can operate only within a limited range of pressure without either distorting the spray angle or creating off-target drift, so you must be observant during applications to ensure that spray remains even and on target. Nozzles that can operate over a wide pressure range are best to use with rate controllers.

Since these adjustments are a direct response to various sensors that collect data as part of the system monitor, the sensors must be periodically checked and calibrated. Do not assume that the monitors are foolproof. Consult the manufacturer's operator's manual to properly calibrate and adjust the sensors. Monitors that give travel speed, spray volume, etc. are usually adequate for most sprayer situations. Newer models of monitors keep track of which booms are being used and the areas they cover so that the calculated area sprayed is very accurate.

Calibrating Granule Applicators

Before beginning to calibrate a granule applicator, be sure that it is clean, dry, and all parts are working properly. Most equipment requires periodic lubrication. Always wear chemical-resistant gloves to prevent contact with residues on the equipment. Calibrating granule applicators involves using actual pesticides, so wear the label-prescribed PPE. Some formulations are dusty and may require respiratory protection.

One practical method of calibrating granule product spreaders requires the following supplies:

- Nine to 15 collecting trays or pans with a grid baffle in the bottom of each (this prevents the material from bouncing out)
- Nine to 15 test tubes (use the same number of tubes a pans)
- Test tube rack
- Funnels (use the same number of funnels as tubes)
- 10-foot measuring tape
- Density scale

Make sure the sizes of the test tubes are in proportion to the rates of application being checked. All trays must be of identical size and shape. Trays should be shallow (2.5 to 4 inches deep) with a collecting area of 1.25 to 3 square feet each. Use collecting trays with tapered sides, because they will nest together and require minimum storage space. Removable plastic grid baffles in the trays aid in preventing the material from bouncing out. Many building suppliers stock plastic grid material (called egg crates) for recessed lights and air ducts that may be cut to size and used satisfactorily in collecting trays. The trays and grid baffles are very light weight and when nested together are easy to handle. Some spreader equipment dealers also have commercially-available kits containing all the necessary tools for spreader calibration. Table 8.2 can be used to determine the pounds per acre rate of application from collecting trays.

Table 8.2. Conversion for grams/square feet to pounds/acre.

Material collected (grams/square feet)	Application rate (pounds/acre)
1	96.0
5	480.2
15	960.3
20	1,440.5
25	2,400.8

The first objective is to determine the spreader's effective swath width. You should have at least a 150-foot length on a flat field test site to lay out the collection trays. You can use a field layout similar to that shown in Figure 8.8. In this example, there are 11 collection trays set on 5-foot centers. Spacing between trays 4 and 5 and 7 and 8 are set at 4 feet to allow wheel clearance for the spreader to be driven directly over tray 6, the center tray.

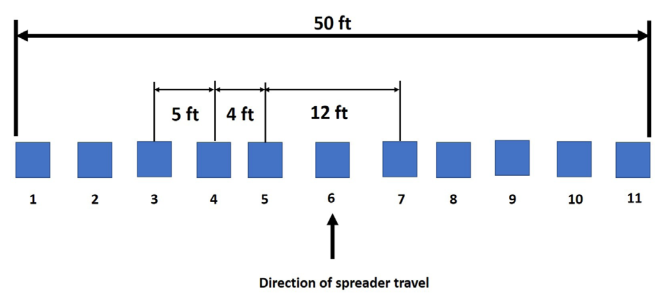


Figure 8.8: Field layout of collection trays to determine spreader swath width. Credit: UF/IFAS Pesticide Information Office.

However, the spacing interval between trays may be changed, depending on swath width. The spreader is adjusted for a given rate of application and operated at normal field speed in a direction perpendicular to the line of trays and straddling the middle tray. Material collected in each tray is then poured into the corresponding test tube in the rack.

The amount of material in the test tubes will then provide a quick visible evaluation of the spread pattern, similar to that shown in Figure 8.9. If a spread pattern is uniform across the swath, all of the center tubes will be filled to approximately the same height.

The effective swath width can be determined by locating the point on the right and left side of the swath where the tubes are filled to about one-half the height in the center tubes. The distance between these points is the effective swath width and should be used as the swath spacing. For example, if tubes 2 and 10 are filled to about one-half of tube 6, the center tube, the effective swath width would by 40 feet since the trays are set on 5-foot centers.

