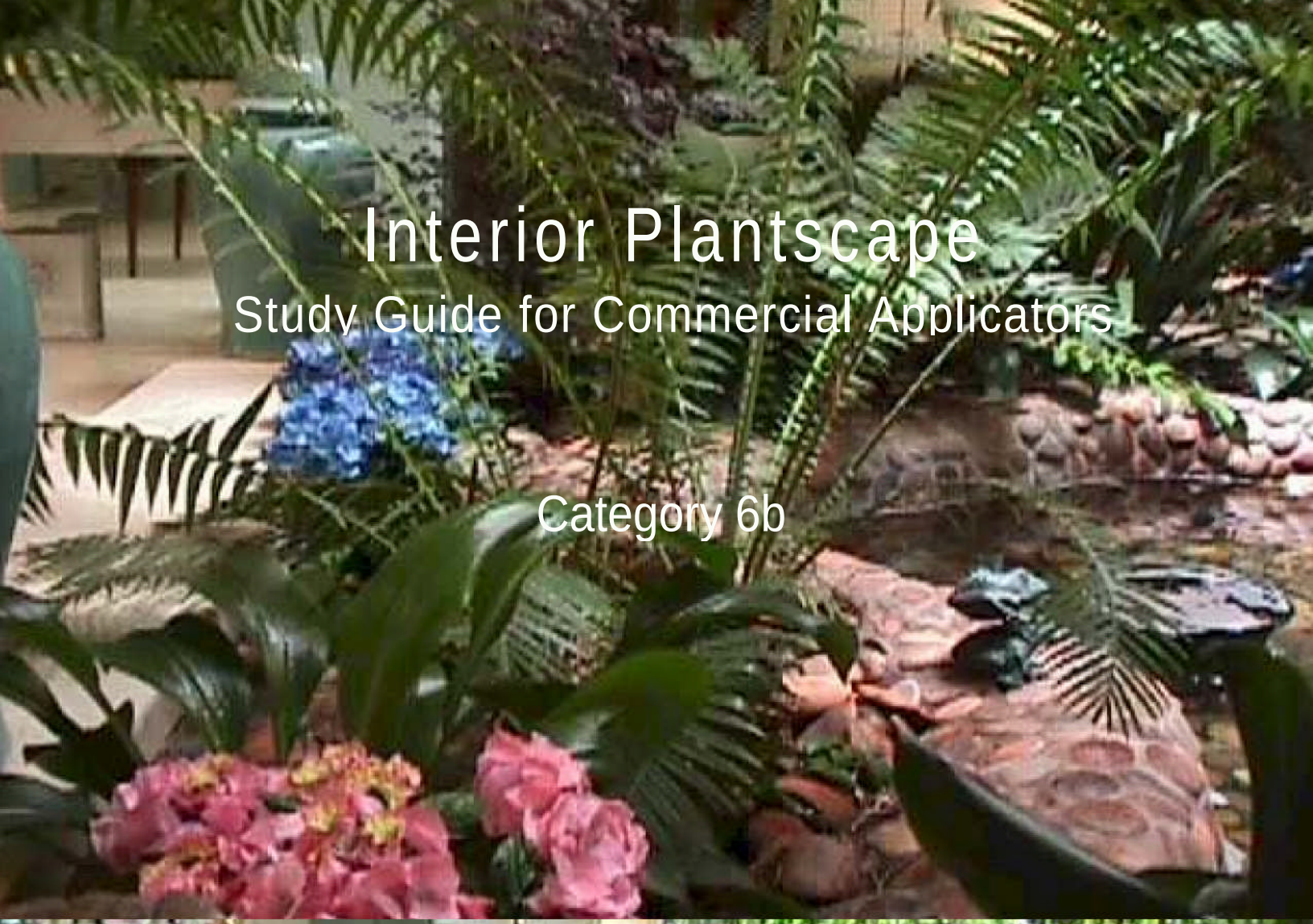

Interior Plantscape

Study Guide for Commercial Applicators

Category 6b

Oct. 2007 - Ohio Department of Agriculture - Pesticide Regulation

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Urban Integrated Pest Management
North Carolina Cooperative Extension Service

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Interior Plantscape Laws and Regulations

CHAPTER ONE
Laws and Regulations Concerning Interior Plantscape Pests

Pest management can be complex. It is a matter of using the right technologies and requires special equipment and safety measures. To be successful, it must be effective and not adversely affect people or the environment. The number and variety of pesticides have increased and pest management professionals need to know more about safety and proper use than ever before. For these reasons, among others, many state and federal laws and regulations have been adopted to help protect the public, the environment, and pesticide handlers from the possible adverse effects caused by pesticide use. In this chapter, you will learn about the state and federal laws that regulate pesticide applicators, particularly commercial pesticide applicators certified in Category 2b, Interior Plantscape. Applicators certified in this category are responsible for pest management in schools, hospitals, businesses, office buildings, etc. It is important that Category 2b pest management professionals understand and keep up-to-date with the laws that affect pesticide application inside or around buildings. Ignorance of the law is never an accepted excuse for a violation.

