Ornamental Pest Control

A GUIDE FOR ORNAMENTAL PLANT MANAGERS IN VIRGINIA

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A Guide for Ornamental Plant Managers in Virginia

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Preface

Ornamental Pest Control provides professional horticulturists with information about pest management. The sections devoted to pest and host identification are specific for the Commonwealth of Virginia. The same is true for the pest management options discussed. Both chemical and nonchemical management strategies are included.

This manual describes how to use pesticides properly when establishing and maintaining ornamental plantings. Pesticides applied to ornamentals must be effective. However, pesticide applications must be carefully managed so they are safe for animals, humans, and the environment.

This manual supports persons preparing for certification in Ornamental Pest Control (Commercial Applicator Category 3A). After certification, it will serve as a resource for pest identification and management decisions.

Ornamental Pest Control certification is required for most landscapers and interiorscapers. This certification may also be necessary for plant retailers, if they apply pesticides to maintain plants they are holding for sale.

Ornamental Pest Control replaces the ornamental portion of **Ornamental and Turf Pest Control** (2nd edition / 1979). This manual does not discuss turf pests, forest pests, the use of fumigants, or vertebrate pests that may damage ornamentals. Use of pesticides to maintain ornamental turf in sites such as golf courses, cemeteries, residential lawns, and parks requires certification in Turf Pest Control (Category 3B). Use of pesticides in forests, forest nurseries, and seed orchards requires certification in Forest Pest Control (Category 2). Chemical control of vertebrate pests requires certification in General Pest Control (7A) and/or Vertebrate Pest Control Excluding Structural Invaders (7D). Use of fumigants requires certification in Category 1C (Fumigation of Soil and Agricultural Products) and/or Category 7C (Fumigation - Non-Agricultural).

This manual describes common ornamental pests and suggests management methods and materials. Knowing the life cycle, biology and habits of common pests, along with practical experience, enables a horticulture professional to design and implement an effective integrated pest management program.

Landscapers, interiorscapers, and plant retailers must learn about state and federal plant quarantines. Plant quarantines are in place to prevent dangerous pests from spreading from infested/infected areas to areas free of such pests. In some situations, plants must be treated when they are received and/or before they can be moved. Some quarantines require the application of specific pesticides to enable the legal movement of host plant material to uninfested/uninfected areas. Always follow pesticide label directions carefully to ensure compliance with all appropriate laws and regulations.

In Virginia, two agencies can advise plant managers about plant quarantines. The Virginia Department of Agriculture and Consumer Services Office of Plant and Pest Services (VDACS OPPS) enforces state quarantine requirements. Federal quarantines are managed by the United States Department of Agriculture Animal and Plant Health Inspection Service (USDA APHIS). Both agencies have field offices throughout the state. Staff members of both OPPS and APHIS will help ornamental plant managers learn about - and comply with - plant quarantine requirements.

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Contents

Unit 1. Introduction

Learning Objectives

After you study the Introduction, you will:

- Describe the benefits of the ornamental industry.
- Name the major types of pests that affect ornamental plants.
- Explain the basic concepts of Integrated Pest Management (IPM).
- Assess the importance of proper pesticide use.

The Introduction describes the importance of the ornamental industry in Virginia. Landscapes and interiorscapes can be evaluated in economic terms. They also contribute to the quality of life in the Commonwealth.

By reading this Unit, you will learn about the major pests of ornamentals — diseases, insects, mites, mollusks, nematodes, and weeds. Principles of Integrated Pest Management are outlined for you. This Unit describes the place of pesticides in pest management programs. It describes the reasons for — and benefits of — pesticide use. It also discusses why pesticides must be used properly and only as needed. Safety must always be considered first.

Terms to Know

Aesthetic - Referring to something that is beautiful or in good taste.

Applied Controls - Pest control measures used by humans. These include biological, cultural, mechanical, and chemical control.

Arachnid - A wingless arthropod with a body divided into two parts. Arachnids have four pairs of legs on the rear body section. They do not have antennae. Mites, spiders, and ticks are arachnids.

Arthropod - An animal with jointed appendages (legs, etc.) and an external skeleton. Arthropods are invertebrates: animals without backbones. They have a hard outer body covering called an exoskeleton for protection and support. This exoskeleton is jointed, which allows them to move. Insects and arachnids are arthropods.

Disease - An abnormal, unhealthy condition caused by a bacteria, fungus or virus.

Exclusion - Using some sort of barrier to keep a pest out of an area.

Exposure - Coming in contact with a pesticide either by ingestion (oral), inhalation, or absorption through the skin (dermal).

Habitat - A specific area or environment in which an organism normally lives.

Insect - An arthropod with three body regions: a head (front), a thorax (middle), and an abdomen (rear). Insects usually have one pair of antennae on the head and two pairs of wings and three pairs of legs on the middle body section. Most have complex mouthparts, adapted for a special type of feeding.

Integrated Pest Management (IPM) - A management system that uses all appropriate pest control strategies to reduce pest populations to an acceptable level. IPM uses an ecological approach to pest management.

Life Cycle - Stages of development. As some organisms go through their life cycle, they change in body form and habits.

Monitoring - Determining the size and distribution of a pest population in an area.

Mite - A small arachnid. Some mites are plant pests.

Mollusk - A soft-bodied animal. Mollusks do not have a backbone. Most mollusks have a hard calcium-based shell covering their body. Clams, snails and slugs are mollusks.

Natural Controls - Natural forces that affect pest populations. Examples include climate, natural enemies, natural barriers, and the availability of food, water and shelter. These natural forces act independently, and may either help or hinder human attempts to control pests.

Nematode - A small eel-like roundworm. Most nematodes are so small that they cannot be seen with the naked eye.

Nontarget Organism - A living thing you do not wish to affect by pesticide use; for example, people, desirable plants, beneficial insects, pets, and wildlife.

Organism - A general term for any living thing.

Personal Protective Equipment (PPE) - Devices and clothing used to protect people from contact with pesticides.

Pest - Any living thing that is undesirable, or causes injury or harm to people, property or the environment. An organism may be a pest in one place or situation but not in another. For example, termites invading a house are pests. Those recycling dead trees in a forest are not.

Pesticide - Any substance used to control or repel a pest, or to reduce the unwanted or harmful effects of a pest.

Residue - The part of a pesticide that remains in the environment or on a surface for a period of time following an application or spill.

Sanitation - A pest management practice of removing food or hiding places that could be used by pests or that would attract pests. Sanitation also includes other types of cleanliness. Other examples include removing and destroying pests and diseased plant materials, disinfecting tools, and sterilizing soil.

Scouting - Regularly searching for, identifying, and assessing numbers of pests and the damage they are causing.

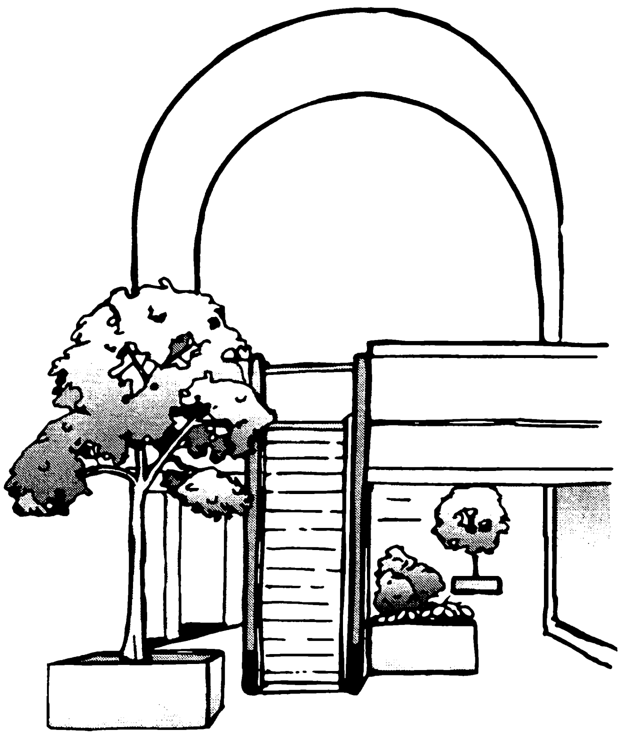
Target Pest - The pest you want to manage or eliminate.

Toxic - Poisonous.

Toxicity - A measure of a pesticide's ability to cause acute, delayed or allergic effects.

Weed - A plant out of place. Any plant growing where it is not wanted is a weed.

Plants enhance our living spaces. Some benefits are obvious, and others are not. Here are some examples of ways ornamental plantings improve the quality of human life. Plants filter pollutants from the air. Their roots anchor soil and prevent erosion. They provide food and shelter for animals we value or enjoy, such as honeybees and songbirds. Trees offer shade. Some types of trees and shrubs can serve as effective windbreaks. As a result, well-planned landscapes can reduce heating and cooling costs. Along rights-of-way, shrub plantings make roadways safer. They reduce glare, serve as a crash barrier, and add interest and color to the corridor. Many types of plantings reduce noise. The beauty of landscapes and interiorscapes contribute to our psychological well being. People like having plants around them, indoors and out.

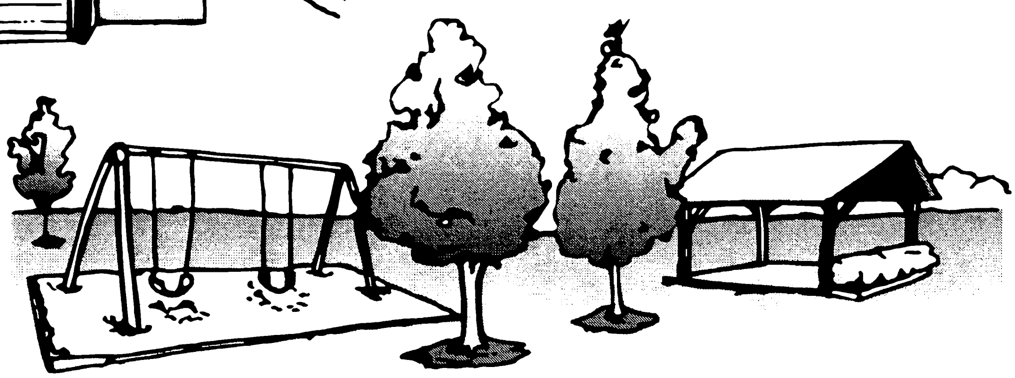


The Ornamental Pest Control Manual

Ornamental Pest Control describes the major ornamental pests found in the Commonwealth — those that are most common and cause the most damage. Professional organizations, universities, industry, and government agencies produce detailed field guides and other pest identification references. These sources will help you learn more about the common pests described here. They will also describe ornamental pests that are not included in this manual.

Many things can be a "pest". Insects, mites, diseases, weeds, nematodes, mollusks, and vertebrates (rodents, deer, and even people!) can harm ornamentals. Vertebrate pests are addressed in the Category 7D manual: **Vertebrate Pest Control (Excluding Structural Invaders)**. However, this manual will help you identify most of the important pests of ornamental plants. It will describe their life cycle. You will learn what to look for when scouting. You will also learn the most vulnerable stages in the life cycles of common pests, and the best times for efficient and effective control.

You will also be introduced to a wide range of pest management options. Applied pest controls include choosing resistant plant varieties, sanitation, and using biological, cultural, mechanical, or chemical management tactics. Integrated Pest Management (IPM) combines all appropriate



pest control tactics into a single, unified plan to reduce pests and their damage to an acceptable level. IPM practitioners monitor pest populations and keep careful records. This allows them to plan ahead, and choose from a variety of control measures. The result is a pest management plan tailored to fit the situation. This manual will help you decide when nonchemical methods alone can control pests, when pesticide use is appropriate, and how to integrate several tactics into a successful pest management program.

For example, careful selection of plant materials may be a practical way to minimize insect and disease problems. Sanitation may eliminate the food sources or sheltered areas that attract insect pests. In some situations, mulching can control weeds.

Pest control decision-making will be addressed throughout this manual. Before attempting any method of pest control, the following questions should be answered:

- Is the problem actually caused by a pest?
- If so, what pest?
- Is the problem severe enough to warrant the use of one or more applied controls?
- Is the pest in a vulnerable life cycle stage?
- What effective, manageable, and affordable control options are available?

Ideally, pest management involves a combination of both natural and applied controls. A good planner makes careful records of pest problems: when and where the problem occurred, solutions, and results. He or she also learns what can be done to prevent future problems with this pest.

This manual will not discuss specific chemical controls. Pesticide registrations and labels change frequently. This means use patterns also change. An important reference for all horticulture professionals is the **Pest Management Guide for Horticultural & Forest Crops** (Virginia Cooperative Extension Publication 456-017). The Pest Management Guide (PMG) series is revised annually by VCE specialists. The PMGs contain the latest chemical and non-chemical pest management recommendations, based on university research. These recommendations are specifically for growing conditions and pest problems found in Virginia. You can obtain a copy by contacting your local Extension office.

This manual will introduce you to the wide range of application materials and methods available for ornamental pest management. New techniques, like tree injection, will be addressed. Traditional methods, such as sprayers and dusters, will also be described. Along with learning about application options, you'll explore how to calibrate, use and maintain equipment.

Plant Health

Natural forces such as drought, heavy rains, extreme temperatures, ice, snow, and wind may damage or even kill plants. Those grown in urban landscapes and interiorscapes may be sheltered from some or all climate changes. However, they rarely live in ideal conditions. Polluted air can harm them. Lawnmowers and other equipment may cause mechanical injury. Foot and vehicle traffic often results in soil compaction. Exposure to chemicals such as salt used on roads and sidewalks or solvents used to clean windows can injure them.

Indoor plants have special problems. Some of these are:

- temperature fluctuations due to heating and air conditioning,
- low humidity,
- dust, and
- low light or extreme variations in light.

In addition, they are frequently mistreated by having coffee, soft drinks or cleaning fluids poured on them or into their soil. Cigarette stubs and other debris can also pollute their growing medium.

The basic needs of plants are light, air, moisture, nutrients (minerals), and a growing medium. However, different plant species and varieties have specific environmental requirements and tolerances. For example, some require more moisture than others do. Light requirements vary. Some can tolerate soil compaction and others cannot.

Ornamental Pests

The major pests of ornamentals are insects, mites, weeds, nematodes, and diseases. A short description of each group follows. Details may be found in Unit 2 (Ornamental Pest Biology and Identification).

Insects and mites are arthropods. They can harm plants by eating them or by sucking plant fluids. In addition, some spread plant diseases. Dutch elm disease, which is spread by a beetle, is an example.

Disease is an unhealthy condition. Disease symptoms include stunted growth, deformities, discolored or spotted foliage, and leaf drop. Sometimes diseases cause plant parts to rot.

Plant diseases may be caused by living (biotic) and by nonliving (abiotic) factors. Often, both work together. For example, several types of common soil fungi cause damping off and root rot. However, these organisms do not grow in well-aerated soil. On the other hand, if soil or growing medium is waterlogged for a long time, these organisms will flourish.

Plants 'catch' biotic diseases, just like people do. Fungi, viruses, and bacteria may cause biotic diseases.

Mollusk pests — snails and slugs — damage ornamentals by feeding on them. Usually, they are active at night. They use their rasp-like tongue to eat soft plant tissues such as foliage, fruit, and fleshy stems. They may eat entire seedlings. As they move, snails and slugs leave a slimy trail. When these mucus trails dry, they look like silver streaks. This discoloration is undesirable on ornamental plants.

Nematodes are small roundworms. Many affect plant growth. Some cause stunting because their feeding weakens the root system. Others cause 'knots' to form on roots. These 'knots' prevent roots from functioning normally. Some nematodes invade plant tissues, causing them to die.

Weeds are plants growing in a place where they are not wanted. Weeds compete with desirable plants for light, water and nutrients. Some harbor insect pests and/or disease organisms.

Pests may harm all plants. However, plants suffering from environmental stress are especially susceptible to pest pressure. For that reason, it is important to consider site characteristics when choosing plant materials. Professional horticulturists can minimize plant health problems by careful planning. Good design, appropriate variety selection, and proper maintenance can limit pest problems. Nonetheless, pesticides can play an important role in maintaining a healthy plant community.

Integrated Pest Management

Integrated Pest Management (IPM) is a term for an ecological approach to pest control. IPM programs use control measures based on pest habits and life cycle. IPM programs employ all appropriate pest control strategies. Usually, IPM plans include both non-chemical and chemical management methods. The goal of an IPM program is to reduce pest populations to an acceptable level.

However, in some settings, the tolerance for pests is rather low. Many ornamental plantings are both decorative and functional. In some cases, aesthetics may set action levels. In other instances, economic losses may drive pest management needs. Safe and effective pest management should be an important part of any landscape or interiorscape plan.

To plan an IPM program, a horticulturist must have good pest identification skills. This involves recognizing the pest and its damage symptoms. It also means knowing the pest's life history.

IPM programs rely on regular monitoring. Control measures are taken only where and when necessary. IPM programs do not rely solely on a pesticide 'spray schedule.' Instead, they integrate appropriate nonchemical and chemical pest management methods.

Effective IPM programs involve:

- proper identification of the pest,
- knowledge of the pest's life cycle and habits,
- accurate assessment of pest population size and distribution (monitoring),
- a list of the factors that attracted the pest to the site,
- good information about management methods, both chemical and nonchemical, and
- long-term plans for prevention or suppression of troublesome pest populations.

Successful long-term programs are evaluated regularly and modified if necessary. This is true for a number of reasons. Pest numbers and activity levels change. New pests may invade an area. New chemicals, new formulations, and better application equipment and methods strive to make pest control safer and more effective.

The Role of Pesticides in Ornamental Pest Management

Pest management in landscapes and interiorscapes is a highly sensitive issue. Many such areas are designed for public use. Some people and their pets spend a great deal of time around ornamental plants, both indoors and out. Home landscapes, public parks, recreational areas, and private gardens are inhabited by wildlife.

As a professional in the field of horticulture, you can have a major impact on environmental quality. Well-designed and maintained plant communities enhance urban areas. They are beneficial to people and wildlife. However, professional plant managers must share the responsibility of protecting our natural resources.

Plant pest management measures must be safe for all concerned. Pesticides should be used only when needed. All label directions must be followed to the letter. Pesticides must be managed so they have a positive effect on environmental quality. A good way to accomplish this goal is adopting Integrated Pest Management (IPM) practices.

Education is the key to success in ornamental pest control. Educated professionals are able to design effective IPM programs. Educated pesticide handlers are able to use pesticides safely without harming themselves, their co-workers, the public, or nontarget organisms.

Pesticides have numerous benefits. However, they can present a danger to the user, other humans, and the environment if not handled properly. Some pesticides have residual effects, and can remain active for relatively long periods of time. Some are highly toxic. Some have the potential for off-site movement. While recognizing the importance of proper pesticide use, it is also important to identify and manage potential hazards.

The Role of a Professional Horticulturist in Pesticide Management

People whose profession involves the use of pesticides must understand the properties of these products. In this manual, you'll learn about the personal and environmental safety considerations that are important when using any pesticide. You'll learn about protective clothing and equipment. When pesticides are used, you must know what to wear, and when and how to wear it.

A commercial applicator working with ornamentals must remember that the public is often in close contact with the pesticides applied to these plants. In this manual, you'll learn how to protect people, pets, and other nontarget organisms from pesticide exposure.

Protecting the environment should be a major concern for every pesticide applicator. A commercial applicator works on sites belonging to the general public or to another citizen. For that reason, he or she needs to be particularly sensitive to possible environmental problems that could occur as a result of improper pesticide usage.

Pesticides will remain useful tools in commercial pest control programs for the foreseeable future, as long as those who use them do so with care and respect. However, it is important to realize that they are not the answer to all pest problems. Cultural, biological and mechanical controls should be included in your "arsenal" of pest management methods.

Test Your Knowledge

Q. When you detect a plant health problem, what is the first step to take when seeking a solution?

A. Identify the cause(s) of the problem. Is the problem caused by a pest organism? Or, is it the result of environmental stress?

Q. What is the first thing you should do when you detect a pest problem?

A. Identify the pest.

Q. Describe scouting, and explain its importance in effective pest management programs.

A. Scouting is checking or monitoring for pests in an area to determine: what pests are present, how many of each kind are in the area, and how much damage they are causing. Scouting is important for effective pest control, because it helps to determine if treatment is needed, and/or if previous control measures were effective.

Q. Where can you get current pest control recommendations?

A. From the Pest Management Guide (PMG) series. The PMGs are produced by Virginia Cooperative Extension. They are revised annually. The recommendations found in the PMGs are research-based and tailored for growing conditions and pest problems found in Virginia.

Q. Why is proper pesticide use important and necessary?

A. Protection of human health, the environment, and protection of property.

Q. What is Integrated Pest Management (IPM)?

A. Integrated Pest Management (IPM) is a unified pest-control plan that uses a combination of appropriate pest control tactics. Applied pest controls include biological, cultural, mechanical, or chemical methods. The goal of an IPM plan is to reduce pests and their damage to an acceptable level.

Q. What are the main categories of pests that harm outdoor ornamental plants?

A. Insects, mites, diseases, weeds, nematodes, and mollusks can be pests of ornamentals. Vertebrates, such as rodents and deer, may also harm ornamentals. However, using pesticides to control them is outside the scope of this manual.

Q. What is the main purpose of this manual?

A. This book is written specifically for people preparing for the Ornamental Pest Control (3A) Commercial Pesticide Applicator certification examination. In general, it is a reference for safe and effective pest management for professionals installing or maintaining ornamentals.

Q. What are some of the benefits of ornamental plants in landscapes or interiorscapes?

A. Landscapes and interiorscapes put plants where people can enjoy them. Ornamental plants add beauty and interest to recreational areas. The same is true for homes, cities, office buildings, and other places people live and work. However, plants improve the quality of human life in ways other than aesthetics. For example, they cleanse the air and prevent erosion. They provide food and shelter for animals. Well-planned landscapes can reduce heating and cooling costs by producing shade and serving as a windbreak. Along rights-of-way, shrub plantings make roadways safer. Plantings can help to reduce noise levels along roadsides and in industrial and urban areas.

Q. List the five basic needs of most plants.

A. Air, moisture, light, nutrients (minerals), and a growth medium.

Q. List five environmental stress factors that can affect plants growing outdoors.

A. Natural forces such as drought, heavy rains, high winds, extreme temperatures, ice, snow, and air pollution may damage or even kill plants. In some landscapes, mechanical injury and soil compaction are serious problems. Exposure to chemicals, such as salt used on roads and sidewalks, can injure or kill plants in the landscape. In urban areas, plants surrounded by blacktop and/or concrete live in very hot, and often very dry, conditions.

Q. Name four unique stress factors that often affect plants growing indoors.

A. Indoor plants have special problems. Some of these are temperature fluctuations due to heating and air conditioning cycles, low humidity, dust, low light or extreme variations in light, poor air quality, and exposure to chemicals.

Unit 2. Plant Health Management

Learning Objectives

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

- List the basic needs of plants.
- Describe the environmental factors that affect plant health.
- Recognize the visual symptoms of plant stress.
- Describe the materials and methods used to diagnose plant health problems.

This Unit lists the basic needs of all plants. It also describes the environmental factors that affect normal plant growth. Management strategies for two general problems, soluble salt buildup and acclimatization, are discussed. A section on diagnosis explains how to look for and recognize symptoms of stress. Why and how to monitor the plant's environment is described.

Terms to Know

Acclimatization - A process in which a plant adapts to a new environment.

Axil - The angle between the upper surface of a leaf stalk and stem.

Cultivar - A cultivated plant variety. Selective breeding produces some cultivars. Others are simply descendents of a plant or plants selected from a variable population.

Degree Day - Units of heat above a threshold temperature for one day (24 hours) or an accumulation of heat units over time. Degree days are used to predict insect and disease development.

Fertilizer - Mineral nutrients plants need to live and grow.

Footcandle - A unit for measuring illumination or light intensity. A footcandle is equal to one lumen per square foot. This measure was originally based on the light produced by one candle, as measured on a surface one foot away.

Growing Media - A substance in which plants are rooted.

Light Duration - The total number of hours of light a plant receives in a day.

Light Intensity - Brightness.

Metabolism - A term for all of the chemical reactions that take place in a living thing. For example, living things use (metabolize) food as fuel.

Monitoring - Determining the size and distribution of a pest population in an area.

Necrosis - Death of plant tissues or a plant part.

Pest - Any living thing that is undesirable, or causes harm to people, property, or the environment. An organism may be a pest in one place but not in another. For example, 'volunteer' corn in a soybean field and cherry tree seedlings in an ornamental bed are pests. The same is true for termites in a house, but not for those recycling dead trees in a forest.

pH - A measure of acidity or alkalinity. Measures between 0 and 7 are acidic. Measures between 7 and 14 are alkaline (basic).

Photosynthesis - The name for the process of making food (carbohydrates), using water and carbon dioxide as raw materials, in the presence of sunlight.

Pore Space - An air pocket or channel in soil or potting medium.

Producer - An organism that can make its own food.

Relative Humidity - A measure of the amount of moisture held in the air.

Scouting - Regularly searching for, identifying, and assessing numbers of pests and the damage they are causing.

Soil Amendments - Materials added to soil, such as sphagnum moss, peat moss, bark, perlite, vermiculite, or sand. Soil amendments are added for many reasons; for example, to improve nutrition, prevent compaction, or to improve drainage.

Soilless Media - An artificial substrate in which plants are rooted. Soilless media serve the same function as growing media. However, there is no soil used, and the mixture is sterilized.

Soluble Salts - Water-soluble salts found in chemical fertilizers and in water supplies.

Stress Factors - Physical, chemical or biological factors that have a negative impact on plant health.

Symptom - A noticeable, abnormal condition.

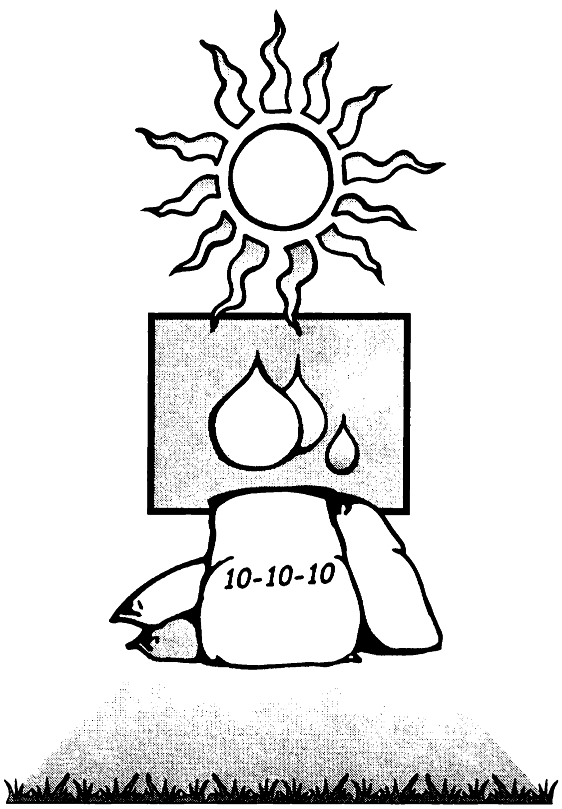
Syndrome - All the symptoms that characterize a disease.

Turgid - Normal fullness produced by fluid content.

A horticulturist strives to grow healthy plants. To be successful, he or she must be aware of the environmental factors that affect them. When a plant is subjected to stress, it is more susceptible to insects and diseases. Healthy plants are less likely to require pesticide treatments.

Environmental conditions affect some pests directly. For example, spider mites flourish in warm, dry conditions. However, this type of weather can cause drought-stress in plants. So, the conditions that favor mites weaken the plants these pests attack. Anything that can be done to manage plant stress will avoid or minimize many pest problems.

Minimizing the need for pesticide use can save time and money. It also may prevent some resistance problems. Fewer applications may reduce exposure risk for humans and nontarget organisms. Reducing reliance of pesticides is especially important in interiorscapes. This is true because there are relatively few pesticide products registered for use on indoor plants.



Basic Needs

Green plants are producers. They use light energy to make food — carbohydrates — from carbon dioxide and water. Even though green plants can make their own food, they have environmental requirements. The main factors affecting plant growth are temperature, light, relative humidity, soil moisture, and the availability of essential minerals. The growing media influences soil moisture and mineral availability.

Different species and varieties of plants are adapted to certain environmental conditions. For example, some need very little moisture and others need a great deal. Some grow best in full sun and others in shade. However, all plants have basic needs.

Temperature

The optimum temperature range for indoor plants is 55° to 90° F. Drastic changes in temperature will harm most plants. Low temperatures will result in slower plant growth and chilling injuries. High temperatures may cause rapid wilting and utilization of stored food reserves.

Temperature fluctuations can create health management problems in the interiorscape. Placing plants near doors, windows or heating ducts where cold or hot drafts can reach the foliage may damage the plant. Watering with cold tap water may shock the roots. Turning off the heat or air conditioning on weekends may weaken the plant, making it more susceptible to pest infestations and diseases.

Outdoors, most temperature problems may be avoided by selecting plant materials adapted for the climatic zone. However, in some outdoor settings, plants are placed in 'concrete islands.' These sites may be protected from cold in the winter. However, they may become extremely hot in the summer. In all seasons, they are usually very dry. Plants grown in many urban sites must be adapted to special conditions.

Temperature affects more than plant growth. It controls the developmental rate of many other living things. As a rule, organisms develop progressively faster as the temperature increases (until a certain maximum is reached.) Some pests (including insects, nematodes, and fungal diseases) need a certain amount of heat to develop from one point in their life cycles to another. Therefore, a measure of accumulated heat can be used to predict the development of a pest. Often plant managers monitor degree days to assess heat build-up.

The concept of degree-days includes two factors: the temperature and the length of time the pest organism is exposed to that amount of heat. An average daily temperature of ten degrees over the developmental threshold for one day results in ten degree days. Five degrees over the threshold for two days also yields ten degree days. The same is true for two degrees over the threshold for five days.

Tracking the temperature in a plantscape can help you design and implement a pest management plan. For example, some fungi reproduce rapidly when the weather is warm. Knowing this allows you to predict and prepare for an outbreak of disease. In some cases, plant health managers should act when the nighttime temperature does not fall below a certain point. In other cases, pest management recommendations direct you to act when the daytime temperature reaches a certain point (or reaches that point for a certain number of days in a row.) Charting degree-days can help you predict and prepare for pest population increases.

Light

All green plants need light. Light is the energy source most plants use to manufacture food. In the process of photosynthesis, plants use light energy to convert carbon dioxide and water into simple sugars. The simple carbohydrates are then transformed into other materials, including complex carbohydrates. Plants use carbohydrates to make leaves, stems and other plant parts. Plants vary in the amount of light needed to survive. In general, the more light a plant gets, the faster it grows. The faster it grows, the more water it needs.

Light intensity refers to the brightness of light. Light intensity is measured in footcandles (fc). Light requirements for plants range from 10fc to over 500fc. For comparison, the average light intensity in an office is between 50 to 100fc.

Light duration refers to the total number of hours of light a plant receives in a day. Combining natural with artificial light can provide the proper light regime for plants grown indoors.

Relative Humidity

Relative humidity is the amount of moisture in the air. Relative humidity (RH) is often a problem for plants grown indoors. Most of the plants used in interiorscapes are tropical in origin. Tropical plants prefer a relative humidity (RH) level above 50%. However, most indoor environments are closer to 20% RH.

Humidity fluctuations in the interiorscape are usually caused by one of two things:

- heating and air conditioning elements, and

- seasonal changes.

Low humidity produces maintenance problems. Wilting, decreased food production, browning of leaf margins (marginal necrosis), scorched leaves and dull foliage are the result of low humidity.

Soil Moisture

Different plant species and cultivars have different moisture requirements. However, some generalizations can be made. In most cases, the roots of a plant absorb its supply of water.

There are two basic types of roots:

- thick, fleshy roots (taproots), and
- thin, fibrous roots.

Fleshy roots gather water much more slowly than fibrous roots. As a result, plants with thick taproots are easier to overwater.

The pore spaces in growing media are important to plants. Roots take in oxygen to metabolize food in their cells. Roots also give off carbon dioxide. Both these processes require air-filled pore spaces. Compacted soil or water-saturated media interfere with gas exchange. Eventually, if its roots cannot absorb oxygen and eliminate carbon dioxide, the plant will die.

Nutrients (Minerals)

Fertilizers are a way of supplying mineral nutrients to plants. Different plant species and cultivars have different requirements. An individual plant's fertilizer needs will vary, depending on the season (outdoors) or the amount of light it receives (indoors). Plants in an indoor environment use less fertilizer than those grown in a nursery. Fast-growing plants that have high light intensity requirements need more minerals than lower light plants that grow more slowly.

Plant nutrients are classified as either macronutrients or micronutrients. The prefix 'macro' means large, and 'micro' means small. Macronutrients are chemical elements plants need in fairly large amounts. The macronutrients are Nitrogen (N), Phosphorous (P), Potassium (K), Sulfur (S), Calcium (Ca), and Magnesium (Mg). On the other hand, 'micro' means small. Micronutrients are needed, but in relatively small quantities. Zinc (Zn), Copper (Cu), Manganese (Mn), and Iron (Fe) are micronutrients. Sometimes micronutrients are called trace elements. Both macronutrients and micronutrients are essential for good health.

Fertilizers come in many different forms. They may be sold as liquids, powders, spikes, granules, or tablets. When fertilizing, use a well-balanced product that also contains the micronutrients a plant needs. Indoors, plants growing in low light need only one application of fertilizer a year. Interiorscape plants grown in high light can be fertilized two to three times annually. Outdoors, fertilization programs vary according to the plant's growth stage and production needs. For best results, make most fertilizer applications during summer when light levels are at their maximum.

It is important to plan a fertilization program. This is especially true for indoor plants, because they are usually grown in less than ideal conditions. Improper fertilization can cause many problems. The presence of high levels of fertilizers will cause root damage, leaf spot, browning of leaf margins, stunted growth, defoliation, and eventually death.

Overfertilization of pot or container grown crops results in high concentrations of soluble salts in the growth media. Exposures to high levels of soluble salts predispose plants to certain root diseases. Common signs and symptoms of overfertilization include:

- a crust of whitish fertilizer on the soil surface,
- yellowing and wilting of lower leaves,
- browning of leaf tips and margins,
- browned or blackened limp roots,
- leaf drop,
- very slow or no growth, and eventually
- death.

Growing Media

A plant's growing medium should provide moisture, support, nutrients, and aeration for the roots. As a rule, the root environment should have a pH in the range of 5.5 to 6.0, which is slightly acidic.

Potting media are composed of different materials. Mixtures may contain soil, sphagnum moss, peat moss, other types of organic matter, perlite, styrofoam pellets, vermiculite, and sand. Soilless media are similar in composition. However, they do not contain soil and are sterilized.

Best Management Practices

There are many factors a horticulturist can manage to promote plant health. Two common problems and solutions are discussed in this section.

Soluble Salts

Preventing soluble salt buildup is critical for the health of container-grown plants. This is most often an issue in interiorscapes. When a plant is first installed into an interiorscape, it usually has an excess of fertilizer stored in its tissues and in the growing media. To help the plant acclimate to an indoor environment, the visible fertilizer on top of the soil should be scraped off and excess fertilizers should be leached from the root zone.

Here is a list of ways to prevent salt buildup:

1. Use a conductivity meter regularly to measure the salt content of growth media.

2. Use a potting mix that suits the plant.

3. Avoid overfertilizing. Reduce the concentration of the fertilizer solution. As a rule, use less than the recommended amount of fertilizer listed on the container.

4. Do not use slow release fertilizer in combination with soluble fertilizer.

5. Do not mix slow release fertilizer into the soil mixture. If new plants arrive with excess slow release fertilizers on the surface of the growth media, scrape them off.

6. Leach excess fertilizer from plants being moved to environments where they will have a slower growth rate.

7. Avoid watering plants with softened water.

Soluble salts are easier to control when subirrigation is used. Over a period of time, salts will rise to the surface. When signs of salt build-up are noticed, the top two inches of media can be scraped off and replaced with fresh soil.

Balance is the key to good health. Overfertilization can damage or even kill ornamental plants. However, nutrient deficiencies are also harmful. They may be caused by lack of specific nutrients in the growing media. They may also be the result of the plant's inability to take in nutrients due to root damage or an excess of soluble salts in the media.

Mineral deficiency symptoms can be grouped into two categories: those that show up first on the older regions of the plant and those that appear on new plant tissue.

Each plant exhibits characteristic symptoms when nutrients are deficient. Nitrogen, phosphorus, magnesium, potassium and zinc all have symptoms that show up on the older or lower leaves. Calcium, boron, manganese, sulfur, and iron deficiency symptoms show up on newer or bud leaves.

Acclimatization

Plants used in landscapes and interiorscapes are moved from the site where they were grown. Most plants will acclimate to a new environment (within tolerances), provided the conditions do not vary greatly from day to day. However, in some situations, plants need special care after they are moved to a new location. Proper acclimatization will help plants adjust to and thrive in a new site.

Acclimatization is of particular importance for interiorscape plants. Most plants placed indoors are grown in lathe houses, greenhouses, or in the field. They are produced where light intensity and duration are high, watering is frequent, and high rates of fertilization are employed to maintain rapid growth. By contrast, most interiorscapes have relatively low light intensities. Water and fertilizer requirements are minimal. Plants used indoors must become acclimatized to new conditions. As the plant adjusts to the lower light intensity, it will drop excess foliage it can no longer maintain. The new leaves formed are better adapted to the indoor environment.

Diagnosis: Methods and Materials

A good plantscape manager is able to identify the causes of plant health problems. However, diagnosis is often difficult. This is true because there are many things that contribute to a plant's health. Soil conditions, watering schedules, fertilization programs, planting and pruning methods, natural aging, weather, climate, physical damage, chemical exposures, and pests can all affect a plant's condition.

Generally, plant problems do not arise from one isolated cause. There may be a primary or obvious cause, such as the presence of spider mites or root rot. There may also be a secondary cause such as unfavorable environmental conditions.

Often, a horticulturist must try to determine the origin of a problem by observing nonspecific symptoms. Examples include leaf yellowing, leaf drop or browning of leaf tips or edges. Unfortunately, nonspecific symptoms are typical of a number of different plant disorders. Therefore, diagnosis of the plant's problem must be the result of logical thinking. Successful diagnosticians narrow the field of possible causes by methodically eliminating problems.

Good records are very important diagnostic tools. Often, proper diagnosis is not possible without a good history of the plant or plants under observation. Here is a list of what a good set of records might tell you:

- When was the present problem first noticed?
- What was the source of the seed or plant material?
- How and when was the planting established?
- What is the soil type / soilless media composition?
- Are the plants mulched? If so, with what?
- What was the nutrient and watering schedule?
- What sort of pests have been detected in the past (what, when, in what numbers)?
- What pest management actions were taken?
- Were pesticides used? If so, what, when, how, how much?

It is also very useful to note whether all or only some plants are affected. If only some are, is there a 'common denominator'? For example, are the affected plants growing in a low-lying area? Are only those in direct sun affected?

The chart on the next page is a sample diagnostic guide for environmental problems of indoor plants. It is a useful tool. However, it also shows the difficulty in relating a symptom to one specific cause. For example,

Common Environmental Problems of Indoor Plants

Symptoms	Possible Cause
1. Stems 'leggy'; long internodes. New leaves undersized; foliage light green. Loss of variegation or normal leaf split.	Not enough light.
2. Leaves closest to sunny windows with yellow or brown spots; leaves pale and thick. High temperatures.	Too much light.
3. Leaf and stem wilt; leaf tips and margins turn brown. Lower leaves yellow and drop. Soil feels dry to the touch.	Not enough water.
4. Stems abnormally soft. Lower leaves yellow; leaf drop; new leaves abnormally small. Plants lack vigor and grow slowly. Soil soggy to the touch. Water moves through the soil slowly.	Too much water.
5. Leaves 'hug' the container; foliage abnormally dark; leaves and stems more brittle or more leathery than normal.	Temperature too low.
6. Leaves wilt, despite proper soil moisture. Plants do not flower, or do not produce a normal number of blooms. Plants lack vigor and grow slowly.	Temperature too high.
7. Leaves yellow, wilted and abnormally small. Plants lack vigor. Records show that no fertilizer was applied during the normal growing season. Plant in soilless media or in same container for a long period of time.	Mineral deficiency.
8. Leaves yellow, leaf veins green.	Iron deficiency (chlorosis).
9. Plants do not flower, or do not produce a normal number of blooms. Foliage abundant and healthy. Records show that high-nitrogen fertilizer is applied often, or that a balanced fertilizer is used more frequently than recommended.	Mineral excess.
10. Crust forms on pot rims and sides of container. Leaves that touch the pot rim wilt and wither. Loss of variegation or normal leaf split.	Soluble salt build-up (ex. from softened water).
11. Leaf edges and tips brown. Lower leaves turn yellow and drop. Plants lack vigor and grow slowly.	Lack of humidity; air too dry.
12. Leaves with yellow streaks or spots (on plants with 'fuzzy' leaves).	Cold water on foliage for too long.
13. Roots growing through bottom drainage holes. New growth abnormally small. Water runs through soil faster than normal. Soil dries quickly between waterings.	Plant is root bound, and has outgrown its container.

Solving plant health problems can be done in three general steps:
1. identifying the problem,
2. determining the cause or causes, and
3. planning a solution.

several things may cause undersized leaves: not enough light, too much water, lack of minerals, or a root-bound plant.

Identifying the Problem

Plant health problems are usually identified because someone notices and describes something unusual. In some cases, an observer sees the pest. A sign is the pest organism itself. However, more often, people notice a symptom of pest activity. A symptom is an unhealthy or abnormal condition caused by a pest.

Plant managers must be both trained and observant to detect some warning signs and symptoms. Some are not visible unless a plant part is magnified. Other symptoms may only be recognizable if healthy plants are near the infected or stressed plants. For example, if all the trees in an area are afflicted with the same pest or environmental stress, an observer may have the impression that all is normal. However, the plants in question may be stunted by the presence of nematodes on the roots or by damaging levels of air pollution. Generally, someone well trained will be able to recognize a subtle symptom before the untrained eye sees any symptoms at all. For example, with experience, a horticulturist notices spider mites before the webbing appears. Monitoring is critical for detecting a potential problem.

There are four perspectives to consider when monitoring plant health. First, study the plant from a distance. Note its general appearance and condition. Does the plant look healthy? Is it the proper shade of green, or does it appear to be yellowing? Is the foliage turgid or limp? Next, take a detailed, close-up view. Use a 10X hand lens on places that do not look normal. Spider mites or powdery mildews can be quickly diagnosed in such a manner. Third, get some idea of how long a plant has shown the symptom or set of symptoms. You may need to monitor a plant or plant group for several weeks before determining the cause of the problem. Good records are invaluable at this stage. Finally, the fourth perspective comes from knowledge and experience. Over time, a good plant manager learns what to look for in particular environmental situations or on certain types of plants. For example, all *Hedera* (Ivy) species are particularly susceptible to mites. *Aglaoenamas* located near an exterior door may suffer from cold stress during the winter months.

Determining the Cause

Usually, plant health problems are not the result of one isolated cause. Determining the origin of a problem is often challenging. It may require more than visual observation. There are some simple tools that make monitoring environmental and cultural factors easier. These include light meters, thermometers, hygrometers, solubridges, pH meters, soil test kits, insect traps, and hand lenses.