Figure 8.9: Typical pattern seen from a double-spinner spreader. Credit: Wayne Buhler, N.C. State University.

Because of the way test tubes are shaped, the first ½ inch of material in each tube represents a rate of approximately 100 pounds per acre. Each 3/8 inch of material after the first ½ inch represents an additional 100 pounds per acre. This assumes the material has a density of 65 pounds per cubic foot, that the material in each tube is collected from an area of 1.25 square feet and that test tubes with an inside diameter of ½ inch are used. Dry products vary in moisture content and in size and particle density. Variations in materials will require slight adjustments in the indicated rates of application because of particle density. A density scale is a useful tool to quickly measure particle density and give you an indication of the necessary adjustments to spreader settings. The method given above will provide a close approximation.

Once an evaluation of a spread pattern is made, the operator should determine what, if any, adjustments can be made to improve the pattern.

Spread patterns for a twin disk dry spreader can be classified into different patterns. The flat top, oval and pyramid patterns are most desirable because they allow a more uniform overlapping of swaths.

Accurate and uniform application depends on:

- **Accurate metering** - Make sure graduations are present on the shear gate to aid in determining application rates for various effective swath widths. Keep a notebook showing settings from calibration tests using various material in the trucks. This is valuable information for future dry material applications.

- **Proper delivery of material to the spinner(s)** - An adequate flow divider and adjustable delivery chute are necessary for uniform application, especially on hillsides and in other adverse field conditions.

- **Uniform distribution across swath** - Spinner speed, blade pitch and delivery chute position are critical. With auger boom distributors, slide position and auger speed must be adjusted for uniform spreading at various application rates.

- **Skilled and conscientious operators** - Accurate spacing of swaths is essential and requires careful driving. Swath spacing should be the same as the effective swath width. A constant ground speed is important for a uniform application with many spreaders. In addition to driving, make sure that operators study the operator's manual for their particular machine and know how to calibrate the spreader for various materials and rates of application. They should give particular attention to cleaning, adjusting, maintaining and repairing their spreaders.

Check spread pattern and make the necessary adjustments when changing the material or the rates of application. Remember, even with proper adjustments, it is difficult to maintain a completely uniform and accurate application rate of granular products if wind speeds exceed five miles per hour.

Calibration of Bulk Dry Fertilizer Applicators, Circular 798, published by the University of Georgia Cooperative Extension was particularly useful for developing this section **http://extension.uga.edu/publications/detail.html?number=C798&title=Calibration%20of%20Bulk%20Dry%20Fertilizer%20Applicators**.

Example 8.7. Chemigation calibration for low-volume micro-sprinklers and drip irrigation systems.

Calculation of the amount of pesticide to inject into an irrigation system is based on the wetted area around the emitters, not on the number of acres in the field.

Step 1. Determine the treated area per each emitter (A).

Example

If the average distance from an emitter to the edge of the wetted area (the radius) measured at the soil surface is 13 inches, then

A = 3.14 x (13 in x 13 in) = 530.7 sq in

Step 2. Determine the area in square feet that is wetted in each acre (B). The number of square inches per square foot = 144.

B = (A x emitters per acre) ÷ 144

Example

If there are 300 emitters per acre, then

B = (530.7 sq in x 300) ÷ 144 = 1,105.6 sq ft

Step 3. Determine the total square feet that is wetted by the system (C).

C = B x (number of acres covered by system)

Example

If the system covers 20 acres, then

C = 1,105.6 sq ft x 20 = 22,112 sq ft

Step 4. Determine the amount of pesticide to inject (S). The recommended rate per acre is R.

S = (C x R) ÷ 43,560

Example

If the desired application rate per treated acre is one quart of product, then

S = (22,112 x 1.0) ÷ 43,560 = 0.50 quart of product

Calibrating Chemigation Systems

Low-volume micro-sprinklers and drip irrigation systems. Because chemigation systems have many elements, you must check the system thoroughly every time it is used, even before starting your calibration. Check to confirm that the irrigation system contains all the equipment specified on the pesticide label and required by FDACS and that the equipment is working properly. One way of testing the functionality of the safety equipment is to start the irrigation system and bring it up to pressure. With the chemical storage tank isolated from the injection system so that no pesticide will be released, start the injection pump and confirm that the injection system interlocked solenoid valve is energized. Manually turn off the irrigation water pump. The following events should occur if the interlock systems and the backflow prevention systems are working properly:

- The irrigation water pump will stop.
- The chemical injection pump will stop.
- The chemical injection solenoid valve will close (de-energize).
- The irrigation system check valve(s) will close.
- Air will be drawn into the irrigation system vacuum relief valve.