PROTECTION: THE APPLICATOR'S RESPONSIBILITY

Ultimately, responsibility for protecting the environment from the possible adverse effects of pesticide use rests on the pesticide applicator. Preserving the biological diversity of our planet by protecting the environment contributes to the overall quality of life. Each plant and animal is part of a complex food chain; break one of the links and others are adversely affected. One disappearing plant can take with it up to 30 other species that depend on it, including insects, higher animals and even other plants. Pest management technicians may see their normal work as unlikely to affect the environment, but spills and leaks during mixing, loading, and transporting, or incorrect disposal can lead to pesticides in groundwater or surface water or in the habitat of non-target organisms.

Pest management professionals often service national parks, schools, and other sensitive areas. Category 6b professionals have an even greater responsibility toward the public because they often work in or around buildings, where there is increased risk of exposing people to pesti-

cides. All efforts should be made to achieve pest management goals through minimal use of pesticides in and around buildings. When pesticides are used, they should be applied in a manner that will prevent human contact.

MORE THAN JUST PESTICIDE APPLICATION

To control pests, pest management professionals use many other activities besides pesticide application. These other practices increase the effectiveness of the control program and often reduce pesticide use or make such use a secondary operation of the program.

An important area addressed throughout the manual is communication. Pest management is a service. Pest management professionals must not only know their job but also be able to communicate effectively with their clients. The pest management professional should be able to explain the basic procedures to the client's satisfaction. The client should feel confident that the pest management professional is able to meet his/her pest control needs safely and effectively. Also, the state of Ohio requires that certain information must be communicated to the customer (see the Ohio Pesticide Law).

STATE AND FEDERAL LAWS

The *Applying Pesticides Correctly bulletin* (825) discusses federal and state laws that govern the handling and use of pesticides. Review the core manual and understand how laws and regulations affect pesticide practices and use. These laws include federal laws such as the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), the Occupational Safety and Health Act (OSHA), and the Endangered Species Act. State laws including these are just some of the laws that affect commercial pesticide applicators. They are briefly described below. Refer to the core manual to learn more about other laws affecting pesticide use and for further details on laws discussed in this chapter. Pest management professionals should keep up-to-date copies of the laws and review their contents periodically. Copies of these laws can be obtained from ODA and from County extension offices.

FEDERAL LAWS

FIFRA

This is the basic federal law administered by the Environmental Protection Agency (EPA) that regulates pesticides—their use, handling, storage, transportation, sale, disposal, etc. FIFRA defines a pesticide as a substance or mixture of substances intended to kill, repel, or mitigate a pest. The Ohio Department of Agriculture (ODA) has a cooperative agreement with the EPA to enforce some provisions of FIFRA in Ohio. Some of the provisions of FIFRA are that the EPA must register all pesticides before they can be sold or used. The pesticides must be classified as either ***"general-use"*** or ***"restricted-use.*** General-use pesticides are those that anyone can purchase without restriction. Restricted-use pesticides can be used only by or under the direct supervision of a certified applicator. FIFRA also stipulates that persons who misuse pesticides (in a manner that is "inconsistent with the pesticide labeling") are subject to penalties.

Endangered Species Act

This act requires the U.S. EPA to ensure that endangered or threatened plant and animal species are protected from pesticides. This act requires each pesticide label to limit its use in areas where these species could be harmed. Category 10b applicators must consider the possibility that endangered or threatened species may be affected by pesticides applied in and around buildings. The Ohio Department of Natural Resources (ODNR) Division of Wildlife administers the Ohio Endangered Species Act (TITLE XV CHAPTER 1518 ENDANGERED SPECIES GENERAL PROVISIONS) and maintains the federal and state endangered or threatened species lists. Michigan applicators who want to be sure they are complying with the act must take the initiative and consult with the ODNR to be sure that there are no endangered or threatened species in their area. One of the goals of pest management is to protect off-target plants and animals from pesticides, whether they are endangered or not.