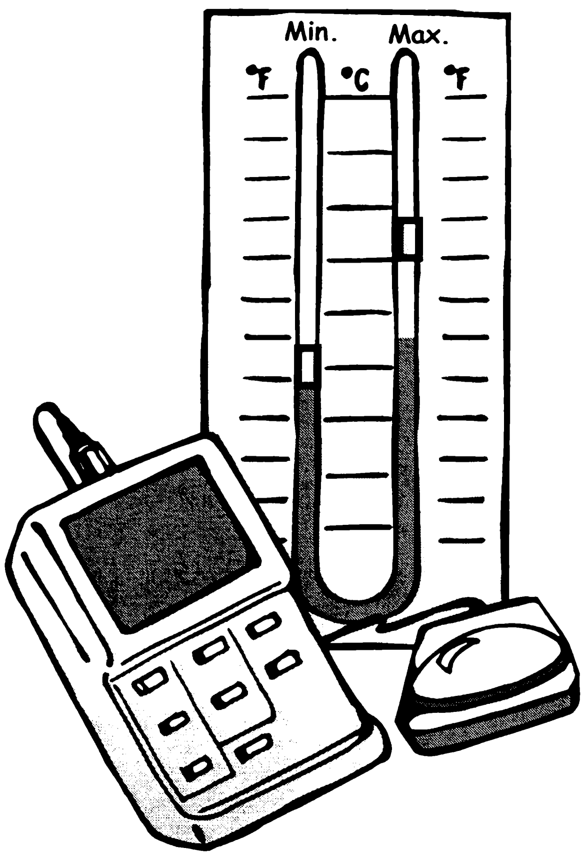
Light Meters

Plants give several clues when they're not getting enough light. These include spindly, weak new growth, loss of older leaves, leaning toward the light, and loss of patterning in colored foliage. Outdoor sunloving plants may suffer if they are planted in places that are (or become) too shady for them. Most indoor ornamental plants grow so slowly that the symptoms listed rarely occur. General poor health may be the only evidence that more light is needed.

The amount of light available can be determined by using light meters or plant-growth photometers. This is necessary when designing an interior landscape. However, these tools should be used to monitor and detect any changes in lighting conditions. Older installations may not be receiving the planned amount of light for a number of reasons. Interiorscapes that rely on natural lighting should be checked under all weather conditions, and during all seasons of the year. The growth of exterior landscape plants may be shading windows; urban development may contribute to persistent hazy skies. Light levels from artificial sources can be altered when bulbs are replaced by ones of different wattage.

Direct-reading light meters measure the intensity of visible light. Recommendations for light levels are available for all indoor plants. However, remember that light meters measure total light intensity. Some window and tinting materials can exclude the blue or red wavelengths of light. Therefore, a light meter reading may show ample light intensity, but the plant may not be getting enough of the type of light it needs.

The blue, red, and far-red portions of light most green plants use are specifically measured in irradiance units per square centimeter by plant-growth photometers. These instruments give an accurate picture of the light available and useful for plants. The high cost of photometers has limited their use in the past. However, they provide a more meaningful light measurement. A photometer may be a wise investment for a commercial interiorscaper.



Thermometers

Many plants can survive short periods of over-heating or chilling with only slight damage. However, some sensitive species may be killed by just a few minutes at extreme temperatures. Symptoms from excessive temperature fluctuations include rapid defoliation, leaf spots, blights or blotches. Consistently hot environments result in plants with small, pale foliage. Cold temperatures cause wilting, leaf blotching and necrosis.

Outdoors, air and soil temperatures may vary greatly within one bed or section of a landscape. Shading, 'heat load' from concrete or glass, and mulch color are just some of the many factors that affect temperatures.

In interiorscapes, bright, direct sun or hot bulbs may create "hot spots." Cold drafts from air conditioners and outside doorways can chill other areas. Even modern heating and cooling systems cannot keep all areas of a building at the same temperature. Interiorscapers should use several thermometers to monitor an area. Placing them strategically should identify problem areas.

For a better picture of temperature conditions, high/low thermometers should be used. These instruments record temperature extremes. Maximum/minimum thermometers are especially useful because they detect temperature fluctuations. For example, an interiorscape worker might note the temperatures when servicing an area. He or she may find them to be in the comfort range for plants. However, symptoms of temperature damage may indicate that the site becomes very hot or very cold at times.

Maximum/minimum thermometers do not tell you when the high and low they record happened. A complete record of temperatures through time can be obtained by using a thermograph. Thermographs are very expensive. As a rule, they are used only in larger installations, where the plants are of considerable value.

Hygrometers

Adequate air moisture is important to the general health of plants. Indoors, the relative humidity changes day to day, through a day, and from one area to another. Relative humidity in interiorscapes is related to air temperatures. Indoors, heating the air lowers the humidity, while cooling the air raises it. Outdoors, warm air can hold more moisture than cool air.

A hygrometer measures relative humidity. The most accurate readings are obtained from wet/dry bulb hygrometers. These instruments are simply two thermometers. Evaporation of water from the wet bulb lowers its temperature reading. The difference between the two thermometers is used to determine the relative humidity.

Direct-reading hygrometers are accurate within two percent at normal room temperatures. These inexpensive instruments are adequate for use in most interiorscapes.

Solubridges

Soluble salts come from minerals in the growing medium, irrigation water, and fertilizer. A solubridge measures soluble salt levels. This instrument measures salt content by testing the electrical conductivity of the soil. These instruments are relatively expensive. However, routine sampling monitors soil conditions and permits corrections before serious problems occur.

The most accurate method of measuring soluble salt concentration is to test a water-saturated paste of a sample of the soil or potting medium. This saturated paste is so wet that it glistens but not so wet that it puddles. The conductivity of this saturated paste extract is an accurate measure of the salts to which the roots are exposed.

The most common method of measuring soluble salts is to start with a sample of air-dry growth medium. Weigh it, and add two to five times that weight in water. Stir to mix. Filter or squeeze the mixture through cheesecloth. Test the filtered water. This method does not take into account varying amounts of organic matter in different potting mixes. However, with experience and good records, this method is adequate. (Records will show which conductivity readings correspond to good growing conditions, and which match poor growing conditions.)

pH Meters

Fertilizer applications and soluble salts from irrigation water can change the pH of the growing medium. Soil that is too acidic causes plants to wilt or drop foliage. Alkaline conditions result in pale coloration and stunted growth. Routine pH testing indicates when corrections need to be made for the continued health of plants.

A complete soil test includes a pH reading. When adjustments are necessary, the report makes recommendations for correcting the pH.

The soil pH can also be determined on the job site with inexpensive pH meters or testing papers (i.e. litmus paper). For most tests, a small portion of growing medium is diluted with distilled water. The mixture can be filtered or simply allowed to settle. The resulting mineral-water solution is tested. Some meters sample correctly moistened soils directly. Reliable results are obtained with any of these methods, as long as directions are carefully followed.

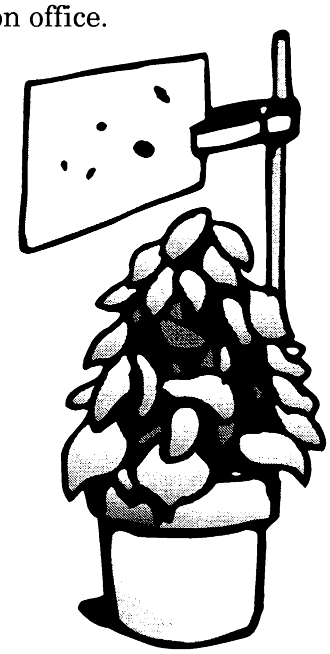
Soil Test

A soil test gives a more complete picture of soil conditions. A routine analysis from the Virginia Tech Soil Testing Laboratory includes:

- the soil pH,
- a nutrient analysis (phosphorus, potassium, calcium, magnesium, manganese, zinc, copper, iron and boron), and
- a recommendation based on test results and plant type.

Special tests for organic matter and soluble salts are also available.

A mixed sample may be taken from several containers or planting areas. If only one plant or site has a problem, its soil should be submitted alone. Specific directions for sample collection are included with soil test kits. These kits are available from your local Extension office.



Insect Traps

Two types of traps are commonly used to monitor for flying insect pests: light/ electrocution traps and sticky traps. Light/ electrocution traps are relatively expensive. They require an electrical outlet near the area to be monitored. They may be better suited to large sites where their presence does not distract from the appearance of the planting. The lights used in these traps attract a wide range of insects. Beneficial or harmless insects may be killed along with those that cause damage.

Sticky traps work effectively because some insects are attracted to specific shades of yellow and blue. Prepared traps are commercially available, or traps can be easily made from any rigid material. A flat surface is painted yellow, then coated with a compound (i.e. Tanglefoot, Stickem or TackTrap) that holds insects that land on it, much like old-fashioned fly strips. Sticky traps are often used to monitor the presence of whiteflies and fungus gnats.

When either type of trap is checked, the number of pests should be recorded. In some cases, low numbers may be tolerated if little or no damage is noticed. When high populations require control measures, a drop in the number trapped indicates the management plan was successful. In small plantings, traps may provide effective control of some pests.

Hand Lenses and Binoculars

A hand lens that provides 10X or 20X magnification is an essential tool for the plant technician. All plant parts should be examined. Pests may be found along the stem, in the leaf axil, on the growing tip, or on the backs of leaves. The eggs, immature and adult stages of many pests can be found on different parts of plants. Occasionally, check the roots

and soil for signs of infestations. Foliage and stems should be studied for changes in color, texture or other disease symptoms. Plant diseases are difficult to identify, but a hand lens can help rule out cultural problems. Spots and discoloration on leaves should be carefully examined. The presence of fungal strands or fruiting bodies could easily be overlooked without magnification.

Binoculars are useful for examining tree crowns.

Planning a Solution

Once a problem is noticed, and the cause (or causes) is described, you can plan a solution. A solution may mean taking steps to cure or manage the problem. Your response will depend on the nature and the severity of the problem.

You may also decide to take no action. Doing nothing is a perfectly appropriate response in some cases. For example, if the problem is a pest, there may be no practical methods of controlling it in its current stage of development. Sometimes, the cost of pest management is greater than the cost of replacing the plant(s). In such cases, it's best to wait until the pest reaches a vulnerable stage, or to replace the infected plant(s).

Unit 3 of this manual is devoted to pest biology and identification. Unit 4 describes pest management options. Before you can plan a solution to any pest-caused problem, you must have a correct identification of the pest. You also need to know about the pest's life cycle. Finally, you must know what effective management options are available to you.

Once a pest management plan is developed and implemented, the plant(s) must be monitored to determine if the program is effective. If the plants do not respond as expected, it may be necessary to change action strategies.

Test Your Knowledge

Q. Name four environmental factors that affect plant growth.

A. The main factors affecting plant growth are temperature, light, relative humidity, soil moisture, and the availability of essential minerals. Natural aging and pest pressure also have an effect on a plant's condition.

Q. Name two management practices that may affect plant health.

A. Planting and pruning methods, physical damage, soluble salt concentration, acclimatization to a new site, and chemical exposures affect a plant's condition.

Q. Why are environmental conditions important to plant health?

A. All plants have environmental requirements and tolerances. Suitable environmental conditions will keep plants healthy and thriving. A healthy plant is less susceptible to pest infestations.

Q. What are the raw materials plants use to make food?

A. Carbon dioxide and water are used to make carbohydrates by photosynthesis.

Q. What is the energy source green plants use to produce food?

A. Photosynthesis is 'powered' by light energy.

Q. Why do plants need to be acclimated to a new environment?

A. Plants grown in greenhouses or in the field are adapted to high light levels and frequent watering and fertilization. If they are moved to an interiorscape or to some landscapes, they need to adjust to the new conditions. For example, in the indoor environment, light levels are lower, and plants require less watering and fertilization.

Q. Describe the ideal indoor temperature range for tropical plants grown indoors, and explain problems associated with drastic temperature fluctuations.

A. The ideal temperature range for indoor plants is between 55 degrees F and 90 degrees F. Lower temperatures will result in slower plant growth and chilling injuries. Excessively high temperatures will result in rapid wilting and utilization of stored food reserves.

Q. Describe the functions of plant roots.

A. Roots absorb water and minerals. They stabilize the stem, and store moisture and excess food.

Q. Why do plants need pore spaces in their growing media?

A. Roots need the pore spaces to allow water to reach the roots, and to allow gas exchange to take place.

Q. Why do plants need fertilizers?

A. Plants manufacture their own food through the process of photosynthesis. Fertilizers are mineral nutrients used by the plant for this process. In some soils and growing media, minerals are lacking or in short supply.

Q. What is the difference between a macronutrient and a micronutrient?

A. Macronutrients are minerals that plants need in fairly large amounts. Plants use micronutrients in relatively smaller quantities. Both are necessary for good nutrition and health.

Q. What is "soluble salt buildup"? How does it affect plant health?

A. Chemical fertilizers, growing media, and water contain soluble salts. These salts build up in the growth media, especially those of container-grown plants. An excess of soluble salts is toxic to plants. Common symptoms of this problem include leaf tipping or blotching, necrotic spots on leaves, stunted growth, damaged roots, defoliation, and eventually death of the plant.

Q. List the steps involved in diagnosing plant health problems.

A. Solving plant health problems involves three steps:

1. identifying the problem symptom,
2. determining the cause or causes, and
3. planning a management strategy to solve the problem.

Q. Describe the four perspectives that should be used to detect and describe plant problem symptoms.

A. First, study the plant from a distance. Note its general condition. Next, make a detailed, close inspection of abnormal plant parts and tissues. Third, consult your records or observe the plant over time. Note if the symptoms are recent or if they've developed over a long period of time. Finally, call on your previous experiences. Relate this incident to similar situations.

Q. Name two possible causes of wilted leaves.

A. The symptoms may be due to lack of soil moisture, excessive heat, or a mineral deficiency.

Q. How can you determine the cause of plant health problems?

A. Careful observation, studying the symptoms, using tools to monitor environmental and cultural factors, and familiarity with pest biology will help you determine the reasons for a plant's poor health.

Q. Why might you want to measure the amount of light a plant is getting? What tool(s) would you use to make this measurement?

A. Plants need light to produce food. Different plants require different amounts of light. A number of factors affect the amount of light plants get, especially in interiorscapes using only natural lighting. Outdoors, too much or not enough light is not a problem if plants are matched to the site. However, it can be a limiting factor in interiorscapes. Measuring the available light should be done when planning an indoor plant community. These readings should be made during all seasons and weather conditions. After installation, light levels should be checked periodically, because conditions can change. A light meter measures total light intensity. A photometer measures the wavelengths (blue, red and far red) used by green plants.

Q. You suspect temperature is causing a plant health problem. How would you take measurements to see if this is true?

A. First, you should take readings in several locations. In an area of any size, air and soil temperatures may vary considerably. In a landscape bed, shading, mulch color, or distance from blacktop or concrete will affect temperature. Second, you should measure temperature at different times. Indoors and out, temperatures fluctuate on daily and seasonal cycles. You can use thermometers to measure temperatures. High-low thermometers record temperature extremes. A thermograph will make a complete record of temperatures over time.

Q. You suspect the chemical makeup of a growing medium is no longer suitable for the plants rooted in it. What should you do to confirm your suspicions?

A. You must first know the mineral and pH requirements of the plants. Then, you can use litmus paper or a pH meter to measure soil pH. A solubridge (conductivity meter) measures soluble salt content. You may see a 'crust' of salt buildup. You will get a more complete picture of soil conditions from a soil test. A routine soil test done at Virginia Tech will measure the pH and mineral content. The report will include a recommendation, based on the type(s) of plants you're growing. Special tests will measure soluble salt level and/or organic matter content.

Q. Name two tools used to monitor plant pests.

A. Traps (for flying insects), hand lenses (for close inspection of plants and plant parts, looking for insects, mites, nematodes, fungal strands or fruiting bodies, and other evidence of a pest's presence), and binoculars (to examine the crown of a tree).

Q. Why might you want to measure the moisture content of the air? What instrument would you use?

A. Adequate air moisture is important to the general health of plants. A hygrometer measures relative humidity.

Q. Why do you need to continue monitoring a plant after you take action to solve a health problem?

A. You should monitor the plant to determine if and how it is responding to the treatment. If the plant is not responding as expected, the management plan may need to be changed.

Unit 3. Ornamental Pest Identification and Biology

Learning Objectives

After completing this Unit, the learner will:

- Name and identify the major pests of ornamentals in Virginia.
- Describe the appearance and life cycle of each pest.
- Match plant damage or symptoms with the probable cause.
- Explain how each pest causes plant damage or injury.
- Recognize the conditions favorable to pest problems.

This Unit describes the most common ornamental plant pests found in Virginia. By reading it, you will learn how these pests harm plants. You will also learn what these organisms and their damage symptoms look like, and where they are usually found. Management recommendations are discussed in the next Unit.

Professional organizations, universities, industries, and government agencies produce detailed field guides and other in-depth pest identification references. These sources will help you learn more about the common pests described here. They will also describe other pests not included in this Unit.

Terms to Know

Abdomen - The hindmost or rear body section of an arthropod. In insects, the abdomen is the third of three body regions. In arachnids, it is the second of two.

Abiotic or Noninfectious Disorders - Plant health problems caused by non-living stresses. Environmental factors, chemical exposure, cultural practices, or other human activities may cause abiotic diseases.

Antennae - A pair of jointed appendages on the head of an arthropod. They are used to sense things in the arthropod's environment.

Arachnid - A wingless arthropod with the body divided into two parts. Arachnids have four pairs of legs on the rear body section. They do not have antennae. Spiders, mites, and ticks are arachnids.

Arthropod - An animal with jointed appendages (legs, etc.) and an external skeleton. Arthropods are invertebrates: animals without backbones. Adult arthropods usually have a hard outer body covering called an exoskeleton for protection and support. This exoskeleton is jointed, which allows them to move. Insects (ex: flies) and arachnids (ex: spiders and mites) are arthropods.

Bacterium (plural = bacteria) - Single celled, microscopic organisms.

Biotic or Infectious Disease - Disease caused by pathogenic organisms, which grow in or on plant tissue. Fungi, viruses and bacteria cause biotic plant disease. These organisms interfere with normal growth and development.

Brood - The immature stages of one generation. A brood includes the eggs, larvae and pupae of one generation.

Cambium - In woody plants, a sheath or layer of tissue just under the bark. The cambium makes new layers of cells.

Canker - A drying or cracking of woody tissue caused by fungi.

Caterpillar - The larval stage of a butterfly or moth.

Chlorophyll - The green pigment that allows plants to manufacture food.

Chlorosis - Reduced amount or lack of green pigment (chlorophyll). Common causes include lack of light or mineral(s). Chlorosis is sometimes called 'yellowing.'

Chlorotic - A plant showing the symptoms of chlorosis. A plant suffering from chlorosis is called chlorotic.

Conifer - A plant that bears seeds in cones. Examples include pine, spruce, and hemlock.

Crawler - The active first instar of some insects that live in one place as older nymphs and adults. Scale insects and mealybugs have a crawler stage.

Decline - A gradual loss of condition; a change from good to poor health; slow death.

Dicot - A plant with two seed leaves (cotyledons). Dicots usually have broad, net-veined leaves and taproots.

Defoliation - Loss of leaves.

Disease - An abnormal condition caused by something interfering with a plant's normal life functions. A number of stress factors — biotic, abiotic, or a combination of both — may cause plant diseases.

Disease Cycle - Stages through which a sick plant proceeds, from start to finish of an infection.

Excrement - Fecal material; waste products from an animal's digestive system.

Frass - Another name for insect excrement, usually in the form of pellets.

Fungus (plural = fungi) - Simple organisms that lack chlorophyll and depend on a host plant for food. Fungi reproduce by forming spores.

Grub - The larval stage of some beetles.

Habitat - A specific area or environment in which an organism normally lives.

Haustorium (haustoria = plural) - A small projection from a parasitic fungus or plant that penetrates the host and absorbs food.

Honeydew - Sugary liquid excreted by several types of sap-feeding insects.

Host - An organism with a parasite living in or on it.

Hypha (hyphae = plural) - A single tubular filament of a fungus.

Infest - To inhabit or overrun in large numbers.

Infestation - A pest population so large that it is harmful or unpleasant.

Inoculum - A material containing a disease organism or its spores.

Insect - An arthropod with three body regions. Insects have one pair of antennae on the head, two pairs of wings, and three pairs of legs on the middle body section. Many have complex mouthparts, adapted for a special type of feeding.

Instar - In insect development, a stage between successive molts. For example, the first instar is between hatching and the first molt.

Larva (plural = larvae) - An immature stage in the life cycle of an insect with complete metamorphosis. Most larvae look like segmented worms with legs. As a rule, the larval stage is an active, feeding stage. Grubs (beetles) and caterpillars (butterflies and moths) are insect larvae. In complete metamorphosis, the larval stage occurs between the egg and the pupal stage.

Lesion - An area of infected (diseased, dying, dead) tissues on a plant part.

Life Cycle - Stages of development.

Metamorphosis - The change in body form during the life cycle. Some organisms are born looking like small adults. Others change considerably in appearance, in stages, as they develop. Most insects go through some sort of metamorphosis during their life cycle.

Complete Metamorphosis - Insect development involving four different body forms or life stages. A good example of complete metamorphosis is the life cycle of a butterfly or moth. A butterfly life cycle starts with an egg. An active feeding stage called a larva hatches from the egg. A butterfly larva is called a caterpillar. When caterpillars get to a certain size and age, they make a protective case. The next stage, which is called a pupa, does not feed. Inside the case, the pupa changes into an adult.

Gradual Metamorphosis - Insect development in three stages. In gradual metamorphosis, the egg hatches into a nymph. A nymph is a small, immature stage resembling the adult in body form. As the nymph grows, it develops wings and functional reproductive organs. Grasshoppers and lace bugs go through gradual metamorphosis.

Midrib - The central, main vein of a leaf.

Mite - A type of arachnid.

Molt - To shed. Arthropods outgrow and shed their exoskeleton (outer covering) when they molt.

Monocot - A plant with one seed leaf (cotyledon). Monocots usually have narrow leaves with parallel veins and fibrous roots.

Mycelium - A mass of thread-like filaments that form the main growing structure (the "body") of a fungus.

Necrosis - Death of tissue.

Nematode - A microscopic roundworm. Nematodes that are plant parasites have stylets (hollow, sharp tubes) which they insert into plant cells for feeding.

Nymph - The immature stage of an insect with gradual metamorphosis. Nymphs hatch from eggs, and gradually develop into mature adults.

Organism - A general term for any living thing.

Overwinter - To survive during the cold months of the year.

Parasite - An organism which gets all or part of its food from another living organism, and in so doing harms that organism (its host).

Pathogen - An organism that causes disease.

Pathogenic - Capable of causing disease or illness.

Pest - Any living thing that is undesirable, or causes harm to people or the environment. An organism may be a pest in one place but not in another; for example, termites in a house vs. those recycling dead trees in a forest.

Petiole - The leaf stalk. The petiole connects the leaf blade to the stem.

Phloem - Plant tissue that transports food. In trees and shrubs, the inner layer of bark is phloem tissue.

Pitch - Pine resin, derived from sap.

Pitch Tube - A small glob of pitch that seeps from the holes made by bark beetles.

Pupa (plural = pupae) - In complete metamorphosis, the stage of development between the larva and adult. Pupae do not feed. Usually, they are not mobile.

Rosette - A low-growing circular cluster of leaves. Some biennial plants, like thistles, normally form a rosette. Other plants grow this way when infected by a virus.

Scavenger - An organism that feeds on decaying plant or animal matter.

Scientific Name - The Latin name (genus, species) assigned to an organism.

Sign - A sign is the actual, visible disease-causing organism. Examples include fungal spores or mycelia or ooze from bacterial cankers.

Sooty Mold - A fungal disease that grows on honeydew. Sooty mold will indirectly damage a plant by restricting sunlight to the plant leaves and attracting other pests, such as ants.

Spore - Reproductive structure of a fungus, similar to a plant seed in function.

Symptom - An abnormal condition. Symptoms can be used to identify a plant health problem.

Syndrome - All the symptoms that characterize a disease.

Systemic Disease - A disease caused by a plant pathogen with the ability to invade a plant's vascular tissue and spread throughout all parts of a plant.

Translocation - Movement of food produced in the leaf to other parts of the plant.

Vascular Plant - A plant with conducting tissue (xylem/water and phloem/food).

Vector - An organism that may carry pests to new hosts. For example, insects with sucking and piercing mouthparts can move a disease from plant to plant.

Virus - A systemic plant pathogen consisting of a single strand of DNA or RNA and a protein coating.

Weed - A plant out of place.

A variety of pests cause problems for ornamental plants. This Unit describes common arthropods (insects and mites), diseases (fungi, bacteria, and viruses), nematodes, and weed pests found in Virginia. To manage a pest effectively, you must be able to identify it. You must also understand its biology: its life cycle and environmental requirements.

Since it does not change, Latin is the common language used by scientists to name living things. Each living thing has its own Latin name. Scientific names are the same throughout the world. On the other hand, common names for a given living thing may vary across the country, and sometimes even within a state or county. To add to the confusion, sometimes people refer to two different plants by the same common name. When discussing a pest problem with another individual, make sure that person is thinking of the same insect or weed as you are. Both common and scientific names are given for the pests described in this Unit.

Arthropod Pests

Many arthropods are pests of ornamental plants. Most of these pests are insects or mites. Usually, arthropod pest problems on outdoor ornamentals are seasonal. However, in interiorscapes, insects and mites can cause problems throughout the year. In either situation, year-round pests may be more numerous at certain times.

Each type of arthropod pest has a set of characteristics that can be used to identify it. This 'profile' includes appearance, host preference, damage symptoms, seasonal life cycle, and periods of activity.

Often, successful pest management depends on early diagnosis. Since many mite and insect pests are small and hard to see, it is important to look for symptoms of plant damage. Effective diagnosis of arthropod pest problems depends on several factors:

1. recognition of symptoms,

2. accurate identification of the cause of the problem,

3. knowledge of the pest's life cycle and habits, and

4. an assessment of the distribution, density, and dynamics of the pest population.

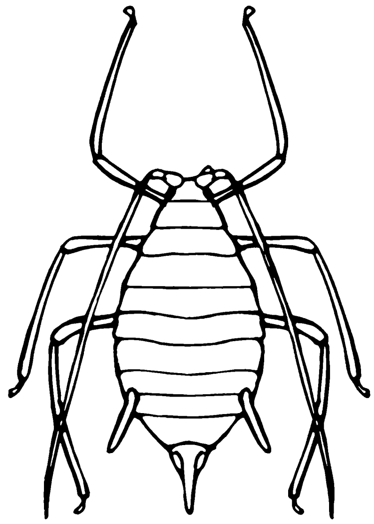
Regular, careful monitoring will detect early warning signs of pest activity. A well-trained plant manager can match symptoms with a probable cause. Close examination will usually find the pest. Knowing the pest's biology allows you to decide when and how to manage it effectively. Population information — size, spacing and whether it is increasing or decreasing — is needed to decide if and when to act.

The rest of this Unit describes common insect and mite pests of ornamental plants. Each section includes a description of the pest, its life cycle, and the damage it causes. Pests are listed alphabetically.

Aphids, Families *Aphidae, Eriostomatidae,* and *Chermidae*

Aphids are also known as plant lice. These insects are small — usually less than 1/8 inch long — and soft-bodied. Aphids are pear-shaped — narrower at the head and wider at the rear end. They usually have a pair of tailpipe-like processes extending from near the end of the abdomen. Aphids vary greatly in color. Some are greenish to blue-green. Others are brown, reddish, and black. Some are wingless. Those that have wings usually hold them up vertically over the body when at rest. Aphids are sluggish. They do not move very far or very fast on their own.

Aphids have piercing and sucking mouthparts. They suck plant juices. Aphid feeding causes plants to wilt and curl. Aphid infestations may result in reduced plant vigor and curled, distorted leaves. In addition,



Aphid

aphids are vectors for a number of plant diseases.

A few species produce wooly or waxy material that covers them, especially in the nymph stages. Some form galls on stems, leaves or buds. A common member of the pine and spruce aphid family forms pineapple-shaped galls on spruce.

Members of the aphid family are found on a variety of plants. Many are serious pests. Aphids usually occur in large numbers on new growth. They are often seen at the base of buds and stems and on the under-surface of leaves.

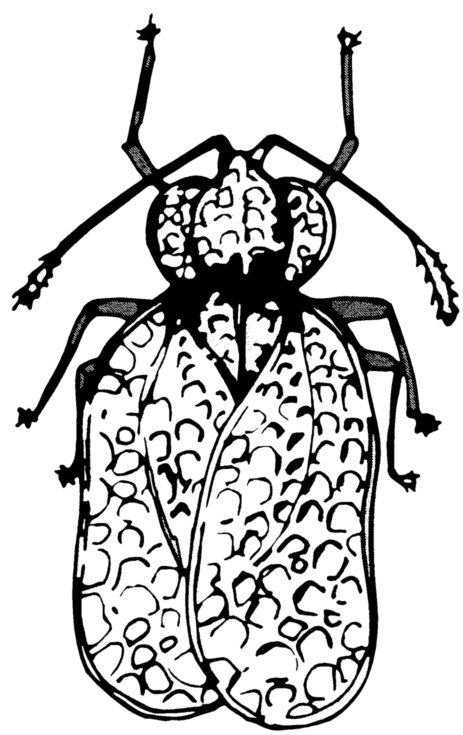
Most aphids have a complicated life cycle. Generally, they overwinter as eggs. In the spring, these eggs hatch into wingless females. These females give birth to live young that are almost identical to the adults in appearance. New generations are produced every 14 days.

Aphids produce a watery, sweet liquid called honeydew. Honeydew is discharged from the aphid's anus. This substance attracts ants and other insects. Some ants live in close association with aphids. They gather aphid eggs in the autumn and keep them over the winter. When the eggs hatch in the spring, the ants move the aphids to a food plant. Ants also transfer aphids from plant to plant during the growing season. The ants feed on the honeydew the aphids produce. Because ants and other insects feed on honeydew, it does not usually accumulate on outdoor plants.

As a rule, interiorscapes do not have large or varied insect communities. As a result, a large amount of honeydew is dropped onto plant leaves. This material attracts ants. It also promotes the growth of a black, sooty fungus on indoor plant leaves. This black covering is unattractive. It also blocks light. This reduces the rate of photosynthesis, which results in slow growth.

Azalea Lace Bug, *Stephanitis pyrioides*

The azalea lace bug is a major pest of azaleas wherever they are grown. They do the most damage to azaleas growing in full sunlight. The azalea lace bug is similar to the rhododendron lace bug in appearance, habits, and life history. However, each insect attacks only its specific host.



Azalea Lace Bug

Adult lace bugs are 1/8 inch long, and brown to black in color. Their bodies are flattened, and oval or rectangular. These insects have netted wings, which fold flat over their abdomen. They have a hood-like covering on their heads.

Azalea lace bugs overwinter as eggs. These eggs are laid in leaf tissue along the midrib. The nymphs hatch in the early spring. They are colorless at first, but later become black and spiny. The nymphs develop into adults within 40 days. The azalea lace bug may have up to four generations per year, depending on the location and temperature.

The nymphs and adults of the azalea lace bug withdraw sap from the underside of leaves. The upper surface of damaged leaves has a blanched or stippled appearance. The undersides become rusty colored and covered with dark spots of tar-like excrement. Often, shed 'skins' left by molting nymphs can be seen. Leaves of severely infested plants change from healthy green to yellow. Plant vigor is greatly reduced.

Bagworm, *Thyridopteryx ephemeraeformis*

The bagworm is native to the United States. This pest moth has a wide host range and an extensive geographical distribution. It is particularly damaging to evergreens such as arborvitae and juniper. Bagworms are unusual in appearance and habits. However, often this pest is noticed only after serious damage has occurred and it is too late for control measures to be effective.

Bagworms spend most of their life cycle in a spindle-shaped bag. These bags are covered with bits of needles or leaves. The fragments of needles and leaves on the bags provide such an excellent camouflage that the presence of these pests is often overlooked until considerable defoliation has occurred.

Eggs overwinter in the bag. Hatching begins in mid-May and extends into June.

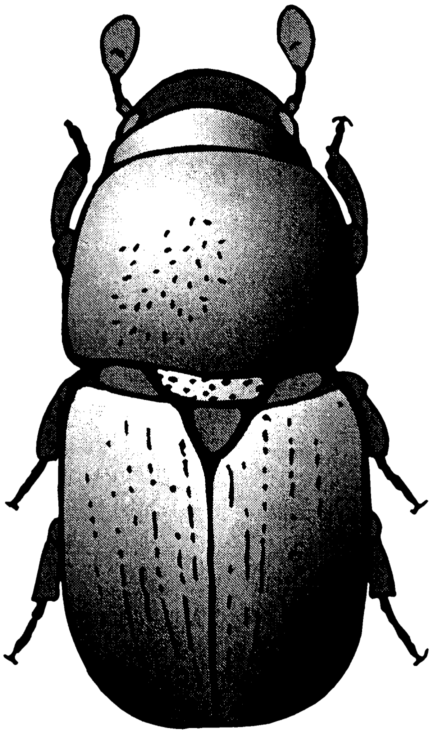
Bagworm

Newly hatched larvae immediately spin a new bag of silk around them. They attach bits of foliage to the outside of this bag as they feed, enlarging their bag as they grow. A full-grown larva is three-fourths of an inch to one inch in length. It lives in a bag that is from one and a half to two inches long. At maturity, the larvae attach their bags to twigs with a strong band of silk. They transform into the pupal stage inside the bags in late summer, and then pupate into the adult stage. Male moths emerge from their bag and fly to mate with females. Females, on the other hand, are wingless. They mate and lay eggs in their bag. Each female lays from 500 to 1,000 eggs. After laying eggs, she drops to the ground and dies. There is only one generation per year.

Bagworms feed on many kinds of evergreen and deciduous woody ornamentals. A heavy infestation of bagworms will strip evergreens of their foliage. Severe defoliation results in death. Deciduous trees are rarely damaged. The thread used to attach the bag to the branch can cause abnormal growth.

Bark Beetles, Family *Scolytidae*

Bark beetles are a large group of insects that cause damage to trees. They range from the size of a rice grain to three times that size. They are dark brown to reddish brown. These insects bore into bark or wood, as both adults and larvae.



Elm Bark Beetle

These insects spend most of their lives in burrows. Adults leave only to find a new host tree. Adults emerge any time of year when temperatures are warm enough to stimulate activity. They leave a buckshot pattern of holes in the bark of the tree. Either sex (depending upon species) may arrive at the tree first and establish a chamber under the bark. This commonly causes a pitch tube to form on conifers. Females lay eggs under the bark of new host trees and larvae make extensive galleries in the phloem.

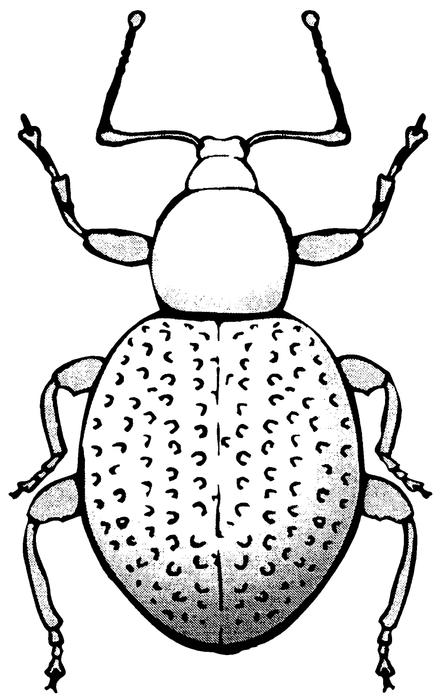
Bark beetle damage occurs from the adults entering the tree and from the tunneling of the adults and their larvae. These beetles tunnel in phloem tissue, which interferes with food transport in the plant.

Bark beetles usually attack weakened, dead or dying trees. However, some attack and kill living trees. Damage to the bark of a tree, for example, is likely to make that tree more attractive to these beetles, and more susceptible to their attack.

Black Vine Weevil, *Otiorhyncus sulcatus*

This insect is a common imported pest. In landscapes, both the adults and grubs cause plant damage. These insects feed on over 100 different plant species, but are commonly associated with yews and rhododendrons in landscapes.

The adults are black and 1/4 to 1/2 inch long. They are hard-shelled. The adults are nocturnal. Usually, adults are not seen in the landscape because they hide in leaf litter at the base of host plants during the daylight hours. Their feeding causes conspicuous notches at the margins of host plant leaves. Usually, this will not cause permanent damage to trees, but is an aesthetic problem. The grub stage feeds on the roots of landscape plants. High population densities can kill a plant.

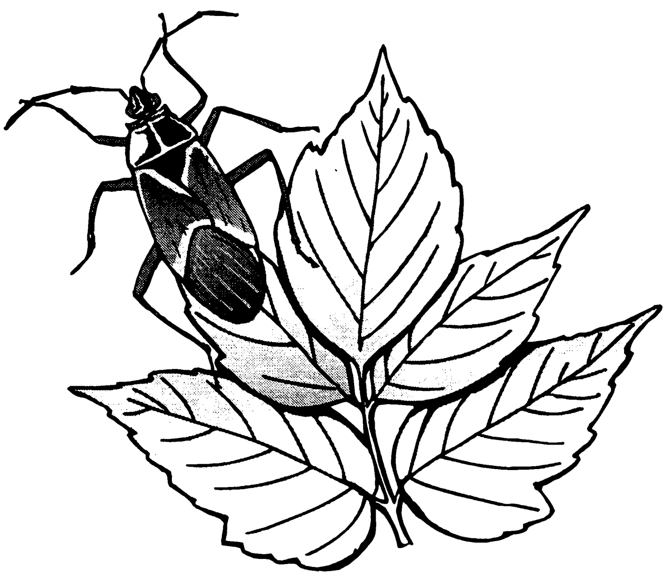


Black Vine Weevil

Black vine weevils are all females. They do not need to mate to reproduce, so all weevils lay eggs throughout the summer months. The grubs develop through the summer and over-winter as last instars. In the spring, the larvae resume development when the weather warms in late April or early May. They pupate and adults emerge in mid-May. There is one generation per year.

Boxelder Bug, *Boisea trivittata*

Boxelder bugs may be found in the landscape and inside homes. They are 1/2 inch long and black in color, with red markings on their body and wings. Like most 'true bugs,' the wings of the boxelder bug are thick at the base and membranous at the tip. The wings lie flat on the back when this insect is at rest.



Boxelder Bug

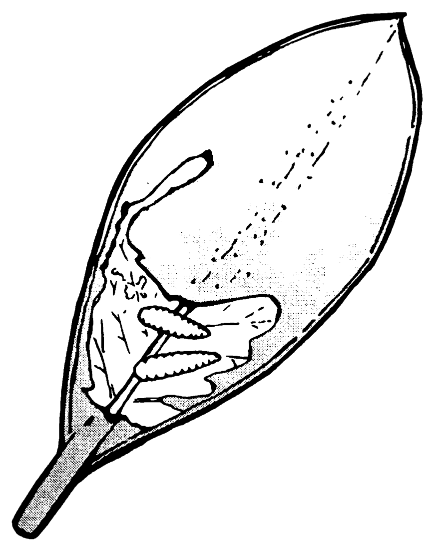
Boxelder bugs feed on maple trees, especially the boxelder (*Acer negundo*). The boxelder is also called the ashleaf maple. Unlike most maple trees, it has compound leaves. This tree is popular in urban and suburban landscapes. Boxelder bugs feed on the leaves, flowers, and seed pods of the host plant. However, even when present in large numbers, these insects do little or no damage to trees or other landscape plants.

There are two generations per year. The second generation overwinters as adults in sheltered places. Adults may move a long distance from their host tree to an overwintering site. Sometimes, the search for a place to overwinter brings adults into homes. Once inside, they hide in small cracks and crevices in walls, door and window casings, attics, and around the foundation. During warm days in winter and early spring, the adult bugs come out and move about the house. They are a nuisance, leaving excrement spots on draperies and other resting-places. Crushed adults also may leave a stain.

Boxwood Leafminer, *Monarthropalpus flavus*

Adult boxwood leaf miners are inconspicuous. They are tiny, light colored flies. A single generation occurs each year. Adults emerge in late spring. Females lay eggs by piercing the underside of leaves and inserting their eggs. Adults are very poor fliers. As a result, females tend to lay eggs close to where they emerged, often on the same plant.

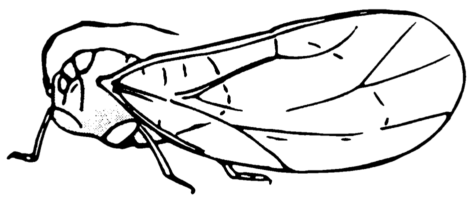
The larvae cause damage as they feed. The mines look like blisters on the underside of leaves. Infested plants are usually not killed. However, they may have a sickly appearance.



Underside of boxwood leaf with mines

Boxwood Psyllid, *Psylla buxi*

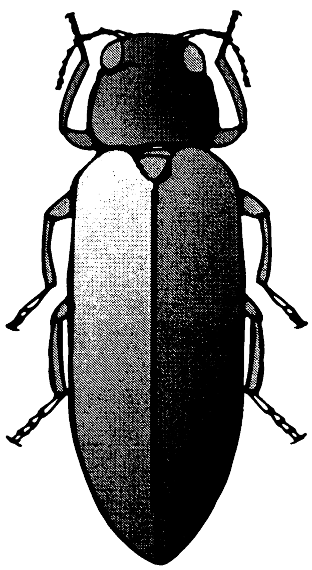
Adults are small, gray-green insects that resemble miniature cicadas. The nymphs are mottled and covered with waxy threads. Boxwood psyllids overwinter as first instars inside their egg shells. Nymphs hatch in early spring as buds break, and begin feeding immediately. This feeding on fast-growing early season leaves results in the leaves having a cup-shaped appearance. Adults emerge in May or early June and continue to feed. However, the serious damage is caused earlier in the year by nymphs feeding on developing leaves. In July or August, adults lay eggs under bud scales. There is only one generation each year.



Psyllid

Bronze Birch Borer, *Agrilus anxius*

The adult bronze birch borer is a greenish bronze beetle 1/4 -1/2 inch long. The slender white larvae are about 3/4 inch long. Adults lay eggs in spring on the bark surface, and the larvae hatch and bore into the trunk or branches of the tree. The larvae form galleries under the bark and develop through the summer. The adults emerge the next spring through D-shaped holes they cut in the bark. There is one generation per year.



Bronze Birch Borer

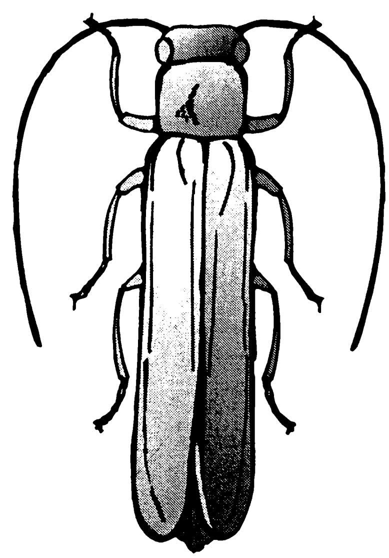
These beetles are associated with the white birch in Virginia. The sawdust and frass that accumulates from their burrowing causes the trunk or branches of an infested birch to have a rippled appearance. Their galleries can completely cut off the flow of sap, causing yellowing of leaves in the crown. Eventually, these insects will kill host trees.

Dogwood Borer, *Synanthedon scitula*

The dogwood borer is a native pest of flowering dogwood in the eastern half of the United States. It is a greater problem in cultivated plantings than in woodlands.

Adult dogwood borers are small, blue-black moths with yellow-banded legs and yellow stripes on segments two and four of their abdomen. Their wings are transparent with blue-black margins. They have a wingspan of 5/8 to 7/8 of an inch.