A small amount of water will be discharged through the low-pressure drain adjacent to the irrigation system check valve(s).

If any of the irrigation equipment specified on the label is not present or is not functioning properly, it would be a violation of federal and state law to proceed with the chemical application.

Once you have confirmed that the irrigation system is functioning properly, you can proceed with the steps for calibrating low-volume micro-sprinkler and drip (trickle) irrigation systems in Example 8.7. With the sprinkler system fully pressurized, connect the chemical injection tank to the injection system and start the injection pump. The operator should record a log of the calibration, including the time of day, the system pressure, wind speed and direction, ambient temperature, and any comments regarding observations that may be pertinent, such as odors or passers-by approaching the treated area. The log should be updated frequently during the calibration. If for some reason you must terminate the calibration (or application), continue operating the irrigation system after the chemical injection has stopped to flush the chemical out of the lines.

Center pivot irrigation systems. As with any irrigation system used for injecting pesticides, it is necessary to be certain that all safety devices are in place and that all parts and the injection system are operating properly. Always check the irrigation system for operating problems and uniformity of water distribution. Remember that the pesticide can only be applied as uniformly as the water applied. To calibrate the irrigation and injection systems, you need to know the following pieces of information step-by-step:

1. Acres the center pivot covers
2. Time it takes to cover the irrigated area
3. Depth of water applied
4. Chemigation application rate
5. Total amount of pesticide needed
6. Injection rate
7. Calibrate the injection pump

Figure 8.10: Center pivot system with an end gun in a corn field. Credit: UF/IFAS Pesticide Information Office.

The irrigation system determines the length of time it takes to apply the pesticide; therefore, the area covered by the system and the length of time necessary for the pivot to rotate completely must be first known. Gallons per minute the system pumps do not affect calibration, but it does determine the amount of water applied per acre.

1. To calculate the acres covered by the center pivot, add sprinkler wetted coverage to the center pivot length to obtain an effective center pivot wetted radius. High-pressure sprinklers cover about 30 to 50 feet past the end of the pivot while spray sprinklers only cover 10 to 20 feet. Finding the area when an end gun is used is more difficult (Figure 8.10). You need to know the effective coverage of the end gun beyond the normal sprinkler

Example 8.8. Determine area covered by a center pivot irrigation system.

A center pivot irrigation system has a radius of 1,320 ft and an end gun that covers 60 feet beyond the normal sprinkler wetted radius; the end gun is operated for one-third of the circle.

Step 1. Determine the area the center pivot effectively wets in acres.

Area of a circle = (radius in ft)^2 x 3.14

(1,320 ft)^2 x 3.14 = 5,471,136 sq ft

5,471,136 sq ft ÷ 43,560 sq ft/ac = 125.6 ac

Step 2. Determine the area in acres that is wetted in addition to the end gun.

(1,380 ft)^2 x 3.14 = 5,979,816 sq ft

5,979,816 sq ft ÷ 43,560 sq ft/ac = 137.3 ac

Step 3. Determine the area covered accounting for two-thirds of the circle with normal sprinkler coverage and one-third with end gun coverage.

Adjusted area = (125.6 x ⅔) + (137.3 x ⅓)
= 129.5 ac

Example 8.9. Determine the time it takes to cover the treated area.

In this example, a center pivot has a pivot to outer wheel track length of 1,280 feet and it takes 32 minutes to travel a 200-foot staked course.

Step 1. To calculate the time to cover a circle use the following formula:

Wheel track circumference (ft) = 3.14 x 2 x distance from pivot to outer wheel track

Example

Wheel track circumference (ft) = 3.14 x 2 x 1,280 ft = 8,038 ft

Step 2. Determine the center pivot's rotation time for one complete revolution.