OSHA

OSHA is administered by the U.S. Department of Labor (DOL). OSHA governs the record-keeping and reporting requirements of all work-related deaths, injuries, and illnesses of businesses with 10 or more workers.

STATE LAWS

THE OHIO LAW

The Ohio Administrative Code Chapter 901:5-11-01 is the state pesticide law that regulates commercial pesticide applicators who perform fumigations.

To become a commercial pesticide applicator for termite control you must take and pass the Core exam and the category specific exam (Interior Plantscape). The definition of termite control in the law is as follows: "**Interior Plantscape means the application of pesticides to control insect, diseases and weeds if indoor ornamentals."**

THE STATE CERTIFICATION PLAN

The state certification plan is an Ohio Department of Agriculture document that sets forth standards of competency by which the Ohio Department of Agriculture abides. This document governs the way the Ohio Department of Agriculture and the Ohio State University Extension conduct the examination process and the pesticide applicator training programs.

The state certification plan sets the standards of competency for the category of Interior Plantscape as follows:

6(b) Interior Plantscape: Commercial applicators shall demonstrate a practical knowledge of:

- Common insects, diseases and weed pests or of ornamental plants, with emphasis on diagnostic characteristics and damage symptoms
- The common pesticides registered for use against these pests,
- Rates, methods, and timing of applications

- Methods to prevent or minimize pesticide damage to cultivated plants, humans, pests and other non-target areas
- Physiognomic disorders of plants resembling pest injury or herbicide damage
- Application and safety equipment
- Information necessary for safe and adequate application of pesticides

PESTICIDE LICENSE INFORMATION

THE APPLICATION PROCESS

The application and fee are valid only for the licensing year noted on the application that is submitted, it cannot be extended to the next licensing year once it is submitted. If all the requirements are not met within the license year listed on the application, then the application is voided and the fee is non- refundable. License fees cannot be transferred from one company to another. When a first time applicant submits the application and fee study material will be sent to assist in preparation for the examinations. Categories are listed on the applications.

The application is only valid for the licensing year in which you have applied. (The year is listed on the application). If you do not meet the requirements within the year that you have applied, then a new application and fee will be required, no refund will be given.

Exams

Examination requirements are: the General-Core examination, which covers the law, regulations, safety, disposal and related topics. An examination for each category is also required. The categorical examinations are specific to what area you will be applying the insecticide, herbicide, fungicide, etc. All examinations consist of multiple choice and some true/false questions. The exams are closed book exams. Exam results are mailed two to three weeks after the test date, **they are not given over the phone. You may also retrieve you exam results from our web site after the exams have been graded; you know your ID used when taking the exam and the correct date the exam was taken.** If you fail the exams, you must wait at least five days to retest. If you need to retest no additional fee is required. Exams are only valid for one year from the date you pass the exam. If you do not meet the other qualifications for a license within that year, the exams will expire and you will need to retest. Please call the Pesticide Regulation Section at (614) 728-6987 or 1-800-282-1955 to schedule your exam or register online at http://www.ohioagriculture.gov

OSUE NEW SCHOOL

Each year in late February or early March, the Ohio State University Extension offers a Pesticide Applicator School for new applicants.

For additional information, access the OSU web site at: http://pested.osu.edu. This site also provides other licensing information; test sites, recertification sites and study material.

COMMERCIAL RENEWAL AND RECERTIFICATION INFORMATION

Once you have passed the applicable exam for the license and a license has been issued, you are certified for three years. The license must be renewed continuously every year in order to keep the three-year certification valid. You need to renew the license every year (at the end of September), which consists of submitting a renewal application and fee. Additionally you are required to earn recertification credits. These credits can be earned by attending recertification programs across Ohio. From the date you pass the exam and are issued a license, you will have three licensing years to accumulate five hours of recertification credits. This requirement will be repeated for as long as you maintain a license. Failure to accumulate the required recertification credits will result in the need to retest. Once you have been issued a license, you may begin obtaining your recertification credits at any time during the three-year recertification cycle. You must obtain the following requirements for recertification – TOTAL MINIMUM OF FIVE HOURS OF TRAINING CONSISTING OF 1 HOUR OF CORE TRAINING AND ½ HOUR IN EACH CATEGORY YOU ARE LICENSED. HOWEVER IT MUST BE A TOTAL MINIMUM OF FIVE HOURS. If you have met your category requirements you must still make sure you meet the time requirement by attending approved classes whether or not they are in your licensed category.

If you do not meet the recertification requirements of 1-hour minimum in Core and at least ½ hour in your licensed category or categories with a total time of 5 hours before the recertification expiration date listed on your license, then you must retest.