Adults emerge from May to October. They mate and lay eggs on bark, usually in roughened areas or in wounds. The eggs soon hatch into white larvae with pale brown heads. After hatching, the larvae enter the



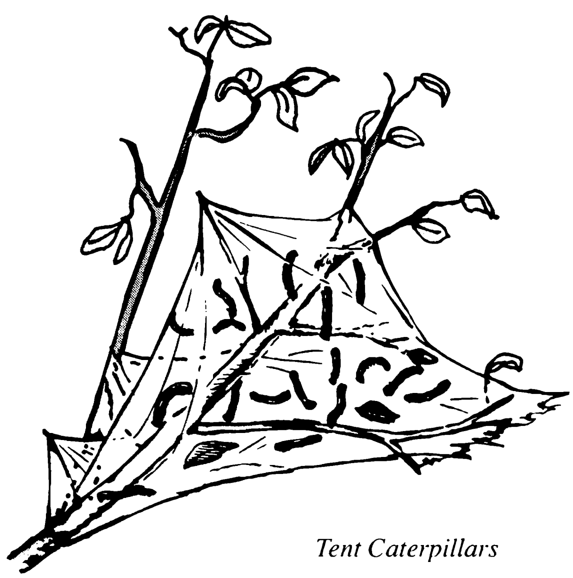
Dogwood Borer

bark. Once under, they feed in the cambium. These borers remain in or under the bark throughout their developmental period. There is one generation per year.

An early symptom of a borer attack is the sloughing of loose bark. Dieback and adventitious (unusual) growth are more advanced symptoms. The borers spend most of their lives underneath the bark. However, one sign of their presence is small, wet areas on the bark. In late summer, you may notice pinholes in bark, and fine white dust-like borings pushed from burrows. Dogwood borers can kill young or unhealthy trees. Mature trees with chronic infestations may survive in an unhealthy condition for years, but they are rarely killed.

Eastern Tent Caterpillar, *Malacosoma americanum*

Adults are medium-sized, stout, hairy moths. The caterpillars are hairy and black with a white stripe and a series of blue spots running the length of the body. Groups of caterpillars construct a silken tent, which they use as a shelter. Usually, these tents are in the fork of a branch. Eastern tent caterpillar larvae feed on leaves, and prefer those of fruit trees in the rose family. Wild cherry trees are commonly infested. The nests of this pest are extremely visible and unsightly, but the caterpillars rarely kill trees.



Tent Caterpillars

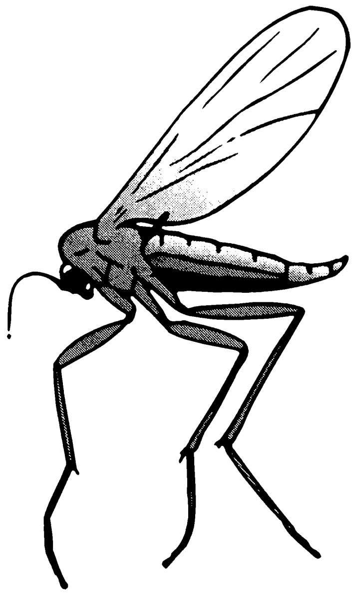
The insect has a single generation per year. They overwinter as eggs, which are laid in a mass on the twigs of host trees (cherry, apple, flowering crab, etc.). The eggs hatch in the spring about the time wild cherry leafs out. Young larvae begin to make their white silken nests in the crotch of a tree. The larvae leave the nest to feed on fast-growing leaves and return. As the larvae grow, they expand their nest. Large numbers of mature larvae are often noticed in June migrating on the ground looking for a pupation site.

Fall Webworm, *Hyphantria cunea*

This insect is a cosmetic pest that rarely threatens plant health. They have a single generation per year. The adults are small white moths. The caterpillars are yellow, hairy and an inch in length.

Fall Webworms

This pest is easily identified by its nest. The larvae build extremely ugly nests at the ends of branches in July. The nest is formed around leaves at the ends of branches. The caterpillars feed on the leaves within the nest. As the caterpillars grow, they enlarge their nest. By late August, nests can be two to three feet long, and will hang on the tree through the winter. Their host range includes dozens of different hardwoods, but they are especially fond of walnut.



Fungus Gnat

Fungus Gnats, Family *Sciaridae*

These small gray-black flies are most common indoors. Their small size (about 1/16 to 1/8 of an inch), delicate smoke-colored wings, and dainty antennae help to identify them. They do not fly very well, and usually do not move far from their breeding site. However, the adults may be seen at windows that are close to potted plants.

Fungus gnats indoors are most often found breeding in the moist to wet soil of indoor plants. House plants and plants in interiorscapes are often overwatered. As a result, the soil remains wet for long periods. Female fungus gnats lay their eggs in this wet soil. Larvae feed on the decaying organic matter in the soil around the plant. Larvae are gray in color. Adults may be seen throughout the year.

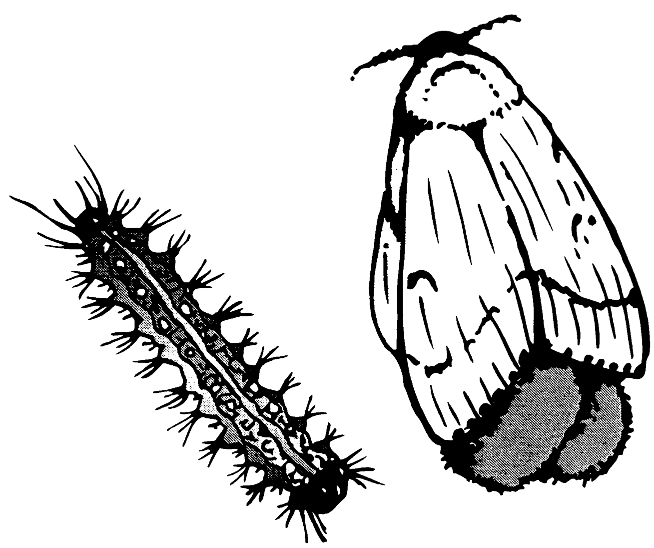
Usually, fungus gnats do not occur in large numbers. However, they have increased in importance recently. This increase may be linked to the use of soilless mixes in the plant industry. Apparently, some of these media, especially those that contain peat moss, are excellent food for these insects.

The main problem with fungus gnats is that they reduce the aesthetic value of an interiorscape. The adult flies often get trapped in the moisture on leaf surfaces. This detracts from the plant's appearance. The larvae may feed on root systems. However, usually the roots are dying or diseased before the larvae invade. The symptoms of a severe infestation are stunting, yellowing, defoliation, and an overall decline in the plant's appearance.

Gypsy Moth, *Lymantria dispar*

Gypsy moth caterpillars damage millions of acres of hardwood forest each year. They can also defoliate urban neighborhoods. Gypsy moth caterpillars are dark with dark hairs. They have two rows of colored spots along their back — five pairs of dark blue spots and six pairs of brick red spots. Female moths are white with dark lines on the wings. Males are brown.

Gypsy moth caterpillars hatch from eggs in mid-spring. The caterpillars can feed on over 300 species of trees and shrubs, but prefer oaks. The male and female



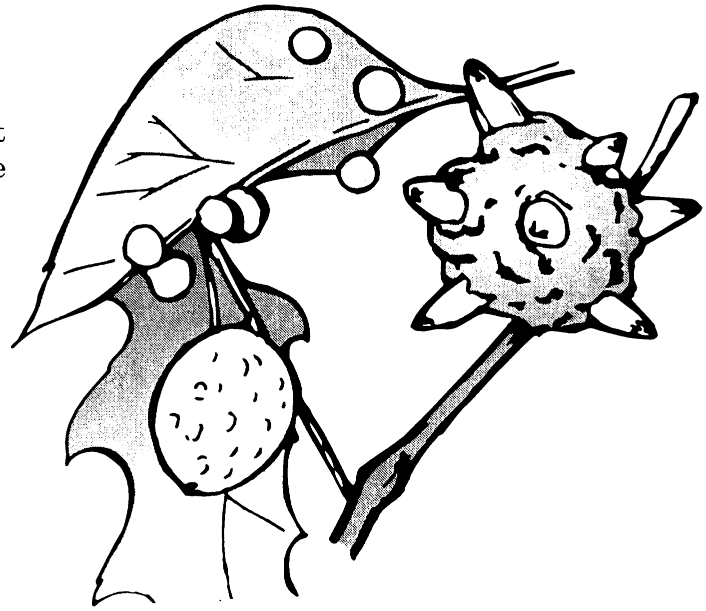
Gypsy Moth caterpillar and adult female

caterpillars pass through five and six instars, respectively. Larger caterpillars migrate from the canopy down the branches and trunk each day. They feed at night and rest in shaded spots on the tree or objects on the ground during the day. They pupate in early to mid-summer (June-July) and remain in the pupal stage for approximately two weeks. Male moths emerge one or two days before the females. Females cannot fly. After emerging from the pupal stage, female moths emit a pheromone (chemical) which attracts males from moderate distances and mating then occurs. The females then lay oval-shaped egg masses, covered with hairs from her body. The buff-colored egg masses contain 100 to 1,500 eggs. The female moth lays eggs on the underside of tree limbs, bark, rocks, and structures including buildings, campers, mobile homes, etc.

Repeated defoliation stresses trees and can lead to death. In addition to the damage to landscape trees, gypsy moth caterpillars are an extreme nuisance during outbreaks in residential areas. Trees lose their foliage, caterpillars crawl everywhere, and their droppings rain from the trees. When disease kills large numbers of caterpillars, as often occurs, the stench is overwhelming. In some cases, people develop an allergy to the hairs of the gypsy moth caterpillars.

Galls

Galls are the result of abnormal plant cell growth. They form in response to an insect or some other organism infesting plant tissue. Gall-forming parasites release growth-regulating chemicals as they feed, causing plant tissue to form a gall. Then, the parasite develops inside the gall, in a relatively secure place. Several different groups of insects and one family of mites induce galls in plants. In addition to arthropods, some nematodes, bacteria, fungi, and viruses can cause plants to form galls.



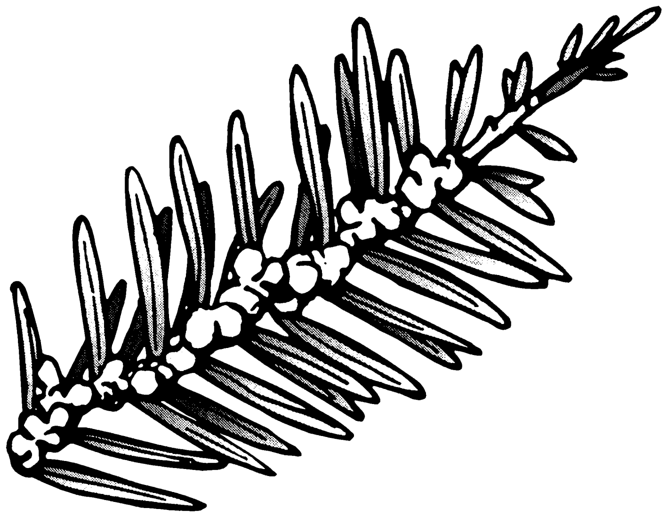
Galls

Many different arthropods cause galls. Each species produces a unique type. By noting the host plant and the structure of the gall, one can identify the gall-making organism without actually seeing it. The most important groups of gall-producing insects are gall mites, aphids, adelgids, phylloxerans, psyllids, gall midges, and gall wasps.

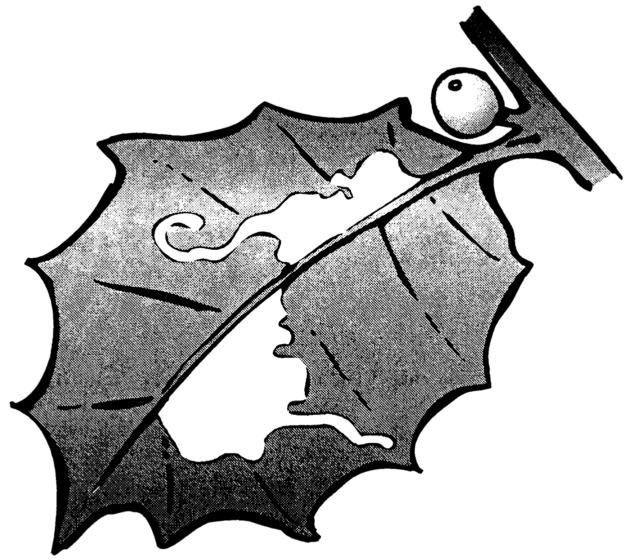
Hemlock Wooly Adelgid, *Adelges tsuga*

The hemlock woolly adelgid is a small aphid-like insect that feeds on several species of hemlock. It was introduced into North America from Asia in the 1920's.

These small insects display several different forms during their life history, including winged and wingless forms. Generally, the adults are brownish-red in color, oval in shape, and about 1/4 of an inch (0.8 mm) in length. Crawler stage nymphs produce white cottony/waxy tufts that cover their bodies and remain in place throughout their lifetime. The white masses are about three millimeters (3 mm) in diameter. Severe infestations can resemble a recent snowfall on the branches of the tree.



Hemlock Wooly Adelgid



Holly Leaf Miner damage

Nymphs and adults damage trees by sucking sap from twigs. On infested trees, needles discolor from deep green to grayish green. Adelgid feeding impairs tree growth because it causes needles to drop prematurely. The loss of new shoots and needles seriously damages tree health. Defoliation and tree death can occur within a few years.

Holly Leaf Miner, *Phytomyza ilicicola*

The holly leaf miner is one of several species of leaf miners that feed on hollies. This insect prefers the American or Christmas holly, *Ilex opaca*.

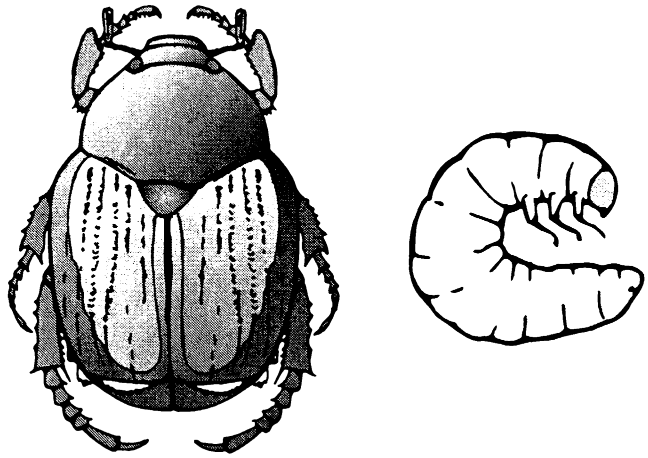
The holly leaf miner is a fly. Adults emerge in the spring over a period of several weeks, when bud break occurs. Eggs are laid soon after. They are deposited in punctures these insects make in the undersides of newly developed leaves. The larvae, or maggots, mine just under the upper leaf surface. Initially, the mines are thread-like and inconspicuous. However, as the larvae grow, their tunnels increase in size. By late autumn the mines widen into blotches or blisters. The larvae overwinter in the mines and pupate in March. There is only one generation per year.

If heavily infested, many one-year old holly leaves may drop off in the spring. However, enough cling to the tree to indicate that the tree was infested the previous year. Damage is confined to the upper side of the leaves. Frequently, several mines join, producing one very large mine which may contain several larvae. These mines frequently destroy the entire leaf.

Japanese Beetle, *Popilla japonica*

The Japanese beetle is an imported pest from Asia. Japanese beetles are serious landscape pests during both the larval and adult stages. Larvae are called white grubs, and are significant turf pests. They feed on roots of turf grasses. Adults feed on various above-ground plant parts — leaves, buds, flowers and fruits. Adult beetles are serious pests of roses, fruit trees, and grapes.

A single generation occurs per year. Last instars overwinter deep in the soil, below the frost line, where they are protected from freezing. In spring, the grubs move upward and begin feeding on grass roots. The grubs pupate in late May. Adults emerge around



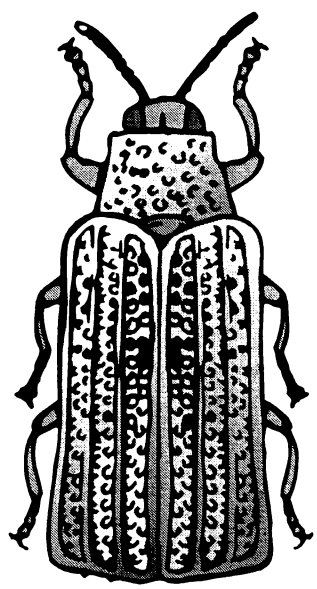
Japanese Beetle adult and grub.

mid-June and are abundant through July. During this time, the metallic copper and green colored beetle adults (1/2 inch long) feed on hundreds of different landscape plants. They also lay eggs in turf during this period. The grubs hatch in early August. They feed extensively through August and September causing major damage to turf.

Locust Leafminer, *Odontota dorsalis*

This leafmining beetle is often present in alarmingly high populations throughout large areas of Virginia. There are two generations per year in the commonwealth. The orange and black striped adult beetle overwinters near the base of the host tree or in bark crevices. In spring, the beetles fly and mate. Females deposit eggs on the underside of leaves. The primary host is black locust, but these beetles do use a few other hosts. The larvae hatch from the eggs and burrow into the inside of the leaf. The larvae feed on the leaf cells, leaving a mine. The larvae pupate in July and the second generation of adults lays eggs in July and August.

The mines these pests produce are small at first, but gradually enlarge until most or all of the leaf is affected. They are clear to begin with, but turn brown as the leaf dries out. By late July, locust trees can look completely brown.

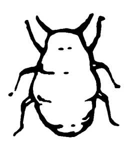


Locust Leaf Miner

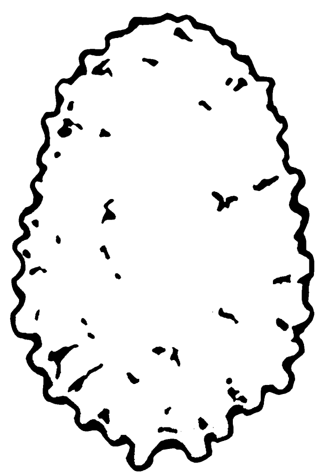
Mealybugs, Families *Pseudococcidae* and *Eriococcidae*

Mealybugs are elongate-oval, flattened insects with segmented bodies. Their name comes from the mealy wax they secrete, which covers their bodies. They have well-developed legs but no wings. Some species lay eggs, and others give birth to live young. If eggs are laid, they are placed in a loose, cottony wax that protects them. Mealybugs attack all parts of host plants. They are common pests of plants grown in greenhouses and interiorscapes.

Foliar or aerial mealybugs are about 3/16 inch long. They are light yellow, with smooth bodies. Aerial mealybugs attack plant leaves



Crawler



Waxy 'shield' covering adult mealybug

and stems. Shortly after they begin feeding, the adults secrete a white waxy material. This wax forms a covering over the insect. Some have waxy filaments radiating from the edges of the body.

Foliar mealybugs do not remain in one spot. They move about, sluggishly, over the entire plant. Eggs are laid in a compact, cottony, waxy sac. Egg sacs are usually found at the base of a stem or leaf, on the upper side. Mealybug eggs take about 10 days to hatch into 'crawlers.' 'Crawlers' reach maturity in six to eight weeks. The 'crawler' stage is the most vulnerable stage in the life cycle. It does not have the waxy covering that protects the adults and eggs.

Soil mealybugs are common pests of some container-grown plants. These insects are sac-like in shape. They have a very large covering of wax, which forms a cross-like pattern. They lack the marginal projections usually seen on foliar or aerial species. Soil mealybugs feed on the root system of the host plant. The entire plant, or just one section, may be affected. Usually, an infestation of soil mealybugs is detected when young are found in soil crevices. These soil spaces or chambers are coated with white waxlike material. The wax may be seen covering the outer surface of the root ball.

Mealybug 'crawlers' and adults insert their mouthparts into plant tissue and suck out plant juices. Symptoms of an infestation include general decline, distorted growth, and leaf drop. Severe infestations can result in stunting or death.

Like aphids, aerial mealybugs excrete honeydew. Unsightly black sooty mold grows on the honeydew. The combination of honeydew, mold, copious wax secretion, and cottony egg sacs is unsightly. More importantly, it interferes with photosynthesis.

Mites, Order *Acarina*

Mites are very small wingless arthropods. Mites are not insects. They are related to spiders and scorpions. Usually, mites are compact and oval in appearance, with little or no differentiation of the two body regions. Adult mites have soft bodies and four pairs of legs.

The stages of mite development are egg, larva, nymph and adult. The larvae, nymphs, and adults are active feeders.

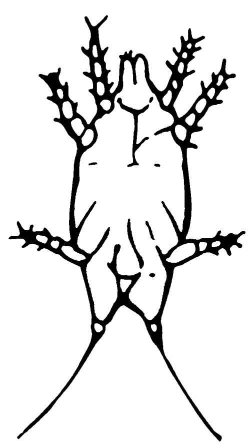
Mites feed on the undersurfaces of leaves. They suck plant juices. They disfigure the plants they feed on, and cause a general decline in condition. Severe infestations will kill a plant.

Three of the more common mites that infest ornamentals are described here.

Cyclamen Mite

These are small, white, green or pale brown mites (1/100-inch long). They usually feed on new growth. Females usually lay eggs at the base of plants or in buds. The eggs hatch in three to seven days. The time from egg to adult is usually four to six weeks. Cyclamen mites attack many kinds of plants. Cyclamen mite development is favored by high relative humidity (80 to 90% or more) and low temperatures (less than 60° F).

Because these mites are so small, they are almost impossible to see, even with a hand lens. Usually, they are detected by damage

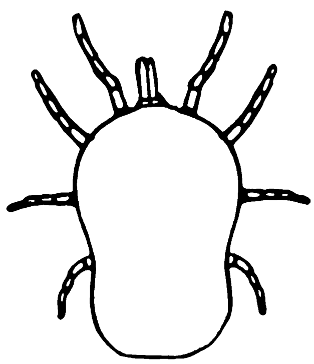


Cyclamen Mite

symptoms. Leaves of infested plants are distorted or curled. Some may have purplish areas. New leaves may be thickened, brittle, and stunted. The margins may be cupped downward. Infested buds often do not open. If they do, they produce small, distorted flowers with a streaked and blotchy look.

Southern Red Mite

Southern red mite is a serious pest of many woody ornamentals. This pest prefers azaleas, hollies, and camellias, but also occurs on Pyracantha, rose, and photinia. Southern red mites are tiny, just barely visible to the naked eye. They range from pink to dark red in color. Eggs are brownish to reddish. Southern red mites overwinter as eggs on host plants. Eggs hatch in early spring. This species is most active in cool weather, and reproduces rapidly in spring and fall.

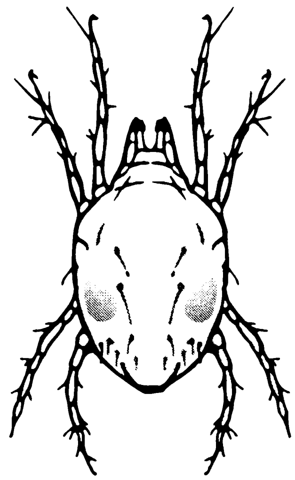


Southern Red Mite

Like other mites, southern red mites feed on the lower leaf surface. Infested leaves turn gray or brown. High populations may cause premature leaf loss, and hasten the death of an already weakened plant.

Spider Mite

Spider mites are only about 1/50 of an inch in length. They are more or less elliptical. Their upper surface is domed. Spider mites have bristles on their legs and bodies. Sometimes they are detected by the presence of webbing — fine strands of silk spun on the undersurface of host leaves.



Two-Spotted Spider Mite

Females lay about 200 eggs. During periods of hot, dry weather, spider mites can complete their life cycle in seven days, allowing for a rapid population explosion. A very common plant pest is the two-spotted spider mite. This pest is greenish or yellowish in color, with a large blackish or reddish spot on each side of the back.

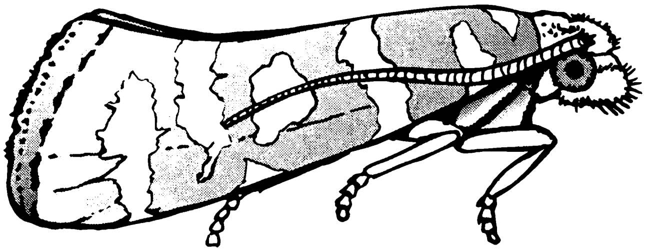
Spider mites damage results in leaves with a speckled or mottled appearance. In severe infestations, leaves dry and fall from the plant.

Pine Tip Moth, *Rhyacionia frustrana*

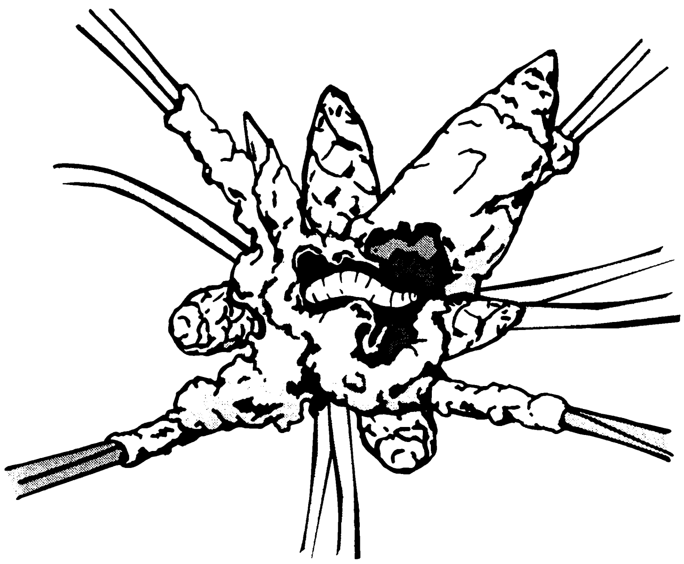
The pine tip moth attacks all pine species except slash and longleaf. Damage is most severe on young trees, from seedlings to those about 12 feet tall.

Adult tip moths are small. They fly mostly at dusk or during the night. As a result, they are not easy to detect. Adult moths can be seen during the day if disturbed by shaking young pines. They will fly for a short distance and return to the tree.

These moths lay their eggs singly on needles, buds, or shoots. Upon hatching, the larvae feed at the base of shoots or buds. Feeding sites are usually marked by 'resin



Pine Tip Moth



Pine Tip Moth larvae feeding

blisters' (exuding pitch) and frass. The growing larvae tunnel into buds or shoot tips and pupate. Except for the overwintering generation, the adult moths emerge in one to two weeks. As many as four generations per year may occur, depending on climatic conditions.

Tip moth larvae injure pines by boring into the tender, growing shoots of the tree's branches. Several inches of the shoot may be killed. Repeated, heavy attacks cause pines to be bushy, crooked, or distorted. Dry weather and poor soil conditions are thought to encourage tip moth infestations. Vigorous trees growing on suitable sites often recover from light attacks, and suffer little damage.

Scale Insects, Family *Diaspididae* (Armored Scales) and Family *Coccidae* (Soft Scales)

Scale insects are a large and diverse group. These insects are named for the waxy protective covering they secrete. Adult females have sac-like bodies. They are usually legless and wingless. Males usually have well-developed legs, eyes, antennae, and one pair of wings. They look like small gnats. Adult males do not feed.

These insects have a complicated life cycle. Typically, mated females lay eggs that develop into first instar nymphs, called 'crawlers.' However, some species give birth to live nymphs. 'Crawlers' have legs and antennae. At this stage of the life cycle, scale insects are fairly active. 'Crawlers' may travel some distance. They are able to live several days without food. Eventually, however, the crawler settles down. It inserts its mouthparts into the host plant. It will usually remain in that spot for the rest of its life. Adult males are an exception. They seek out females to mate.

Scales normally require four to eight weeks to complete development. In protected environments, there may be three to six generations per year.

Armored Scale

Armored scales have a covering like a shield over the body of the insect. This shield is made of wax and outer coverings cast off from earlier molts. Females live under the scale, where they feed and reproduce. The shape of the scale varies by species. It can be used for identification.

An example of an armored scale pest is San Jose scale. This introduced pest has spread throughout the country. It is a serious pest of a variety of trees and shrubs. The scale is circular in shape. This species gives birth to live young.

The oystershell scale is another armored scale pest. It is named for the shape of its scale. This scale also attacks a number of trees and shrubs. Female oystershell scales lay eggs, which overwinter under the female's scale.

Soft Scales

Females of soft scales may be flattened, oval or globular. They have a smooth and rubbery outer covering, which cannot be separated from their body. These insects excrete honeydew while feeding.

Two of the most common soft scales found in interiorscapes are the brown soft scale and the hemispherical scale. Tea scale infests ornamentals indoors and in landscapes. Wax scales are outdoor ornamental pests.

The brown soft scale cover of the adult female is flattened, soft and pliable. It is shiny yellowish or brownish in color, with dark brown grid-like mottling. Females produce living young that crawl around the plant before settling down to feed and form a scale. This insect attacks a wide range of host plants.

The hemispherical scale cover of the adult female is strongly convex, hard, and smooth. It is a shiny brown in color. The underside of the female is cupped to accommodate large numbers of eggs. Ferns are one of its favored hosts. Occasionally, the reproductive sori found on the back of mature fern frons are misidentified as hemispherical scales.

Tea scale is one of the worst pests of outdoor camellias in the southern U.S. Tea scale is also a serious problem on Chinese holly. In addition, this pest may infest dogwoods, ferns and several other plants. The tea scale also infests greenhouse grown camellias in the northern U.S. The adult female tea scale is about 1/16 inch long. The male is shorter — about two-thirds the length of the female. The female is oval and dark brown to black. The male scale is narrow and white, with a dark ridge down its middle. Both the males and the females are held in a tangle of white cottony threads. The female lays 10-16 yellow eggs. These eggs remain beneath her scale until they hatch one to three weeks later. The yellow 'crawlers' become stationary two to three days after they hatch. The tea scale completes its life cycle in 40-65 days. Several overlapping generations may occur from March through November.

Soft Scale

Amored Scale

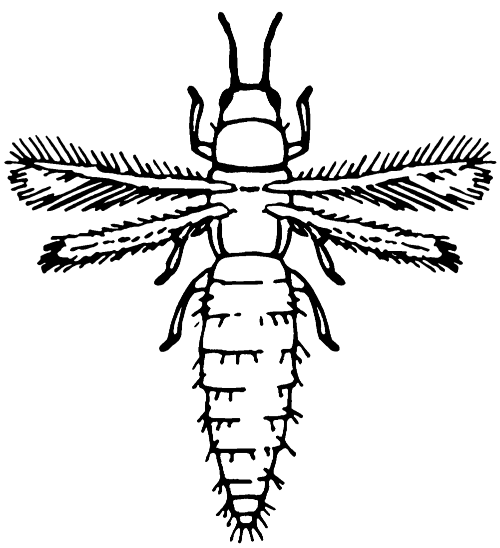
Wax scales are generally found in warmer climates. They have a large host range, and can attack a variety of plants. Adult wax scales are about 1/4 inch in diameter. They have a thick, heavy covering of white wax. Females lay their eggs in late April. The eggs hatch four to six weeks later. The 'crawlers' settle and begin to excrete wax from their bodies. Early in development (second instar), the wax gives the scale a cameo appearance. These scales are mature by August. Typically, a female scale lays an average of 2000 eggs. This high reproductive potential explains wax scale 'population explosions.'

If they are not monitored, scales can build up to damaging population sizes without being noticed. They are small and inconspicuous. These pests may not be noticed until they have extensively damaged the host plant.

Scale insects are sap suckers. They damage their host by removing plant fluids. Typically, they feed on the underside of leaves or on new growth. Infestations can be diagnosed by the presence of chlorotic, yellow blotches on the upper side of an infested leaf. Scales cause foliage to be distorted and stunted. Other symptoms include premature leaf drop, twig dieback, and a reduction in the number of flowers produced. The whole plant will have a generally unhealthy appearance. Some species also excrete a sweet honeydew. Honeydew attracts ants, which may be a nuisance in some plantscapes. However, if honeydew is not consumed or washed off, an unsightly black, sooty mold will grow on it. This blocks sunlight and slows plant growth.

Thrips, Family *Thripidae*

Thrips are small, slender insects, less than 1/8 of an inch in length. They have short legs and two pair of long, narrow wings. Their wings have a fringe of long, feather-like hairs around the edges.



Thrips

Females have a saw-like ovipositor at the end of their abdomen. They use this structure to make slits in leaves. They insert their eggs into these slits. Eggs hatch in two to seven days. The wingless nymphs that emerge feed actively and molt twice. The two stages before the adult stage have short wing pads. They do not feed. These late-stage nymphs may be found on the host plant or in the soil. Pupation normally occurs in the soil. Adults emerge in five to seven days. The entire life cycle may be completed in two to four weeks. The rate of development depends on temperature.

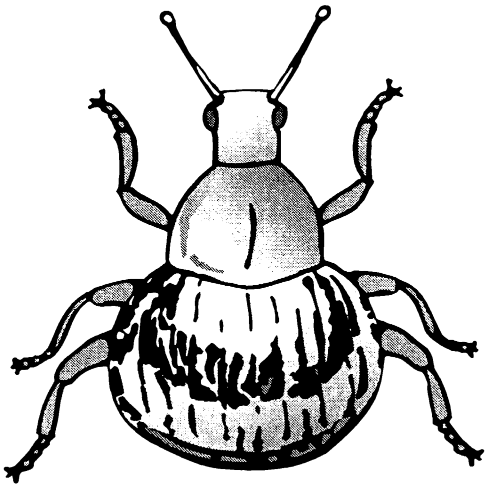
Thrips damage plants by feeding on plant juices. They scrape tender plant tissues with rasp-like mouthparts, and suck the sap that oozes from the wounds they make. Injured plant tissue turns white. Affected foliage and flowers have silvery blotches or streaks. Thrips may also be detected by the presence of reddish-brown drops of excrement on plant foliage. Thrips droppings turn black when dry. Thrips feeding reduces plant vigor.

Two Banded Japanese Weevil, *Callirhopalus bifasciatus*

The Japanese weevil was first reported in the U.S. in early 1900's. It is now found in New England, the Mid-Atlantic states, and west to Kentucky and Indiana. It feeds on many types of ornamentals.

The adult Japanese weevil is 1/4 to 1/2 inch long. It is tan to brown with darker markings. It has fused wings, and is unable to fly. The weevil is slow moving. When bothered, it will drop to the ground and lay motionless. Eggs are deposited in the folds of dead leaves, which the female fuses to form a pod. Hatching larvae enter the soil and feed on the roots of the host plant. The adults appear in July. There is only one generation per year.

Initially, this weevil produces notches in the leaves as it feeds. Eventually, only the petiole remains. Heavily infested plants are usually badly defoliated by autumn. The weevil usually attacks new leaves and shoots first.



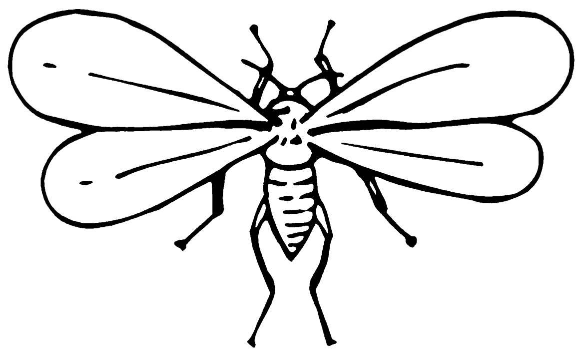
Two Banded Japanese Weevil

Whiteflies, Family *Aleyrodidae*

Whiteflies are tiny insects, seldom over two to three mm in length. They resemble a minute moth. The bodies and wings of adults are covered with a white dust or waxy powder. When the adult is resting, the wings are held horizontally over the body. Adults are active feeders.

The life cycle of the greenhouse whitefly is typical of this insect group. Each female lays an average of 150 eggs over its 30 to 40 day life. These eggs are laid in a circle, ranging from a few to 20 or more eggs in a group. The egg cluster is spindle-shaped. It is attached to a plant leaf at one end by a short petiole. Eggs hatch in five to ten days into first instar 'crawlers.' These 'crawlers' are yellowish-green. They have legs and antennae. After settling, they insert their mouthparts into the plant tissue and begin to feed. After shedding their skin (molt), they lose their ability to move and become scale-like. They secrete a flat, transparent, greenish-yellow cover. The larvae molt three times in about three weeks. After the last molt, a non-feeding pupa emerges. The pupa has a plump yellowish-green body with conspicuous black eyes. This inactive stage transforms into an adult in two to four weeks. The adult female lays eggs within its first week of life. The life cycle may be completed in three to five weeks, depending on the environment.

Adults and larvae feed on the foliage of the host plants, usually on the undersurface. They suck juices from the plants and excrete large amounts of honeydew. A black, sooty mold grows on the honeydew. In addition to making a plant unattractive, the sooty mold interferes with the plants' photosynthetic processes. Loss of fluids and reduced photosynthesis may result in the plants' death. Feeding damage caused by whiteflies is like that of other sap feeders.



Whitefly

Test Your Knowledge

Q. Name several factors to consider when diagnosing an arthropod pest problem.

A. First, be sure that an arthropod is actually the cause of the problem. If so, here is a list of important things to know:

- What sort of damage is the pest causing?
- What is the identity of the pest?
- What is its life cycle, and what stage is the pest in now?
- How large is the pest population? Is it increasing or decreasing? How is it distributed?

Q. List two common soil dwelling, root-damaging insect pests.

A. Soil dwelling pests include fungus gnats and soil mealybugs.

Q. What environmental conditions favor high mite populations?

A. Cyclamen mites prefer high humidity and low temperatures. Southern red mites are also active in cool weather. On the other hand, spider mites flourish in hot, dry weather.

Q. Define honeydew. Name several of the insect pests that produce honeydew. Describe the problems this substance causes on ornamental plants.

A. Honeydew is a sugary sap secreted by certain insects. Aphids, mealybugs, scale, and whiteflies all produce some type of honeydew. Honeydew buildup is most often a problem on indoor plants.

Honeydew is a problem for three reasons. First, it attracts other potential pests such as ants. Second, it serves as a substrate for the growth of a sooty, black mold. This mold grows on the surface of plant leaves and stems. It is harmful because it reduces the amount of light a plant can absorb. This, in turn, interferes with photosynthesis and reduces food production. Third, the sticky honeydew and the sooty black mold that grows on it are unattractive on ornamental plants.

Q. What is the most vulnerable stage in a mealybug's life cycle?

A. Mealybug eggs hatch into 'crawlers.' At this stage, the mealybugs move sluggishly about the plant. 'Crawlers' do not have a cottony, waxy protective sac covering them like eggs and adults.

Q. What are some symptoms of a mite infestation?

A. Mites usually feed on the undersurface of leaves. They feed on plant fluids. These tiny arthropods are often hard to see. The leaves of heavily infested plants are discolored or disfigured. Mites cause plants to decline in condition. A large infestation may result in death.

Q. How do spider mites damage a plant?

A. Spider mites damage plants by sucking plant juices. Usually, spider mites feed on the underside of the leaves. Severe infestations cause leaves to dry up and fall off. Mites are also insect vectors for disease pathogens.

Q. Name three insect pests that suck plant fluids.

A. Aphids, lacebugs, mealybugs, scale, thrips, and whiteflies are all pests that suck plant juices. (Spider mites also feed on plant juices. However, mites are not insects.)

Q. Name one insect that defoliates its host plant.

A. Both bagworms and two banded Japanese weevils feed on plant leaves. Bagworms attack evergreens. The weevil feeds on a variety of ornamental plants. Large populations of either pest can cause defoliation.

Q. Name one insect pest that damages its host by damaging the growing tips.

A. Pine tip moth larvae injure their host by boring into the tender, growing shoots of the tree's branches. Several inches of the shoot may be killed. Repeated, heavy attacks cause pines to be bushy, crooked, or distorted.

Q. Describe the signs and symptoms of an aphid infestation.

A. Aphids usually occur in large numbers on new growth. Look for them at the base of buds and stems and on the under-surface of leaves. Aphids are small, sluggish, soft-bodied insects. Nymphs and adults are pear-shaped — narrower at the head and wider at the rear end. They usually have a pair of tailpipe-like processes extending from near the end of the abdomen. Aphids vary greatly in color. Some are wingless. A few species produce wooly or waxy material that covers them. Aphids are one of several insects that produce a sugary liquid called honeydew. Aphid feeding causes plants to wilt and curl. Aphid infestations may result in reduced plant vigor and curled, distorted leaves.

Q. Describe the signs and symptoms of an azalea lace bug infestation.

A. As the name indicates, this insect is found on azaleas. They do the most damage to azaleas growing in full sunlight. Adult lace bugs are 1/8 inch long and brown to black in color. Their bodies are flattened and oval or rectangular. These insects have netted wings, which fold flat over their abdomen. They have a hood-like covering on their heads. The upper surface of leaves damaged by lace bug feeding have a blanched or stippled appearance. The undersides are rusty colored. An observer may see dark spots of tar-like excrement. Often, shed 'skins' left by molting nymphs can be seen, too. Leaves of severely infested plants change from healthy green to yellow. Plant vigor is greatly reduced.

Q. Describe the signs and symptoms of a bagworm infestation.

A. Bagworms prefer to feed on evergreens, but may also be found on deciduous woody ornamentals. This pest spends most of its life in a spindle-shaped bag covered with bits of needles or leaves. Since these 'camouflaged' bags are easily overlooked, these pests may not be noticed right away. A heavy infestation of bagworms will defoliate and even kill evergreens. However, bagworms rarely cause serious damage to deciduous ornamentals.

Q. How can you recognize a boxelder bug?

A. These insects are black in color, with conspicuous red markings on their body and wings. Like most 'true bugs,' the wings of the boxelder bug are thick at the base and membranous at the tip. Boxelder bugs feed on maple trees, especially the boxelder (*Acer negundo*).

Q. Why is the boxelder bug considered a pest?

A. Large numbers may invade dwellings in the fall, searching for a sheltered place to spend the winter. These bugs may move a long distance from their host tree to an overwintering site. Crushed insects or their excrement may stain fabrics. However, they do not harm host trees or other landscape plants.

Q. What is a symptom of bark beetle activity? How do these insects damage the host plant?

A. Bark beetles leave a buckshot pattern of holes in the bark of the tree. They usually attack weakened, dead or dying trees. However, some attack and kill living trees. Bark beetle damage occurs from the holes the adults make when entering and leaving the tree, and from the tunneling of the adults and their larvae. These beetles tunnel in phloem tissue, which interferes with food transport in the plant.

Q. How does the black vine weevil damage landscape plants?

A. Both the adults and grubs of this pest cause plant damage. This insect feeds on over 100 different plant species. However, they are commonly associated with yews and rhododendrons in landscapes. The adults are leaf feeders, making conspicuous notches at the margins of host plant leaves. Usually, this will not cause permanent damage to trees, although it causes an aesthetic problem. The grub stage feeds on plant roots. High population densities can kill host plants.

Q. What is the primary host plant of the bronze birch borer in Virginia? How can you recognize an infested tree?

A. In Virginia, these beetles are associated with the white birch. The sawdust and frass from their burrowing causes the trunk or branches of an infested tree to have a rippled appearance. Their galleries can completely cut off the flow of sap, causing yellowing of leaves in the crown.

Q. Describe how a boxwood leafminer infests and damages its host.

A. Adults females pierce the underside of boxwood leaves and insert eggs. Adults are very poor fliers. So, females tend to lay their eggs in the same general area where they emerged, often on the same plant. The larvae cause damage as they feed. The mines look like blisters on the leaves. Usually, this insect does not cause boxwoods to die. However, infested plants may have a sickly appearance.

Q. Describe a boxwood psyllid adult and the damage the nymphs cause.

A. Adults are small, gray-green insects that resemble miniature cicadas. Nymphs feed on fast-growing early season leaves, which causes the leaves to have a cup-shaped appearance.

Q. Describe the signs and symptoms of a dogwood borer problem.

A. The dogwood borer is a pest of flowering dogwoods. It is usually found in cultivated plantings. Adults are small, blue-black moths with yellow-banded legs and yellow stripes on segments two and four of their abdomen. Their wings are transparent with blue-black margins. They have a wingspan of 5/8 to 7/8 of an inch. Larvae bore through the bark of dogwoods and feed in the cambium. An early symptom of borer attack is the sloughing of loose bark, and small wet areas on bark. In late summer, you may notice pinholes in bark, and fine white dust-like borings pushed from burrows. Dieback and adventitious (unusual) growth are more advanced symptoms.