Rotation time = wheel track circumference x (time between stakes ÷ distance traveled)

Example

8,038 ft x (32 min ÷ 200 ft) = 1,286 minutes

Step 3. Convert minutes to hours.

Divide by 60

Example

1,286 min ÷ 60 min/hr = 21.43 hr or 21 hr and 26 min

Example 8.10. Determine the depth of water applied.

In this example, assume a center pivot is applying 800 gpm with an 85% efficiency reading and it requires two days to make a complete revolution over a 125-acre circle.

Step 1. To calculate the depth of water applied, use the following formula:

Depth (in) = gpm x rotation time (hr) x (0.85/acres/450) (a conversion found in Appendix C)

Example

800 gpm x 48 hr x (0.85/125 ac/450) = 0.58 in

Step 2. You may also want to determine the center pivot's gallons per acre (gpa) of water applied.

gpa = depth (in) x 27,154 gal (number of gallons in one acre-inch of water)

Example

0.58 in x 27,154 gal/ac-in = 15,745 gpa

wetted radius and the proportion of time that the end gun is run. Don't use the maximum wetted coverage of the end gun, but only the area that gets well-watered. Example 8.8 shows a calculation for a system that the end gun effectively wets 60 feet beyond the normal sprinkler wetted radius and operated for one-third of the circle.

2. Determine the time it takes to cover the treated area. You need to know how much time is required for the pivot to cover the entire circle or part of the circle. This can be done in one of two ways. One way is by operating the system while watering at the same speed that will be used for chemigation and record the setting and the time it takes for one revolution. The other method involves measuring the distance the pivot travels, such as 100 or 200 feet along the outer wheel track, during a measured period. Example 8.9 shows this calculation.

3. Determine the depth of water applied. Some product labels may require a specific depth of water to be applied. Depth of water applied can be determined by placing several rain gauges around the field or by calculating it as in Example 8.10. When measuring depth in the field, always keep the timer setting on the pivot the same as will be used for chemigation.

4. Determine the chemigation application rate. This rate is the volume of chemical or chemical mixture that is

Example 8.11. Determine the total amount of pesticide needed.

In this example, assume a pesticide label states to apply at 1.5 pints of product per acre. The area covered by the center pivot system is 125 acres.

Step 1. To calculate the total amount of product needed, use the following formula:

Total product needed = label rate x acres covered by the center pivot

Example

1.5 pints x 125 acres = 187.5 pt/125 ac

Step 2. Convert to gallons

Total pints ÷ 8 pt/gal = total gallons

Example

187.5 pt/ac ÷ 8 pt/gal = 23.4 gal/125 ac

Example 8.12. Determine the injection rate.

In this example, use the total rotation time of 21.43 hours from Example 8.9 and the total volume of pesticide of 23.4 gallons from Example 8.11.

Step 1. To calculate the injection rate, use the following formula:

Volume of product ÷ rotation time

Example

23.4 gal ÷ 21.43 hr = 1.1 gal/hr

Step 2. Convert to milliliters/minute

1 gal = 3,785 ml (a conversion factor found in Appendix C)

Example

gal/hr x 3,785 ml/gal = 4,163.5 ml/hr

4,163.5 ml/hr ÷ 60 min/hr = 69 ml/min

required per acre. This will be listed on the pesticide product label. Some pesticides may be in concentrated formulations that make it necessary to mix with water before injecting. You need to determine the mixing rate and volume of the chemical and water mixture prior to calibration since that volume will be used to calculate the injection rate. This should also include any adjuvants that may be also applied.

5. Determine the total amount of pesticide needed. This must be known to calculate the injection rate. See Example 8.11.

6. Determine the injection rate. The injection rate is the volume of chemical solution divided by the rotation time or time to cover the desired part of the field. See Example 8.12. It is important to select an injection pump that has a rating similar to the required injection rate. Accuracy of the calibration may be affected if the injection rate is different from the rating of the pump. The injection rate must fall within the recommended range of pumping rates for the pump. If the required injection rate does not match the performance of the available pump, use a different pump or the chemical may need to be diluted with water, and the injection rate will need to be adjusted accordingly.