CHAPTER TWO
INTEGRATED PEST MANAGEMENT
IN THE INTERIOR PLANTSCAPE ENVIRONMENT

To maintain healthy interior plants a plant technician must understand the optimal growing conditions for the species of plants he or she is working with. These include proper light, temperature, humidity, soil moisture and PH. Providing these conditions becomes challenging when an interior landscape can contain 20 or more species of plants in a variety of environments. Appropriate planning, placement, monitoring, and maintenance will help to limit plant stress. Using all available tactics or strategies to manage pests so that an acceptable appearance and quality can be achieved economically and with the least disruption to the environment is called integrated pest management (IPM.)

The goal of IPM is to reduce the occurrence of plant problems and maintain insect populations and disease problems at levels where aesthetic and economic losses are tolerable. Rarely is pest eradication a goal nor is it possible. All economically and environmentally sound practices that help prevent or reduce plant injury are used. Integrated pest management incorporates a wide range of pest controls such as resistant plant varieties, cultural practices, mechanical controls, biological controls and pesticides.

The basic components of an IPM program include:

- Regular monitoring and early detection of disorders.
- Proper diagnosis and identification of plant disorders.
- Determination of economic significance.
- Selection of management methods.
- Evaluation of management methods

MONITORING AND DETECTION

Typically, a plant manager visits an interior landscape on a regularly scheduled basis. The task of monitoring should be an integral part of each visit. During routine tasks of watering, rotating, and cleaning, be alert to health conditions of the plants and presence of potential pests. Detection of low-level pest populations is doubly beneficial. Early detection allows the technician to manage pests or alter conditions before host plants suffer serious injury. In addition, low levels of pest infestation are typically easier to manage and the use of less toxic management strategies will still be an option. Washing the foliage with a 2 percent soap solution, pruning the problem out, or correcting a poor site condition may eliminate the problem without the use of a pesticide.

Some insect species can be detected with the use of yellow or blue sticky cards. These cards are approximately 3-inches by 3-inches and have a sticky substance on the surface. The cards are either hung in the canopy of the plant or attached to a stick inserted in the soil. Yellow cards are highly attractive to whiteflies and thrips, while blue cards are more specific for attracting only thrips. Both colors will also attract fungus gnat adults. Fungus gnats are seldom a problem for interior plantscape plants, but may become a nuisance. Insects that come in contact with the card's sticky surface cannot escape. Observation of these cards will help determine what insects are present and changes in population density. It is important to write down the numbers of insects per card on each visit. Change the cards on a regular basis or when they become so heavily covered with insects that it is too difficult to count them, or after a pesticide treatment.

Keep monitoring and detection information uniform, develop a system to rank plant condition. If time allows, documenting healthy plant conditions provides a written record of your inspection. If a problem does occur, this background information will help in making a diagnosis. Record information useful for planning management strategies:

- Level of light (foot-candles)
- Plant species
- Plant age and size
- Date of installation
- Size of container
- Type of soil media
- Life stage of the pest
- Type and level of damage
- Date of detection, etc.

DIAGNOSIS AND IDENTIFICATION

When damage or poor plant health is detected, the interior-plant manager needs to determine what cultural or environmental conditions, diseases, insects, mites, or human activity is responsible. Remember, there is often more than one damaging influence. Identify all conditions that may have stressed the plant, causing it to be more susceptible to the problem or pest observed. Table 1 provides a general guide to common symptoms and possible causes of indoor plant disorders.

Diagnosing Plant Disorders
Making an accurate diagnosis of plant problems comes with experience. Adopt the following diagnostic techniques:

Identify the plant
Certain problems are more common with certain plants. Ficus are susceptible to scales, schefflera are susceptible to mealybugs, palms are susceptible to spider mites, ferns are prone to bacterial leaf spots, and dracaenas are prone to root and stem rots. It is important to recognize the correlation between host plants and the pests they are susceptible to. Inspect the whole plant including leaf surfaces- especially the underside- stems, and twigs. If possible, carefully remove the plant from its container to examine root and soil conditions. Inspecting the root environment is often difficult but necessary.

Clearly define the symptoms. Where do the symptoms occur on the plant; are they at random locations, localized, or in a pattern? Are the symptoms that you identify the same as the symptoms your client is concerned about? (See Table 1)

Categorize the cause of the problem as contagious or non-contagious.