Q. How can you tell the difference between eastern tent caterpillar and fall webworm? Do either cause serious damage to host plants?

A. Eastern tent caterpillar larvae are hairy and black with a white stripe and a series of blue spots running the length of the body. Fall webworm larvae are hairy, yellow caterpillars. Typically, eastern tent caterpillars build tent-like nests in the fork of a branch or the crotch of a tree in the rose family (cherry or apple). They leave their nest to feed on leaves. Fall webworms form a nest around leaves at the ends of branches. They feed on leaves inside their nest. Fall webworm caterpillars will infest dozens of different hardwoods, but they are especially fond of walnut. The nests of these pests are extremely visible and unsightly. However, as a rule, neither type of caterpillars will kill a tree.

Q. Describe the signs and symptoms of a fungus gnat problem.

A. Fungus gnats breed in moist to wet soil of indoor plants. Adults are small, dainty gray-black flies. They may be seen throughout the year. Larvae are root feeders. A severe infestation may result in stunting, yellowing, defoliation, and an overall decline in the plant's appearance. Some soilless media, especially those that contain peat moss, are excellent food for these insects.

Q. Why is the Japanese beetle a significant pest?

A. It causes plant damage during both the larval and adult stages. Larvae (white grubs) are significant turf pests. They feed on roots of turf grasses. Adult beetles feed on various above-ground plant parts — leaves, buds, flowers and fruits. Adults are serious pests of roses, fruit trees, and grapes.

Q. What life cycle stage of the gypsy moth causes damage? Describe the damage this pest does.

A. The larval (caterpillar) stage is a defoliator. Gypsy moth caterpillars damage millions of acres of hardwood forest each year. They can also defoliate urban neighborhoods. Repeated defoliation stresses trees, and can lead to death. In addition to the damage to landscape trees, gypsy moth caterpillars are an extreme nuisance during outbreaks in residential areas. Trees lose their foliage, caterpillars crawl everywhere, and their droppings rain from the trees. When disease kills large numbers of caterpillars, as often occurs, the stench is overwhelming. In some cases, people develop an allergy to the hairs of the gypsy moth caterpillars.

Q. What are galls? What causes galls?

A. Galls are the result of abnormal plant cell growth. They form in response to an insect or some other organism infesting plant tissue. Gall-forming parasites release growth-regulating chemicals as they feed, causing plant tissue to form a gall. Then, the parasite develops inside the gall, in a relatively secure place. Several different groups of insects and one family of mites induce galls in plants. In addition to arthropods, some nematodes, bacteria, fungi, and viruses can cause plants to form galls.

Q. How can you identify an infestation of hemlock wooly adelgid?

A. This insect prefers to live and feed on hemlock trees. Hemlock wooly adelgids are small aphid-like insects. They display several different forms during their life history, including winged and wingless forms. Generally, the adults are brownish-red in color, oval in shape, and about 1/4 of an inch (0.8 mm) in length. Crawler stage nymphs produce white cottony/waxy tufts that cover their bodies and remain in place throughout their lifetime. The white masses are about three millimeters (3 mm) in diameter. Severe infestations can resemble a recent snowfall on the branches of the tree.

Q. Describe the signs and symptoms of a leafminer attack. Name one common pest leafminer found in Virginia.

A. Leaf miner larvae tunnel and feed in plant leaves. Infested leaves have transparent areas where plant tissue was removed. Some mined leaf areas turn brown after they dry out.

The holly leafminer is a common ornamental pest. As its name suggests, this insect prefers the American or Christmas holly. The holly leaf miner is a fly. The larvae, or maggots, mine just under the upper leaf surface. Damage is confined to the upper side of the leaves. Initially, the mines are thread-like and inconspicuous. However, as the larvae grow, their tunnels increase in size. By late autumn the mines widen into blotches or blisters. These mines may destroy an entire leaf. If a plant is heavily infested, many one-year old holly leaves will drop off in the spring.

Another common leafminer is the locust leafminer. The adult beetle is orange and black striped. The primary host is black locust. The larvae hatch from the eggs and burrow into the inside of the leaf. The larvae feed on the leaf cells, leaving a mine. These mines are small at first, but gradually enlarge until most or all of the leaf is affected. They turn brown as the leaf dries out. By late July, locust tree canopies may be completely brown.

Q. Describe the signs and symptoms of a mealybug infestation.

A. Mealybugs may be found on a variety of indoor plants. They are elongate-oval, flattened insects with segmented bodies. Their name comes from the mealy wax they secrete, which covers their bodies. They have well-developed legs but no wings.

Foliar (aerial) mealybugs are about 3/16 inch long. They have smooth, light yellow bodies. Shortly after they begin feeding, the adults secrete a white waxy covering. They move about, sluggishly, over the entire plant as they feed. The 'crawler' stage is the most vulnerable stage in the life cycle, because it does not have a waxy covering. Foliar mealybugs produce honeydew.

Soil mealybugs are found in the soil of container-grown plants. These insects are sac-like in shape. Usually, an infestation is detected when young are found in soil crevices. These soil spaces or chambers are coated with white waxlike material. Wax may be seen covering the outer surface of the root ball. Symptoms of an infestation include general decline, distorted growth, and leaf drop. Severe infestations can result in stunting or death.

Q. What clues may indicate an infestation of scale?

A. Scale insects are named for the waxy protective covering they secrete. Armored scales have a covering like a shield over the body of the insect. The shape of the scale varies by species.

Female soft scales may be flattened, oval or globular. Soft scales have a smooth, rubbery outer covering, which cannot be separated from their body. Soft scales produce honeydew. Adult female scales have sac-like bodies. They are usually legless and wingless. Males usually have well-developed legs, eyes, antennae, and one pair of wings. They look like small gnats. Adult males do not feed. Scale insects usually feed on the underside of leaves or on new growth.

Infestations can be diagnosed by the presence of chlorotic, yellow blotches on the upper side of an infested leaf. Scales cause foliage to be distorted and stunted. Other symptoms include premature leaf drop, twig dieback, and a reduction in the number of flowers produced. The whole plant will have a general unhealthy appearance.

Q. Describe the signs and symptoms of an infestation of thrips.

A. Thrips are small, slender insects, less than 1/8 of an inch in length. They have short legs and two pairs of long, narrow wings. Thrips wings have a fringe of long, feather-like hairs around the edges. Thrips feeding injures plant tissue. Affected parts may turn white, or have silvery blotches or streaks. Thrips may also be detected by noticing drops of excrement on foliage. Thrips droppings are reddish-brown when first deposited, but turn black when dry. Thrips infestations reduce plant vigor.

Q. Describe the appearance and damage symptoms caused by the two banded Japanese weevil.

A. This weevil feeds on many types of ornamentals. Adults are 1/4 to 1/2 inch long, and tan to brown in color with darker markings. It has fused wings, and is unable to fly. This weevil is slow moving. When bothered, it will drop to the ground and lay motionless.

The weevil usually attacks new leaves and shoots first. Initially, this weevil produces notches in the leaves as it feeds. Eventually, only the petiole remains. Heavily infested plants are usually badly defoliated by autumn.

Q. Describe the signs and symptoms of a whitefly infestation.

A. Whiteflies are tiny insects, seldom over two to three mm in length. They resemble a minute moth. The bodies and wings of adults are covered with a white dust or waxy powder. When the adult is resting, the wings are held horizontally over the body.

Adults and larvae feed on the foliage of host plants, usually on the undersurface. They suck juices from the plants and excrete large amounts of honeydew. The damage they cause is like that of other sap feeders.

Diseases

All living organisms have diseases. Sometimes one specific organism causes a disease, which results in a quick death. Late blight of potato is a good example. If conditions are right, blights can overwhelm some ornamentals very rapidly, too. On the other hand, some plant health problems are the result of a whole complex of conditions — "naggy" insect pests, nematode infections, and long-term "decline" of an undetermined cause(s). Old boxwoods are perfect examples. A single plant might live for centuries, despite being in poor health. Examples can be seen on old plantations and historic sites in Virginia.

Diseases can exact an unbelievably serious toll. They affect plants wherever they grow — in nurseries, landscapes and interiorscapes. Plant diseases can cause a dramatic change in an area. For example, picture a shady tree-lined city street — and then picture the same street without the trees! Plant diseases have a serious impact on landscapes, and as a result, on real estate values. Losses in the billions of dollars are sustained yearly. Some problems are so stubborn and unresolved that various species and cultivars of plants simply cannot be grown in some locations.

There are more plant diseases than there are researchers to identify and develop management procedures for them. Also, there are a good number of as yet unsolved problems. Examples include boxwood decline and sudden death syndrome in certain trees. All experienced horticulturists have lost plants to disease despite their best efforts.

Plant Diseases and Disorders: An Overview

Fungi commonly called "molds" cause most ornamental plant diseases. There are thousands of fungal pathogens. Often, only an expert can identify them. Other disease-causing organisms include bacteria and viruses.

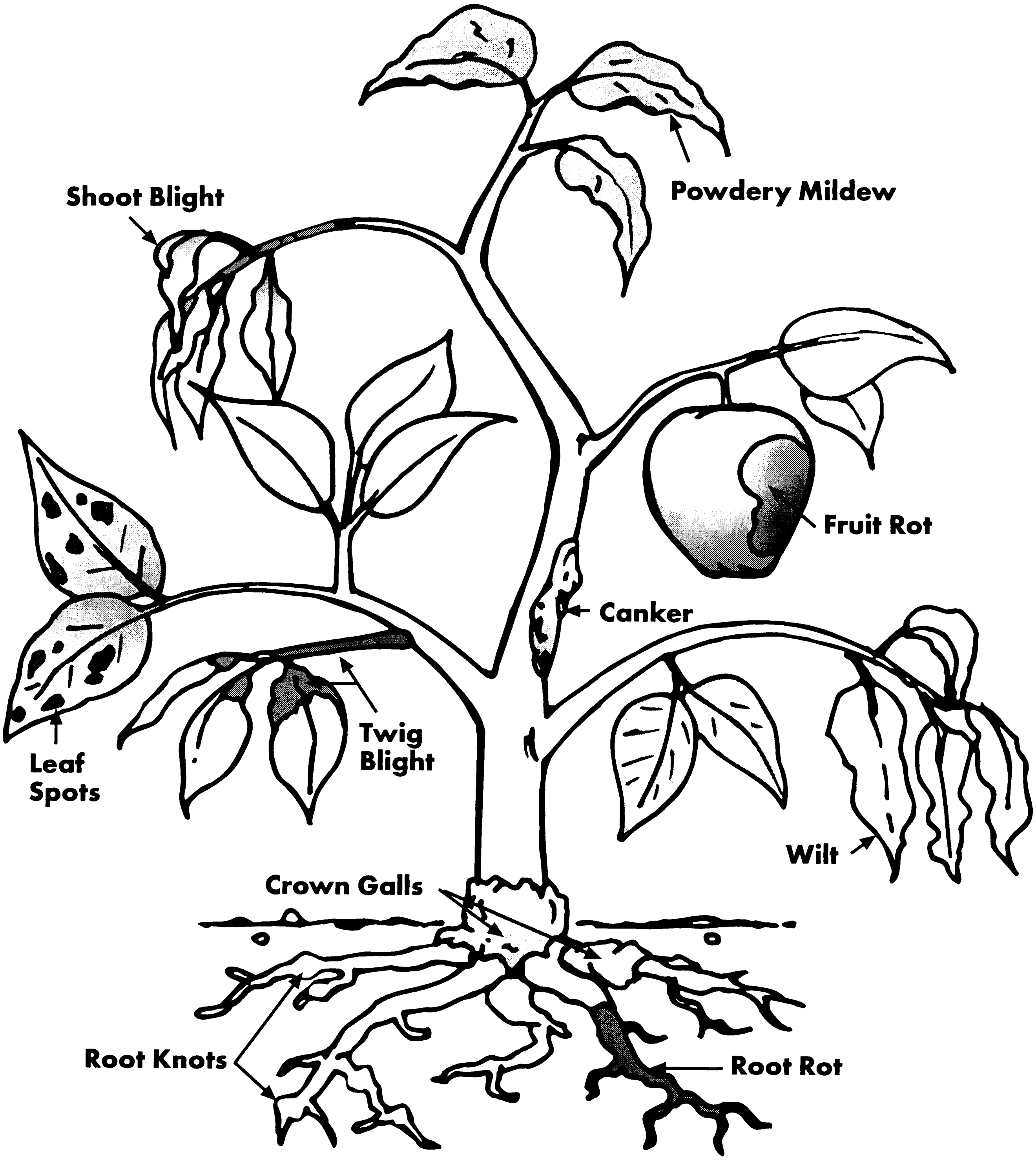
However, non-living factors also belong in the "disease picture." Moisture, temperature, and fertilizers (too little or too much) are just a few of the things that can favor plant diseases. Just to further muddy the waters, often both living and non-living stress factors work together to cause disease. A good example of a combination problem is "damping-off." Certain types of fungi such as *Phytophthora, Pythium, Rhizoctonia* or *Fusarium* cause "damping off." However, this disease requires an extended period of low temperatures and waterlogged soil. "Damping off" is a common problem for germinating seeds and young seedlings. Both the pathogen and the environmental factors must be present to cause this disease.

Certain plant diseases are so specific that you can almost certainly match a symptom or syndrome ("disease picture") to a specific cause. Good examples are Dutch elm disease and fireblight. If you see an elm tree with yellowing leaves, "flagging" (dead leaves hanging down like flags), a thin crown, and stained sapwood, it most likely has Dutch elm disease. The fungus *Ophiostoma ulmi* causes Dutch elm disease. If you see a woody plant in the Rose family (apple, pear, Pyracantha, etc.) with blackened branch ends, you should suspect fire blight. Fire blight is a disease caused by a bacterium.

Biotic (infectious) diseases are caused by pathogens. Pathogens are organisms that infect the host plant. The pathogens that cause biotic diseases grow, reproduce, and spread from plant to plant. If one plant has a biotic disease, it is possible that nearby susceptible plants will get the disease. Once an infection begins, the disease process continues until:

- the pathogen is removed or suppressed,
- environmental conditions no longer favor the pathogen's growth and development, or
- the host plant dies.

Plant pathogens include fungi, bacteria, viruses, and other microorganisms.


Shoot Blight
Powdery Mildew
Fruit Rot
Canker
Leaf Spots
Twig Blight
Wilt
Crown Galls
Root Knots
Root Rot

Abiotic or noninfectious disorders are caused by nonliving factors. Abiotic disorders do not spread from plant to plant. However, the same disorder may affect a number of plants in one site. This is especially true if a group of similar plants are all exposed to the same environmental stresses. Abiotic disorders are very common in plants grown out of their normal habitat. They also affect plants in sites disrupted by human activity. Any environmental stress factor can interfere with normal growth and development. Abiotic disorders may be caused by light, moisture, nutrient and temperature extremes, chemical exposure (including air and water pollution), mechanical injury (ex. soil compaction or excavation around roots), and other human activities. The diagnosis of an abiotic disorder can be difficult. This is because one symptom can be caused by many different things.

A plant manager needs to look for characteristic signs and symptoms to diagnose health problems. A symptom is a visual clue indicating the plant is suffering from some sort of disease or disorder. Symptoms may include slow growth and stunting. Roots may be limp, 'mushy' or abnormally dark in color. Leaves may be discolored, have brown tips or margins, spots, or scabs. Some symptoms are not visible unless the affected part is magnified. Sometimes, the disease-causing pathogen itself can be seen. Examples include fungal spores or mycelium and bacteria-filled ooze from cankers.

Disease Organisms

Fungi

Fungi are simple organisms that lack chlorophyll. Fungi cannot make their own food. They obtain food by decomposing dead plant or animal material or by infecting other living things. Fungi cause more plant diseases than any other type of infectious agent.

Many fungi are composed of fine, thread-like filaments (hyphae). Masses of hyphae are called mycelia. Fungi can penetrate plant surfaces, even without a natural opening or a damaged surface. Fungi usually form circular lesions. These lesions may overlap, giving the affected plant part a blotchy appearance. Often lesions form concentric rings, which give a bull's-eye appearance.

Most fungi produce reproductive spores. Spores function like the seeds of flowering plants. Each spore can start a new fungal infection. Usually, individual hyphae and spores can only be seen with the aid of a microscope. Some fungi however, develop masses of hyphae (mycelia) or aggregations of spores, which may be visible to the naked eye. Fluffy, 'moldy' growth on a plant surface and pinpoint-like pustules within a lesion indicate the presence of a fungal disease. Some of the more common fungal diseases include leaf spots, root rots, and powdery mildew.

Bacteria

Bacterial pathogens are single celled, microscopic organisms. Pathogenic bacteria obtain their food energy from the organisms they infect. Bacteria usually require some type of opening in a plant surface to enter.

Bacterial infections on leaves often appear as oily, greasy or water-soaked spots. Other symptoms include stem or leaf rots, sour smelling roots, cankers, and wilting. One common sign of many bacterial diseases is the oozing of a viscous, slimy mass from infected tissues. Bacterial diseases can be divided into two categories: systemic and localized.

Systemic bacterial diseases can invade plant vascular tissues and spread systemically throughout all parts of the plant. Under certain conditions, these pathogens may begin to multiply in localized areas of the infected plant and cause stem rots, leaf blights, wilts, and root rots.

Bacterial rots can affect any part of the plant, including stems, roots, buds, crowns, and flowers. Rots are characterized by plant tissue that is slimy, 'mushy' and foul smelling. You can usually recognize bacterial wilts by observing streaked and discolored stem tissue, foliage that yellows from the crown downward, and severe wilting. Localized bacterial diseases include leaf spots or blights. *Pseudomonas* and *Xanthomonas* bacteria are common plant disease-causing organisms.

Viruses

Viruses cause many ornamental plant diseases. Symptoms of viral infections include yellow rings on leaves, stunting, and wilting. Viral diseases cause decline and sometimes death.

Viruses are the smallest of the plant pathogens. They consist of a single strand of genetic material and a protein coat. They are systemic pathogens. Viruses can grow and reproduce only in living cells of their host. Viruses cannot penetrate an intact host and must be introduced into plants through an opening caused by a mechanical injury, pruning, or grafting. These organisms can be spread from plant to plant on worker's hands or by tools. Sucking insects such as aphids or leafhoppers may also spread them.

Viruses are generally too small to be seen even with a light microscope. Usually, viral diseases are identified by characteristic symptoms. Symptoms vary with the virus involved, the species of plant infected, and the environmental conditions. Common symptoms include a yellowish or light green ringed pattern on foliage, vein banding, mosaic, flecking, yellow blotching, growth abnormalities, and stunting.

Disease Development

In general, four things contribute to disease development:

1. Pathogen: The abundance and vigor of the disease-causing organism.
2. Host plant: The genetic resistance and general health of the plant.
3. Environmental conditions: Abiotic factors, including weather, climate, soil conditions, plant density, cultural practices, and site characteristics.
4. The time element: The time between infection or onset, diagnosis, and action.

Descriptions of Common Ornamental Plant Diseases

Leaf Spots

Leaf spots are a real mixed bag of diseases and causal organisms. Most are fungal. They occur on a wide variety of ornamentals. Such diseases include "zonate leaf spot," "anthracnose," "*Phyllosticta* leaf spot" (on maple), "oak leaf blister," and "rose black spot." The name "leaf spot" is descriptive. All involve some sort of spotting on plant leaves. Leaves are the plant's food factories. Leaf spot diseases interfere with food production and translocation. They also detract from the appearance of the plant.

Dry (fungal) leaf spots on oak, and watery (bacterial) leaf spots on an indoor plant

Leaf spot diseases may be more damaging to tree health than previously thought.

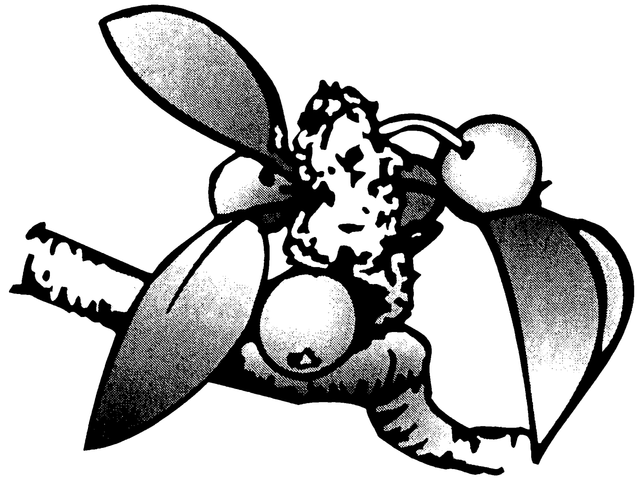
Leaf spots caused by fungi generally have a dry appearance. Often, they are tan or gray in color. Within the colored area, small dark brown to black pimple-like structures are usually present. These fungal structures, called fruiting bodies, produce spores which can spread to cause more disease. Leaf spot symptoms include leaf spots of various sizes, shapes and colors, "shot-holes" in leaves, yellowed and withered foliage, and overall poor plant health.

Bacterial leaf spots are characterized by dark green, water-soaked spots that may turn tan, dark brown, or black with a yellow border. The spots can enlarge until the entire leaf blade is affected. Sometimes these lesions spread into the petioles and stems. When they do, the leaf spot may look like a systemic bacterial disease.

To determine if a leaf spot is caused by a bacterium or a fungus, examine a cut surface under a microscope. Cut through a spotted area, and place it in a drop of water on a microscope slide. When viewed through a microscope, bacterial ooze can be observed streaming from the cut edge of the spot. No ooze streams from a cut in healthy leaf tissue or from tissue infected by fungi.

Rusts

Rusts are caused by a group of fungi in the Basidiomycete class. Typical symptoms are rusty-looking orange areas on leaves. However, lesions may also be gray or brown. The fungus *Gymnosporangium* commonly causes rust on ornamental crab apples, hawthorns and quinces. This pathogen requires an alternate host. This means it must alternate between two totally different types of plants to complete its life cycle. In the case of apple rust, the alternate host is red cedar. Rust fungi can cause entire branches or plants to die. Lesions may also occur on the fruit.



Rust symptoms on crab apple

Juniper Twig Blight

This is a common problem on many junipers. Symptoms include a browning and dieback of young leaves and twigs. The plant genera *Cryptomeria*, *Chamaecyparis* and *Thuja* (arborvitae) may be affected. Cool, moist weather conditions favor disease development. This is commonly a spring disease in Virginia. Juniper twig blight can be very destructive in seedbeds and lined-out nursery stock. Proper diagnosis is important, since winterkill or even voles (mouse-like rodents) may cause similar symptoms in juniper ground covers.

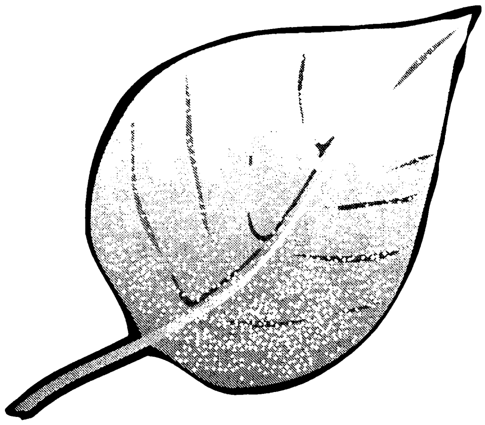
Scabs

Some horticulturists might group this with leaf spot. However, we will consider it as a separate disease complex. Scab often occurs on apple, crab apple (such as cultivars Almey, Hopa, Jay Darling, Strathmore), Pyracantha and other related plants. Symptoms include leaf spots, premature defoliation, and scabby fruits. If this disease is not controlled on ornamentals, they will be unsightly and non-marketable.

Powdery Mildew

This disease is well named. The leaves look as though someone dusted them with a fine white powder. Other symptoms may include stunting, curling and drying of infected tissues, and buds that are malformed or fail to open properly. This disease is seen often on lilacs, grape ivy, kalanchoe, begonias and pileas.

The white 'coating' on leaves and other plant parts with a powdery mildew infection is the fungus growing on the tissue surface.



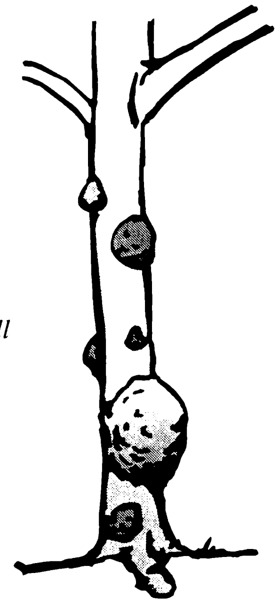
Powdery Mildew on lilac

Small structures called haustoria penetrate the cells of the affected tissues, injuring them as they obtain food. Powdery mildew usually will not kill a plant. However, the unsightly fungus lesions greatly reduce its ornamental value. The 'powdery coating' reduces the amount of light energy the plant absorbs. This reduces the amount of food the affected plant produces, which in turn results in slow growth.

Crown Gall

This disease is caused by a bacterium. It is easily transmitted from plant to plant. Once in place, the pathogen is almost impossible to eradicate from an infection site or center. Even worse, the disease occurs on a number of different plants, including Pyracantha, certain ornamental stone and pome fruits, roses, chrysanthemum, dahlia, daisy, euonymus, poplar and willow to name a few. Abnormal growth is the major symptom. Tumors or galls of differing sizes and forms develop on the crown, roots, stems or leaves. There may be excessive or abnormal organ development, with or without an

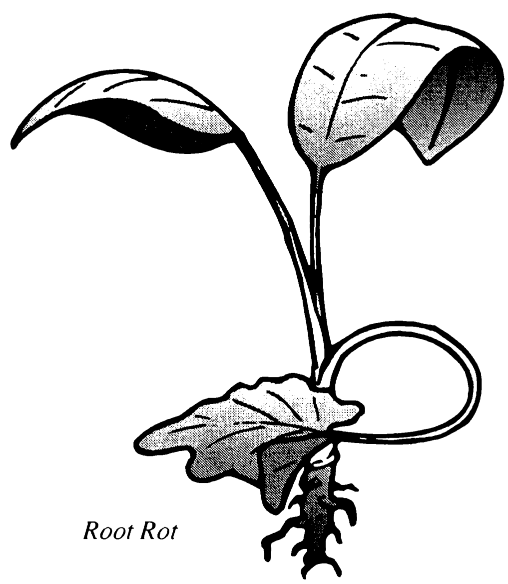
Crown Gall



accompanying swelling. Since the galls or tumors occur so commonly on trunks at the ground level (or "crown"), the disease has been called "crown gall." Galls range from pea-sized to overgrowths weighing many pounds. Plants with crown galls are deformed and unattractive. Galls also interfere with plant functions.

Root Infections / Root Rots

There are many types of root infections. Some examples are *Phytophthora* root rot, rhododendron wilt, and *Cylindrocladium* root rot. Symptoms include limp, 'soggy' or dark-colored roots. (Normal roots and root tips are



Root Rot

white in color, and brittle and crisp in texture.) Affected plant roots literally die, decompose or rot away. If an infected plant is pulled up, the outer layer of cells strips off, leaving only the central strand of water-conducting tissue.

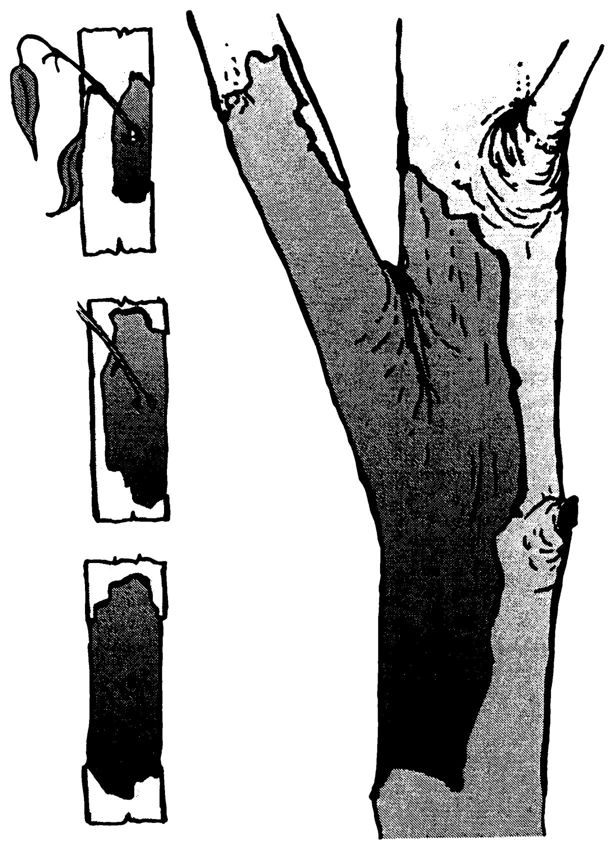
Other symptoms of root rot include slow growth, older leaves that turn yellow and drop off, and dead or discolored leaf margins.

Damping Off

Damping off is a 'first cousin' to the root rots just described. This disease affects seeds and emerging seedlings, causing seed, seedling or root rots. In Virginia, damping off is a spring disease. Soils that are cool and damp for prolonged periods favor disease development. The fungal pathogens that cause damping off include *Fusarium*, *Phytophthora*, *Pythium*, and *Rhizoctonia*. These common soil organisms are opportunistic. They grow well in hypoxic (low oxygen) conditions. Hypoxic conditions exist when soil pore spaces are filled with water.

Fire Blight

Fire blight is another disease with a descriptive name. Affected plants have brown twigs or branches. They look as though flames singed them. Fire blight is caused by the bacterium *Erwinia amylovora*. It affects a number of woody ornamentals, particularly members of the Rose family. Certain varieties of apple, flowering crab, pear, Pyracantha, and quince are very susceptible. This disease also affects hawthorn, Japanese quince, mountain ash, rose, cotoneaster, spirea, loquat, and Amelanchier. The bacterium overwinters in cankers. Often, an orange 'gum' or slime oozes from the cankers. Bees transmit it as they move from blossom to blossom, by infested pruning shears, wind-blown rain, and by a number of other methods.



Fire Blight

Test Your Knowledge

Q. Describe the difference between a disease sign and a disease symptom.

A. Disease sign is the actual disease causing agent. Typical signs could include visible spores, mycelia, cankers, and bacterial ooze. A symptom of a disease is an abnormal condition indicating a disease may be present. Symptoms on plants may be leaf distortion or necrosis, scabs or galls, roots that are limp or darkened, sour smelling roots and stems, or water-soaked lesions on plant parts.

Q. Explain how biotic (living) and abiotic (nonliving) factors play a role in plant diseases.

A. Plant pathogens — fungi, bacteria, and viruses — are living things. These organisms cause disease. However, abiotic factors are important in disease development. A plant growing in stressful conditions (too much or too little moisture, unfavorable temperatures, improper soil type or growing medium, etc.) will often result in poor health. Plants in poor condition are more susceptible to disease than healthy plants. Finally, there are some diseases that require both a pathogen and a certain set of environmental conditions. A good example is damping off. This disease is caused by a pathogen (certain types of fungi such as *Pythium, Phytophthora, Rhizoctonia* or *Fusarium*). However, even if a pathogen is present, damping off will not occur without favorable environmental conditions (an extended period of low temperatures and waterlogged soil.)

Q. Describe the four factors that influence disease development, and explain why it is important to consider each when diagnosing diseases.

A. The four factors include the presence of the pathogen, the susceptible host plant, environmental conditions that favor disease, and time (for disease to develop, or the length of time the plant has had the disease). Knowing the factors that caused or contributed to a disease problem will help a horticulturist plan effective management strategies.

Q. How can you tell the difference between bacterial and fungal leaf spot?

A. Leaves infected with a bacterial leaf spot disease have dark areas that appear to be greasy, oily or water-soaked. The affected areas can have a yellow border. On the other hand, a fungal leaf infection is usually dry in appearance. Fungal leaf spots may be various sizes, shapes and colors. Often, within the discolored spot, 'pimple-like' fungal fruiting bodies can be seen. If examined under a microscope, the cut edge of a bacterial leaf spot will have brownish bacterial ooze streaming from it. No ooze streams from healthy leaf tissue or from leaf tissue infected by fungi.

Q. Match the description with the disease:

1. Leaves look like they have white powder on them.

2. Leaves look like they were singed by fire.

3. Leaves have rusty-looking orange areas.

4. Tumors or galls on stems, roots or leaves; commonly seen at the base of the trunk.

A. These symptoms match those of:

1. powdery mildew.
2. fire blight.
3. rust.
4. crown gall.

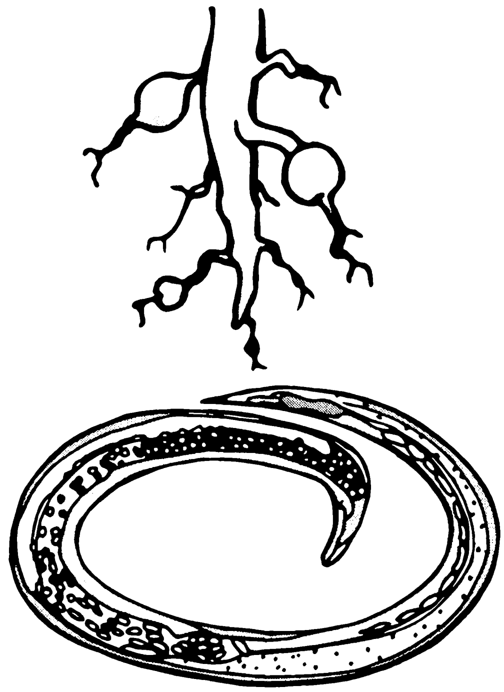
Nematode Pests

Nematodes are tiny, transparent roundworms. Most are microscopic. They have long, round bodies that taper at both ends. Because most nematodes are not visible to the naked eye, it is easy for people to spread them. Nematodes may be moved from place to place in soil on footwear, tools, and equipment.

Nematodes are very abundant. A bucket of soil or pondwater may contain thousands of them. Most species are free-living and harmless. However, some are parasites of plants and animals. Some of the parasitic types are beneficial, because their hosts are pests. Nematode parasites of pest insects are an example. However, those that attack living plant tissues are pests. Nematodes cause some plant disorders. Ornamental plants with nematode infestations grow slowly or decline and die.

Nematodes that are plant parasites have a hollow, sharp tooth called a stylet. A stylet is like a hollow needle. Plant parasitic nematodes insert stylets into host plant cells and feed on the contents. Some plant-infecting nematodes lay eggs, develop, and feed inside a host plant. Other types feed outside the host and lay eggs in soil.

Different species of nematodes attack different plant parts. Lesion nematodes (*Pratylenchus*) and spiral nematodes (*Helicotylenchus*) cause plant stunting and poor growth because their feeding weakens the root system. The root-knot nematode (*Meloidogyne*) causes nodules (galls) to form on roots, thus impairing root function. The foliar or spring crimp nematode (*Aphelenchoides*) lives within the leaf tissues of many indoor plants. It kills leaf tissue, resulting in brown lesions on older leaves. Plants weakened by nematode infestations are more susceptible to other infectious diseases.



"Typical" nematode and nematode damage

Test Your Knowledge

Q. Describe the damage caused by nematodes.

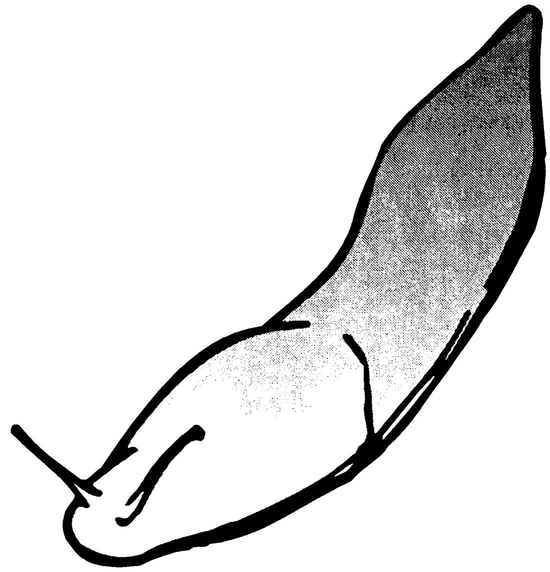
A. Nematode infections cause stunting, slow growth, and even death. Lesion and spiral nematodes attack and weaken plant root systems. The root-knot nematode interferes with normal root function. Foliar nematodes cause necrosis of leaf tissue. Nematodes weaken a plant. Plants in poor health are more susceptible to secondary infections and infestations.

Mollusk Pests

Mollusks are soft-bodied animals. Most have shells. The group includes snails, slugs, clams, oysters, octopuses and squids. Snails and slugs are found on land. They have a distinct head and well-developed sense organs.

Pest mollusks — snails and slugs — damage ornamentals by feeding on them. They use their rasp-like tongue to eat soft plant tissues such as foliage, fruit, and fleshy stems. They may eat entire seedlings. Slugs can be very damaging to shade-loving plants like hostas.

Snails and slugs are most active when humidity is high. They usually feed at night or during cool, misty mornings. As they move, snails and slugs leave a slimy trail. When these mucus trails dry, they look like silver streaks. This discoloration is undesirable on ornamental plants.



Slug

Test Your Knowledge

Q. Describe the damage caused by pest mollusks.

A. Snails and slugs eat plant tissues. They can eat entire seedling or leaves. They leave a mucus trail behind as they move. This mucus dries to form silvery streaks, which detract from the appearance of ornamental plants.

Weeds

The usual definition of a weed is a plant out of place. For example, a corn plant growing in a soybean field is a weed. Morning-glories growing in a landscape bed are considered weeds, but some people grow morning-glories in their flower garden. Thistles are sometimes raised to attract birds, but certain thistle species are considered noxious weeds.

There are a number of reasons to control weeds. They compete with desirable plants for water, nutrients, light, and space. Some weed species harbor insects and diseases that can move to, and infest, ornamental plants. Sometimes weeds pose a public safety hazard. This may occur if weeds block visibility or grow on signs along roads. Certain weeds produce chemicals that people find irritating or allergenic. Ragweed, poison ivy and stinging nettle are examples. Other plants, like water hemlock, horse nettle, black nightshade, and jimsonweed are toxic. They pose a hazard to livestock and even humans. Often, weeds detract from the appearance of a landscape. Some plants are considered weeds for aesthetic reasons.

Most of the plants we consider weeds are very hardy. They are also good competitors. Many weeds produce a large number of seeds. The seeds of some species may remain viable for long periods. In addition, many weeds have good ways to spread their seeds. Some weeds invade new areas by vegetative means. For example, some plants send out 'runners' above or below ground. Dewberry and johnsongrass are examples. Some plants, including certain weeds, produce chemicals that inhibit the growth of other plants. This 'chemical warfare' is called allelopathy.

As with other pests, proper identification is the first step in developing a weed management strategy. Weeds can be classified in several ways. One method is to group them taxonomically, based on their structure and similarity to other plants. Another method is to group them by life cycle. Members of the same taxonomic group usually respond to herbicides in the same way. Weed life cycles are often the basis of an effective management strategy. For example, different methods are often used for perennial vs. annual weeds. This section will discuss both ways to describe and classify weeds.

Plant Taxonomy

There are three major plant groups:

1. Vascular plants (plants with tissue that transports water and nutrients),

2. Mosses and liverworts, and

3. Algae and fungi.

Algae can be a weed problem in irrigation ponds and other aquatic areas. Mosses can occasionally be a nuisance in shady, poorly drained lawns. However, most weeds are members of the vascular plant group.

The vascular plants contain conducting tissue called xylem and phloem. There are three groups within the vascular plants:

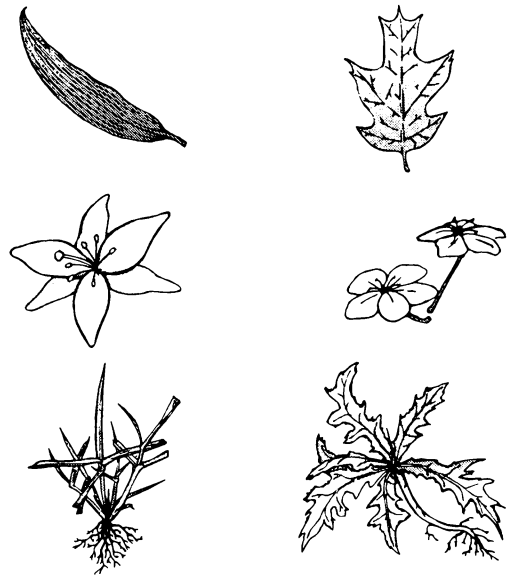
1. Ferns, horsetails, and club mosses;

2. Conifers and related species (pines, spruce, junipers, firs, etc. — plants that bear seeds in cones); and

3. Flowering plants.

Ferns, such as bracken fern, can be weeds in pastures and other areas. Certain conifers, such as red cedar, may also be considered a pest in pastures, along rights-of-way, and in other locations. However, most of the common weeds are flowering plants.

Flowering plants (called Angiosperms) are sorted into two subclasses—the monocots (one seed leaf) and the dicots (two seed leaves). Monocots usually have narrow leaves with parallel veins, and fibrous roots.



Monocot *Dicot*

The flower parts of monocots are in three's or multiples of three. Grasses, sedges, and lilies are monocots. On the other hand, dicots usually have broad leaves with net veins. The flower parts of dicots are in twos, fours or fives. Dicots typically have taproots. Dandelions, clover and oak trees are dicots.

There are several subgroups of monocots. The lily family includes such weeds as wild onion and wild garlic. Both the sedge family (*Cyperaceae*) and the grass family (*Poaceae*) contain important weeds.

Grasses and sedges respond differently to certain herbicides, so it is important to be able to separate these two groups. Grasses and sedges differ in the shape of their stems and in their leaf arrangement. Grass stems are rounded or flattened in cross-section. However, sedges usually have triangular stems. ("Sedges have edges!") When looking down a grass stem, the leaves come out from two directions. When looking down a sedge stem, leaves emerge from three different places. In addition, grasses generally have a row of hairs or a membrane at the area where the leaf blade meets the leaf sheath, called the collar region.

Sedge *Grass*

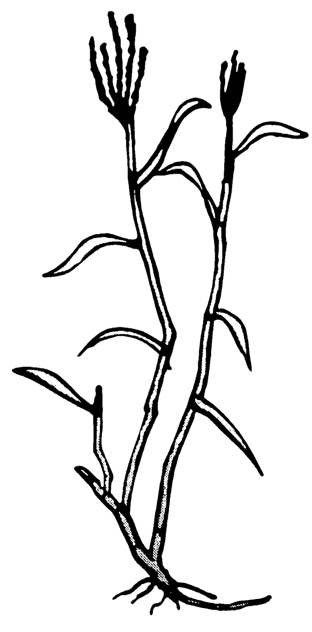
Weed Life Cycles

Weeds can also be classified based on their life cycle. A weed is an annual, a biennial or a perennial.

Annual weeds complete their life cycle — germinate from seed, grow, flower and die — in one growing season. Annual weeds can be divided into summer and winter annuals. Summer annuals germinate in the spring and summer, and flower in late summer or early fall. The first hard frost in the fall usually kills most summer annuals. Winter annuals germinate in the late summer, fall or winter. Winter annuals flower in the spring.

Biennials take two years to complete their life cycle. For the first year, a biennial produces a rosette. In the second year, the rosette produces a flower stalk. Biennials and annuals die after flowering.

Perennial weeds live two or more years. Perennials do not die after flowering. Perennials can be divided into woody species and herbaceous species. Woody perennials have woody above-ground stems that survive throughout the winter. Herbaceous species die back to the ground in the winter. They regrow in the spring from roots, rhizomes,



Annual – Crabgrass

tubers or some other underground structure. Perennials are generally much harder to control than annual weeds.

Here is a short list of common weeds, sorted by both taxonomic group and life cycle.

Annuals

Summer annual monocots:

Grasses — goosegrass, large crabgrass, smooth crabgrass, giant foxtail, barnyardgrass.