7. Calibrate the injection pump. Always do the first calibration using water with the pivot pressurized. Convert the injection rate in gallons per hour to ounces or milliliters per minute as seen in Example 8.12. Start with an initial injection pump setting and check to see how close the setting is to that required. A calibration tube and a stopwatch are helpful when doing this. A calibration tube is a clear plastic tube such as a large graduated cylinder. Connect the tube to the intake side of the injection pump. It is convenient to have fittings and valves that permit switching between the calibration tube

Example 8.13. Calculating the area of irregular-shaped sites using various shapes.

Important formulas include:

- Area of a rectangle = length (ft) x width (ft)
- Area of a triangle = ½ x base (ft) x height (ft)
- Area of a circle = 3.14 x (radius (ft) x radius (ft))

Area conversion factors:

- 1 acre = 43,560 sq ft
- 1 mile = 5,280 ft

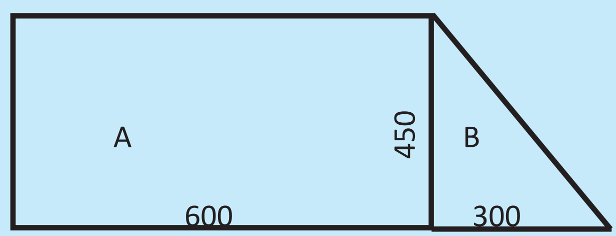
Example 1. Below, the rectangular area A measures 600 feet by 450 feet and the base of the triangular area B is 300 feet:

Area of A = 600 ft x 450 ft = 27,000 sq ft

Area of B = 0.5 x 300 ft x 450 ft = 65,500 sq ft

Total area = 27,000 sq ft + 65,500 sq ft = 337,500 sq ft

Total acres = 337,500 sq ft ÷ 43,560 sq ft/ac = 7.75 ac



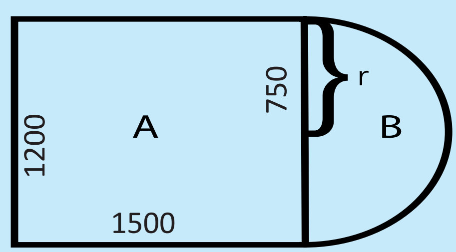
Example 2. This field contains both a rectangular and a half-circle section. Break the shape into a rectangle A and one-half circle B. The rectangle is 1,500 feet by 1,200 feet, and the radius of the circle is 750 feet.

Area of A = 1,500 ft x 1,200 ft = 1,800,000 sq ft

Area of B = 3.14 x (750 ft x 750 ft) ÷ 2 = 883,125 sq ft

Total area = 1,800,000 sq ft + 883,125 sq ft = 2,683,125 sq ft

Total acres = 2,683,125 sq ft ÷ 43,560 sq ft/ac = 61.6 ac



and the main chemical supply tank without shutting off the injection pump.

To obtain the final calibration, connect the injection equipment to the irrigation pipeline, pressurize the center pivot, and operate the injection pump with the pesticide solution. Check the calibration and, if necessary, adjust the injection pump. Piston-type pumps must be shut down to make adjustments while diaphragm pumps and Venturi injector units can be adjusted while the unit is operating.

Calculating Site Sizes

If the target site is a rectangle, circle, or triangle, you can use simple measurements and formulas to determine its size. However, many sites are not perfect circles, rectangles or triangles. Often, farm fields have curved corners, have a bulge along one or more sides, or have a notched or "missed" portion because an obstacle along, or in, the field doesn't allow equipment access. Irregularly-shaped sites often can be reduced to a combination of rectangles, circles, and triangles. With these irregularly-shaped sites, calculate the area of each regular shape and sum them together to obtain the total area (Example 8.13). Because the site is an irregular shape and you are basing your calculations on regularly-shaped objects, your square footage calculation will not be precise; however, you should expect this calculation to fall within 10% of the actual area of the site.

Test Your Knowledge

Q: It takes your equipment three minutes to travel 792 feet. How fast, in miles per hour, is the equipment traveling?

A. 1 mph
B. 2 mph
C. 3 mph
D. 4 mph

A: C

Q: How many acres per minute are being treated by a sprayer with a swath width of 60 feet traveling at 180 feet per minute?