Contagious disorders may be caused by:

- Insect or mite infestations
- Disease or virus infection

Non-contagious disorders may be caused by problems with:

- Light, temperature, humidity
- Water, media, pH, soluble salts
- Volatile gas, cleaning compounds
- Relocating, breakage, food/beverage wastes, watering with excessively cold water

Although fungal, bacterial, and viral infections can be common in production environments, the interior landscape environment is generally not favorable for disease organisms when appropriate cultural and environmental conditions provide for stress-free plants. Keeping foliage dry and relative humidity low, in indoor landscapes is perhaps the best control for foliar diseases. Root rots can be a problem for indoor plants, but generally only when the roots are first damaged by over or under watering or high levels of soluble salts in the soil. Therefore, if a root problem occurs, evaluate watering and fertilizing practices and the drainage of the soil and container.

Tools are necessary for thorough investigations and sampling the roots, soil and foliage for pests. Bring hand and pole pruners, a trowel, a soil probe, a sharp knife, a hand lens, specimen bags or containers, and a drop cloth to protect the clients' floor during inspection.

Make observations about the surrounding micro- and macroclimate (conditions in close proximity to the plant and those in the larger, surrounding area). Signs of disease, mites and insects such as thrips are more easily diagnosed with a magnifying lens. Examine soil conditions, drainage, pH and fertility levels.

Consider these factors of the macroclimate: Where are the heat or air-conditioning vents? Are there drafts from doorways? Are light levels adequate? Note temperature and humidity levels and the plant's proximity to windows.

Ask the client about activities that may disturb the plant. Is the container being used as a receptacle for coffee, cigarette butts, or cleaning compounds?

Have ready access to diagnostic references such as Extension bulletins and agents, books, site records, and fellow technicians.

A checklist can help ensure that all pertinent information is collected and considered. Table 1 outlines common symptoms associated with indoor plants and their possible causes.

An organism should not be classified and treated as a pest until it is proven to be one. Insects may pass through several life stages, changing in appearance and activity during their development. Most insects and related pests are affected by pesticides only during one or two phases of their life cycles. For example scale and whiteflies are most successfully treated while they are crawlers. Regular monitoring of the interior landscape detects early infestations when populations are low and indicates the life stages present. Control measures used on small numbers of pests during their susceptible life stage are likely to accomplish your pest management goals. Missing this period of the pest's vulnerability can lead to more severe infestations. When considering pest management treatments:

- Identify the pest.
- Know which of the pest's life stages is susceptible to management tactics.
- Identify the pest in its susceptible life stage (many pests change dramatically in physical appearance as they mature).

The interior plantscape environment has unique qualities compared to other horticultural settings. In an interior landscape the variety of organisms observed is significantly less than that found outdoors. Yet, as in an outdoor setting, certain plants tend to be vulnerable to specific pests.

English ivy and Schefflera spp. are noted to be susceptible to several insect pests. Thus, you may want to avoid their use, particularly in areas with chronic pest problems or access to the out-of-doors and open windows. Pests from the exterior landscape may come into the interior landscape through doorways and open, unscreened windows. If selection of pest-prone plants is unavoidable, use them on a limited basis and be cautious of where they are placed.

Also, unique to the interior landscape is climate control. The climatic conditions within a building are manipulated for the comfort of people and their activities with little consideration for the plants and pest populations in the same surroundings. Low relative humidity and high temperatures increase the development of spider mite populations. Recognize that plants will not live forever in some environments and some plant decline is expected.

Overall, once an abnormal plant health condition is detected, it is extremely important to devote ample time and research to the diagnostic process. Identify and assess all factors that have contributed to the abnormal condition.

A thorough and systematic diagnostic approach to problem solving will help you evaluate, select, and accurately time the most appropriate management practice(s) for the host plant, pest(s), and site. This process is also the key to avoiding unnecessary applications of pesticides.

ECONOMIC AND AESTHETIC SIGNIFICANCE

All pest management activities have costs in terms of materials, time, or environmental impact. Routine plant management activities that serve as preventative pest management practices are typically defined in a service contract between the client and plant maintenance company. Account for the costs of plant maintenance activities and predicted pest management procedures before signing a contract. It is important that the client and contractor can justify the costs and related benefits of pest management practices.

Replacement plants and their value are often accounted for in the service contract with the understanding that some indoor conditions are harsh and sustaining long- term plant health is extremely difficult. Therefore, cost of replacing or rotating plants is calculated into the original work agreement. Any activity that reduces the frequency of plant replacement will increase the profitability of the account. A plant may be pest free, but poor appearance (limited foliage, long internodes, weak structure, poor color) may be the determining factor for replacement.