Sedges — rice flat sedge.

Summer annual dicots: common ragweed, tall morning-glory, prostrate spurge, redroot pigweed, lambsquarters, common purslane.

Winter annual monocots:

Grasses — annual bluegrass, annual ryegrass.

Sedges — none. (Sedges are warm weather plants and do not grow during the winter.)

Winter annual dicots: bittercress, common chickweed, dandelion (in colder regions of the state), henbit, horseweed, yellow rocket.

Biennials

Only a few biennials are problem weeds. All of these are broadleaf plants. Common biennial dicot weeds are musk thistle, bull thistle, cutleaf evening primrose, common milkweed, yarrow, and queen anne's lace (wild carrot).

Biennial – Bull Thistle

Perennials

Perennial monocots:

Grasses — bermudagrass, quackgrass, johnsongrass.

Sedges — yellow nutsedge, purple nutsedge.

Other monocots — greenbriar, wild onion.

Perennial dicots: poison ivy, horsenettle, field bindweed, dandelion (in milder areas of the state), mugwort, creeping woodsorrel, tree of heaven (*Ailanthus*), multiflora rose.

Perennial – Poison Ivy

A good field guide and/or taxonomic key will help you identify plants, including weeds. With experience, you will learn to recognize the common weeds in your area. If you need help with weed identification, contact your local Extension office. To plan an effective weed management program, you need to identify the problem weed and learn about its anatomy and life cycle.

Test Your Knowledge

Q. What characteristics separate broadleaf plants (dicots) from monocots?

A. Broadleaf plants have a network of leaf veins, flower parts in twos, fours or fives, a taproot and two seed leaves. Grasses have parallel leaf veins, flower parts in threes, a fibrous root system, and one seed leaf.

Q. What characteristics can be used to separate grasses from sedges?

A. Grasses have round or flattened stems. Sedges generally have triangular stems. Grass leaves are two ranked, and sedge leaves are three ranked.

Q. When do summer annuals germinate? When do winter annuals germinate?

A. Summer annuals germinate in spring or summer. Winter annuals germinate in late summer, fall or winter.

Pest Problem Diagnosis Guide

This is a general guide describing the most common visible clues to pest problems. Please refer to sections describing specific pests for details.

Sign(s) or Symptom(s) of Infestation	Possible Cause(s)
Honeydew and/or sooty mold.	aphids, whiteflies, soft scales, mealybugs
Leaves mottled or discolored.	aphids, whiteflies, scales, mealybugs, mites
Leaves yellow, curled or distorted.	aphids, whiteflies, mealybugs, cyclamen mites
Leaves with yellow specks (later bronzed and dry). Webbing.	spider mites
Leaves turn gray or brown.	southern red mites
Leaves and stems with light spots.	soft scales
Leaves yellowing, with a blanched or stippled look. Leaf underside rusty colored. Frass.	lace bugs
White, waxy filaments.	foliar mealybugs
Silver lines and/or dark spots.	thrips
Tiny brown objects on leaves or in branch or stem angles. Leaf drop or dieback. Leaves or growing points distorted.	scales or mealybugs
Evergreen defoliation; small 'camouflaged' bags covered with needles on branches.	bagworms
Defoliation.	weevils
Pinholes in bark. Fine dust near pinholes. Small, wet areas on bark.	borers
Pines with distorted, bushy growth.	pine tip moth

Sign(s) or Symptom(s) of Infestation	Possible Cause(s)
Leaf spots, blotches, blisters or scabs.	disease (fungal or bacterial)
Foliage yellow-green.	insect infestation or root rot
Leaves yellow and drop.	root rot
Roots brown and soft.	root rot
Seeds do not germinate. Young plants wilt and die.	damping off
Rusty-colored orange areas on leaves. Gray or brown lesions may also occur.	rust
Juniper leaf and twig browning and dieback.	juniper twig blight
Foliage appears whitish or gray.	powdery mildew
Tumors, distorted growth.	crown gall
Twigs or branches brown, looking as though singed by a flame.	fire blight
Stunting and poor growth.	lesion or spiral nematodes; fungus gnats, scales, soil mealybugs
Root nodules.	root-knot nematode
Brown lesions on older leaves; leaf death.	foliar (spring crimp) nematode
Holes in leaves, or feeding damage along leaf margins. Silvery streaks on foliage.	snails or slugs

Remember two important things when attempting to diagnose a plant health problem. One, good records are invaluable. Two, some of these symptoms may have abiotic causes (see Unit 2).

Unit 4. Ornamental Pest Management

Learning Objectives

After completing this Unit, the learner will:

- Describe the principles of Integrated Pest Management (IPM).
- Recognize how pests spread, and how to prevent infestations.
- Identify vulnerable stages of each pest described in Unit 3.
- List appropriate methods of controlling selected ornamental pests.
- Describe 'phytotoxicity,' recognize its causes, and discuss how to prevent it.

This Unit discusses the principles of Integrated Pest Management (IPM). It also explains how to prevent pest problems by best management practices and sanitation. This Unit lists management methods for the common pests of ornamental plants found in Virginia. Both chemical and non-chemical control measures are included.

Pest management is a rapidly changing field. New control methods and materials are developed and put to use every year. For this reason, this manual does not include specific chemical recommendations. However, chemical and non-chemical pest management recommendations are available from a number of sources. Here are several:

- Virginia Cooperative Extension Publication 456-017, **Pest Management Guide for Horticultural and Forest Crops**. The VCE Pest Management Guides are revised annually. They contain research-based pest management recommendations customized for pest problems in Virginia.
- The Virginia Tech Insect Identification Laboratory, Plant Disease Clinic, and Weed Identification Clinic. These clinics will identify pests. They will also provide management recommendations. Their services are available to all citizens of Virginia. You may submit specimens and questions through your local Extension Office.

Terms to Know

Abiotic Disorders - Plant health problems arising from poor cultural practices or environmental conditions. Abiotic disorders may be caused by factors such as light, temperature, fertilizer levels, moisture, soil conditions, and chemical exposures.

Annual - A plant that lives for one growing season.

Beneficials - Predators, pathogens or parasites released to control pests.

Biennial - A plant that lives for two growing seasons.

Degree Day - Units of heat above a threshold temperature for one day (24 hours) or an accumulation of heat units over time. Degree days are used to predict insect and disease development.

Directed Spray - Spray applications aimed at a target. Directed sprays avoid contacting desirable plants with an herbicide.

Entomopathenogenic Nematodes - Nematodes that attack insects.

Fungicide - A pesticide used against fungal pathogens.

Geotextile - A general term that refers to landscape fabrics and related materials.

Herbicide - A pesticide used to kill or alter the growth and development of undesirable plants (weeds).

A *contact* herbicide only affects the portions of a plant covered by the spray.

A *systemic* herbicide translocates (moves) throughout a plant.

A *nonselective* herbicide affects or kills all plants.

A *selective* herbicide controls some plants but does not affect all species.

A *postemergence* herbicide is applied to existing weed plants. Postemergence herbicides are applied after weed seeds germinate.

A *preemergence* herbicide is applied to soil prior to weed germination. Preemergence herbicides affect and control germinating seeds.

Infusion - Introduction of liquids into trees in an "intravenous" fashion, without pressure. Infusion uses the "gravity flow" principle, or uptake by the tree's own natural processes.

Injection - Forceful introduction of liquids into trees with a variety of pressure devices.

Inoculum - Infectious (contagious) material. Disease organisms or their spores.

Insecticide - A pesticide used to control insect pests.

Integrated Pest Management (IPM) - A management system that uses all appropriate pest control strategies to reduce pest populations to an acceptable level. IPM uses an ecological approach to pest management.

Landscape Fabric - A woven or nonwoven fabric that allows water to pass through.

Mulch - A substance placed around a plant to control weeds. Many mulches also help plants by conserving water.

Black plastic mulch is made of a solid polyethylene material. Inorganic mulch is made of things like white marble rock, lava rock, or black plastic. Organic mulch is made of pine bark, hardwood bark, pine straw or other materials derived from plants.

Nematicide - A pesticide that controls nematodes.

Nocturnal - Active at night.

Overtop Applications - Treatments applied above ornamental foliage when there is little chance of leaf damage.

Perennial - A plant that lives for more than two growing seasons.

Pesticide - Any substance used to control or repel a pest, or to reduce the unwanted or harmful effects of a pest.

Phytotoxicity - Injury or damage to a sensitive plant caused by a chemical exposure.

Predator - An animal which hunts and kills other animals for food.

Resistance - The ability of a plant to withstand infection or attack by a pest. There are levels of resistance. For example, some plant strains may be susceptible, weakly resistant, or strongly resistant to a specific type of pest. Total resistance is "immunity."

When setting pest management priorities for public landscapes and interiorscapes, horticulturists must consider four factors: human safety, environmental safety, efficacy, and economics. The goal of an Integrated Pest Management (IPM) program is not the eradication of all pests from the management area. The landscape or interiorscape as a whole is the managed area. It should be viewed as an ecosystem. As a rule, the most effective IPM programs use an interdisciplinary approach.

A good pest management program prevents pest problems whenever possible. In plantscapes, such programs begin by using high quality, disease and insect free plants. If possible, choose resistant strains or varieties. Environmental controls and cultural practices provide the best conditions for plant health. Maintenance emphasizes sanitation of plants, tools and containers.

Remember that environmental stresses weaken plants. Imbalances in light, temperature, moisture and soil conditions produce abiotic disorders. Unhealthy plants are much more vulnerable to pest pressure. Healthy plants are less susceptible to damage from pathogens, insects and mites. They are more able to compete with weeds.

Routine inspection results in early detection and identification of problems. Inspection is essential for any successful IPM program. If plants and plant health are not monitored, pest populations may exceed tolerable levels before being detected. Specific inspection intervals depend on the plant, pest, site, and season. Focus your attention and efforts on key pests, plants, and locations.

A key pest in ornamental plant systems meets at least one of following criteria:

1. It occurs regularly in densities that justify management.

2. It attacks and damages very conspicuous or valuable plants.

3. At low densities, it is capable of killing or disfiguring a plant or transmitting disease.

Key plants in ornamental plant systems meet one of the following criteria:

1. They are very conspicuously located, are unusual and unique, or historically significant specimens. Even if they sustain infrequent damage, they need more attention because of their placement in a landscape or their historical value.

2. They sustain damage from pests on a regular basis, or have a particular pest that can kill or disfigure them in low densities.

Key locations in landscapes and interiorscapes are:

1. Areas that merit frequent attention because they are heavily used or are significant in some way.

2. Areas where plants have chronic problems with pests, and sites that have more severe pest problems than plants of the same species growing in different locations. An

example of a key location is an isolated plant in a site with high exposure to sunlight, like a single tree or shrub in the middle of a lawn. Many insect and mite problems are more severe on plants in isolated locations.

The tactics described here provide the framework for Integrated Pest Management (IPM). IPM programs use all appropriate pest control strategies to reduce pest populations to an acceptable level. IPM programs use an assortment of specific strategies aimed at providing the desired control for the site and situation. When an infestation or disease requires action, IPM plans use the best of one or more applied controls. These may include biological control, cultural control, mechanical control, and chemical control.

A primary point in developing an IPM program is determining what is an acceptable pest population. In many cases, low numbers of pests may be present without a major loss in plant quality or plantscape attractiveness. In fact, a limited number of pests are necessary for some biological controls. For example, natural predator populations cannot survive without a food source. If consumers and the public will tolerate low pest numbers, a wider choice of control methods is possible. A desire to eliminate all pests limits control options. In some situations, a zero pest population level is not possible or necessary.

Features of the installation affect the use of various controls. Hand removal of pests is too costly for large sites. Predators released in areas with few barriers may be lost. Pesticide use options may be limited. Many products are not labeled for use in some sites. Many labels carry restrictions or special precautions intended to protect sensitive areas. For example, some products may not be used near food service areas. Others have special precautions for use near childcare and healthcare facilities. Many have restrictions to protect water quality. Other considerations include availability of predators, control costs, possibility of objectionable odors and access to installations during non-use hours.

An all-too-frequent cause of pest problems is pesticide misuse or overuse. Both can lead to outbreaks of secondary pests. Overuse can also lead to resistance in target pests. Applying pesticides 'off label' is illegal. Applying properly labeled pesticides at ineffective times and using pesticides to prevent an anticipated problem may contribute to secondary pest problems and target pest resistance.

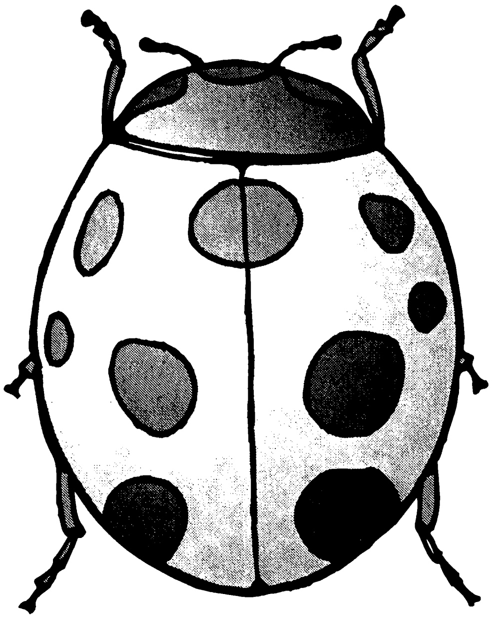
IPM plans are not meant to be static. They change, based on results and to take advantage of new materials and methods. Pest management procedures may produce unanticipated or undesirable effects. Always monitor the effects of your pest management actions. Adjust your plan as needed.

Biological Control

Biological control involves a number of different management tactics. All, however, use some aspect of the pest's biology to combat it. One traditional method involves the use of natural enemies — parasites, pathogens or predators that attack the pest. A natural enemy is a biological agent that controls a pest.

One type of natural enemy is a predator. As a rule, insect predators must be present in large numbers to manage a pest population. For this reason, releases of predatory insects work best in closed settings where the predator will find adequate food. They do not work well on single plants. Predators may not control large populations. However, in some cases, they will keep small populations small.

Successful use of predators requires careful, regular inspection. Accurate information on numbers of both pests and predators is necessary. Locate and identify serious or recurring pest problems. Monitor populations of specific pests. Act when numbers approach the visible injury level.



Ladybug Beetle

Also, check the number of predators remaining and the success of their activity. This requires the ability to identify both pest and predator species. When releasing predatory insects, keep a few individuals for comparison purposes. This will allow you to recognize them during later inspections.

In established plantings, the switch from chemical to biological controls takes careful planning and timing. For example, if a release of beneficial insects or nematodes is to be successful, residues of toxic chemicals must be gone. The time needed for pesticides to break down varies. Two important factors are the half-life of the pesticide and the environmental conditions of the site.

You can attract and sustain beneficial insects with flowering plants. Flowers serve as alternative food sources for many predators and parasitoids.

The active ingredients in some registered pesticide products are organisms or their byproducts. Examples include 'milky spore' disease and *Bacillus thuringiensis* (*Bt*) toxins.

Some pesticides are compatible with biological control organisms if used as directed. These include insecticidal soaps, petroleum oils, and *Bacillus thuringiensis* formulations. If other pesticides are used, they must be managed with care so biocontrol agents are not exposed to them.

Biological control systems using natural enemies work best when they have time to become established. In ideal situations, the number of beneficial organisms comes into balance with pest populations at a level below the visible injury rate. Once a biological control program involving predators or parasites is established, you may need to make additional releases.

Biological control includes the use of altered pests. An example is the release of large numbers of irradiated sterile male insects. The sterilized males compete with normal males for mates. However, they do not produce offspring when they mate with normal females.

Biological control also includes the use of pheromones or juvenile hormones to control insects. You may use pheromones in traps to monitor pest populations. In some situations, pheromone traps are also a very good control method. They are most effective when used to control insects that are pests in the adult stage. Applications of juvenile hormones can prevent immature insects from becoming normal adults. Since only adults reproduce, exposure to juvenile hormones can lower pest populations. Juvenile hormone applications are most useful when the pest does damage in the adult stage.

Cultural Control

Cultural control refers to changing the physical environment of the plant, its condition, or the behavior of the pest. Cultural control measures disrupt the normal relationship between pest and host in order to prevent or suppress an infestation. Cultural controls make the pest less likely to survive, grow or reproduce.

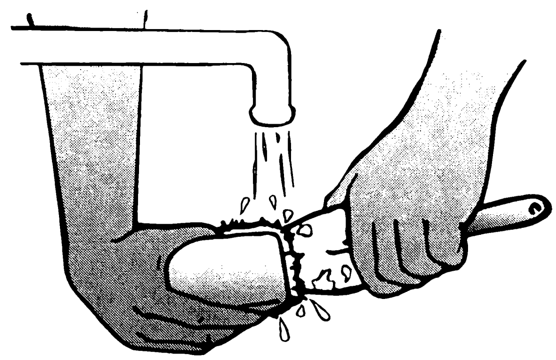
Common cultural practices include cultivating soil. Hoeing and hand weeding fall into this category. Hand removal of insects is a cultural control tactic. So are varying planting times and planting trap crops. Other cultural control methods include adjusting spacing or row width, pruning, and thinning. If possible, remove soluble salts. In an interiorscape, you may change the light, heat or humidity regime. Outdoors or indoors, change watering or fertilization regimes. Isolate and treat or remove and discard infected or infested plants or plant parts.

Mechanical (Physical) Control

Mechanical controls involve the use of some mechanical device or machine to control pests. For example, aerating soil is a mechanical control. Use of traps, screens, nets, or other barriers to prevent pests from entering an area are also examples of mechanical control. Other practices include the use of sticky yellow monitoring cards for flying insects.

Sanitation

Sanitation involves general cleanliness. This is a way to reduce the levels of pathogens and other pests in the plantscape. Using pest-free seeds or seedlings is a sanitation strategy. Careful disposal of diseased parts pruned from plants is another. Sanitation also involves using clean growing media. Washing plants with soap and sanitizing feather dusters used in interiorscapes are examples of sanitation.



Tools and containers must be clean to prevent spreading pathogens from one plant to the next. First, remove accumulations of soil, plant sap or other debris. Then, disinfect tools, equipment, and plant containers. Once

Treatments For Disinfecting Tools, Equipment, and Containers

MATERIAL / RATE	APPLICATION	TARGET PESTS
70% alcohol (grain, rubbing, or wood)	Dip or swab object and let dry. Do not rinse.	Insects, nematodes, bacteria, fungi
Sodium hypochlorite (Clorox) 10% solution	Dip, spray or brush on. Keep wet for 10 minutes, and then rinse with clean water.	Nematodes, bacteria, fungi
Steam or dry heat	Heat materials to 180-200° F for 30 minutes under cover to contain heat.	Weeds, insects, nematodes, bacteria, fungi

cleaned, tools must not come in contact with dirty surfaces. Place them in a bucket of disinfectant, wrap them in clean newspaper, or place them in a clean plastic bag when not in use.

Chemical Control

Pesticides are chemicals designed to kill diseases, insects and other pests. However, they can also harm humans or nontarget organisms in some situations. For that reason, it is extremely important to use them properly.

A pest control program that relies only on pesticides is severely limited. This is true for a number of reasons. In some cases, there are few or no legal, effective pesticides registered for use. Federal and State regulations govern all pesticide uses. In many situations, only certified applicators may use pesticides. In some cases, customers or the public object to the use of chemical controls. Increasing pest resistance is another issue.

However, a sound, effective IPM plan often includes chemical controls. When selecting a pesticide, always follow these steps.

1. Identify the source of the problem. Be sure a pest caused it. Be sure a pesticide can solve the problem.

2. READ THE LABEL. Be sure you can use the product for the problem at hand, and in the manner you plan to use it. Consider efficacy, timing, site, equipment available, etc. Be sure the product will not leave an offensive odor or residues.

3. Be sure the product has a low potential for producing phytotoxic effects.

The label is the law! It provides specific directions on how to use a pesticide product. Never do anything the label prohibits. Always follow label directions to the letter. Pesticides may only be used on sites and plants listed on the label. Follow directions specifying use amounts (application rates, number of applications) exactly. Legal use of a pesticide does provide for the following:

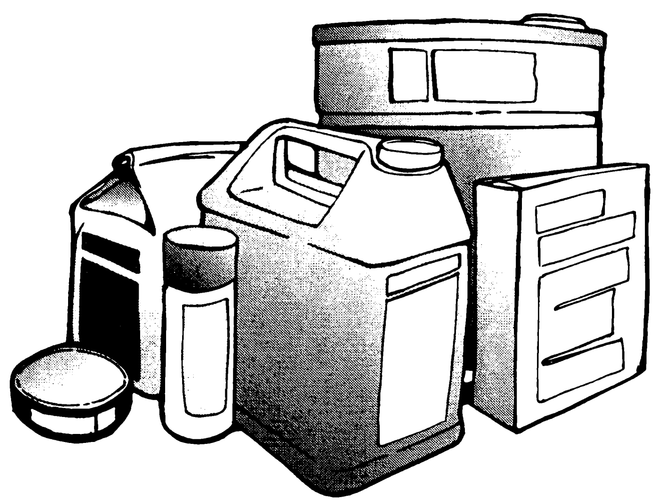
- Applying pesticides at a concentration or frequency less than that specified on the label.

- Applying a pesticide for a pest not listed on the label. However, the site or plant must be labeled, and all instructions (timing, application equipment) must be followed.

- Mixing with fertilizers and other pesticides unless specifically prohibited by the label.

- Removing plants from an interiorscape and treating them outdoors when interior use is prohibited by the label.

For some interiorscape uses, it is important to note where and how plants may be treated. Again, read the label. Some label directions prohibit use indoors. This means that interiorscape plant material may not be treated on site. In such cases, you must move plants outdoors or to a properly ventilated treatment area. Often, treated plants must remain out of the interiorscape for a period after pesticide application. Waiting periods protect workers and other people from the risk of pesticide exposure. For further protection, the treatment area must be secure, without public access. It is a good idea to post holding areas with warning signs.



Phytotoxicity

Phytotoxicity is plant injury. Phytotoxic effects may be caused by exposure to chemicals, including pesticides, fertilizers or growth regulators. They may also be the result of accidental or careless exposure to cleaning solutions or other harsh chemicals. Air pollution and acid rain cause phytotoxic effects. For pesticides and fertilizers, the following situations may result in phytotoxicity:

- Using a material improperly (ex: wrong site, rate, time of year).
- Applying a chemical during adverse environmental conditions.
- Offsite movement (for example, due to drift or runoff).
- Accumulation of persistent residues in the soil or on plant surfaces.

Symptoms of phytotoxicity include:

- death of rapidly growing tissues,
- stunting or delayed development,
- misshapen or distorted stems, leaves or fruits,
- russeting or bronzing of leaves or fruit,
- dead spots or flecks on leaves, dead leaf tips or margins, and dead areas between leaf veins.

Dead spots of uniform color that go through the leaf may also be clues to phytotoxicity. In addition, evidence of plant damage without signs of plant pests may indicate a chemical imbalance is the source of the problem. Another warning sign is injury occurring over a short period of time that does not spread from plant to plant. For pesticides, consult spray records. They may tell you that a pesticide the injured plant is sensitive to was used nearby.

Here is a short list of factors that influence phytotoxicity.

1. Pesticide / Plant Growth Regulator (PGR) Active Ingredient Characteristics:

   Some plants are very sensitive to certain chemicals. That is one reason to be sure that the product label lists the plant/site you wish to treat. Use pesticides according to label directions to prevent overexposure.

2. Formulation Characteristics:

   Dusts and wettable powders are generally less phytotoxic than emulsifiable concentrates (EC's). EC's can sometimes dissolve the waxy coating on plant surfaces.

3. Additives:

   Some additives such as spreaders, stickers, and wetting agents may cause plant injury.

4. Concentrations:

   The use of chemical concentrations higher than label rates is likely to cause plant injury. Exceeding the label rate or the number and interval of applications is illegal. Applying a material more frequently than the label directs may result in a toxic buildup. This is especially true of soil drenches.

5. Method of Application:

   If the label describes a specific method of application, use it. Be sure foliar applications are thorough and even. High-pressure sprays may force chemicals into sensitive tissues.

6. Growing Conditions:

   Temperatures during and after treatments should be moderate. High temperatures favor chlorinated hydrocarbon and sulfur toxicity. Low temperatures favor oil, carbamate, and organophosphate toxicity.

Unless the label states otherwise, treat foliage when dry. Wet foliage at the time of application or prolonged wetness of foliage after spraying can result in injury.

7. Plant Growth Stage:

   Seedlings and fast growing, tender young tissues are often more sensitive to chemicals.

8. Mixing Pesticides or Pesticides and Fertilizers:

   Some chemical mixtures are incompatible. In some cases, chemicals may react to form a new substance, which may be harmful to the plant you wish to protect. If product labels do not have tank-mix instructions, do a 'jar test.' Mix a small amount of the chemicals in the same proportion you will apply them. Observe this mixture for visible signs of a chemical or physical change. If you do not see any danger signals, apply the mix to a test area and watch for signs of phytotoxicity. Use the tank-mix only if there are no ill effects.

To avoid phytotoxicity:

1. Be certain the pesticide or PGR label lists the plant or site you wish to treat.

2. Measure and prepare the chemical carefully, following all label directions. Be sure you are using the proper concentration.

3. Use the proper application technique.

4. Do not apply chemicals to plants under stress. Avoid treating plants in the heat of the day. Make spray applications when conditions will favor drying of wetted plant surfaces.

5. Manage the application to prevent off-target movement. Protect nearby plants that may be sensitive.

6. Do not apply a chemical more frequently than the label directs.

Arthropod Pest Management

Successful arthropod pest management depends on a working knowledge of the pest's life cycle. Effective programs are tailored to the pest (biology and habits) and to the landscape. Chemical control options and application methods vary from pest to pest. A problem-solving approach to pest management is critical. IPM involves identifying the pest, learning about its life cycle, and using a combination of appropriate management measures. IPM means planning a management program that involves minimal disruption of the natural enemy complex and the environment. Safety should be a major consideration in deciding if, when and how to use a pesticide.

The following is an alphabetical list of the common insect and mite pests described in Unit 3. For each, management strategies are noted. These methods include cultural and biological tactics.

Aphids, Families *Aphidae, Eriostomatidae,* and *Chermidae*

On a weekly basis, spray warm soapy water directly on these insects. Remove aphids with alcohol on a cotton swab. Remove weed host plants. Prune infected areas and sterilize tools. If possible, increase humidity to discourage these pests.

Ladybugs, lacewings, and the predatory midge, *Aphidoletes aphidimyza*, can control aphids in some situations.

Spray foliage, crown, and buds or wherever aphids are present with a properly registered pesticide. Use systemic insecticides to minimize the impact on beneficial insects.

Azalea Lace Bug, *Stephanitis pyrioides*

Do not plant azaleas in full sun.

Control nymphs hatching from overwintering eggs before they become adults and lay more eggs. Monitoring should begin when azaleas are in bloom. During the summer, be alert to reinfestations from nearby plantings.

Direct foliar insecticide sprays to the undersides of the leaves. Sprays are most effective if high pressure is used.

Bagworm, *Thyridopteryx ephemeraeformis*

Picking off the bags can control infestations on small trees and shrubs. For best results, remove bags in the winter and spring, before the eggs hatch. Collect and destroy bags you pick off infested plants.

Chemical control is only effective in spring and early summer, when the bags are 1/4 to 1/2 inch long. Treat before or as soon as there is noticeable damage to plants. Bt is an effective choice at this time.

Bark Beetles, Family *Scolytidae*

The only effective management strategy is to avoid bark beetle attack in the first place. Once bark beetles are inside a tree, they are out of the reach of most control measures. As a rule, bark beetles do not attack healthy trees. Cultural methods that encourage vigorous plants are the most effective management tool. Monitor plants for this pest. If you notice bark beetle damage, prune and destroy infested limbs to prevent this pest from spreading.

Black Vine Weevil, *Otiorhyncus sulcatus*

The best time to control the black vine weevil is in early spring, when the adults first emerge. For the first three weeks of their adult life, the weevils do not lay eggs. Using a foliar insecticide in early June to control young adults may avoid problems. However, these insects are often common and numerous in the landscape. Therefore, effective control is often very difficult and short-lived.

Boxelder Bug, *Boisea trivittata*

These insects feed primarily on the fruits of female boxelder trees and other members of the maple tree family. Removing female boxelder trees is a management option. Removing large accumulations of leaves close to structures may discourage overwintering by large numbers of adults and nymphs. This, in turn, may reduce populations next year.

Treat adults and nymphs with liquid insecticides in the late summer and fall. Several applications may be necessary, especially if populations are large. Treating infested trees when nymphs are small may also reduce populations.

In the home, a vacuum cleaner is an effective way to remove these insects. Do not crush them because they can leave a red stain on fabrics and other porous surfaces.

Boxwood Leafminer, *Monarthropalpus flavus*

Planting resistant varieties of boxwood is the best management method for this pest. Apply systemic insecticides to control larvae. Foliar insecticides may be effective against the adults. Because the adults are only alive for a few days in the spring, timing is very important.

Boxwood Psyllid, *Psylla buxi*

Use foliar insecticides early in the spring to avoid damage to leaves.

Bronze Birch Borer, *Agrilus anxius*

The best way to manage this pest is to avoid planting white birch in Virginia. The river birch is a similar looking tree, and it shows resistance to bronze birch borer. Tree bark protects bronze birch borer larvae. Therefore, it is difficult to control them with chemicals. However, insecticides may control adults during their spring flight.

Dogwood Borer, *Synanthedon scitula*

Avoid mechanical injury with lawn mowers by placing a guard around the trunk. Prevent borers from entering trees through injured bark surfaces. Protect pruning cuts and other openings with tree wound dressing.

Pheromone traps can help you decide on an optimum time for spray applications.

Eastern Tent Caterpillar, *Malacosoma americanum*

Usually, nests are in the crotches of trees. Therefore, it is not practical to remove them by pruning. Sometimes nests are burned, but burning can cause more damage than the insects.

If insecticides are used, apply them to foliage of infested trees when nests are small and larvae are young. Do not treat migrating larvae. They will not cause further damage because they have finished feeding.

Fall Webworm, *Hyphantria cunea*

The best and easiest control method is removing infested branches by pruning.

Fall webworm damage occurs late in the season. As a rule, infested trees do not suffer permanent damage. Usually, insecticides are not used to control this pest. If insecticide is necessary (for example, if a small tree has so many nests that pruning all of them is not an option), it must be applied with enough force to penetrate the silken nest and reach the leaves.

Fungus Gnats, Family *Sciaridae*

Use sterilized media with reduced amounts of bark or peat moss. Avoid overwatering. Do not crowd plants. Use yellow sticky cards to monitor and control flying insects. Remove fallen leaves or flowers from soil surface. Replace the top four inches of soil with fresh sterilized soil. Wash pot saucers to kill maggots.

Spray the surface of growing media to control emerging adults. Make several applications, four to five days apart. Soil drenches at two to three week intervals will control larvae. Entomopathogenic nematodes are also effective.

Gypsy Moth, *Lymantria dispar*

Gypsy moth is a very difficult pest to manage, especially when it infests mature trees. However, healthy trees can withstand more defoliation than trees under stress can. Whenever possible, protect landscape trees from pests, injury, competition, and other causes of stress.

There are several ways to minimize gypsy moth damage in the landscape. These include destroying egg masses and installing barriers to control crawling caterpillars.

Foliar insecticides or growth regulators are applied to large forest tracts. Trees in parks and cities may also be sprayed to control this pest. However, foliar applications may not be practical for small landscapes.

Galls

Controlling gall insects is difficult. Any treatment applied after galls are present is useless, because the galls will remain after the parasite that caused them is dead. Most galls are not injurious and are of no economic importance. Most plants can support many galls and continue to grow normally. Pruning heavily galled portions of a plant may improve its appearance. Removing pruned sections may also reduce gall insect populations.

Hemlock Wooly Adelgid, *Adelges tsuga*

Insecticide treatment is currently recommended for this insect. For smaller trees, horticultural oil is effective if the spray can cover the entire tree. Use a 1% rate from May through September and 2% at other times. Insecticidal soap may be effective, but it may be toxic to the tree. For large trees, soil drench applications of systemic insecticides are an effective (but expensive) option. Systemic treatments should be applied in the spring. High rates of nutrient movement will transport the insecticide to all parts of the tree.

Holly Leaf Miner, *Phytomyza ilicicola*

Parasites may partially control the leaf miner population.

For control of heavy infestations, apply insecticides after the fly emerges in the spring but before they lay eggs. If the spray is applied too early, a second application may be necessary. Control young miners with a foliar application of a systemic insecticide in July.

Japanese Beetle, *Popilla japonica*

Treatments exist for both the grub stage and the adult stage of this pest. When treating plants to control adults, a foliar spray of insecticide may be effective. However, foliar applications will probably need to be repeated regularly. Japanese beetle traps are effective for monitoring populations. However, they are not reliable for adult beetle control. Apply grub treatments to turf when you detect eight to twelve grubs per square foot.

Locust Leafminer, *Odontota dorsalis*

Black locust is not often planted as an ornamental or shade tree. Despite the degree of visible damage this pest causes, locust leaf miner does not usually kill host trees. Therefore, pest management action is usually unnecessary. If treatment is called for, a systemic insecticide applied in spring when adults are active will be most effective.

Mealybugs, Families *Pseudococcidae* and *Eriococcidae*

Choose plant species least susceptible to damage and infestations. Prune infested branches. Increase amount of light an infested plant is receiving.

The Australian lady beetle, *Cryptolaemus montrouzieri*, is somewhat effective for most species of foliar and aerial mealybugs. This beneficial insect will also feed on aphids and immature scale insects when mealybugs are in short supply. Lacewings and parasitic wasps may control mealybugs.

For small, confined infestations, spray a mixture of alcohol and water directly onto the insects. Alternatively, dab insects with a cotton swab dipped in alcohol. Repeat weekly until problem is under control.

Use insecticides to control heavy infestations. If foliar sprays are used, they should contain soap or a wetting agent to penetrate the protective wax covering over the adults and egg sacs. Another chemical control means is the use of systemic insecticides, applied to soil or the potting medium.

Mites, Order *Acarina*

Most types of mites do well in hot, dry conditions. Outdoors, the onset of hot weather causes mite population growth to increase. Rainfall or overhead irrigation will suppress mite populations. Indoors, increase humidity if possible. Mist plants frequently. Remove plants from hot, dry areas. Filter sunlight with curtains or blinds. Lower fertilizer rates and keep infested plants moderately moist at all times.

Use predatory mites. Species of beneficial mites include P*hytoseiulus persimilis, Metaseiulus occidentalis, Amblyseius californicus*, and *Alimonicus spp.*

Spray foliage of infested plants with an insecticidal soap or a miticide. Apply a systemic miticide to the soil of the infested plant. Repeated applications of a miticide are sometimes necessary to prevent or control population explosions. Rotate materials to avoid developing resistance in a pest population.

Pine Tip Moth, *Rhyacionia frustrana*

These pests are most vulnerable in the adult stage. However, they are easy to overlook. Adults are small, and they usually fly at night.

Planting resistant varieties can minimize damage. Infestations of established trees may be managed by controlling adults with insecticides. Timing of applications, particularly those made in early spring and mid-summer, is very important. Pheromone traps and degree-day models can help in planning.

Scale Insects, Family *Diaspididae* (Armored Scales) and Family *Coccidae* (Soft Scales)

Prune infested branches before crawlers hatch. Mist or hose plants to remove sooty mold and honeydew and to dislodge crawlers. If possible, increase the amount of light the plant receives.

Two small lady beetles, *Chilocorus nigritus* and *Lindorus lophanthae*, control both soft and armored scales. The parasitic wasp, *Metaphycus helvolus*, controls several soft scale species, particularly hemispherical scale. The tiny parasitic wasp *Aphytis melinus* controls a limited number of armored scale species.

Treat plants with insecticidal soap, petroleum oil or foliar insecticide sprays every two to four weeks when crawlers are present. Note that soaps may cause discoloring, especially in hot weather. Be sure to cover the undersides of leaves. Sprays do not affect adult females. Usually, bringing an infestation under control requires two to three applications. Instead of foliar applications, systemic soil-applied insecticides may be used.

Thrips, Family *Thripidae*

Sanitation is important, as is weed control. Mist or rinse plants several times a week to wash off adults and larvae. Use yellow sticky traps to monitor and reduce population. Remove or prune out affected plant parts.

Predatory mites, *Amblyseius cucumeris* and *A. mckenziei*, offer some control. Some types of nematodes may also control thrips that pupate in soil.

Chemical sprays may be used as well. As a rule, several applications are needed.

Two Banded Japanese Weevil, *Callirhopalus bifasciatus*

The Japanese weevil is often overlooked because of its size and color. However, early detection is essential for control of this insect. Insecticide applications in early July will suppress this weevil before it lays eggs.

Whiteflies, Family *Aleyrodidae*

Select cultivars or plant species least susceptible to whitefly infestations. Mist frequently to remove honeydew and sooty mold on leaves. Prune infested plants. Use yellow sticky traps to monitor and reduce populations.

The parasitic wasp, *Encarsia formosa*, has been used successfully for over 50 years to control whiteflies indoors. A fungal disease, *Verticillium lecani*, controls both adults and larvae. However, this disease also affects the parasitic wasps.

Management with chemical sprays alone is difficult, because the eggs and immature forms are resistant to many insecticides. Contact foliar sprays and systemic soil-applied insecticides may be effective in some situations.

Disease Management

Understanding the factors that favor or cause plant diseases will help you plan a management program. In some cases, environmental stresses (heavy soil, too much water, temperature extremes, etc.) bring on ornamental diseases. In such situations, plant managers must deal with these situations in the most practical way. If possible, remove the abiotic cause(s) that predispose the plant to disease.

However, in many cases we can avoid plant diseases by keeping the plant away from the disease organism. This might be culturing or planting plants or seeds in clean soil. Another method is growing plants or planting seeds at a time or in a site in which the disease organism will not be present.

Diseases may enter the plantscape environment in many ways. Sources of the disease problems may include:

- Diseased plants in the landscape or interiorscape.
- Debris from diseased plants.
- Infected soil used as a potting mix. Infected soil on tools, in reused containers or liners, or on hose ends.
- Contaminated water in reservoirs for hydroponic systems, fertilizer proportioning systems, and irrigation systems.
- Air-borne spores.
- Infected plant material — seeds, seedlings, bulbs, cuttings, and rooted plants.
- Insect or mite vectors.

Good sanitation can prevent many of these problems.

If a disease is introduced to a nursery, greenhouse, or garden center and sanitation practices are not followed, the pathogen inoculum may build up to a high level quickly. Plants coming from that site will almost certainly be infected. Nurseries and greenhouses are especially vulnerable to pest problems. This is true because nursery and greenhouse plants grow in close proximity in confined (and maybe enclosed) spaces. Often, plants of the same type grow in the same section. It is important, then, to choose a supplier with care. Be sure to use only healthy plant material.

If the plant and pathogen (disease organism) are both present, the best way to manage disease is to reduce the inoculum. That is, if we can keep the pathogen at very low levels, we can often grow our ornamentals successfully. This is why, in times past, people had sanatoriums for tuberculosis patients. By keeping diseased individuals away from the healthy population, we kept the amount of bacterial inoculum to a minimum. This reduced the incidence of disease. If, for example, a planting of pyracanthas ("firethorn") in a nursery liner has fire blight, we need to prune out (well beyond the blackened tissues) all diseased tissues. Destroy infected cuttings by burning or burying them. This keeps the amount of bacteria in the environment down to a very low level. This sanitation practice may eradicate the disease. Another way to resolve many plant diseases in situations such as this is to use resistant plant stock that will not contract the disease in the first place. However, resistance is not always possible.

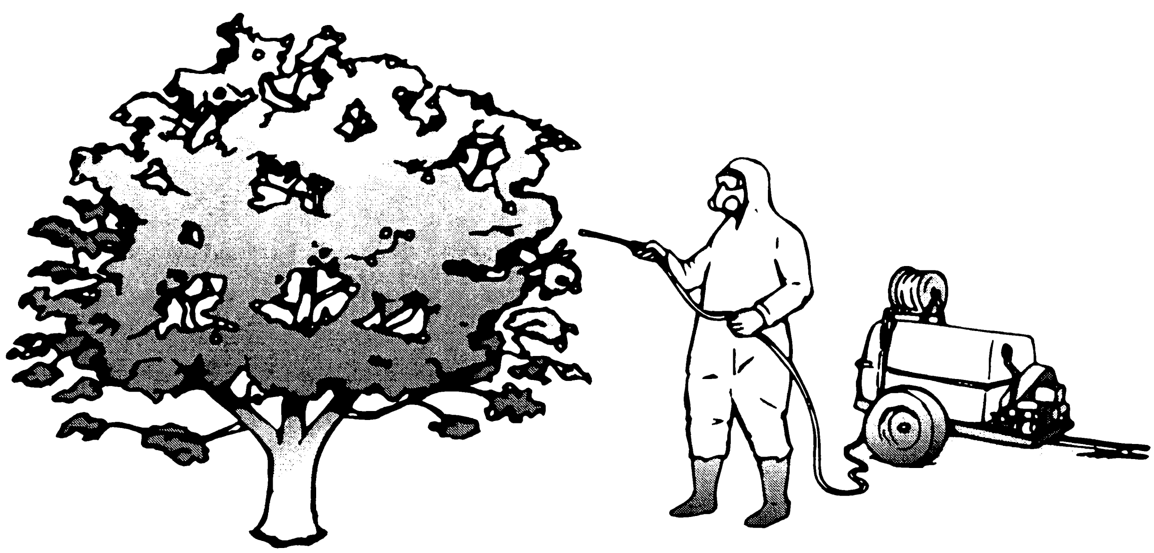
Disease Cycles and Pathogen Life Cycles

Knowledge of the cycles of the diseases and of the microorganisms that cause them is crucial to successful disease management. If we know these cycles, we can break the weak link in the cycle. Often, this allows plant managers to lower the incidence of disease or avoid some diseases altogether.

A good example of this is one of the many leaf spot diseases, dogwood anthracnose. This new fungal disease is lethal to the native flowering dogwood, *Cornus florida*, the state tree of Virginia. The fungus produces spores ("seeds") in early spring during long, wet periods. At this time, spores are deposited onto newly forming (expanding) leaves. In addition, some spores may already be in the opening bud. To control this disease, apply an effective fungicide at budbreak, and twice thereafter as the leaf is expanding. This keeps a coating of a fungus-killing material on the leaf. Protecting the leaf kills anthracnose spores before they germinate and penetrate the leaf, causing the leaf spot (lesion). Fungicide application is worthless after the lesion (spot) has developed. Therefore, knowing when the disease is initiated and knowing when the fungal spores will be deposited (the cycles) is crucial in managing this disease.

So it is true with most — if not all — other diseases! Another example is Dutch elm disease. The European bark beetle carries this disease. It deposits the fungus causing this disease in young twig crotches in the tree crown in early spring. One effective way to manage infection is to prevent the beetle from inoculating the tree. Another way to manage the disease is to inject a systemic fungicide into the tree before the fungus arrives. Like fireblight, removal and destruction of all diseased tissues and sick trees will manage Dutch elm disease successfully, probably even without doing anything else.

Plant health managers should consult the VCE Pest Management Guides for current information on what, when and how to use plant protection chemicals. Since new materials or technologies are constantly changing, one must keep up to date. Pesticide applicator recertification sessions



and professional organization meetings offer good continuing education programs.

Classes of Fungicides

Fungicides are grouped into "families" based on their chemical structure. They can also be grouped based on how they are applied: contact or foliar sprays vs. systemics applied as drenches to roots or injected into trunks/stems. Finally, they may be grouped by how they work. For example, some prevent fungal growth, while others cure existing disease. How a pesticide works is called its "mode of action."