A. 0.25 ac/min
B. 0.33 ac/min
C. 0.41 ac/min
D. 0.50 ac/min

A: A

Q: How many gallons per acre is a sprayer with an output of 0.62 gal/min at a rate of 0.31 ac/min applying?

A. 1.5 gpa
B. 2.0 gpa
C. 2.5 gpa
D. 3.0 gpa

A: B

Q: How many acres can a full 200-gallon spray tank treat if applying a volume of 35 gallons per acre?

A. 7.8 acres
B. 7.1 acres
C. 6.2 acres
D. 5.7 acres

A: D

Q: How much product, at a labeled rate of 1.5 pints/ac, should be mixed to prepare a full 200-gallon tank applying an output of 25 gal/ac?

A. 4 pints
B. 8 pints
C. 12 pints
D. 16 pints

A: C

Q: If preparing a 1.5% solution, how much product should be mixed with two gallons of water?

A. 4.2 ounces
B. 3.8 ounces
C. 3.2 ounces
D. 2.4 ounces

A: B

Q: True or False

The use of system monitors and controllers do not completely eliminate the need for sprayer inspection and calibration.

A: True

Q: If the average distance from a micro-sprinkler emitter to the edge of the wetted area, measured at the soil surface, is 15 inches, how many acres in a 15-acre site are being treated if there are 250 emitters per acre?

A. 9,846 sq ft
B. 14,945 sq ft
C. 18,398 sq ft
D. 23,789 sq ft

A: C

Q: How many acres are being treated with a 980-foot center pivot with a 50-foot end gun?

A. 9.2 ac
B. 19.1 ac
C. 27.4 ac
D. 31.9 ac

A: B

Q: A center pivot irrigation system has a pivot to outer wheel track length of 1,000 feet and it takes 28 minutes to travel a 250-foot staked course. What is the center pivot's rotation time for one complete revolution?

A. 22 hours, 14 minutes
B. 18 hours, 8 minutes
C. 14 hours, 54 minutes
D. 11 hours, 43 minutes

A: D

Q: How much total pesticide is needed to inject into a center pivot irrigation system to treat 95 acres if the product rate is 2.0 pints per acre?

A. 18.45 gal/ac
B. 23.75 gal/ac
C. 27.50 gal/ac
D. 32.25 gal/ac

A: B

Q: What is the proper injection rate for a center pivot irrigation system that has a total rotation time of 20 hours and the total volume of pesticide required is 28.4 gallons?

A. 89.6 ml/min
B. 72.4 ml/min
C. 48.2 ml/min
D. 29.8 ml/min

A: A

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) 815-4000

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
Statewide number (850-245-2118)

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 above]. If federal reporting is required, also call the National Response Center [see Emergency Reporting Telephone Numbers above.)

Florida Department of Agriculture and Consumer Services
Bureau of Licensing and Enforcement (850) 617-7997

Florida Department of Environmental Protection
NPDES Stormwater Program: 866-336-6312
Waste Cleanup Program: 850-245-8705

Florida Department of Environmental Protection District Offices
Northwest (Pensacola) (850) 595-8300
Northeast (Jacksonville) 904-256-1700
Central (Orlando) 407-897-4100
Southeast (West Palm Beach) 813-470-5700
Southwest (Tampa) 813-470-5700
South (Ft. Myers) 239-344-5600

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

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) 533-7500
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) 756-8519	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) 252-4800	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) 255-7450	Osceola	Kissimmee	(321) 697-3000
Escambia	Cantonment	(850) 475-5230	Palm Beach	West Palm Beach	(561) 233-1700
Flagler	Bunnell	(386) 437-7464	Pasco	Dade City	(352) 518-0156

County	City	Phone	County	City	Phone
Franklin	Apalachicola	(850) 653-9337	Pinellas	Largo	(727) 582-2100
Gadsden	Quincy	(850) 875-7255	Polk	Bartow	(863) 519-1041
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) 861-9900
Hendry	LaBelle	(863) 674-4092	Seminole	Sanford	(407) 665-5560
Hernando	Brooksville	(352) 754-4433	Sumter	Bushnell	(352) 569-6862
Highlands	Sebring	(863) 402-6540	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) 226-4330	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

Appendix C

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
Conversions for chemigation calibration	
450 gal/min = 1 acre-inch/hour	
27,000 gal = 1 acre-inch	

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