Special cases requiring additional pest management strategies are likely to arise over the long term. Cost-benefit analyses are determined when these situations occur. The decision to treat for a pest or to replace a plant may be the responsibility of the account manager. As a plant technician, consult with the appropriate persons before action is taken. For example, a large specimen palm infested with spider mites presents a problem in a shopping mall. Several special circumstances arise when spraying pesticides in a public area; yet, taking no action will result in a costly, labor-intensive replacement. Early pest detection may allow time for treatment with predatory mites or less toxic pesticide materials.

Cost-benefit analysis requires educating the customer on basic plant-growth habits and requirements, pest management alternatives and techniques. Be informed and prepared to explain the decision and need for pest treatments. Educate the client when negotiating a contract and when unique pest outbreaks occur. The clients' input is vital in this process, since it is their interpretation of the cost-benefit analysis that dictates whether a pest management tactic will or will not be implemented.

The client and the plant management company need to agree on acceptable plant appearance. What is acceptable to one may not be acceptable to the other. Aesthetic thresholds are as important as injury thresholds in the interior plantscaping industry.

SELECTION OF MANAGEMENT METHODS

Many factors limit pest populations. These include natural enemies of pests such as predator insects, plant defenses, and a host of controls implemented by people. The pest management methods most appropriate for a specific circumstance will depend upon the biology of the pest and host plant, and the interior landscape situation. For every pest problem consider all available management tactics and evaluate the benefits and risks of each.

Choose methods that are:

- Practical in an indoor setting.
- Least toxic to non-target organisms.
- Enhance natural controls and plant defenses.
- Likely to limit the pest permanently.
- Least hazardous for the applicator to handle.

Options will include selecting appropriate plant species for a given site; applying water and fertilizer correctly; pruning, washing, rotating, and replacing plants; altering environmental conditions such as temperature, humidity, exposure to direct light or drafts; sanitation; providing adequate drainage, soil pH and soluble salt levels; and making pesticide applications when necessary.

Most likely, a pest management program will be made up of a combination of methods. No matter how environmentally sound or effective the options are, a pest management program is only successful if it can be economically and practically implemented. Keep in mind the factors which limit the number of appropriate management options:

- Budget.
- Availability of equipment.
- Availability of personnel.
- Time frame allowed for management procedures- any procedure must be implemented during the pest's vulnerable stage of life, when no one occupies the interior landscape and the area can remain vacant until the reentry period has been observed.
- Public/client acceptance of management methods.
- Availability of labeled products for interior use.

Also, as a plant manager, consider the option of removing the plants to be treated from an interior landscape and temporarily relocating them outside or to a greenhouse. Relocating plants makes available a larger selection of products registered for use in those areas (including some that may have been canceled for use in the interior landscape setting.) Furthermore, the conditions in a greenhouse (light, temperature, and water) may be more conducive to the plant's recovery. Once the plant has been treated and the problem corrected, it can be replaced in its original interior landscape location.

IPM EVALUATION

It is extremely important to evaluate the results of your pest management strategies. This can be done in several ways. Record pest counts or level of infection before and after treatment, comparative damage ratings, length of recovery time, etc. Sticky cards, as discussed under monitoring in this section, are helpful in evaluating the results of an insect management treatment. Keep written records of successes and failures, timing of treatment, and special conditions.

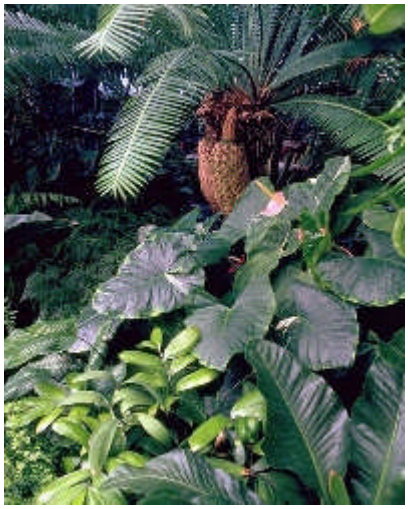
Table 1. A General Diagnostic Guide for Indoor Plants