The oldest fungicide is sulfur. It is still effective in some cases. Other 'older' fungicides, such as copper compounds and the dithiocarbamates, are still widely used. Newer fungicides include the sterol inhibiting ("SI") fungicides. Disease management options change constantly. New products come to the market every year. Sometimes, old products are withdrawn or cancelled. For that reason, it is very important to keep up with pest management research and follow current, valid recommendations.

Management Strategies for Selected Diseases

Following is a short description of ways to manage the diseases described in Unit 3.

Bacterial Diseases

Sanitation is an important way to manage bacterial diseases. Promptly remove and destroy infected plants or plant parts. Splashing water, contaminated hands and pruning tools may spread bacteria.

In interiorscapes, control systemic bacterial diseases through a combination of sparse watering and low fertilization. Cooler temperatures may control some bacterial diseases.

Chemicals may control some bacterial diseases. However, some pesticides may not be effective if the pathogen is systemic.

Crown Gall

The best way to manage this difficult disease is to choose resistant plants. Infected grafting or cutting (pruning) tools commonly transmit the bacterium (pathogen). The pathogen resides in soils. Placing a susceptible plant in infested soil may initiate the disease. Therefore, sanitation is a good preventative measure. This disease is often more serious in limed than in acid soils. This is because bacteria tend not to flourish in acid environments. To manage this disease, plantscapers should be sure soil is not infested. Discard any infected plants. Disinfect tools.

Biocontrol measures using a competing bacterium are effective in certain situations. There are few effective chemical control options for this disease.

Fire Blight

The first step in managing fire blight is monitoring — both the plant's growth stage and the weather conditions. This disease can be managed by an integrated approach: timely applications of bactericides, pruning old infections, and sanitizing cutting equipment. A good way to prevent having the disease is choosing resistant strains of plant material.

Viral Diseases

There are several ways to manage viral diseases. Purchase only virus-free plants. Destroy infected plants. Disinfect tools used on virus-infected plants. Avoid wounding plants. Control sucking insects that spread viral diseases.

Currently, there are no chemicals registered to cure a virus-infected plant.

Fungal Diseases

A number of fungicides are available. Some are very effective. However, others are relatively ineffective, and some are totally ineffective. This lack of efficacy may be due to the nature or quantity of the active ingredient in the product. It may also be due to other factors; for example, because of the anatomy of the plant, pest life cycle stage, or climatic conditions.

Leaf Spots

Air, water, insects, or people can spread fungus leaf spot disease organisms. Take care when handling infected plants. Cultural control includes trimming out and destroying all infected portions of the plant. Avoid splashing water on leaves. Reduce humidity levels if possible. Thinning can improve air circulation. Disinfect tools and equipment.

Fungicides control many leaf spot diseases. Make applications in early spring at budbreak, and follow with several more foliar sprays as the new leaves are expanding. Leaf development depends on climatic factors (temperature and moisture). As a result, there is not always a 'cookbook' formula. However, timing is critical. One cannot cure a leaf spot once it has developed; one can only prevent the lesion from developing.

Rusts

Because they have two hosts, some people think that eliminating the alternate host can control rusts. However, often this is not practical. For example, it is unlikely that one can manage apple rust by destroying all the cedar trees in the vicinity of a crab apple to control the disease. One may apply a properly labeled fungicide to prevent the lesions from developing.

Juniper Twig Blight

Proper diagnosis is important, since winterkill or even voles (mouse-like rodents) may cause similar symptoms in juniper ground covers. Fungicides can be very effective in managing this complex of diseases.

Scabs

Sanitation (removal and destruction of diseased plant tissues) is recommended as a first step. There are, however, effective fungicides to control this type of disease. One should always try to use disease-resistant cultivars if available.

Powdery Mildew

Often, sound cultural practices can control powdery mildew. Water plants earlier in the day to allow humidity levels to drop by afternoon. Do not crowd plants. Thin branches or use other means to allow for good air circulation. However, avoid cold drafts in interiorscapes. Also, avoid extreme variations in moisture. If possible, do not splash water on foliage. In some cases, it is effective to trim off and destroy infected plant parts.

Use an appropriate fungicide as the need arises. Careful product choice and timing of application are required for effective management on susceptible plants.

Root Infections / Root Rots

Using resistant cultivars and observing strict sanitation measures are good ways to prevent this disease. Manage root rots in the early stages to avoid losses. Carefully inspect new plants before placement. If root rot is present, do not use the plant.

Avoid stressing the plant by creating a favorable root environment. Keep soil from becoming compacted. Avoid excessive dryness or wetness. Low soil temperature, low light intensity, poor air circulation, and overcrowded plants favor the growth of root rot fungi.

In some cases, using fungicide drenches or root dips can be effective.

Damping Off

To prevent this disease, prevent the low oxygen conditions that favor the opportunistic fungi that cause it. Aerate soil. Do not allow it to become waterlogged and cool for long periods.

Alternatively, plant seeds coated with a fungicide. Dip transplant roots in a fungicide solution. Do not plant too deep.

Nematode Pest Management

Good sanitation is the primary way to control nematodes. Disinfect tools and do not reuse growing media.

Soil sterilization will kill adults and eggs of root nematodes. Fumigants and steam treatments are effective. However, be aware that there are no fumigants registered for use in interiorscapes. Fumigate soil or growing media before bringing them indoors.

The best way to control nematodes is to reduce other stress factors. For example, be sure plants have an adequate supply of nutrients and water. A biological control agent made from the chitin-protein of crustacean skeletons is available. This product stimulates the growth of normal soil microorganisms (e.g., fungi, and bacteria). These, in turn, produce an enzyme that may destroy plant pathogenic nematodes and their eggs.

Some pesticides control nematodes. In some cases, nematicides can be applied to plant roots. In other cases, treat soil before planting.

Mollusk Pest Management

Mollusk pests cannot withstand hot, dry conditions. Therefore, they often feed on plants growing in shade. However, they are active at night and during cool, damp mornings. During those times, they will feed on a variety of plants.

There are pesticides registered for use on snails and slugs. Many contain the active ingredient metaldehyde. However, some contain silicon dioxide (diatomaceous earth). In addition, 'homemade' baits — for example, shallow pans containing beer — will trap and kill these pests.

Weed Management

There are many ways to control weeds in landscapes. These include tilling, hoeing and hand weeding, use of various types of mulches and landscape fabrics, and chemical control. Generally, an integrated vegetation management program involves a combination of methods.

This section will discuss the available options for weed control in landscape plantings. It will also relate weed life cycles to effective pest plant management.

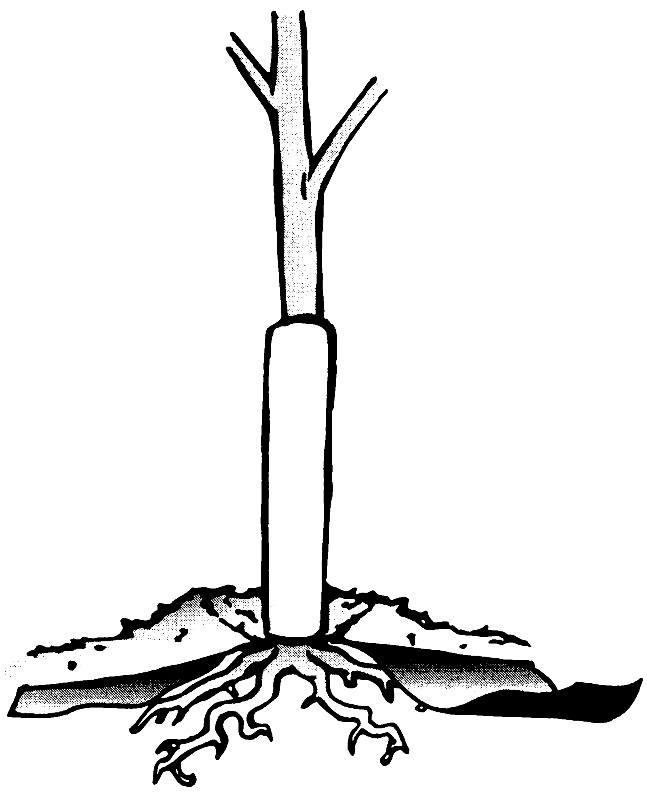
Biological Control

At present, there are very few biological agents available for weed control. Certain weevils may suppress thistles in Virginia. There are other biological control agents for controlling specific weeds in rice and citrus. More practical, effective biocontrol agents may be developed in the future. For example, research efforts include animals that consume the weed plant or its seeds, insect parasites, diseases, and competition from or inhibition by another type of plant. However, biological control is currently not an option for weed management in Virginia landscapes.

Cultural and Mechanical (Physical) Controls

Hand weeding is a time-consuming, labor-intensive way to control weeds in a landscape. However, it may be the best choice in some situations. Hand weeding is a good control strategy if only a few weeds are present or if weeds are growing close to the stem of a desirable plant. On the other hand, perennials and other plants with large, well-developed underground parts are hard to control this way. Hand weeding does not usually remove all of a large underground system. Consequently, plants may regrow. Two good examples are yellow nutsedge and dandelion. It is hard to remove all of the nutsedge's underground tubers or the entire taproot of the dandelion by hand.

Hoeing and cultivation can control weeds in landscapes. When hoeing a site, try to move as little soil as possible. Disturbing the soil brings weed seeds to the surface, where they can germinate. Cut annual weeds at the soil surface, making sure to remove all above ground buds. For grasses, the tissue that produces new growth is at the base of the leaves. Leaves cover and protect this tissue. So, be sure to remove the entire shoot of grasses. Cultivating a site will destroy existing annual weeds and will suppress perennial weeds. Take care when cultivating so you do not injure a tree or shrub's root system.



Use of organic mulches such as pine bark is an attractive way to control weeds in landscapes. Mulches will reduce the need for hand weeding. Ideal mulch depth is two to four inches. Overmulching can lead to poor soil drainage. Remember that plant roots require oxygen for growth. Poor drainage can invite root rots. Do not pile mulch against the bark of a tree or shrub. Do not use mulch that has an offensive odor. Organic mulch, if stored improperly, can produce chemicals toxic to plants. Mulches such as pine bark will control annual weeds but not perennials. As organic mulch breaks down, it becomes a good growing medium for weeds. So weed control often declines as time passes. Replenish organic mulches as they degrade.

Rock mulches can control annual weeds better than organic mulches since rocks generally do not act as a growing medium. Like organic mulches, rocks do not control perennial weeds such as yellow nutsedge. Do not use rocks near mowed areas to avoid the possibility of a lawn mower throwing pieces of rock. When using rock mulch, consider placing a landscape fabric beneath the mulch to prevent the rocks from sinking into the soil over time. Solid black plastic provides better weed control than organic mulches or rock mulch. However, it will not let water or gases pass through. Consequently, its use is discouraged in landscapes.

Landscape fabrics and other geotextiles were developed to replace black plastic in the landscape. Landscape fabrics allow gases and water to pass through them, overcoming the major disadvantage of solid black plastic. In general, landscape fabrics do not control weeds as well as black plastic. This is because certain weeds can push through the fabrics. In addition, roots of weeds germinating in the mulch layer above a fabric can pass down through some fabrics. Landscape fabrics with a lower ratio of open to closed space appear to provide better weed control than those fabrics with more openings. However, the more porous ones allow for better water infiltration and gas exchange.

Effective use of landscape fabrics requires proper installation and maintenance. Keep landscape fabrics covered with a thin (about one inch) layer of mulch. Sunlight can degrade fabrics. Control weeds that germinate in the mulch layer when small to prevent root penetration. Consider use of a rock mulch instead of an organic mulch above a landscape fabric. Using rock mulches should improve weed control.

A landscape fabric covered by mulch is better for weed control than mulch alone. Landscape fabrics are most useful for long term weed control in woody landscape plantings. Fabrics are not practical in annual and perennial flowerbeds. The same is true for beds with groundcover plantings, because the groundcover must spread along the ground and root into the soil.

Chemical Control

There are two types of chemicals for weed control in landscapes: fumigants and herbicides. Fumigants kill all weeds in the soil, including dormant weed seed. Fumigants also kill diseases and insects in the soil. Herbicides only affect that portion of the weed seed reservoir that germinates.

Fumigants

Fumigants are applied to warm, well-tilled soil for weed control before establishing a new planting. To be effective, fumigants must remain in the soil for a certain period, and then removed. Fumigants move throughout the soil as a gas. A waiting period before planting allows the gas to dissipate from the site. Many fumigants are highly toxic. Use them with extreme caution. Fumigants do control most weeds. Deep-rooted perennials are more difficult to control than annuals.

Herbicides

Herbicides are useful weed control tools. They do not disturb soil; therefore, erosion and weed seed germination are not encouraged. There are several ways to use herbicides selectively. Herbicide management decisions must include three things:

- placement,
- timing, and
- product selection.

However, herbicides can injure nontarget or desirable plants. Using a herbicide at the wrong (too high) rate or in the wrong place may cause phytotoxicity.

Foliar herbicides are applied directly to plant leaves. Other herbicides are applied to soil. Some products are broadcast, which means an entire area is covered. Directed applications only contact the target weeds. Desirable plants are not treated.

Herbicides can be divided into two groups, based on when they are applied. Preemergence herbicides are applied to soil before weeds germinate. They are most often used in weed-free sites. Postemergence herbicides are applied to emerged, growing weeds. Depending on the situation, you may use a combination of a postemergence herbicide and a preemergence herbicide, or a postemergence alone, to control existing vegetation.

Preemergence herbicides control weeds as they germinate. They are absorbed by the roots of the germinating plant, or by the emerging shoot as it pushes up through the soil. Some preemergence herbicides control germinating weeds for up to two months, while other chemicals can last for six months or longer in the soil. As a rule, preemergence herbicides do not affect established plants. However, only a few preemergence herbicides can be applied to some annual flowers such as marigold, petunia and geranium. More preemergence herbicides are registered for use on perennials and woody ornamentals. These plants can tolerate herbicides that injure many annuals. Check herbicide labels and references such as the

VCE Pest Management Guides to determine what preemergence herbicide to use in a specific situation.

Certain preemergence herbicides control annual grasses better than annual broadleaf weeds. You must identify the weed problems at a given site in order to choose an effective herbicide. A chart listing the effectiveness of ornamental-use herbicides on various weeds is available in the VCE Pest Management Guides. Since preemergence herbicides must be applied before weed germination, applications should be made in late summer or early fall for controlling winter annuals such as common chickweed. Apply herbicides in late winter or early spring for summer annual weed control. If the herbicide does not last for an entire growing season, you may need to make a second application. Herbicide labels give retreatment intervals. In most cases, preemergence herbicides will not control perennial weeds.

Preemergent herbicides need to be activated (moved into the top inch or two of soil where weed seeds germinate) by rainfall or irrigation. You may need to irrigate after applying certain granular herbicides. Irrigation (or rainfall) will wash the chemical off the ornamental foliage to reduce the chance of leaf injury. In some cases, granular herbicide formulations are safer for desirable plants. This is because they are less likely to cause phytotoxicity than overtop applications of some spray formulations.

Postemergence herbicides kill emerged weeds after being absorbed. Postemergence herbicides can be classified as either selective or nonselective. Some postemergence herbicides affect most (if not all) weeds. Others are only effective on certain types of plants. Product selection involves careful consideration of several factors:

- mobility (contact vs. translocated), and

- control spectrum (selective vs. nonselective or broad spectrum).

Contact herbicides only affect treated plant parts. They do not affect untreated leaves, stems, or underground parts. Contact herbicides, therefore, will not affect the root system of perennial weeds. Contact herbicides generally work faster than systemic herbicides.

Systemic herbicides translocate throughout a plant. They are absorbed and move from the application site. Therefore, systemic herbicides are usually a better choice for controlling perennial weeds.

Selective herbicides control certain plants but do not affect others. For example, 2,4-D controls most broadleaf weeds but does not affect grasses. Sethoxydim controls grasses but does not affect sedges or broadleaf weeds. Weed identification is very important when using selective chemicals. Certain selective herbicides can be applied over the top of ornamental foliage. Check the label to determine which ornamental species you can treat in this manner.

Nonselective herbicides injure almost all plants. Glyphosate is an example of a nonselective, systemic herbicide. Some nonselective herbicides are called soil sterilants or total vegetation control products. They are useful in areas where no plants are wanted, like walking paths in a landscape or a gravel parking lot. The term soil sterilant is a misnomer, since herbicides do not sterilize the soil. Unlike fumigants, they do not affect insects or diseases, they only affect plants. Total vegetation control products are used to control weeds in cracks in sidewalks, gravel driveways, and similar areas. However, they can injure trees and shrubs if their roots extend under the treated soil. Rainfall may move these products into the root zone, leading to injury.

To protect valuable ornamentals, use extreme care when applying nonselective herbicides. Directed sprays are used to prevent contact with leaves or shoots of desirable plants. Shielded sprays, where a

cone surrounds a nozzle, can prevent the spray from hitting the foliage of a desired plant. A wiper (wick) application, where a herbicide solution is wiped on weed foliage only, is another way to use nonselective herbicides safely around desired plants.

Spray formulation herbicides can injure nontarget plants through spray drift. In addition, a few herbicides are volatile, meaning they may evaporate and move as a vapor (gas) from the application site. Both particle and vapor drift can cause serious injury or even death to nontarget plants. Avoid applications during windy conditions. Always follow label directions, and heed label precautions. Volatile herbicide labels have restrictions to avoid vapor drift. Do not use these products during warm weather. Do not apply a volatile product during the heat of the day or in the morning of a day when very warm temperatures may occur.

Apply postemergence herbicides to actively growing weeds under warm weather and good soil moisture conditions. Avoid applications under hot, dry weather. Postemergence herbicides are not very effective on weeds under drought stress. Certain postemergence herbicides are absorbed slowly. A rain occurring a few hours after application could wash such a chemical off foliage before it is absorbed. Do not apply such chemicals if there is a chance of rain following application. Consult the label for specifics.

If an herbicide is mistakenly misapplied, try to remove the treated soil before the next rainfall if there is potential for damage. Incorporating activated charcoal into treated soil will inactivate certain herbicides. There is no cure for herbicide injury. However, you should maintain optimum growing conditions for injured plants (watering, fertilization, etc.). Plants may outgrow phytotoxic effects.

Plant Life Cycles and Weed Management

As a rule, plants are most susceptible to the effects of herbicides when they are actively growing.

The best time to control annual weeds by hoeing or hand weeding is when they are small. The larger the plant, the more difficult it is to remove from a landscape. Apply mulches and preemergence herbicides to weed-free soil. Use postemergence herbicides to control existing weeds.

Since preemergence herbicides must be applied before weed seeds germinate, apply them in late winter or early spring applications to control summer annuals. Make late summer or early fall treatments to control winter annuals. Most preemergence herbicides have no effect on weeds after they are established. Contact postemergence herbicides should be applied to small weeds. Thorough leaf coverage is required for control. Obtaining good coverage with contact postemergence herbicides becomes more difficult when larger weeds are treated. This may result in decreased control. Systemic postemergence herbicides will generally control annual weeds over a wider range in size. However, lower rates may be used and better control will probably result when small weeds are treated. It is better to treat annual grasses before tillering. Treat annual broadleaf weeds when they are less than four inches tall. As stated, it is better to treat weeds when they are young and relatively small. However, they need to be large enough to allow for good coverage.

Biennial weeds should also be treated or hoed when small. Like annuals, these weeds are harder to control when large or when they are beginning to flower.

Most preemergence herbicides do not control perennial weeds. However, a few preemergence herbicides control certain specific perennial weeds. Mulches such as pine bark will not control perennial weeds such as yellow nutsedge and bermudagrass. Repeated tillage or mowing will gradually reduce the infestation of established perennials. It is difficult to control perennials by hand weeding. This is because, often, portions of the root system remain in the ground. The weed will regrow from the root or root fragment. Many applications of a contact herbicide would be needed to control perennial weeds. Generally, the better option for chemical control of perennial weeds would be use of systemic postemergence herbicides. Check the herbicide label for the optimum time to treat. Certain systemic herbicides work best when applied to young, actively growing weeds. Others work best when applied at the flowering or fruiting growth stage.

Test Your Knowledge

Q. Name several things you need to make an accurate diagnosis of a pest problem.

A. Description of the type and extent of plant damage, identification of the pest, familiarity with the life cycle of the pest, a good estimation of the size and distribution of the pest population, and whether it is increasing or decreasing.

Q. Define the term "Integrated Pest Management." List IPM tactics used in ornamental pest control.

A. Integrated Pest Management refers to the use of a combination of pest control tactics. IPM programs use many types of techniques in a single plan or strategy to reduce pests and keep their damage to an acceptable level. IPM tactics include monitoring and early detection, sanitation, and cultural, mechanical (physical), biological and chemical control methods.

Q. What is cultural control? List several cultural control tactics used in plantscapes.

A. Cultural control involves changing the plant's environment, its physical condition, or the behavior of a pest. Cultural control methods for ornamental pest control include:

- varying planting times,
- planting trap crops,
- cultivating soil,
- hand weeding or handpicking insects,
- adjusting plant placement, spacing or row width,
- thinning,
- isolating infected plants,
- pruning and destroying infested plants or plant parts,
- removing soluble salts,
- changing the light, heat or humidity regimen in an interiorscape,
- changing watering and fertilizing programs.

Q. What is biological control? Give one example.

A. Biological control involves using some aspect of the pest's biology to control it. Examples include use of natural enemies, introduction of genetically altered competitors (ex. release of sterile male insects), use of pheromones to draw insects to a trap, or use of hormones to prevent normal development.

Q. What is mechanical control? Give some examples.

A. Mechanical controls use some device or machine to control pests. Examples include aerating soil, use of traps, and using barriers to discourage or exclude pests.

Q. What is sanitation? Give two examples.

A. Sanitation is general cleanliness. Sanitation reduces the levels of pathogens and other pests in the plantscape. Using pest-free seeds or seedlings is a sanitation strategy. Careful disposal of diseased parts pruned from plants is, too. Sanitation also involves using clean growing media, containers, and tools. Washing plants with soap and sanitizing feather dusters used in interiorscapes are examples of sanitation.

Q. When and where are biological controls most effective?

A. Biological controls are the most effective where there are large groupings of plants. They do not work well on single plants where the pest population is low. Without enough food to live on, the beneficial insects starve and die off.

Q. Why is the timing of a pesticide application important?

A. To be effective, pesticides must be applied correctly and at the proper time and rate. In many cases, pesticides need to be used at a certain stage in a pest's life cycle. Applying them too early or too late is a waste of time and money. In addition, poorly timed applications may pose a threat to the target as well as to other organisms and the environment.

Q. When making a pesticide application, why is proper coverage important?

A. Uniform coverage, directed at the target pest, is necessary for effective pest control. For example, if an insect lives underneath leaves, an overtop foliar application may be ineffective. Spot treatment with herbicides is an effective way to control isolated weeds. However, broadcast applications must be uniform or results will be streaked and spotty.

Q. What is phytotoxicity? How can you recognize this problem?

A. Phytotoxicity is injury or damage to a sensitive plant caused by a chemical exposure. Symptoms of phytotoxicity include:

- death of rapidly growing tissues,
- stunting or delayed development,
- misshapen or distorted stems, leaves or fruits,
- russeting or bronzing of leaves or fruit,
- dead spots or flecks on leaves, dead leaf tips or margins, and dead areas between leaf veins.

You might suspect phytotoxicity if you see plant damage but no sign of pest presence. Another warning sign is injury that occurs suddenly or over a short period of time that does not spread from plant to plant. Consulting spray records might give you a clue if pesticide use is causing phytotoxic effects. Records may document the use of a pesticide near a sensitive plant showing signs of injury.

Q. Describe some pesticide uses that might result in phytotoxicity.

A. Conditions that might result in phytotoxicity include:

- application of a pesticide during adverse environmental conditions,
- use of a pesticide contrary to label directions (ex. wrong site, wrong rate),
- movement offsite from a target area to a sensitive area (ex. drift, runoff), and
- accumulation of persistent residues in the soil or on the plant.

Q. How can you avoid causing phytotoxicity when using pesticides?

A. To avoid phytotoxicity, be certain the plant you plan to treat is listed on the product label. Measure and prepare chemical carefully. Use the proper rate and application techniques. Follow label directions for the number and timing of applications. Apply and store pesticides according to label directions. Do not treat stressed plants. Direct pesticides to the target. Do not allow offsite movement. Do not treat plants when they are subjected to extreme heat or cold.

Q. Describe the proper methods for cleaning and disinfecting tools, containers, and equipment.

A. First, remove heavy accumulations of soil, plant sap, and other debris. Disinfect items using a surface-applied chemical or heat. If you use alcohol, dip or swab the material and allow it to dry. Do not rinse. If you use sodium hypochorite (bleach), dip, spray or brush it on. Keep the treated surface wet for at least 10 minutes. Then, rinse with clean water. Heat-treat materials at 180-200 degrees (F) for 30 minutes. Store tools and equipment properly to avoid contact with dirty surfaces or infected plants or plant parts.

Q. How may a disease enter a plantscape?

A. Diseases enter in a number of ways, including:

- on debris from diseased plants,
- on infected soil found on tools, hose ends, reused containers and potting mixes,
- in water, either free standing or from reservoirs,
- via air borne spores or pollutants,
- from infected plants, seeds, seedlings, or rooted plant parts,
- on insect or mite vectors, and
- when cultural practices used are unfavorable to good plant health.

Q. Describe some cultural control practices for controlling bacterial diseases.

A. Remove and destroy infected plants or plant parts, isolate infected plants, avoid splashing water on plant foliage, disinfect tools and equipment. Reducing water and fertilizer applications may be effective in some situations. Cool temperatures may control some bacterial diseases.

Q. List some effective ways to control viral diseases.

A. Purchase virus-free plants. Destroy virus-infected plants. Disinfect tools and equipment. Avoid wounding plants. Control insect vectors.

Q. List some general ways to manage fungal diseases.

A. Sanitation, removal of infected tissue, and use of fungicides are usually effective.

Q. Describe some specific ways to prevent or control leaf spot diseases.

A. Avoid splashing water on leaves. Decrease humidity and increase airflow by thinning plants. Sanitation, removal of infected tissue, and use of fungicides are also effective.

Q. How can you manage powdery mildew?

A. Water plants early in the day, when the foliage is likely to dry. Be sure there is good air circulation. Do not crowd plants. Thin them as necessary. Do what you can to reduce humidity and avoid splashing water on leaves. Some fungicides are effective in certain situations if used properly.

Q. What conditions promote root infections, root rots and damping off? How can plant managers prevent these diseases?

A. Root diseases flourish in low-oxygen situations. They usually occur when soil is damp or waterlogged and cool. To prevent them, provide a favorable root environment. Soil aeration is very important. Depending on the situation, you can use fungicide treated seeds, root dips, or soil drenches.

Q. Describe how to manage crown gall.

A. The best way to manage this difficult disease is to choose resistant plants. Sanitation is also a good preventative measure. Do not use infected soil. Discard any infected plants. Disinfect tools. Biocontrol measures are effective in certain situations. There are few effective chemical control options for crown gall.

Q. Describe how to control fireblight.

A. Note plant growth stages and weather conditions to monitor disease development. Use bactericides, prune old infections, and sanitize cutting equipment.

Q. Name several leaf, bud and stem feeding arthropod pests.

A. Aphids, lace bugs, bagworms, borers, foliar mealybugs, gypsy moths, Japanese beetles, leaf miners, mites, pine tip moths, scale, weevils, webworms, tent caterpillars, whiteflies and thrips feed on above-ground plant parts.

Q. Describe some good ways to control aphids and thrips.

A. Prune affected sections. Sterilize tools. Release predators. Use insecticides as directed. If possible, wash (aphids) or rinse (thrips) plants regularly. Controlling ants indoors may help control aphids. They may also be removed by hand. You can use yellow sticky traps to monitor and reduce thrip populations. Controlling host weeds will also help control thrips.

Q. Describe what must be done to control azalea lace bugs.

A. First, monitor plants when they begin to bloom. Control nymphs as they hatch, before they have a chance to mature and mate. If you use insecticides, be sure to treat the underside of leaves.

Q. Describe how to control bagworms.

A. Scout for them. Often, bags are not noticed until an infestation is large. Small populations can be controlled by removing bags by hand. Hand pick them in winter and spring, before eggs hatch. Insecticides must be applied early, when bags are small (1/4 to 1/2 inch long).

Q. How would you prevent or discourage dogwood borers?

A. Prevent them from entering. Avoid mechanical injury from mowers by placing a guard around the trunk. Protect pruning cuts and damaged areas of bark with wound dressing.

Q. Name several cultural control methods for fungus gnats.

A. Choose media containing low amounts of bark or peat moss. Use sterilized media. Do not reuse infested media. Avoid overwatering, and drain off standing water from containers. Do not crowd plants. Use yellow sticky cards to monitor and control flying adults. Remove debris, old staging, etc., from top of pot. Replace the top four inches of soil with fresh, sterilized soil. Wash pot saucers to kill fungus gnat maggots.

Q. How should you time insecticide applications for control of holly leaf miner?

A. Control adults in the spring after they emerge but before they lay eggs. Treat infested plant foliage with a systemic insecticide in July to control young miners.

Q. What is the most vulnerable stage in a mealybug's life cycle?

A. Crawlers (nymphs) move sluggishly about the plant. They lack the compact, cottony, waxy sac that covers and protects the eggs and adults.

Q. Describe control methods for mealybug infestations.

A. Select plant materials that are least susceptible to damage. Prune and discard infested plant parts. If possible, increase amount of light the plant receives. Release predators (beneficial insects). Treat small, confined infested areas with alcohol. Use properly registered insecticides to control heavy infestations. If a foliar-applied product is chosen, be sure it contains soap or a wetting agent to penetrate their waxy covering. Alternatively, choose a systemic insecticide.

Q. When is the best time to act to control black vine weevil in a landscape?

A. The most effective time to control black vine weevil is in the spring, when the adults first emerge.

Q. How may hemlock wooly adelgid infestations be treated?

A. Treatment with horticultural oil will control this pest on small trees. The spray must cover the entire tree. Systemic insecticides are effective if used properly on large trees. Soil applications are most effective in the spring.

Q. Describe two ways to manage the boxelder bug.

A. Remove host trees. Treat foliage with a liquid insecticide. Remove accumulations of leaf litter to reduce the survival rate of overwintering larvae and adults.

Q. What are some strategies for control of gypsy moth?

A. Keep trees healthy. They are more likely to survive defoliation. Destroy egg masses. Install barriers to control crawling caterpillars. Use insecticides or growth regulators if practical.

Q. Which pest is best controlled by pruning: Eastern tent caterpillar or fall webworm?

A. Pruning is an effective way to control fall webworm. This is true because fall webworm nests are usually at the end of branches. Tent caterpillars nest in the crotch of trees.

Q. What is the best way to deal with galls on landscape plants?

A. Chemical treatments are not recommended. This is because killing the parasite will not eliminate the gall. Most plants can live and grow normally with galls. Pruning can remove unsightly galls.

Q. Which pest does not usually require pest management action: locust leaf miner or holly leaf miner?

A. Locust leaf miner rarely kills host trees. Moreover, black locust trees are not often used in landscapes. For that reason, pest management measures are not usually recommended for locust leaf miner.

Q. What control measures are effective for Japanese beetles?

A. For adults, use foliar insecticides. Retreatment may be necessary. To control grubs, treat turf if infested with eight to twelve grubs (or more) per square foot.

Q. In what situation might chemical control measures be called for to control fall webworm?

A. Usually, fall webworm causes late season damage and does not cause permanent damage. However, if a young, small tree is severely infested, chemical control measures might be considered. Sprays must be forceful enough to penetrate the silken web nest.

Q. Name one common pest of outdoor ornamentals that may be controlled by choosing resistant plant varieties.

A. Boxwood leaf miner is one example. Some varieties of boxwood are resistant. Another good example is choosing river birch instead of white birch to avoid problems with the bronze birch borer.

Q. What is the best way to manage bark beetles in the landscape?

A. The best way to manage bark beetles is to prevent them from attacking trees in the first place. Use good cultural practices to keep woody plants in good condition. Prune, remove and destroy infected limbs to control a localized infestation.

Q. What environmental conditions favor spider mites? What cultural control tactics suppress these pests?

A. Spider mites flourish in hot, dry environments. Outdoors, rainfall or overhead irrigation may control them. Indoors, increase humidity and/or mist plants often. Filter sunlight with blinds or curtains. Remove plants from hot, dry areas.

Q. Why must insecticide applications be timed properly to control pine tip moth?

A. Effective treatments control the adult stage of this pest. However, adults are small and nocturnal. Pheromone traps and degree-day models can help you know when adults are present.

Q. Describe some effective control methods for scale insects.

A. Prune and discard infested plant parts before crawlers hatch. Hose plants to dislodge crawlers. If possible, increase amount of light the plant receives. Release predators (beneficial insects). Use an approved pesticide when crawlers are present. Be sure to treat the upper and under surface of leaves. Repeated applications will be needed, because foliar sprays will not kill adult females. Alternatively, choose a systemic insecticide.

Q. Describe some ways to control whiteflies.

A. Select resistant plant varieties. Mist or hose to remove sooty mold and honeydew from leaves. Prune infested sections. Yellow sticky traps will monitor and reduce populations. Eggs and immature forms are resistant to many insecticides. Therefore, chemical control alone is not always effective. A parasitic wasp and a fungal disease will control whiteflies indoors.

Q. Describe some ways to manage nematodes.

A. Sanitation, soil sterilization, biocontrols and nematicides can control nematode pests.

Q. How can you manage mollusk pests (slugs and snails)?

A. Properly registered pesticides and some homemade baits will control these pests.

Q. If you have a weedy ornamental bed, which type of herbicide should you use: preemergent or postemergent. Why?

A. Postemergent. Preemergent herbicides control germinating seeds but not established plants.

Q. How can you manage herbicides in a plantscape and avoid injuring valuable ornamentals?

A. In general, manage herbicides by placement, timing and/or product selection. For example, direct sprays to the target weeds. Use preemergent herbicides around established plants. Use a selective product that will control problem weeds but not the desirable plants in the landscape.

Q. How do contact herbicides differ from systemic herbicides?

A. Contact herbicides affect only treated areas. Systemic herbicides are absorbed by and move within the plant.

Q. What is the best time to apply a contact postemergence herbicide to an annual weed?

A. Treat annual weeds when they are small, generally less than four inches tall.

Q. When should preemergent herbicides be used for annual weed control?

A. For winter annuals, apply products in the late summer or fall. Apply preemergents for summer annual weed control in the winter or early spring.

Q. When should mulches be applied for weed control?

A. Apply mulches to weed free sites, after hand weeding or using herbicides in an area.

Q. What do you need to know to choose a preemergence herbicide for an ornamental bed?

A. Consult the label to be sure the product will control the weeds present and that it can be used on the intended site.

Q. Compare black plastic and landscape fabrics regarding movement of water and gases, and the ability to control weeds.

A. Black plastic generally is more effective for weed control. However, it blocks the movement of water and gases. Landscape fabrics are porous, allowing these essential materials to penetrate the soil.

Q. What is the ideal depth for mulch in a landscape? What problems are caused by overmulching?

A. Use two to four inches of mulch. Overmulching can lead to root damage due to excess soil moisture and poor air circulation. Piling mulch around the base of woody plants can cause stem injury due to excess moisture and can invite disease.

Q. How may total vegetation control products cause harm when used near landscapes?

A. Total vegetation control herbicides can injure trees and shrubs if their roots lie under the treated soil, or if the product moves offsite into their root zone.

Q. In general, which is best for control of perennial weeds: a preemergence or a postemergence herbicide?

A. Most preemergence herbicides do not control perennial weeds. Systemic postemergence herbicides are best for control of perennial weeds.

Unit 5. Specific Safety Considerations

Learning Objectives

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

- Recognize sensitive areas and situations affecting ornamental pest control decisions.
- Describe special considerations and precautions for applicators working in or near such places.

VCE Publication 456-210, The Virginia Core Manual, **Applying Pesticides Correctly**, is a comprehensive guide to pesticide safety. The Core Manual discusses basic safety considerations for all applicators. This Unit will focus on special issues facing professional horticulturists. This Unit will help you identify sensitive areas and situations. It will also guide you in making sound pesticide management decisions.

Terms to Know

Drift - Pesticide moving away from the release site in air.

Leaching - Movement of pesticide in water or other solvent downward through soil or other planting medium.

Particle Drift - Drift of particles, usually spray droplets.

Runoff - Movement of pesticide in water or other liquid moving horizontally across the surface of a treated area.

Vapor Drift (Volatility) - Drift in vapor form. In some cases, volatile pesticides applied in liquid form evaporate back to the air before they have time to be absorbed by treated plants. In other cases, pesticides applied in gaseous form (ex. fumigants) escape and are carried away from the application site.

Periodically, most plantscapes will need to be treated for pest infestations to sustain quality. This is true for both indoor and outdoor settings. However, the person making pest management decisions and the pesticide applicator must be aware of the inherent liabilities involved in treating ornamental plantings. Applications made in public areas require special planning and care. The same is true for pesticides used in enclosed spaces.

Pest management is problem solving. To be successful, a plantscape manager must follow a logical series of steps. First is identification of the pest. Once identified, knowledge of the biology and habits of the pest is important. If you know the life cycle of the pest, you can act when the pest is in a vulnerable stage and control measures are most likely to be successful. Second is a careful study of the site and the pest's habitat. Third is an evaluation of the problem - is it severe enough to require some sort of action? If so, the next step is careful consideration of all appropriate management strategies. Finally, investigate the cause of the problem. How did the pest get to the site? Can access be prevented? What is the pest using for food and shelter? Can you change the site to make it unsuitable for the pest? Work to prevent future infestations and to design an integrated pest management plan.

If pesticide use is called for, consider all labeled products. Selecting a pesticide involves considering a number of things. First, the product must be labeled for use on the plant or site you want to treat. Next, evaluate factors like formulation, toxicity, environmental fate, mode of action, and any other site-specific criteria. Learn about the product's physical and chemical characteristics, including its toxicity. For example, it may be important to know how well the pesticide dissolves in water. Water solubility is a factor affecting ground water infiltration, absorption into the plant, absorption into the skin, and perhaps compatibility with other materials. In

summary, choose a product that is well suited for the site, situation, and pest.

Before using any pesticide, read the label. The label will tell you where and how to use the product. It will list the legal uses for the product. It may also note specific sites that may not be treated, or application methods that are not permitted. Labels give directions for mixing and use. They also describe safety precautions. Follow all label directions to the letter. Be sure you are applying pesticides at or below the label rate. Use the proper application equipment. Minimize the number of applications you need to make, if possible.

Study an area before treating it. Observe the use patterns of people, pets and wildlife. Pesticide use in and around some outdoor sites and buildings, such as hospitals, nursing homes, day-care centers, and schools, requires very special care. Troubleshooting before an application can identify sensitive areas and situations. Plans to prevent potential problems should be in place before application. It may be helpful to post the treated area.

Indoors and outdoors, here are some special concerns for plantscape managers:

1. How will the pesticide affect the site?

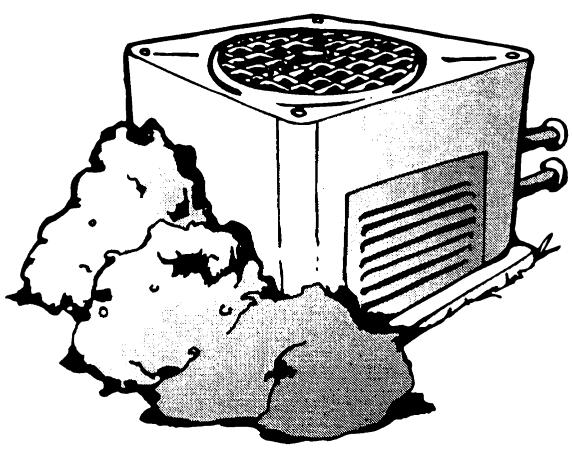
2. What nontarget organisms must be protected?

3. Is there any chance for the pesticide to move offsite?

Sensitive Areas

Each pesticide application should be planned and made with care. However, extra planning and extra caution is the rule when working in a sensitive area. These places have one or more features that require special management.

Some areas are sensitive because of the people, plants or animals that use or live on the site. For example, hospitals, nursing homes, and day care centers are inhabited by people who, as a rule, are more likely to be affected by pesticides than healthy adults are. Pesticides must be directed at the target. Applications must be managed so that humans, wildlife, domestic and agricultural animals, and nontarget plants are not harmed.



Other areas are sensitive because of construction or design features. For example, if making a pesticide application in a yard or in an interiorscape, identify the location of air intakes. Avoid treating in places where pesticide particles or vapors will be drawn into heating or cooling systems. Before treating an area, look for places where pesticides may reach water sources. For example, identify and leave an untreated buffer zone around a well head.

Still other sites are sensitive because of environmental factors. These may be permanent features; for example, a shallow water table. They may be temporary; for example, a temperature inversion or hot, dry weather — conditions that favor drift.

Here is a short description of some common sensitive sites and situations.

Water Sources

Some pesticides will harm aquatic organisms, including fish and crayfish. Some persist in the environment. A chemical that remains active for a long time may move into water supplies. This is especially true if the chemical dissolves readily in water. Surface-applied chemicals can move in solution down through soil layers. This can occur in any site, but pesticides are most likely to reach groundwater through sandy soil or limestone rock. Pesticides may also move with surface runoff. Observe both label and common-sense precautions when working around water sources. When planning a pest management program, identify and protect connections to water supplies, such as wells, cisterns, and drains.

Playgrounds, Outdoor Play Equipment, and Lawn Furniture

Pesticide residues on surfaces may present unnecessary exposure to people or pets. Avoid treating these sites unless there is a specific need for doing so.

Bird Feeders, Pet Food and Water Dishes, Fish Ponds

Some pesticides are toxic to birds and fish, even at very low concentrations. Always manage spray applications, indoors and outdoors, to avoid drift. Removing water dishes and covering feeding stations or water gardens may provide added security.

Air Conditioners and Heat Pumps

Appliances that redistribute air may also move pesticides applied near them. Before treating around the outside of buildings, locate fresh air returns. When working indoors, study the plans for the ventilation system — heating and cooling. Do not use formulations that may be drawn into them, such as liquids and dusts, around air intakes.

Environmental Effects

Microbes, chemical processes, and light cause pesticides to breakdown, or degrade, in the environment. The rate of breakdown depends on certain other environmental factors. Soil organic content, moisture, temperature, available oxygen, and pH are factors that influence the rate of microbial degradation. As a rule, microbes are most active in moist, warm soils. This is especially true if the microbes have adequate nutrient levels and the soil pH is at or near neutral. Similarly, chemical degradation is fastest when there is adequate moisture, oxygen, and warmth. It is worth noting that the conditions unfavorable to one form of degradation may be favorable for another. For example, as the pH goes to either extreme on the pH scale, microbial activity will decrease. However, chemical activity may increase. Photodegradation is influenced by the length and intensity of sunlight. Interiorscapes block most of the light responsible for this type of degradation. Photodegradation is not a major process in these environments. Ideally, pesticides persist long enough to do their job, but not to accumulate in the environment and/or be carried offsite.

To be effective, pesticides must reach the target. Besides being wasteful, offsite movement is potentially dangerous. In general, pesticides can move off target two ways. One way is to be carried in air currents or by wind, and the other is to be transported by water.

Movement In Air

How can you prevent or minimize pesticide drift? Drift to non-target areas is a concern for both outdoor and indoor applications. Indoors, heating, cooling and ventilation systems move air throughout a building. Pesticide particles or vapors may be drawn into these systems and move within the structure. Outdoors, wind and weather conditions influence drift.

Drift can be an asset or a liability. Drift within an enclosed structure or limited area may improve coverage; for example, coat both the upper and lower sides of leaves. However, drift outside of the target area may damage non-target plants, products, and surfaces. Offsite drift may directly or indirectly cause people or other living things to be unintentionally exposed.