Symptom	Possible Causes
Brown or scorched leaf tips	1) Poor root health from over watering, excessive soil dryness (especially between

	watering), excessive fertilizer or other soluble salts in the soil or root rot disease. 2) Specific nutrient toxicities such as fluoride, copper or boron. 3) Low humidity. 4) Pesticide or mechanical injury.
Leaf spots, blotches, blemishes, blisters, or scabby spots	1) Intense light (sunburn) associated with a recent move of the plant or excessive soil dryness and wilting. 2) Chilling injury (below 50° F). 3) Chemical spray injury. 4) Over watering. 5) Fungal or bacterial infections (not common unless plants have recently come from a field or greenhouse).
Older leaves yellow-green; **Newer leaves yellow-green;** **All leaves yellow-green;**	1) Insufficient fertilizer, especially nitrogen. 2) Poor root health due to pot-bound growth, compacted soil, or poor drainage. 3) Insufficient light. 4) Senescence (natural aging process, individual leaves). 1) Soil pH (acidity) imbalance. 2) Trace element imbalance. 1) Too much light. 2) Insufficient fertilization. 3) High temperatures, especially when associated with dryness. 4) Insect infestation or roots rot disease.
Leaf drop	1) Poor root health from over watering, excessive dryness or excessive fertilizer or other soluble salts in the soil, compacted soil or pot- bound roots. 2) Sudden change in light, temperature, or relative humidity. 3) Root rot disease.
Wilting or drooping of foliage	1) Poor root health from over watering, excessive dryness or excessive fertilizer or other soluble salts in the soil, compacted soil, or a poorly drained container or root rot disease. 2) A toxic chemical poured into the soil.
Roots brown in color, soft or rotted; roots with tissue that can easily be "slipped off" leaving behind the string-like center tissues; roots massed at top or bottom of pot.	1) Poor root health from over watering, excessive dryness, excessive fertilizer or other soluble salts in the soil, compacted soil, or a poorly drained container.

	2) A toxic chemical poured into soil. 3) Over or under watering. 4) Roots rot disease.
Yellowed leaves with tiny speckling; leaves later bronzed and drying; webbing noted near growing points.	1) Spider-mite infestation.
Leaves or stems covered with a sticky substance; mold growing on leaves; tiny brown or white objects seen on leaves or in crotches of branches; leaf drop or branch dieback; leaf or growing point distortion.	1) Scale or mealybug infestation.

Material adapted from Michigan State University
Extension Bulletin E-2308 Interiorscape Pest Management.
A Training Manual for Commercial Pesticide Applicators. Julie Stachecki, Editor.



Interior Plantscape Integrated Pest Management

CHAPTER TWO
PLANT SELECTION AND MANAGEMENT

Consistent success with indoor plants is most likely to be achieved by:

- Selecting plants that match the conditions of a given interior environment.
- Purchasing high quality plants from a known and reliable source.
- Acclimating the plant before installation by reducing light, moisture, and fertilizer.
- Watering, fertilizing, cleaning, and pruning appropriately.

PLANT SELECTION

The most important practice in interior plantscaping is the selection of plants matched correctly with the environmental characteristics of the planting site. Plants differ significantly in their light needs, sensitivity to temperature, and ease of maintenance.

Light Requirements

Light is probably the most important environmental condition, and plants should be placed and grouped according to their need for light. Plants grown under correct light conditions are vigorous, compact, and bushy. Color is vibrant, leaves are normal in size, stems are sturdy, and flowering is promoted.

Light helps balance food production (photosynthesis) and food consumption (respiration) by the plant. The rate at which plants make their own food is determined essentially by the quantity and duration of available light. The higher the light level, the greater supply of food. The rate of food consumption is basically determined by temperature. The warmer the temperature, the greater demand for food. Therefore, in interiorscapes, the low light and warm temperatures create a high demand for food, but a slow rate of production.

Plants grown at a light intensity below their optimum will have smaller leaves and less vivid color. They often grow more open and leggy, and pruning may be necessary for compact form. They need to be kept drier than those in bright light and fertilized less frequently. A plant that receives significantly less than its required amount of light may survive for several months to a year, while gradually deteriorating in appearance and vigor. A wide variety of light meters is available for measuring light intensities in indoor environments. Light meters can eliminate much of the guesswork in selecting plants that are adapted to light levels in a given location.

Plants for low, medium, and high light locations are listed in Table 1. In general, there are three categories of light intensity for interior plants. These are described in foot-candles (fc). A foot-candle is the amount of light cast by a candle on a white surface at a distance of one foot. Ranges for low, medium, and high light intensity overlap and vary in different references:

- low: 25 to 75 foot-candles,
- medium: 75 to 150 foot-candles,
- high: 150 to 1000 foot-candles.

Leaf structure in plants produced under near or full sunlight is different from leaf structure in plants produced under low light. Leaves of plants in high light conditions are structured to avoid some of the strong light intensity. These small, thick "sun" leaves have an extra layer of cells on the upper leaf surface. The light-trapping chloroplasts in sun leaves are arranged vertically along the sides of the cells. This leaf structure allows for efficient use of high light but is very inefficient indoors.