Here is a list and short discussion of the factors affecting spray drift:

Spray Characteristics:

- Chemical (active ingredient)
- Formulation
- Additive(s)
- Droplet size

Any spray application can drift. However, herbicide drift is usually more noticeable than other types of pesticide drift. This is especially true if the herbicide is nonselective.

As a rule, larger droplets are heavier and drift less than smaller droplets. They are also less likely to evaporate before they reach their target.

Application Equipment:

- Nozzle type
- Nozzle size
- Nozzle orientation
- Release height
- Nozzle pressure
- Spraying system technology (ex. nozzle design effect on spray droplet)
- Operating speed

As a rule, larger nozzles and lower pressures produce larger droplets. Choose an appropriate spraying system, based on the site and pesticide. Configure it according to manufacturer's specifications. Operate within prescribed pressure and operating speed ranges. A lower release height and/or slower operating speed will decrease the chance of drift.

Environmental Factors:

- Air movement (direction, speed)
- Temperature
- Humidity
- Air stability (inversions)
- Topography

Do not spray when winds are strong or variable and gusty. Do not apply volatile materials during hot weather. (Be aware of and follow temperature restrictions on product labels.) Spray droplets may evaporate before they reach their target and move as vapors. Fine particles and hot, dry weather (low humidity) increase the risk of evaporation.

There are several steps applicators can take to prevent unacceptable drift. Some of these are:

- Select a pesticide that is safe for both target and non-target plants.
- Provide a physical barrier or open space 'buffer zone' between target and non-target plants.
- Remove non-target plants, temporarily or permanently.
- Use proper application equipment and techniques. For example, use low pressure for liquid applications. Use low-drift nozzles — ones that produce large, heavy droplets — or other application control features to direct liquid sprays to the target.
- Use a formulation (ex. granular) or an application method (ex. soil drench) which will eliminate the chance for drift. Avoid using products that are volatile or are applied as fine particles.
- Do not make applications when conditions are unfavorable. Indoors, work with maintenance people so airflow will not carry pesticides offsite. Outdoors, do not spray when weather conditions favor drift.

More information about offsite movement in air and drift management may be found in Unit 5 (Pesticides in the Environment) of VCE Publication 456-210, The Core Manual.

Movement With Water

How can you control leaching and runoff? Indoors and out, an overapplication may result in runoff.

Runoff is potentially serious anywhere. This is particularly the case indoors, if runoff has nowhere (or nowhere safe) to go. Pesticides that run into a drain may cause unexpected damage far from the application site. Pesticides that run off the target and pool on a floor, even when dry, may expose people who use a building.

Outdoors, pesticides may move with irrigation or rainwater. More information about offsite movement in water and how to manage leaching and runoff may be found in Unit 5 (Pesticides in the Environment) and Unit 6 (Special Environmental Concerns) of the Core Manual.

Personal Protection

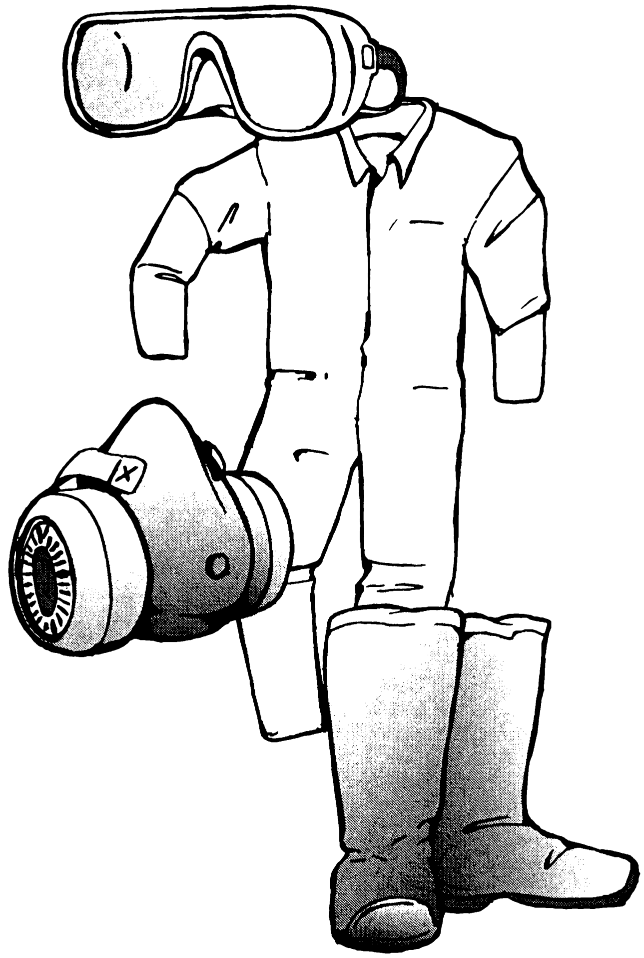
Safety is always a concern for you as a pesticide handler. You must consider your own safety, as well as that of your coworkers, your clients, and the people who will use the areas you treat. Human safety is addressed throughout the Core Manual. Unit 7 (Harmful Effects and Emergency Response) and Unit 8 (Personal Protective Equipment) are devoted to human heath and safety issues. Unit 7 describes the signs and symptoms of pesticide injury or illness. It also describes how to determine whether allergies or heat stress could be involved. Most importantly, it tells you how to respond to a poisoning emergency. Unit 8 discusses how to select, use and care for protective clothing and equipment.

Personal protective equipment (PPE) is the name given to clothing and devices that protect the body from contact with pesticides. Each pesticide product label lists the minimum PPE required for using that pesticide. Different handling activities (mixing and loading, applying, cleaning application equipment, etc.) may call for different PPE. Federal and state laws require pesticide users to follow all instructions on the product label, including wearing PPE.

Always read the label of a pesticide product before you purchase it, and again before you use it. Be sure you have the necessary PPE and application equipment to use the product as directed. Before opening a pesticide container, put on all of the required PPE.

In choosing PPE for a job, consider:

- label directions,
- label human hazard warnings,
- application situation and site, and
- common sense!



As a pesticide handler, your risk depends on two factors: the toxicity of the product and your exposure to it. You can reduce risk when using pesticides by choosing low-toxicity products, and by eliminating or minimizing exposure to them. Proper use of PPE is one way to reduce or eliminate your exposure to pesticides.

There are some situations in ornamental pest management that call for special safety precautions. In some cases, due to the nature of the application, exposure risk increases. Examples include spraying overhead and walking through just-treated areas. In these situations, the application must be planned with extra care. If no alternative to the high-risk method exists, applicators should consider using more protective clothing than the product label requires.

Consider using additional PPE for:

- mixing / loading operations,
- using hand-held equipment (excluding "spot spraying"),
- entering the path of just-released pesticide,
- walking into a recently-treated area,
- making an application that is directed upwards and overhead, and
- applying fine particles, like dusts or aerosols, especially indoors.

Mixing involves handling pesticide concentrate. Often, loading involves transferring a relatively large amount of material into application equipment. That is why many product labels require more protective equipment for mixers and loaders than for applicators. Choosing ready-to-use products can reduce exposure risk. Another strategy is to choose products formulated or packaged to reduce exposure. Many of these materials, like water-soluble packaging and dry-flowable formulations, also simplify measuring and reduce handling.

If you use a backpack sprayer or other hand-held application equipment, you are very close to the pesticide you carry and release. Be sure your equipment is in good working order. Be sure it does not leak. If you are applying a liquid, use the proper nozzle and be sure it is in good condition.

When using hand-carried equipment, take care so you do not intercept the pesticide you are releasing. Avoid walking through a just-treated area, or reduce the number of times you do so, by planning your application path and pattern in advance. Consider using PPE that offers additional protection. For example, if the label requires only shoes and socks, wear chemical resistant boots over them. Remember that if you walk through an area that is still wet from a liquid application, you will 'track' the pesticide outside of the treated area. In the case of some herbicides, you will leave 'footprints' for all to see.

Spray tall-growing plants only when wind and weather conditions are ideal. Usually, high volumes and/or pressure are needed to spray tree canopies. The pressure and the distance between release and target may allow for drift. In addition, the spray may 'rain' back down and expose the applicator. Consider alternatives to overhead spraying. If you must spray overhead, use extra PPE to cover your head and neck and protect your face and eyes. Spray only when weather conditions do not favor drift.

Fine particles pose a hazard for several reasons. For one, they are small and light and more likely to be carried offsite by air movement. For another, they are an inhalation hazard. Consider alternative formulations or application methods, if available. Take steps to manage drift if you must apply pesticides in the form of fine sprays or mists. If the label does not require a respirator, consider wearing one anyhow.

In summary, remember that it is your responsibility to use pesticides properly. This includes protecting yourself, other people, and the environment.

Test Your Knowledge

Q. What are some things you should know to plan a pesticide application?

A. First, evaluate the problem. Identify the pest causing it. Learn about this pest's life cycle, and act when control measures are most likely to be successful. Read labels, and choose a product suited for the site, situation, and pest. Be sure you have the equipment and expertise to use it as directed. Study the site before making an application.

Q. Why should you study an area before you treat it with a pesticide?

A. If you study an application area in advance, you can identify sensitive areas and situations. For example, observe if (and when) children or foraging wildlife visit the site. You can plan an application time and method that will reduce or eliminate exposure for yourself and for others. Plans to prevent potential problems should be in place before application.

Q. Describe some 'sensitive areas' that call for extra planning and precaution when using pesticides in them.

A. An area may be considered 'sensitive' for a number of reasons. One is because of who uses the site (ex. children and/or the elderly.) Another is due to design features (ex. airflow, enclosed space.) Still another is because of environmental factors, like a shallow water table or weather conditions that favor drift.

Q. For each situation listed below, explain why it is potentially hazardous. Note at least one thing you can do to manage pesticides in the situation.

- **Mixing / loading operations.**
- **Using hand-held equipment.**
- **Entering the path of just-released pesticide and/or walking into a recently treated area.**
- **Making an application that is directed upwards and overhead.**
- **Applying fine particles, like dusts or aerosols, especially indoors.**

A. Mixing involves handling concentrate. Loading involves transfer of relatively large volumes of material. Most product labels require more PPE for mixers/loaders. If the one you are using does not, consider wearing extra PPE when performing these chores. Alternatively, choose formulations or packaging that reduce or eliminate the amount of handling involved.

Using hand-held equipment means you are carrying pesticide. In addition, you are close to the material you are releasing. You can reduce exposure by ensuring your equipment is in good condition and by wearing extra PPE.

Walking through just-released pesticide or a treated area can result in exposure. It can also cause you to carry ('track') pesticide offsite. Plan your application to avoid or at least minimize walking through a just-treated area. Again, choose extra PPE.

Overhead spray applications may result in pesticide falling back to ground on the applicator. In addition, there is increased possibility of drift. Again, wear additional PPE to protect the upper body. Spray only when conditions do not favor drift.

Fine particles pose an added inhalation hazard. In addition, they are more prone to drift. Wear extra respiratory protection. Apply fine particles only when environmental conditions do not favor off-target drift.

Unit 6. Pesticide Application Equipment

Learning Objectives

After completing this Unit, the learner will:

- Recognize the types of pesticide application equipment commonly used in interiorscapes and landscapes.
- Describe the function(s) of the basic components of pesticide application equipment.
- List the uses, advantages, and disadvantages of different types of application equipment.
- Match a plant health problem, situation, and site with the most effective pesticide delivery method.
- Describe the proper use and maintenance of pesticide application equipment.
- Explain when and why application equipment must be calibrated.
- List the factors that affect application rate. Explain how each increases or decreases the amount of pesticide released by the equipment.
- Describe how to calibrate and adjust pesticide application equipment.

This Unit describes some of the application equipment commonly used in interiorscapes and landscapes. By reading it, you will learn how these devices work. You will also learn how to use them properly. This Unit discusses the factors that affect application rate. It explains how to do some common pesticide calculations. It also describes equipment calibration and maintenance.

When you use a pesticide, your principal objective is to make effective contact between the pesticide and target organism(s). Proper coverage is an important part of pest control. As a rule, a uniform application to all target surfaces increases pesticide efficacy. It will also reduce phytotoxicity problems. To apply pesticides according to label directions, application equipment must be working properly and used correctly. If application directions instruct you to apply a given amount to a certain size area, you must use calibrated equipment to apply the correct amount in the target area.

Terms to Know

Aerosol Applications - Small droplets (15 to 20 microns) dispersed from pressurized cylinders. Some are "bombs," which may be set to release pesticide into an enclosed, secure area.

Aqueous Spray - An application in which the pesticide product is diluted with water and applied as a liquid spray.

Backpack Sprayer - A hand pumped sprayer carried on the back of the operator. Backpack sprayers are usually used for treating small areas and for making spot treatments.

Backsiphoning - Movement of liquid from the application equipment back into the water source.

Calibration - The process of measuring and adjusting the amount of pesticide a piece of equipment applies to a target.

Dust - A dry pesticide formulation diluted by a solid carrier such as talc or clay. Dust particles are very small. Dusts are ready-to-use. They do not require mixing or dilution.

Fog - Small droplets (10 to 60 microns) produced when an oil-base preparation is dispensed through a special device that uses heat to vaporize the pesticide.

Granule - Like a dust, a granule is a dry pesticide formulation diluted by a solid carrier such as talc or clay. However, granule particles are larger than dusts. They are usually between the size of a sand grain and that of a feed pellet. Granules are ready-to-use. They do not require mixing or dilution. Granules are usually applied with a spreader.

Hydraulic Sprayer - A solidly-built, long-lasting machine that uses a pump to generate the pressure needed to spray liquid pesticides. Often, a hydraulic sprayer will have a piston pump and mechanical agitators to keep the pesticide mixture from settling or separating.

Knapsack Sprayer - Another name for a backpack sprayer.

Labeling - The pesticide product label and any other materials with directions pesticide users are legally required to follow.

Micron - A unit used to measure spray droplets. A micron is 1/1000 of a millimeter. The diameter of a human hair is approximately 50 microns.

Mist Spray - A concentrated spray for ultralow volume (ULV) applications. Mist applications use very small quantities of a highly concentrated pesticide that is diluted with air for delivery to the target.

Nozzle - A tip that releases pesticide from application equipment. The construction of the nozzle regulates the pattern and amount of discharge. Some applicators have a built-in nozzle, which may or may not be adjustable. Others are constructed to allow you to use a variety of different nozzle tips. In this case, you can choose a nozzle or set of nozzles based on the pattern and flow rate you want.

Orifice - The opening in a sprayer nozzle. This opening regulates the flow through the nozzle.

Phytotoxicity - Injury or damage to a sensitive plant caused by a chemical exposure.

psi - Pounds per square inch, a measure of pressure in sprayer systems.

Spray - A liquid application method. To produce a spray, a liquid is forced through a nozzle under pressure, forming droplets. The term 'spray' is also used to describe the liquid output of a sprayer.

Swath - The area treated by a sprayer or duster in one pass.

ULV - Ultralow volume. In an ULV application, a concentrated pesticide is applied at very low volume; for example, at a rate of 1/2 gallon per acre or less.

Effective pesticide application depends on many things. Factors include proper timing (to treat susceptible pest stages), favorable treatment conditions (temperature, humidity, moisture, time of day, and plant condition), and thorough coverage. If you use a pesticide, you want it to be effective. You must use a product labeled for the site you wish to treat and effective against the pest you want to control. However, proper operation of pesticide application equipment is as important as the chemical(s) you select for the job. Pesticides must be delivered to the target in the proper manner and applied at the correct rate to do their job.

Pesticides are available in many formulations. However, most formulations have a prescribed application method. In some cases, an active ingredient may be available in only one formulation. If you wish to use a particular formulation, you must use the proper application equipment.

There are many types of application equipment available today. Before choosing an application device, learn how it works, and how to operate and care for it. Read about its intended uses. Evaluate its advantages and disadvantages.

When evaluating equipment, ask yourself these questions:

- Is the equipment well-suited for the target(s)?
- Will it apply the formulation(s) you wish to use?
- Is it affordable?
- Is it sturdy and durable enough to do the job?
- Is it easy to fill, operate, and clean?
- Will it apply pesticides in an environmentally sound manner?

After choosing a piece of equipment, you must use it correctly and take good care of it. Study the manufacturer's directions and follow these instructions carefully. The section that follows describes some of the devices commonly used to apply pesticides to ornamental plants.

Pesticide Application Equipment

There are a number of ways to apply pesticides to manage plant pests. Spraying may be the most common method. However, many other treatment methods may be useful and effective in some situations. What follows is a short description of common application devices used to treat ornamental plants in interiorscapes and landscapes. The advantages and disadvantages of each are noted.

In some situations, a plant health manager may wish to move plants in order to treat them effectively or safely. Moving a plant to a specific site may allow you to use a specific formulation and application method. For example, you may wish to transfer interiorscape plants to an outdoor holding area. Alternatively, you may leave them indoors but move them to a site away from the public when they need to be treated for a pest problem. Group outdoor containers or move them to an enclosed area for a fog or mist treatment.

Liquid Applicators

One way to apply a liquid pesticide is as a soil drench. However, most liquid applications are made as a spray.

Spraying is one of the most widely used and effective methods of applying pesticides. In a spray application, liquid droplets containing dilute pesticide are directed at the target. Many spray applications use water as a carrier. Small-volume spray applicators are usually simple and inexpensive devices.

Larger units may be complex and costly. Larger applicators usually have more parts to maintain and adjust, such as pumps and interchangeable nozzles.

In ornamental pest management, the target of a liquid application is usually plant foliage. Usually, insecticides and fungicides are applied to the foliage of the plant needing protection. However, sometimes the pest insect or disease organism is treated. Usually, liquid herbicides are applied directly onto the pest weed.

Spray application devices produce droplets and direct them to the target. When treating plant foliage, the applicator often has a large target because of the amount of surface area involved. Usually, sprayers are easy to use. Many pesticide products direct you to apply a given volume to a specified area. This requires calibrating the sprayer. Other products simply instruct the applicator to mix the product to a prescribed concentration and explain how much coverage is needed. In cases like this, spray equipment does not need to be calibrated. In all cases, however, the applicator must ensure the droplets reach the target and do not drift away as fine particles or vapors. If the target is plant foliage, the applicator must make sure the spray 'sticks' to it. Sometimes, both upper and lower leaf surfaces need to be treated, which requires special care.

The common components of any spraying system are:

- a holding tank.
- a nozzle (or several nozzles).
- a hose or tube (or system of hoses) connecting the tank with the nozzle(s).
- the device or system that provides pressure.

In addition, some sprayers have a way to agitate the spray mixture.

The tank holds the mixed liquid pesticide. Hoses or tubes channel the liquid from the tank to the nozzle. Pressure forces the liquid through a nozzle. The shape and size of the nozzle orifice affects the flow rate and the spray pattern. The larger the orifice (opening), the greater the flow rate.

All sprayer components, including gaskets, hoses, and other fittings, should be chemical-resistant. This will prevent these parts from swelling or breaking down when exposed to organic solvents like those found in many liquid pesticide formulations. A sprayer must be configured properly and used correctly to produce a uniform spray.

Some systems have filters or screens to trap particles. These strainers can be located in the tank, in the lines, or at the nozzle. Proper use of filters protects the working parts of the sprayer and reduces nozzle wear. Many systems also have pressure gauges, pressure regulators, and agitators.

Keep tanks in good condition. Handle them with care so they do not crack or leak. Tanks must be clean. Debris from a dirty tank may block narrow passages in hoses or tubes, screens, and nozzles. Contaminants may affect a spray solution, resulting in incompatibility or phytotoxicity. For example, herbicide residue from a previous application in a tank may harm the plants an insecticide or fungicide application is supposed to protect. For that reason, plant health managers should have at least two spraying systems — one dedicated to herbicides and another for applying fungicides and/or insecticides.

Nozzles are an important part of a spraying system. The nozzle you select affects both the output (spray volume) and the distribution (spray pattern). A complete nozzle assembly consists of the body, screen, cap, and tip or orifice plate. The nozzle tip is an atomizing device. It produces liquid droplets that form the spray pattern. Nozzles are made for many different spraying requirements. Manufacturers of sprayer nozzle tips supply data sheets for the delivery rate (usually in gallons per minute within a range of pressures) and pattern. However, these specification sheets cannot give the actual application rate. This is because application rate is also dependent on speed and pressure.

Never operate nozzles at a pressure outside the prescribed range to compensate for selecting the wrong size. If the pressure is too low, the pattern the nozzle is supposed to produce will not form properly. Spray distribution will not be even or as expected. High pressure increases the rate of nozzle wear and the drift hazard.

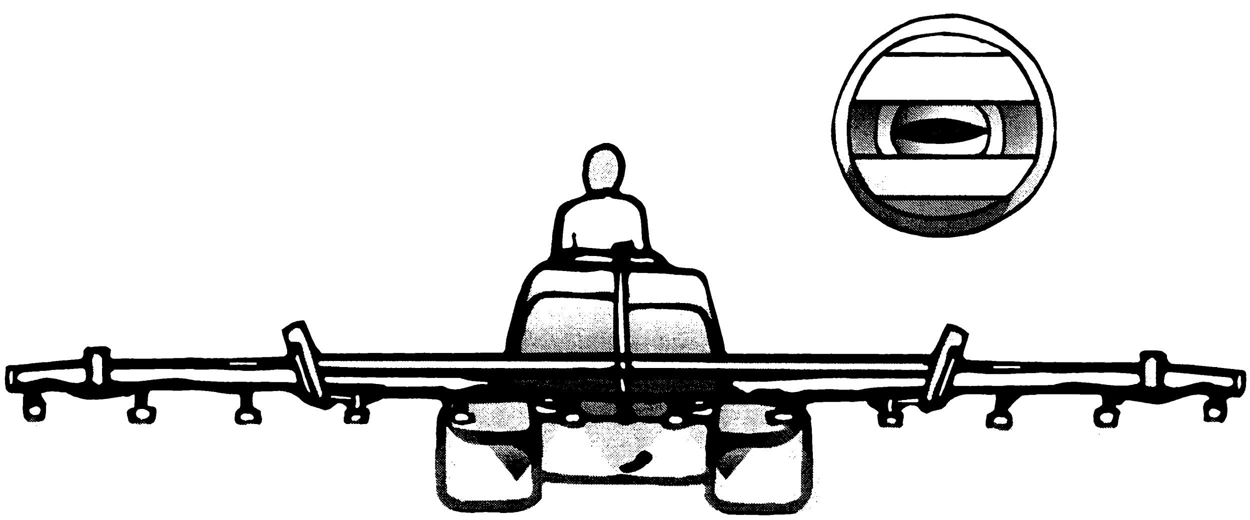
Nozzle tips are made of a variety of materials: aluminum, brass, ceramic, plastic or polymer, nylon, stainless steel, and hardened stainless steel. Ceramic and hardened stainless steel are more resistant to wear. They will last longer when used with abrasive formulations such as wettable powders. They are also more expensive than other materials.

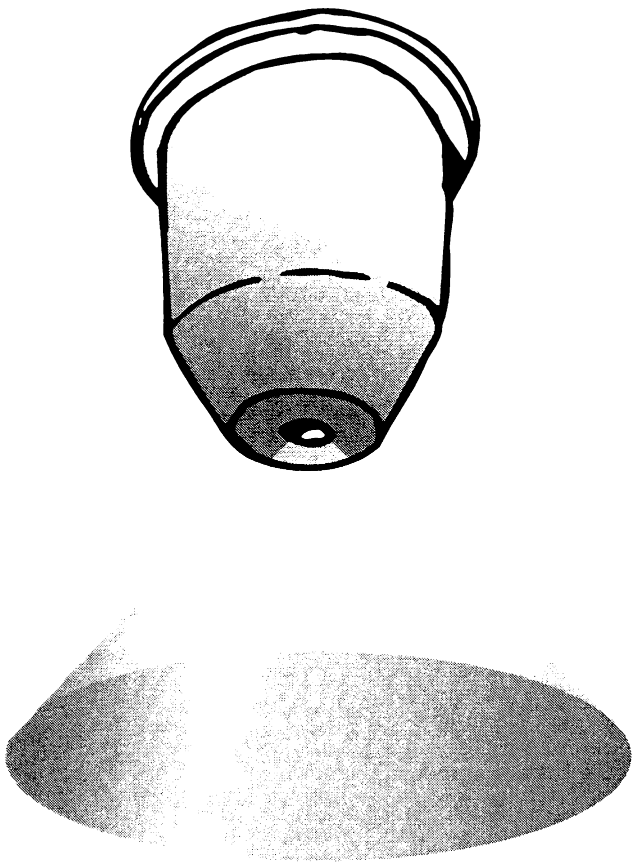
Nozzle tips are classified according to the spray pattern they produce. Many types of spray tips are available today. Two common types are the flat fan and the cone nozzle. There are many, many sizes and varieties of each. Here is a general description of each.

A fan nozzle produces a fan-shaped spray. The liquid released is narrow at the nozzle and becomes increasingly wider as the distance from the nozzle increases. A regular flat fan nozzle makes a narrow oval (elliptical) pattern with lighter edges. The orifice (opening) in this type of nozzle is also elliptical.

Flat fan nozzles are usually used for broadcast spraying. Regular flat fan nozzles are designed to be mounted on a boom. They are positioned so the liquid they release is overlapped 30-50 percent for even spray distribution across the boom. When a series of flat fan nozzles are properly configured on a boom, the spray material is distributed more evenly than it would be with any other type of nozzle. Flat fan nozzles are well suited for making herbicide applications. The most commonly used flat-fan pattern nozzles have a spray angle of 65, 80, or 100 degrees. For herbicide spraying using a relatively short boom (20 to 35 feet), the 80-degree flat-pattern nozzle is best. It is possible to keep the boom relatively low to reduce the drift hazard. If the sprayer is configured properly, it will produce a uniform distribution of spray material over the entire length of the boom.

Special flat-pattern nozzles, usually called even flat fan nozzles, are available for band spraying in rows. They may also be used with a backpack (single nozzle) sprayer.





Cone nozzles produce circular patterns. The hollow-cone nozzle delivers most of the material to the circumference of the circle. The full-cone nozzle delivers liquid droplets to the entire area of the circle. Both types of nozzle tips have circular openings. They are well suited for applying insecticides or fungicides in situations where complete coverage of the leaf surfaces is extremely important. They are not ideal for mounting on a boom.

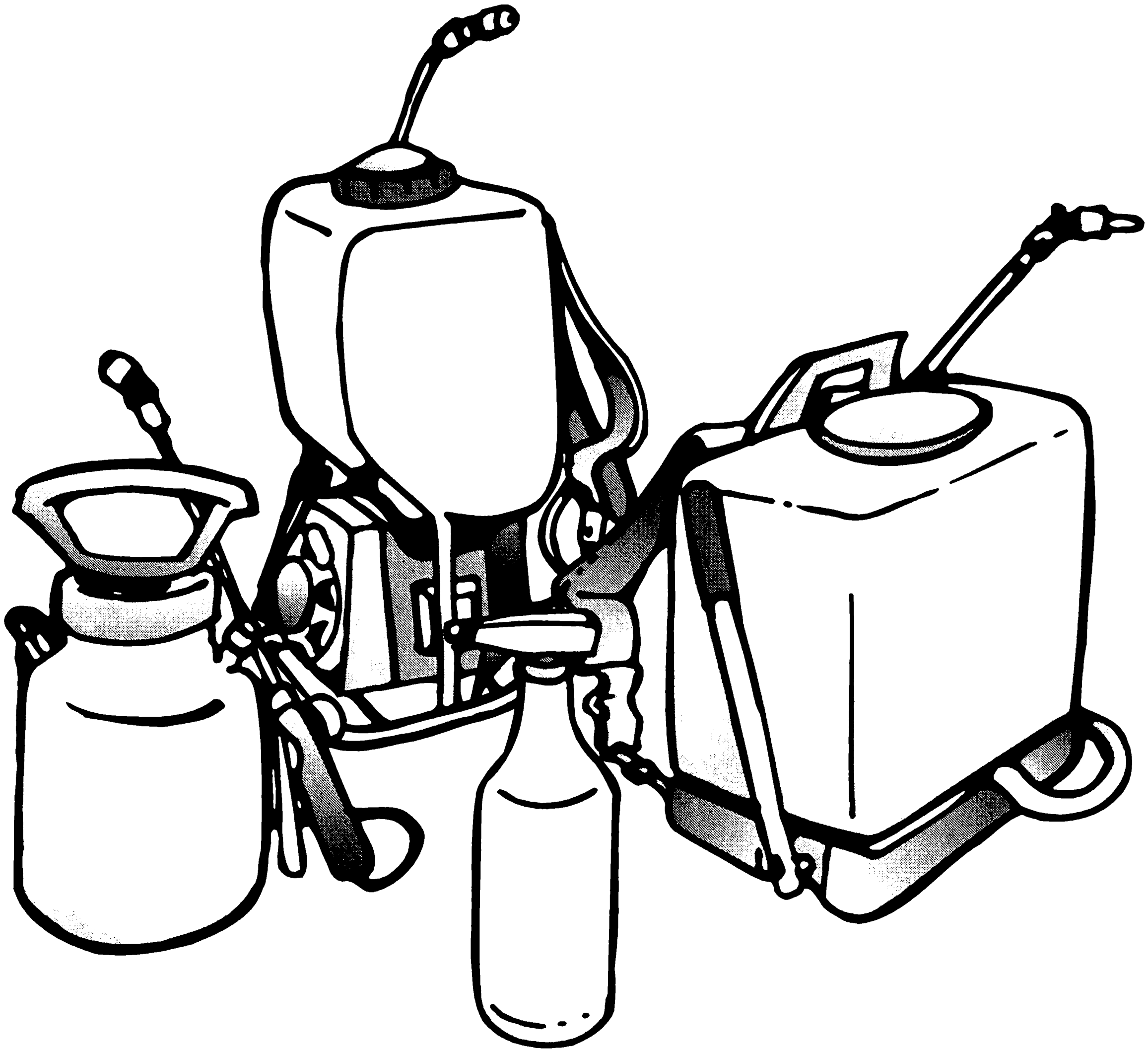
Placing nozzle screens behind the nozzle tip and in the nozzle body helps to eliminate, or at least reduce, clogging. The size of the nozzle opening and/or the type of chemical being sprayed dictate the size and type of nozzle screen that should be used. For most spraying, use a 100-mesh screen. However, if you are spraying wettable powder suspensions, choose a coarser (50-mesh) screen. When a sprayer is turned on and off frequently — when working in small plots or when spot spraying — nozzle "dribble" may become a serious problem. A nozzle screen with a check valve in it will help eliminate "dribble" and will not affect the operation of the sprayer. However, be sure to maintain and inspect the check valve. Be sure the ball bearing does not "stick" to its seat. Also, be sure that dirt or chemical particles do not hold the ball bearing off its seat.

Keep nozzles clean and in good condition. Check the flow rate and pattern on a schedule. Replace nozzles before they become worn. The nozzle orifice will enlarge with wear, especially if abrasive materials are used. Nozzle wear changes both the spray pattern and the flow rate. If the flow rate of a nozzle is 'off' by 10%, replace it. Also, replace any nozzle that is producing a non-standard pattern.

Some sprayers use pressure provided by a plunger device, which is pumped by hand. Others use fuel-powered pumps: roller or piston pumps, for example. All pump parts should resist corrosion and abrasion. Never operate a pump at speeds or pressures that exceed the manufacturer's recommendations. The spray liquid moving through pumps lubricates them and prevents overheating due to friction. Operating a dry pump will damage it. Operating one when the system flow is restricted will also cause damage. If your sprayer clogs, stop the pump and fix the problem.

As a rule, liquid formulations such as emulsifiable concentrates (EC) and true solutions (S) are easy to apply as a spray. The same is true for soluble powders (SP). However, materials that do not dissolve in the carrier you are using (which is usually water) must be agitated during application. Constant agitation will keep particles from settling in the spray tank. To make a uniform application with a wettable powder (WP) and water-dispersible granule (WDG) formulation, use a sprayer with an agitator.

Here is a description, along with a discussion of the advantages and



disadvantages, of some of the commonly used spraying systems:

Hand sprayers have a number of advantages. They are relatively inexpensive, simple to operate, maneuverable, easy to clean, and easy to store. Most backpack sprayers have an adjustable handgun. However, small spray booms are available on some models. They are well suited for spot treatments and spraying small areas. They are also used for treating sites that are not suitable for larger units. For example, they can be used to treat steep slopes or areas with limited access. However, they have some limitations. Their capacity is small (usually one to four gallons.) Pressure and output may fluctuate. Some do not have a good way to provide agitation. Therefore, they are not useful for applying suspensions like wettable powder spray mixtures. Examples of hand sprayers include pressurized aerosol cans, trigger pump sprayers, hose-end proportioners, push-pull pump sprayers, and backpack (knapsack) sprayers.

Trigger pump sprayers are used to apply solutions to foliage or soil. Various capacities are available, but most are small. Choose a size and shape that is easy to handle. To operate a trigger pump sprayer, you pump or depress the trigger. This forces spray mixture through the nozzle. Some models have adjustable nozzles, which allows you to control the droplet size and/or the shape of the liquid stream produced. Cleaning the pump and trigger assembly after each use will prevent residues from forming and clogging equipment. A trigger pump hand sprayer is most useful when only a few plants are involved.

Hose end proportioners are useful when a water hose can reach to all parts of the area(s) you wish to treat. Hose end proportioners are efficient tools to use when a large amount of foliage needs to be sprayed, and the target plants are clustered in one area. Any formulation that uses water as a carrier can be applied with this type of equipment. Note that wettable powder and emulsifiable concentrate formulations require frequent shaking. Always check to ensure your equipment is working properly, and calibrate before each application. Take extra care to prevent spills and splashes onto floors or other surfaces. Prevent backsiphoning. Use hose end proportioners only if you have an air gap or a fail-safe backflow prevention device between the hose-end proportioner and the water supply.

Backpack sprayers and push-pull pump sprayers are useful when the plants or areas you wish to treat are some distance from a water supply. They are also useful for spot applications. They are portable, but limited in volume. Most have tanks with a capacity in the two to four gallon range. Take care they do not tip, spill or leak. Before using a backpack sprayer to apply a product, read the label to see if the sprayer must be calibrated. Because of variables that depend on the applicator, such as walking speed and the distance between the nozzle and the target, each person using it must calibrate a backpack sprayer. Backpack sprayer calibration is explained later in this Unit.

As a rule, small motorized sprayers have a larger capacity than hand sprayers. They can operate within a wider range of pressures. Many have built-in hydraulic agitation. Some are small enough for use in confined areas or small spaces. However, they may not be suitable for wide-area use. They may not generate enough pressure and flow to allow for good coverage of a large tree. Power backpack and estate sprayers are two examples of small motorized sprayers.

Large high-pressure sprayers are used to spray dense foliage and reach the canopy of a tall tree. These power-driven devices are sometimes called hydraulic sprayers. Usually, they are mounted on a tractor, truck, or trailer. They carry and deliver large spray volumes. Mechanical agitators are usually standard equipment. High-pressure sprayers can be fitted with a single handgun to spray trees. They may be used with a boom to spray a wide area. They provide good penetration, reach, and coverage. They are relatively expensive. However, they are usually durable and long-lasting if cared for properly. They require large amounts of water and fuel. Because of their size, they may not be suitable for all sites.

All spray applications can drift. However, when used correctly, high-pressure sprayers are more likely to result in pesticide drift than hand carried or small motorized devices. This is true for several reasons. High pressure usually produces small spray droplets. Because of their small size and mass, small particles are more prone to drift. In addition, high-pressure sprays are used to reach distant targets. Therefore, the spray must travel a long way between release and deposition. This provides more chance for drift. Moreover, in the case of tree canopy treatment, the spray stream is directed upwards, not towards the ground. Any particles not deposited in the canopy will fall back towards earth. Some of these may drift off target as they drop.

Special Application Equipment for Herbicides

Some sprayers may be modified to direct liquid herbicide to a target weed without contacting nearby desirable plant foliage.

Shielded sprayers are one example. Shields enclose and direct the spray from a nozzle. Wick applicators are another example. Wick applicators use a piece of rope, absorbent fabric, or sponge to transfer the pesticide to the target. Wick applicators apply a concentrated herbicide mixture. The wet wick is 'wiped' directly onto the weed. Wick applicators are easy to operate. If used properly, only the target is affected. There are no particles to drift. However, wick applicators are not appropriate for all pesticides or in all situations.

Aerosol Generators and Foggers

Aerosol generators and foggers are sometimes used with certain insecticide formulations. They convert these products into very small, fine droplets. Single droplets are too small to see with the naked eye. Large numbers of droplets are visible as a fog or mist. This method is a good way to treat a large number of plants in an enclosed area. Fogging can be a very efficient method of pesticide application, provided the operator follows instructions. The machine must be clean and properly calibrated to dispense pesticides according to label directions. Proper mixing is very important.

Aerosol generators and foggers fill a space with a pesticidal fog. In some cases, insects are killed on contact. Some formulations provide residual control and others do not. In other cases, the mist simply repels the insects. In the case of repellents, the insect pests may return after the mist settles.

Thermal foggers use heat to vaporize special oil-based formulations. As the warm pesticide vapor is released into cooler air, it condenses into fine droplets, producing a fog. Other aerosol generators (cold foggers) break a liquid stream into an aerosol by mechanical means.

The mists produced by aerosol generators and foggers can penetrate dense foliage. Some indoor-use devices are automated. Limitations include the potential for drift, due to the very small droplet size these devices produce. However, plant health managers can avoid drift in enclosed settings by sealing the area to prevent drafts or air leaks. It is important to follow label directions for keeping a treated area 'off limits.' Some labels require that you close the treated area for a prescribed period. As a rule, treated areas must be properly ventilated before people return to the site.

Treat all pesticides in vapor form with extreme caution. This is especially important when working in enclosed spaces. There is a risk of explosion when these devices and formulations produce fine particles. Wear a respirator. Follow label directions and take all special precautions. For example, some labels have specific conditions (dry foliage, temperature range) for applications. For example, applications made at cool temperatures may not be effective. However, if the temperature is too hot, plants may be injured.

Smoke Generators

Smokes are cans of insecticide mixed with combustible materials, which are ignited in their container. They produce an insecticidal smoke. Smokes are easy to handle. They are particularly useful in small enclosed areas.

Ready-To-Use Aerosols

Ready-to-use aerosol containers contain a pesticide dissolved in a volatile liquid under pressure. When discharged from the pressurized cylinder or "bomb," the pesticide vaporizes. After release, fine particles of pesticide are suspended in the air.

Aerosol cans or "bombs" are convenient for applications made in small installations or to a limited number of plants. They are easy to use. Most products available are labeled for insect and mite control. Ready-to-use aerosols do not penetrate soil. Aerosol bombs or spray cans require the same precautions involved with aerosol generators and foggers. Read the label!

Before using a ready-to-use aerosol, check the application directions. Make sure the container is the correct distance from the plants. Exposure to the escaping propellants can damage plant tissues. As a rule, do not use ready-to-use aerosol products when temperatures exceed 85 degrees or leaf surfaces are wet.

Dry (Dust/Granular) Applicators

Duster applicators combine a dust formulation pesticide with air to distribute the pesticide evenly over a target area. Power dusters use a motorized fan or blower to propel the dust to the target. Bulb or hand dusters are used in small areas. They use devices like a squeeze bulb, bellows, shaker, or hand-cranked fan to distribute the dust. Some dusters have attachments to extend the reach of the tube and the direction of the dust.

Dust applicators have several advantages. Because dusts are ready to use, there is no mixing or dilution involved. Dust applicators are lightweight, simple in construction, and easy to maintain. No water is needed. Dusts may be propelled into hard-to-reach places. However, dusts may not stick to foliage. Because dust particles are small and light, drift potential is high. Applications may be hard to direct to the target, and coverage may not be uniform.

Granular formulations are commonly used for soil treatment in established vegetation, like turf, because they fall through or roll off the plant surfaces and land on the surface of the ground. Granule applicators distribute particles by several methods, including forced air, a shaker, and gravity-feed outlets (ex. lawn spreaders). Some granular products are applied so the particles are evenly distributed over an area. Other product labels may direct you to place a certain volume around the base of a plant, or use a certain amount per container. Some are applied at the surface of the growing medium and watered in. Others are soil incorporated. Like dusters, granule applicators are simple. They are ready to use, so there is no mixing. No water is needed. They have little or no drift potential. They pose a very low exposure hazard to the applicator. However, they will not adhere to foliage. If using a drop spreader, you must re-calibrate for each formulation.

Baits / Traps

Most baits consist of a pesticide mixed with a food or an attractant. Many are available in ready-to-use, tamper-proof stations. Well-designed bait stations attract only the target pest. If used properly, there is little or no exposure risk to applicators, building occupants, or nontarget organisms. The entire area does not need to be treated, because the pest comes to the bait.

However, use baits with care. Always keep baits out of the reach of children and pets. Baits that become contaminated by sprays or dusts may actually repel pests, not attract them. Baits are most effective if competing food sources are reduced or eliminated.

To be effective, baits must be placed properly and monitored regularly. Locate baits near nests, trails, and in areas where pests are seen or likely to be found. In some cases, pre-baiting is necessary. Once they are in place, do not disturb bait stations so pest feeding patterns are not disturbed. However, check them often. Refill, replace, move, or remove baits and bait stations as needed.

Baits are effective management methods for many types of pests. They are well suited for controlling social insects such as ants, wasps and termites. This is true because workers share food they collect within the colony. Baits with an attractant or feeding stimulant are effective for cockroaches, silverfish, and other foraging pests. Baits may be a good way to control rodents in a confined area.

Traps use something to attract and hold (or kill) pests. For example, insect traps may use pheromones or color to attract insect pests. Rodent traps use food. Traps may be a good way to monitor pest populations. In some situations, traps are also a very effective pest control method.

Injection Technology

Injection technology is a way to apply pesticides to large woody plants. One method places pesticide to the soil surrounding a tree, where it is taken up by the tree. Another introduces chemical directly into the tree's transport tissue.

Soil Injection

Soil injection places pesticides, dissolved or suspended in water, into the soil within the root zone of the tree. This is an acceptable method of controlling many ornamental insect pests. The soil injection method puts the pesticide in contact with the absorptive root system of the tree. Most of a tree's absorbing roots are found within the top 12 inches of soil. The root system of the tree will absorb pesticide placed in this zone. Once into the tree's transport system, the pesticide will be distributed to the leaves and other living parts.

For example, as insects feed on the foliage of a tree treated with insecticide by soil injection, they will ingest small but lethal amounts of an insecticide. Some soil injections involve a small volume of insecticide placed into a concentrated area of the root zone. Liquid fertilizer injection requires a comparatively large volume of material. Fertilizer injections are distributed in a grid under the canopy to cover the entire root system.

When applying an insecticide via soil injection, there are three important considerations:

1. The pesticide you wish to inject must not be phytotoxic to the plant roots. Improper use of pesticides can cause serious injury, and even death, to a tree.

2. The soil type and condition must be compatible with the pesticide. Sandy soils may leach pesticides into groundwater. Be sure to read the instructions for each pesticide carefully. Be sure your injector is properly calibrated. Follow all directions regarding the injection placement. Soil moisture is another important consideration. There must be adequate moisture in the soil for the roots to absorb the pesticide. Therefore, injections are not recommended during the hottest parts of the summer unless frequent irrigation is provided.

3. Environmental factors and plant growth characteristics must be favorable. The timing of soil injections depends on the soil temperature and species of tree to be treated. However, as a rule, injections may be made during the fall and spring. It is

best to avoid using soil injection during the hot dry summer months and in the winter when the ground may be frozen. Tree uptake depends on environmental factors such as soil temperature and moisture. Additionally, tree vigor will play a major role. For most medium sized trees, two to three months are required for soil-injected pesticides to move throughout a medium sized tree. As many as six months may be required before some pesticides move throughout large trees, depending on their condition.

Many pesticides are compatible with liquid fertilizers. This makes application of both at the same time convenient. However, be sure the method of application is compatible. Liquid fertilizers concentrated around a limited area of the root zone can burn the roots of the tree.

Tree Injection

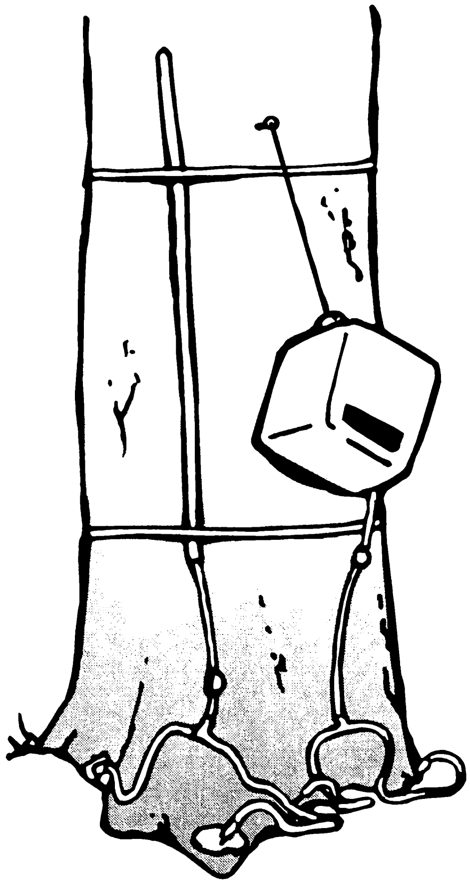
Tree injection is an application technique still in development. Because it is invasive, it should be considered only when other options are not practical or effective. However, this method offers some intriguing alternatives to managing tree stresses caused by fungi, insects and nutrient deficiencies.

In one sense, a tree should never be "violated" by unnecessary wounding. However, there are exceptions to every rule. For example, consider the case of limb and branch loss. Pruning can be very beneficial. Done properly, it often enhances health, longevity and productivity. On the other hand, storm damage can often bring about the premature death of landscape trees because of the introduction of rot fungi. The difference in the two examples is careful management. The same principle applies to tree injection.

There are specific instances in which there may be no other alternatives to wounding. One example is the case of tree injection. Injection may be the application method of choice in several situations. It may be the best application method to use on a landscape tree surrounded by pavement and sidewalks. It may be the treatment method of choice for a valuable tree located in a spot where spraying is prohibited or not advised. In other cases, injection may be the best or only way to apply the most effective pest control chemical.

Trees may be injected with nutrients, insecticides, fungicides, and plant growth regulators. The technology of injection has been developed over many years. Although plant health researchers have a long way to go, there are systems in place that are relatively safe and effective. Early on, plant managers drilled large and deep holes into tree trunks to inject chemicals. This application method caused many problems. Today, there are methods to introducing liquids at the tree crown (root/shoot interface), especially in root flares, which appear to be effective and relatively harmless. However, long term, subtle effects on tree physiology due to injection are still unknown. Injection ports (holes) should be as small and shallow as possible. They should always be clean and edged-out. After injection, flush the injection ports with clean water.

The term, "tree injection" needs to be defined because this term has been used for a number of techniques used to introduce chemicals into trees. Technically, "tree injection" indicates the forceful introduction of a chemical into a tree. Used this way, the term "injection" is comparable to a "shot" a person gets from the doctor. "Tree infusion" or "gravity flow" is like an intravenous application. A reservoir of liquid hangs from the tree trunk, and the liquid is drawn in by the tree's own uptake system. Trunk implantation devices are also used. Trunk implants use a capsule, which is placed into a freshly drilled hole in the trunk or in the root flare area. The head of the implant device is placed in the growth layer (cambium), so wound closure can occur. Trunk implantation



Tree Injection (infusion)

devices often contain a dry powder formulation. Upward sap flow dissolves the material, which becomes part of the "sap solution" that eventually reaches the leaves. Some leaf feeding insects, nutrient deficiencies, and foliar diseases (caused by fungi) can be managed this way.

In both injection and infusion, solutions are fed by gravity or pressure into holes (drilled or punched) in trunk or root buttresses. Best uptake occurs on warm sunny days when trees are in leaf. Most movement of injected chemicals is upward. For this reason, infusions and injections are not used for pests and diseases of roots. Suspensions containing insoluble particles are not satisfactory for injection because the particles tend to clog the water-conducting vessels of the wood.

The depth of the hole is important. A woody plant's transport tissue lies in the outermost sapwood. Infusion or injection holes should be placed into this tissue to introduce the chemical into the plant's system. Holes that extend deep into the wood are not desirable. Attempts to inject or infuse chemicals into woody layers will not allow much of the pesticide to reach the target — the wood of the current season, bark, or leaves. The diameter of the hole is also important. The smaller the better, because small holes heal quickly.

Healing processes in woody plants occur in both the wood and the bark after a tree is wounded. For this reason, an infusion or injection site can be used only once. Within several days after a hole is drilled into healthy sapwood, the tree reacts by isolating the wound from healthy tissues. This occurs before visible evidence of healing. Liquids cannot move into or out of a tree through such a wound.

Injection and infusion have several advantages. All or nearly all of the pesticide is placed within the tree, where it is distributed upward to the fine branches and leaves. There is little waste. The chance for off-target movement is low. Heavy, expensive equipment is not required. However, there are some disadvantages. Internal distribution of chemicals may not be uniform. The proper total dose depends upon tree size, and must be determined for each tree to be treated. Bleeding of sap or resin from injection sites sometimes occurs, especially in spring.

Injection and infusion technology is still in its infancy. There are several types of devices available today. Others are in development.

Tree implants usually introduce chemicals packaged in a capsule. Capsules are inserted into holes drilled into the outer sapwood. Sap from the living wood dissolves the capsule or the inner membrane holding the chemical. This allows the pesticide to be carried upward in the sap stream. Capsules are inserted so that the outer end is flush with the surface of the wood, and are not removed. Like infusion and injection, implantation contains and controls the pesticide. There is little or no risk of drift or other off-target movement. Applicator exposure is reduced as well. No specialized equipment is necessary. The main disadvantage is that the technique can be used only for applying small amounts of chemicals.

In summary, there are many ways to apply pesticides to ornamental plants. When chemical use is called for, consider all options. Choose the method best suited for the site. In all cases, remember that a piece of equipment used in pesticide applications should not be used for any other purpose. For example, a hose end proportioner may be used to make large-scale applications of fertilizers or pesticides. If both types of applications are made in a worksite, two proportioners are needed. Both should be labeled to avoid misuse. The same practice should be used with tools used for granular applications. Don't assume pesticide equipment is free of chemicals even after careful cleaning. Small traces of pesticides can cause unexpected damage. For this reason, you should not use one applicator for all types of pesticide products. Traces of herbicide in a sprayer used for an insecticide or fungicide application can cause plant injury. It is wise to have one set of application tools for herbicides only and another for fungicides and insecticides.

Calibration

The term calibration refers to all the operations an applicator takes to ensure that the correct amount of pesticide is applied to the target. Calibration involves figuring out how much pesticide is needed to cover a given area.

There are many reasons for proper calibration:

- environmental safety,
- efficacy,
- legality, and
- economics.

Failure to calibrate equipment often results in ineffective pesticide control. As a rule, for a pesticide to do its job, the prescribed amount of active ingredient must be delivered to the target. An ineffective application wastes time and money. It puts chemicals into the environment for no useful purpose. In addition, an overapplication may cause phytotoxic effects and damage the plants you are trying to protect. It may result in excessive or illegal residues. It increases the exposure risk to applicators, the public, and nontarget animals and plants. Overapplication also increases the risk for off target movement.

A number of factors affect the sprayer output. These include:

- the nozzle (orifice size, pattern, condition),
- the sprayer configuration (boom height, number of nozzles, nozzle placement),
- the speed the applicator travels, and
- the pressure.

Usually, equipment is set up in advance to meet the needs of the application site. The operator makes minor changes in output by changing the speed and/or pressure. To make major changes, the operator must change nozzle tips.

Note: when using any wettable powders, calibrate the sprayer frequently. As a nozzle wears, the size of the orifice increases. Therefore, the amount of the spray material delivered also increases. In some cases, nozzle wear is not uniform. Uneven wear changes both the flow rate and the pattern.

To calibrate your equipment, you must first determine the amount of pesticide and water to be applied and the appropriate rate of application. You may need to adjust sprayer pressure or change nozzle size or modify application patterns to achieve the desired rate of application.

You can calibrate a sprayer by measuring the amount of liquid released by the nozzle(s). Compressed air sprayers lose pressure during operation, so they must be pumped frequently. Operate mechanical pump sprayers at the recommended pressure during calibration. Fill the tank about half full of water. Collect the liquid delivered. Record the volume and the time it took to spray it.

Here are instructions for calibrating a backpack sprayer. You can use the same general method to calibrate a boom sprayer. Before calibrating any sprayer, be sure it is clean and in good condition. Select the correct nozzle(s) for the job. Be sure a sprayer is set up properly (boom height, nozzle spacing, etc.) before calibrating it. If you change the sprayer set-up in any way, re-calibrate it. Make calibration checks throughout the season at regular intervals.

Backpack Sprayer Calibration

Here are the specific factors that affect backpack sprayer calibration:

- nozzle type (orifice size, pattern, condition),
- sprayer configuration (wand length, wand angle),
- person using sprayer (walking speed, release height), and
- nozzle-sprayer-operator interaction (swath width).

Most good-quality backpacks have a built-in pressure regulator. This device allows the backpack sprayer to operate at a constant pressure. You do not need to know the exact operating pressure to calibrate a backpack sprayer. However, the pressure must be constant. This means that the backpack must be in good working order, and the person using it must walk and pump at a relatively steady pace.

The person who will use it should calibrate a backpack sprayer. This is because each person will have an individual walking speed and release height (hence, swath width). If several people will use one sprayer, each should calibrate it. It is not advisable to try to walk at an unnatural speed, or hold the sprayer wand in an uncomfortable or unnatural position. You should change the sprayer or its configuration to suit you. For example, if your swath width is too narrow, change the wand or use another sprayer with a shorter wand. Some applicators use a sling or arm rest to ensure a constant release height. This, in turn, produces a uniform swath width.

Here are the things you will need to calibrate a backpack sprayer:

- area markers (ex: chalk, flags),
- measuring tape (50 ft. or more),
- water,
- backpack sprayer,
- watch / stopwatch,
- graduated container,
- bucket,
- PPE, and
- product label(s).

It is convenient to have conversion charts (ex. ounces - gallons) and a calculator. Some commonly used conversions are listed below.

- 32 ounces = 1 quart;
- 4 quarts = 1 gallon;
- 128 ounces = 1 gallon.

To convert liquid ounces to gallons, multiply by 0.0078125 (approximately 0.008).

Here are the procedures for calibrating a backpack sprayer:

1. Start with a clean sprayer, set up exactly as it will be used.

2. Mark off a test area.

   For small-area applications, a calibration test area between 1/5 and 1/4 the size of the normal application area is recommended. For example, if you usually apply in units of about 1,000 square feet, you should calibrate using a test area of about 200 to 250 square feet.

   - 5 x 50 or 2.5 x 100 = 250 square feet.

   - 4 x 50 or 2 x 100 = 200 square feet.

   It is very convenient to set up a linear course. If you know the swath width of the sprayer, you can calculate how far you must walk (one way or out and back) to treat 200 or 250 square feet. For example:

Swath Width (using an even flat fan nozzle)	**Linear Course = 200 ft^2**
12"	200 feet
13"	184 feet, 7 inches
14"	171 feet, 5 inches
15"	160 feet
16"	150 feet
17"	141 feet, 2 inches
18"	133 feet, 4 inches
19"	126 feet, 4 inches
20"	120 feet
21"	114 feet
22"	109 feet
23"	104 feet, 4 inches
24"	100 feet

3. Fill your sprayer (about 1/2 full), and pump it to the normal operating pressure.

4. Time yourself as you spray the test area with water, walking at normal speed.

5. Spray into a bucket for the same length of time it took you to spray the test area.

6. Pour the water from the bucket into a graduated container. This will allow you to measure the volume you would apply to the test area accurately.

7. Calculate:

   - Your output in gallons per minute.

   - The volume you would apply to 1,000 square feet.

If you are within the label-directed range for the target area, simply mix the product as directed, using the volume of water you will need to apply it. If you are applying too much or not enough to the test area, change your nozzle and recalibrate. (When using a boom sprayer, changing the speed and/or pressure can make minor adjustments to application rate. However, in most cases, these variables are not changed when using a backpack. So, if you need to increase or decrease the volume you apply to a test area, change the nozzle.)

Boom Sprayer Calibration

There are four variables that govern the amount of spray delivered per unit area by a boom sprayer. They are:

- boom configuration (nozzle spacing and boom height),

- nozzle tip orifice size,

- pressure, and

- speed.

There are several ways to calibrate boom type field sprayers. One way is to use the same method described for a backpack. The only difference is that your test area may be larger. Spray a test area with water, calculate the time it took, and spray at the same pressure for that length of time. Catch and measure your output. Use this to calculate application rate. You can make minor adjustments by changing pressure or speed, within limits. To make major changes, change nozzles. You can buy calibration jars to put along your boom to measure application rate over a given distance. Flow meters can check the output of each nozzle.

Hydraulic Sprayers

High-pressure hose and handgun devices (estate sprayers) are commonly used to spray ornamentals. They are often used to treat foundation plantings and shade trees. Usually, they have piston pumps and mechanical agitators. Foundation plantings can be treated with hydraulic sprayers of moderate pumping capacity such as six to ten gallons per minute at 400-500 psi. Tall shade trees require high pressure and high volume pumps capable of 35 to 60 gallons per minute at 650 psi. Make dilute spray mixtures for shade trees and other ornamentals according to label directions. Apply as directed; for example, to the point of runoff. In situations like this, the sprayer does not have to be calibrated. However, it must have the capacity to cover the target.

Granular Applicator Calibration

Granular pesticides must be applied with precision. Using less than 90% of the label rate may result in ineffective control. Applications greater than recommended amounts are costly. In addition, an overapplication may injure the target as well as nontarget organisms. To make an application according to label directions, spreaders must be carefully calibrated.

The amount applied depends on the size of the metering opening, the applicator speed, the terrain, and the flow rate of the granules. Granules flow at different rates, depending on size, density, type of granule, temperature, and humidity. Therefore, it is necessary to recalibrate your applicator for each different formulation.

There are several types of broadcast granular applicators. Some are hopper types with sliding gate openings or augers. Others use air or spinning discs to cover swaths much wider than the machines themselves.

With the full width sliding gate and auger types, check the evenness of distribution. You can do this by setting the gate at a particular opening, turning the drive mechanism, and comparing the output over a given time from each opening. Use calibration blanks that match the formulation of pesticide you will apply. Choose a preliminary setting based on the equipment manual for the pounds per acre desired. A catch tray will allow you to measure the amount you apply to a given area.

For the air and spinning disc types, select a preliminary setting as recommended by the operator's manual for the application rate desired. Select and determine your actual travel speed. Then check the distribution pattern in the field. Containers deep enough to keep the granules from bouncing out should be placed on two foot centers across the swath at several intervals along the first pass. Then compare the output at each station. This will alert you to any correction needed and allow you to select the best swath width.

To check the application rate, fill the hopper with calibration granules, allow them to settle, and then add more if needed. Treat a prescribed test area. Be sure to use at least 10% of the hopper contents in your trial. Determine the pounds of granules required to refill. Alternatively, use a device to catch the granules you spread. Once you know the amount used (in pounds), you can calculate the amount (pounds) you would use per 1000 square feet or per acre.

If the application rate in the test is within 10% of the rate desired, treat another test area and recheck the delivery rate. Make minor adjustments to correct the rate to within 5%. If the amount used is more than 10% in error, change the rate settings and recalibrate. Keep calibrating until the rate is within 5%.

Re-check the delivery rate often. Remember that most units require that speed be constant to keep the application rate constant. Weather conditions can affect granular flow rates, so be alert for changes.

Operating Guidelines and General Precautions

- Never use a pin, knife, or other metal object to unplug a sprayer nozzle. Use compressed air, an old toothbrush, or a brush with soft bristles. Never blow into a nozzle to clean it.

- Never allow dirty water or debris to enter the spray tank. Keep the hopper of a granular applicator free of debris. Keep your equipment clean.

- Control spray drift by using the largest nozzle and the lowest pressure that will apply the pesticide properly. Use low-drift nozzles if possible. Use the lowest release height or boom height you can. Spray when winds are low and steady. Avoid strong, gusty winds and inversion conditions.

- Do not use corrosive fertilizer solutions in a pesticide sprayer. Parts made of brass, copper, steel, aluminum, galvanized materials, plastic, or rubber may be damaged.

- Never operate a sprayer with the screens or filters removed. If the screen is plugging often, check your water source. Replace the screen with one having the proper mesh size and capacity.

- Never allow any sprayer pump to run without water, even for a short time. Pump seals, bearings, and other working parts may be damaged.

- Always pump a large amount of clean water through the sprayer at the end of the day or when changing from one pesticide to another. Clean all nozzle tips and screens at the same time.

- Dedicate one sprayer for herbicide use only. Use another to apply insecticides and/or fungicides.

Maintenance Guidelines

Often, traces of chemicals in solution will remain in porous tanks, hoses, pressure regulators, selector valves, or screens. Chemicals in suspension are not as hard to remove as solutions, but traces may still be present unless all parts are thoroughly cleaned. That is one reason for having a sprayer for herbicides only.

Cleaning Spray Equipment

At the end of the day or whenever wind or weather conditions stop you from spraying, clean the sprayer. Regular flushing will prevent gum or powder deposits in the pressure regulator, selector valve, nozzle tips, and screens. Follow these steps:

1. Rinse the inside and outside of the tank with clean water. Flush the tank and the hoses.

2. Refill the tank with a moderate amount of clean water and spray it out again. A small amount of liquid detergent added to the water will help clean the inside of the sprayer system. If you use detergent, be sure to flush with clean water again.

3. Clean the nozzles, nozzle screens, and suction screens with compressed air or a soft brush. Replace the screens and nozzles.

4. Never clean a sprayer near susceptible plants. Capture your rinsate to use later for mixing, if possible. If not, be sure to apply the dilute cleaning solution to a legal site.

Storing Spray Equipment

When you store your sprayer properly, you add years to its useful life. Put it away clean. Be sure to drain it completely. (This is critical if the sprayer will be stored where the temperature may fall below freezing. Water expands as it freezes. Water that freezes in small spaces such as in the pressure regulator, hoses, valves, or boom, may cause these parts to rupture.) Lubricate all moving parts according to the manufacturer's recommendations. Fill the tank with water and add the recommended quantity and type of rust inhibitor or light oil (see your instruction manual). Then drain the tank. Leave the tank open for ventilation, but screen it to keep out dust debris, insects and animals. Clean all nozzle tips and screens with compressed air or a soft brush and kerosene. Store the tips and screens in a jar of unused light oil or kerosene. If the sprayer has tires, take the weight off them. Remove, clean and drain the pump. Fill it with the light oil, anti-freeze or rust inhibitor recommended by the manufacturer. Seal all pump openings. Make a list of all faulty parts and order the new ones to be ready for the following season.

Test Your Knowledge

Q. Name some of the things that affect the efficacy of a pesticide application.

A. The effects of a pesticide application depend on a number of things. Some important factors are proper timing (to treat susceptible pest stages), favorable treatment conditions (temperature, humidity, moisture, time of day, and plant condition), and thorough coverage. Pesticides must be delivered to the target at the correct rate to do their job.

Q. How are dusts, granules and wettable powders alike? How are they different?

A. All three are solid formulation pesticide products. Wettable powders are not ready-to-use. They must be mixed with water and sprayed. Because they do not dissolve in water, the mixture (suspension) must be agitated. On the other hand, dusts and granules are ready-to-use. They are applied dry, right out of the container. However, dust particles are much smaller than granules. Dusts and granules require different types of application equipment. Usually, granules are applied to soil and dusts are applied to foliage.

Q. What are some things to consider before choosing a piece of application equipment?

A. When evaluating equipment, ask yourself these questions:

- Is the equipment well suited for the target(s) you need to treat?
- Will it apply the formulation(s) you wish to use?
- Is it affordable?
- Is it sturdy and durable enough to do the job?
- Is it easy to fill, operate, and clean?
- Will it apply pesticides in an environmentally sound manner?

Q. What are some advantages and disadvantages of spray applications?

A. Spray applications use water as a carrier. If done properly, a spray application produces droplets containing dilute pesticide. These droplets are directed to a target, where they coat its surface. Many types of spray equipment are on the market. However, some pesticide formulations cannot be applied as a spray. Others must be agitated to keep insoluble particles from settling. Liquid spray particles can drift if not managed properly.

Q. Name the major parts of a spraying system.

A. The common components of any spraying system are:

- a holding tank.
- a nozzle (or several nozzles).
- a hose or tube (or system of hoses) connecting the tank with the nozzle(s).
- the device or system that provides pressure.

In addition, some sprayers have a way to agitate the spray mixture.

Q. Why is sprayer configuration (set-up) important?

A. A sprayer must be configured properly (and used correctly) to produce a uniform spray.

Q. Describe the function of the spray tank.

A. The tank holds the mixed liquid pesticide.

Q. How should you care for a spray tank?

A. To keep tanks in good condition, handle them with care. Careful handling and proper storage can help to prevent cracks and leaks. Keep spray tanks clean. Debris from a dirty tank may block narrow passages in hoses or tubes, screens, and nozzles. Contaminants may affect a spray solution, resulting in incompatibility or phytotoxicity. For example, herbicide residue from a previous application in a tank may harm the plants an insecticide or fungicide application is supposed to protect. For that reason, plant health managers should have at least two spraying systems — one dedicated to herbicides and another for applying fungicides and/or insecticides.

Q. What do the hoses do?

A. Hoses carry the liquid from the tank to the nozzle. Like all sprayer components, they should be chemical-resistant. This will prevent them from swelling or breaking down when exposed to organic solvents like those found in many liquid pesticide formulations. Check them on a regular basis to be sure there are no cracks or leaks.

Q. What is the function of the nozzle?

A. Pressure forces the spray liquid through one or more nozzles. The shape and size of the nozzle orifice affects the flow rate and the spray pattern. Nozzles are made for many different spraying requirements. Manufacturers of sprayer nozzle tips supply data sheets for the delivery rate (usually in gallons per minute within a range of pressures) and pattern. However, these specification sheets cannot give the actual application rate. This is because application rate is also dependent on speed and pressure.

Q. Why is it a good idea to have some sort of filter or screen in your spraying system?

A. Filters or screens will trap particles. Particles in the system can cause problems by plugging hoses and damaging the pump. Proper use of filters protects the working parts of the sprayer and reduces nozzle wear.

Q. What are the parts of a complete nozzle assembly?

A. A complete nozzle assembly consists of the body, screen, cap, and tip or orifice plate. The nozzle tip is an atomizing device. It produces liquid droplets that form the spray pattern.

Q. Why is it important to match the pressure of a sprayer with the nozzle(s) used?

A. Nozzles have a prescribed pressure range. If the pressure is too low, the pattern the nozzle is supposed to produce will not form properly. Spray distribution will not be even or as expected. High pressure increases the rate of nozzle wear and the drift hazard.

Q. What is the difference between a flat fan and a cone nozzle?

A. Nozzle tips are classified according to the spray pattern they produce. A fan nozzle produces a fan-shaped spray. The liquid released is narrow at the nozzle and becomes increasingly wider as the distance from the nozzle increases. A regular flat fan nozzle makes a narrow oval (elliptical) pattern with lighter edges. The orifice (opening) in this type of nozzle is also elliptical. Cone nozzles produce circular patterns. The hollow-cone nozzle delivers most of the material to the circumference of the circle. The full-cone nozzle delivers liquid droplets to the entire area of the circle. Both types of nozzle tips have circular openings.

Q. How are flat fan nozzles best used?

A. Flat fan nozzles are usually used for broadcast spraying. Regular flat fan nozzles are designed to be mounted on a boom. They are positioned so the liquid they release is overlapped 30-50 percent for even spray distribution across the boom. When a series of flat fan nozzles are properly configured on a boom, the spray material is distributed more evenly than it would be with any other type of nozzle. It is possible to keep the boom relatively low to reduce the drift hazard. Special flat-pattern nozzles, usually called even flat fan nozzles, are available for band spraying in rows. They may also be used with a backpack (single nozzle) sprayer. Flat fan nozzles are well suited for applying herbicides.

Q. How are cone nozzles best used?

A. Cone nozzles are well suited for applying insecticides or fungicides in situations where complete coverage of the leaf surfaces is extremely important. They are not ideal for mounting on a boom.

Q. Why is it a good idea to use a nozzle screen?

A. Placing nozzle screens behind the nozzle tip and in the nozzle body helps to eliminate, or at least reduce, clogging. In addition, when a sprayer is turned on and off frequently — when working in small plots or when spot spraying — nozzle "dribble" may become a serious problem. A nozzle screen with a check valve in it will help eliminate "dribble." The screen will not affect the operation of the sprayer, as long as you maintain and inspect the check valve.

Q. What should you check to be sure a nozzle is working properly?

A. Keep nozzles clean and in good condition. Check the flow rate and pattern on a schedule. Replace them before they become worn. The nozzle orifice will enlarge with wear, especially if abrasive materials are used. Nozzle wear changes both the spray pattern and the flow rate. If the flow rate is 'off' by 10%, replace it. Also, replace any nozzle that is producing a non-standard pattern.

Q. What is the function of the sprayer pump?

A. The pump forces the liquid through the system. It moves the pesticide mix or solution from the tank through the hoses and out the nozzle(s).

Q. Name one formulation that requires agitation to be applied as a spray.

A. To make a uniform spray application with a wettable powder (WP) or a water-dispersible granule (WDG) formulation, use a sprayer with an agitator. Neither of these materials dissolves in water. Constant agitation will keep particles from settling in the spray tank.

Q. Name some types of hand sprayers.

A. Examples of hand sprayers include pressurized aerosol cans, trigger pump sprayers, hose-end proportioners, push-pull pump sprayers, and backpack (knapsack) sprayers.

Q. List some advantages and disadvantages of using a hand sprayer.

A. Hand sprayers have a number of advantages. They are relatively inexpensive, simple to operate, maneuverable, easy to clean, and easy to store. Most backpack hand sprayers have an adjustable handgun. Small spray booms are available on some models. They are well suited for spot treatments and spraying small areas. They are also used for treating sites that are not suitable for larger units. For example, they can be used to treat steep slopes or areas with limited access.

Their limitations include a relatively small capacity (usually one to four gallons.) Pressure and output may fluctuate. Some do not have a good way to provide agitation. Therefore, they are not useful for applying suspensions like wettable powder spray mixtures.

Q. What special risk must be managed when using a hose end proportioner?

A. When using a hose end proportioner, be sure to prevent backsiphoning. Use these devices only if you have an air gap or a fail-safe backflow prevention device between the hose-end proportioner and the water supply.

Q. List some advantages and disadvantages of using a small motorized sprayer, like a power backpack sprayer or an estate sprayer.

A. As a rule, small motorized sprayers have a larger capacity than hand sprayers. They can operate within a wider range of pressures. Many have built-in hydraulic agitation. Some are small enough for use in confined areas or small spaces. However, like hand sprayers, they may not be suitable for wide-area use. They may not generate enough pressure and flow to allow for good coverage of a large tree.

Q. List some advantages and disadvantages of using a large high-pressure sprayer.

A. Large high-pressure sprayers are able to treat dense foliage and reach the canopy of a tall tree. They may be used with a boom to spray a wide area. They provide good penetration, reach, and coverage. They are usually durable and long-lasting if cared for properly.

However, they are relatively expensive. They require large amounts of water and fuel. Because of their size, they may not be suitable for all sites.

Q. What is a shielded sprayer, and how is it best used?

A. Shielded sprayers direct liquid herbicide to a target weed without contacting nearby desirable plant foliage. Shields enclose and direct the spray from a nozzle.

Q. What is a wick applicator? Describe a situation where a wick applicator would be useful.

A. Wick applicators use a piece of rope, absorbent fabric, or sponge to transfer the pesticide to the target. Wick applicators apply a concentrated herbicide mixture directly to a target weed. The wet wick is 'wiped' directly onto the weed. Wick applicators are easy to operate. If used properly, only the target is affected. There are no particles to drift.

Q. When and where are aerosol generators and/or foggers used?

A. Aerosol generators and foggers are used with certain insecticide formulations. They convert these products into very small, fine droplets. Single droplets are too small to see with the naked eye. Large numbers of droplets are visible as a fog or mist. This method is a good way to treat a large number of plants in an enclosed area. Aerosol generators and foggers fill a space with a pesticidal fog. In some cases, insects are killed on contact. Some formulations provide residual control and others do not. In other cases, the mist simply repels the insects. In the case of repellents, the insect pests may return after the mist settles.

The mists produced by aerosol generators and foggers can penetrate dense foliage. Some indoor-use devices are automated. Limitations include the potential for drift, due to the very small droplet size these devices produce. However, plant health managers can avoid drift in enclosed settings by sealing the area to prevent drafts or air leaks. It is important to follow label directions for keeping a treated area 'off limits.' Some labels require that you close the treated area for a prescribed period. As a rule, treated areas must be properly ventilated before people return to the site.

Q. How do ready-to-use aerosols work? How are they usually used? What are some advantages and disadvantages?

A. Ready-to-use aerosol containers contain a pesticide dissolved in a volatile liquid under pressure. The pesticide vaporizes when it is discharged from the pressurized cylinder or "bomb." After release, the pesticide is suspended in the air in fine particles. Aerosol cans or "bombs" are convenient for applications made in small installations or to a limited number of plants. They are easy to use. Most products available are labeled for insect and mite control. Ready-to-use aerosols do not penetrate soil. Follow all label directions, including the distance between the release point and the plant. Exposure to the escaping propellants can damage plant tissues. As a rule, do not use ready-to-use aerosol products when temperatures exceed 85 degrees or leaf surfaces are wet.

Q. What special risks must be managed when using pesticides in vapor form?

A. Vaporized pesticides pose an inhalation exposure risk. This is due to their small particle size and the fact that the particles are airborne. Treat all pesticides in vapor form with extreme caution, especially when working in enclosed spaces. Wear a respirator. Sometimes there is risk of explosion. Some labels have specific use conditions (dry foliage, temperature range). For example, applications made at cool temperatures may not be effective. However, if the temperature is too hot, plants may be injured. Follow label directions and take all special precautions.

Q. What are smokes, and how are they used?

A. Smokes are cans of insecticide mixed with combustible materials. They are ignited in their container. They produce an insecticidal smoke. Smokes are easy to handle. They are particularly useful in small enclosed areas.

Q. How are dusts applied? Describe some common dust applicators.

A. Dust applicators combine a dust formulation pesticide with air to distribute the pesticide evenly over a target area. Power dusters use a motorized fan or blower to propel the dust to the target. Bulb or hand dusters are used in small areas. They use devices like a squeeze bulb, bellows, shaker, or hand-cranked fan to distribute the dust. Some dusters have attachments to extend the reach of the tube and the direction of the dust.

Q. What are some advantages and disadvantages of using dusts?

A. Because dusts are ready to use, there is no mixing or dilution involved. Dust applicators are lightweight, simple in construction, and easy to maintain. No water is needed. Dusts may be propelled into hard-to-reach places. However, dusts may not stick to foliage. Because dust particles are small and light, drift potential is high. Applications may be hard to direct to the target, and coverage may not be uniform.

Q. When and how are granular pesticides best used?

A. Granular formulations are commonly used for soil treatment in established vegetation, like turf. This is because they fall through or roll off the plant surfaces and land on the ground. Some granular products are applied so the particles are evenly distributed over an area. Other product labels may direct you to place a certain volume around the base of a plant, or use a certain amount per container. Some need to be 'watered in.' Others are soil incorporated. Like dusters, granule applicators are simple devices. Granules are ready to use, so there is no mixing. No water is needed. They have little or no drift potential. They pose a very low exposure hazard to the applicator. However, they will not adhere to foliage. If you use a drop spreader to apply granules, you must re-calibrate for each formulation.

Q. What is a bait? When and where are baits usually used?

A. Most baits consist of a pesticide mixed with a food or an attractant. Many are available in ready-to-use, tamper-proof stations. Well-designed bait stations attract only the target pest. If used properly, there is little or no exposure risk to applicators, building occupants, or nontarget organisms. The entire area does not need to be treated, because the pest comes to the bait. They are best used to control social insects, foraging insects, and rodents. Baits are most effective if competing food sources are reduced or eliminated.

Q. How can traps help you manage certain pests?

A. Traps use something to attract and hold (or kill) pests. Traps may be a good way to monitor pest populations. In some situations, traps are also a very effective pest control method.

Q. What is injection technology?

A. Injection technology is a way to apply pesticides to large woody plants. One method places pesticide to the soil surrounding a tree, where it is taken up by the tree. Another introduces chemical directly into the transport tissue of the tree.

Q. How does soil injection work?

A. Soil injection places pesticides, dissolved or suspended in water, into the soil within the root zone of the tree. This method puts a pesticide in contact with the absorptive root system of the tree. Once into the tree's transport system, the pesticide will be distributed to the leaves and other living parts. As insects feed on the foliage of a tree treated with insecticide by soil injection, they will ingest small but lethal amounts of an insecticide. Some soil injections involve a small volume of insecticide placed into a concentrated area of the root zone.

Q. Describe tree injection and infusion.

A. Technically, "tree injection" indicates the forceful introduction of a chemical into a tree. Used this way, the term "injection" is comparable to a "shot" a person gets from the doctor. "Tree infusion" or "gravity flow" is like an intravenous application. A reservoir of liquid hangs from the tree trunk, and the liquid is drawn in by the tree's own uptake system. Trunk implantation devices are also used. Trunk implants use a capsule, which is placed into a freshly drilled hole in the trunk or in the root flare area. The head of the implant device is placed in the growth layer (cambium), so wound closure can occur. Trunk implantation devices often contain a dry powder formulation. Upward sap flow dissolves the material, which becomes part of the "sap solution" that eventually reaches the leaves. In both injection and infusion, pesticides are fed by gravity or pressure into holes (drilled or punched) in trunk or root buttresses.

Q. Describe some advantages and disadvantages of tree injection or infusion.

A. Infusion and injection have a number of advantages. All or nearly all of the pesticide is placed within the tree, where it is distributed upward to the fine branches and leaves. There is little waste. The chance for off-target movement is low. Injection and infusion do not involve heavy, expensive equipment. Best uptake occurs on warm sunny days when trees are in leaf. Injection or infusion may be the best way to treat a landscape tree surrounded by pavement and sidewalks. It may be the treatment method of choice for a valuable tree located in a spot where spraying is prohibited or not advised. In some cases, this is the best way (or the only way) to apply the most effective pesticide. Most movement of injected chemicals is upward. For this reason, infusions and injections are not effective for root pests. Suspensions containing insoluble particles are not satisfactory for injection because the particles tend to clog the water-conducting vessels of the wood. In some cases, internal distribution of chemicals may not be uniform. The proper total dose depends upon tree size, and must be determined for each tree to be treated. Bleeding of sap or resin from injection sites sometimes occurs, especially in spring.

Q. What is calibration?

A. The term calibration refers to all the operations an applicator takes to ensure that the correct amount of pesticide is applied to the target. Calibration involves calculating how much pesticide is needed to cover a given area.

Q. Why is calibration important?

A. There are many reasons for proper calibration: environmental safety, efficacy, legality, and economics. Failure to calibrate equipment often results in ineffective pesticide control. As a rule, for a pesticide to do its job, the prescribed amount of active ingredient must be delivered to the target. An ineffective application wastes time and money. It puts chemicals into the environment for no useful purpose. In addition, an overapplication may cause phytotoxic effects and damage the plants you are trying to protect. It may result in excessive or illegal residues. It increases the exposure risk to applicators, the public, and nontarget animals and plants. Overapplication also increases the risk for off target movement.

Q. List the factors that affect the output of a sprayer.

A. The factors that affect the output of a sprayer are:

- nozzle orifice size, pattern, condition,
- sprayer configuration (boom height, number of nozzles, nozzle placement),
- speed, and
- pressure.

Q. What is usually changed if/as needed to calibrate spray equipment?

A. Usually, equipment is set up in advance to meet the needs of the application site. The operator makes minor changes in output by changing the speed and/or pressure. To make major changes, the operator must change nozzle tips.

Q. In general terms, what is involved in calibrating a sprayer?

A. You calibrate a sprayer by measuring the amount of liquid released by the nozzle(s). Collect the liquid delivered. Record the volume, the time it took to spray it, and the area covered. Calibration is like figuring out how much paint or siding you need to cover a house.

Q. Your backpack sprayer treats a swath 16 inches wide. You walk and spray for 150 feet. How large is the area you treated?

A. Area is equal to Length times Width. Your swath width is sixteen inches, which equals 1.33 (1 1/3) feet. Therefore, the area you treated is 1.33 feet wide by 150 feet long. In this case, area is equal to 1.33 x 150 = 199.5 square feet (about 200 square feet).

Q. You want to calibrate a backpack in a 200 square foot area. Your swath width is 21 inches. How far must you walk and spray?

A. You know that Area = Length times Width. In this case, however, you know the area you want (200 square feet.) Therefore, you have to rearrange the equation to solve for what you need to know: one of the dimensions. If A=LxW, then you solve for one of the dimensions by dividing the area (in square feet) by the one dimension you know to get the one you don't know. In this case, Length = Area divided by Width. To solve, 200 divided by 1.75 = 114.3 (or about 114 feet.)

Q. The label of the product you wish to use calls for using two quarts of product per 1000 square feet delivered in one to two gallons of water. When you made your first calibration test, you used twenty ounces of water to treat 200 square feet. Is the sprayer calibrated to deliver this product as directed? Explain.

A. No. Here's why. In your first trial, you used twenty ounces of water to treat 200 square feet. 200 square feet is 1/5 of 1000 square feet. As configured, your sprayer will deliver five times that amount of liquid to cover 1000 square feet. Twenty times five = 100 ounces. However, there are 128 ounces in a gallon. One hundred ounces is 'short' by about 20%. (100 divided by 128 is about equal to 80%.)

Q. If you need to increase the amount you apply per unit area with a backpack sprayer, what should you do...change the speed you walk, increase the pressure, or change the nozzle you're using? Explain your answer.

A. Change the nozzle. In the case just above, the sprayer as configured applied too little carrier (water.) You should substitute a nozzle with a larger orifice and a greater flow rate, and try again. Many backpack sprayers do not have a setting for adjusting pressure. Most applicators find it is not practical to adjust their normal walking speed; they revert to what is natural for them. The simplest and most effective thing to change is the nozzle. You can choose one with a larger orifice for a greater flow rate or one with a smaller orifice for a lower flow rate. It is a good idea to use a sling or some method (resting your arm on your hip) to be sure that your release height stays the same. That will help to keep your swath width uniform.

Q. You have calibrated your backpack sprayer for the product you wish to apply. The product label calls for

applying five quarts of product per 1000 square feet in two gallons of water. How much product and water should you use to treat 500 square feet?

A. Half the amount: two and one half quarts of product (2.5 quarts = 80 ounces) and one gallon of water.

Q. Using a backpack sprayer: if you walk faster, will you apply more or less chemical than you do when you walk slower?

A. Less. The sprayer is putting out material at a (more or less) constant rate in a unit of time, based on the pressure (range) of the sprayer and the nozzle you're using. If you walk faster, you cover a larger area in a given unit of time. If you walk slower, you treat a smaller area in the same unit of time. Your sprayer delivers the same amount of product in both cases. For example, you will apply the same amount of chemical in 60 seconds — more per unit area when you walk slower, and less when you walk faster. For comparison, imagine the amount of paint you would apply with a swift vs. a slow brush stroke.

Q. The application directions for Herbicide A tell you to "Mix this product in clean water and apply to the foliage of the vegetation to be controlled. Make applications on a spray to wet basis. Spray coverage should be uniform and complete. Do not spray to the point of run-off. Use a 1% rate to control annual weeds, a 2% rate to control herbaceous perennials, and a 5% rate for woody brush." Right below this paragraph is a chart, which tells you how much product to mix in water to get the right dilution (1, 2 or 5%.)

The application directions for Herbicide B instruct you to use one to two gallons of water to apply six quarts of product per 1000 square feet.

Which product must be applied with a calibrated sprayer? Explain.

A. Herbicide B must be applied with calibrated equipment. This is because a set amount — no more, no less — is used to cover a given area. On the other hand, herbicide A is sprayed on a 'spray to wet' basis. Foliage is covered. However, even when using Herbicide B, you should figure out how many plants you have to treat, so you can mix up the right amount.

Q. Why is precise calibration needed when applying granular pesticide products?

A. When using granular products, applying less than 90% of the labeled rate to the target area may result in ineffective control. Applications greater than recommended amounts are costly. In addition, an overapplication may injure the target as well as nontarget organisms.

Q. What factors affect the amount of product applied by a granular applicator?

A. The amount applied depends on the size of the metering opening, the applicator speed, the terrain, and the flow rate of the granules.

Q. Why is it necessary to recalibrate a granular applicator for each product?

A. As a rule, the application rates for granular products are expressed in weight to be used per unit area. Each product may differ in density and in the amount that must be applied per unit area. Granules flow at different rates, depending on their size and density, and on environmental factors like temperature and humidity. Therefore, it is necessary to recalibrate your applicator for each different formulation. It is also wise to re-check the delivery rate often. Weather conditions can affect granular flow rates, so be alert for changes.

Q. How should you unplug or clean a nozzle?

A. Use compressed air, an old toothbrush, or a brush with soft bristles. Never blow into a nozzle to clean it. Never use a pin, knife, or other metal object to unplug a sprayer nozzle.

Q. How can you minimize spray drift?

A. Control spray drift by using the largest nozzle and the lowest pressure that will apply the pesticide properly. Use low-drift nozzles if possible. Use the lowest release height or boom height you can. Spray when winds are low and steady. Avoid strong, gusty winds and inversion conditions.

Q. Why is it a good idea to have one sprayer for herbicides only and another for insecticides and/or fungicides?

A. In some cases, it is difficult to remove chemical residues from a sprayer. For example, herbicide residues may remain in the bottom of a tank, in hoses, and other sprayer parts. Some products are active at very low rates. If a sprayer containing herbicide residue is used to treat a sensitive plant, the plant may be injured or even killed.

Q. Explain when and how to clean a sprayer.

A. Clean your sprayer at the end of the day or whenever wind or weather conditions stop you from spraying. Regular flushing will prevent gum or powder deposits in the pressure regulator, nozzle tips, and screens. Follow these steps:

1. Rinse the inside and outside of the tank with clean water. Flush the tank and the hoses.
2. Refill the tank with a moderate amount of clean water and spray it out again. A small amount of liquid detergent added to the water will help clean the inside of the sprayer system. If you use detergent, be sure to flush with clean water again.
3. Clean the nozzles, nozzle screens, and suction screens with compressed air or a soft brush. Replace the screens and nozzles.
4. Never clean a sprayer near susceptible plants. Capture your rinsate to use later for mixing, if possible. If not, be sure to apply the dilute cleaning solution to a legal site.

Q. Explain how to store a sprayer.

A. Put it away clean. Be sure to drain it completely. (This is critical if the sprayer will be stored where the temperature may fall below freezing.) Lubricate all moving parts according to the manufacturer's recommendations. Fill the tank with water and add the recommended quantity and type of rust inhibitor or light oil (see your instruction manual). Then drain the tank. Leave the tank open for ventilation, but screen it to keep out dust, debris, insects, and animals. Clean all nozzle tips and screens with compressed air or a soft brush and kerosene. Store the tips and screens in a jar of unused light oil or kerosene. If the sprayer has tires, take the weight off them. Remove, clean, and drain the pump. Fill it with the light oil, anti-freeze or rust inhibitor recommended by the manufacturer. Seal all pump openings. Make a list of all faulty parts. Order new / replacement parts to be ready for the following season.

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