In contrast, plants grown under low light have "shade" leaves designed to trap as much light as possible. They are wider and thinner than sun-grown leaves, and they usually have only one layer of cells on the upper surface. Their chloroplasts are arranged horizontally along the upper cell surface to capture as much light as possible. Mature leaves apparently do not change their size or internal arrangement. The plant can, however, produce shade leaves during a period of acclimation to a low light environment.

Three factors lower the light requirement for a plant moved indoors. First, the plant's growth slows dramatically or even stops. This growth reduction triggers a lesser demand for food. Second, while the existing leaves cannot change their structure, they can increase their chlorophyll content. Third, the new leaves that are produced in the indoor environment will be structured as shade leaves. This has been shown to result in a reduction in the plant's light compensation point.

The light compensation point is defined as the minimum light level at which the amount of food produced by photosynthesis is equal to the amount of food consumed during respiration. Shade leaves have lower light compensation points than sun leaves. Acclimation to low light involves a reduction in the plant's light compensation point either by changes in leaf metabolism so light energy is captured more efficiently in low light or by replacement of inefficient sun leaves with shade leaves tolerant to low light levels.

Artificial light can be used to supplement or replace natural sunlight. Cool-white fluorescent lights used alone or in combination with warm-light fluorescent lights are the most economical and best all-purpose lamps. Typically, a fixture holding two 40-watt tubes is positioned approximately 12 inches above the plants. Most plants need 12 to 16 hours of artificial light per day for good growth. For large specimen plants, use spot or flood lights to maintain good appearance and accent the plant. Lighting

design should take into account anticipated use of indoor plants. Indirect and track lighting are very effective design features for this purpose.

Temperature Requirements

Understanding how a plant reacts to temperature stress will increase the interior plantscaper's ability to make adjustments to correct problems and improve plant longevity. In addition to problems caused by chilling, heat from registers can dry out media and foliage quickly. A minimum/maximum thermometer will record temperature differences plants may be experiencing in the interior landscape.

Most public buildings are heated and cooled with human comfort in mind rather than the growth requirements of indoor plants. Fortunately, the desirable temperatures for humans fall within the optimum range for most foliage and flowering plants. Daytime temperatures of 70 to 80°F and a nighttime range of 60 to 70°F are satisfactory for most species. Many flowering plants bloom longer at the lower end of these day-night temperature ranges. Variations in temperature ranges should be considered in selecting plants for the interior environment. Temperature ranges for several interior plants are listed in Table 1.

Plants differ in their degree of sensitivity to chilling. Generally, most foliage plants cease to grow at 60°F. Temperatures between 45 and 55° F often result in chilling. Chilling causes changes in cell membrane structure, which, in essence, causes the cells to "leak" their contents. This causes a loss in plant vigor and reduced growth. The damage may not be visible for months after chilling has taken place. Many times a secondary problem such as disease will begin to increase due to the loss of vigor. This secondary problem is then blamed for the damage, and chilling goes undetected.

Chilling damage is very subtle and may be very difficult to detect unless maintenance personnel are looking for it. Symptoms of chilling injury include:

- Foliage discoloration.
- Poor growth or wilting.
- Foliage bending or curling.
- Flower bud drop.
- Plant death.

The severity of chilling damage is a result of temperature and length of exposure. For example, exposure to 50°F for 12 hours may cause chilling injury as severe as exposure to 40°F for 2 hours. Chilling injury can result from only a few minutes exposure at freezing temperatures. Plants can get chilled in the truck going to a job site, during transfer from the truck to the indoors, and from exposure to cold winds near doorways. The following conditions can contribute to chilling injury in the interior environment:

- Shopping malls and public buildings that maintain lower temperatures.
- Air drafts from air conditioning units, doorways, and windows can cause sudden changes in temperature.
- A reduction of temperature in public buildings on weekends and holidays.

Table 1. Light and temperature ranges for selected indoor plants (a)

LOW LIGHT (25-75 FC)		
Aglaonema commutatum	Silver Evergreen	Warm
Aglaonema commutatum 'Silver King'	Silver King Evergreen	Warm
Aglaonema modestum	Chinese Evergreen	Temperate
Aspidistra elatior	Cast-Iron Plant	Temperate
Aspidistra elatior 'Variegata'	Variegated Cast-Iron Plant	Temperate
Chamaedorea elegans	Parlor Palm	Warm
Chamaedorea elegans 'Bella'	Neanthe Bella Palm	Warm
Epipremnum aureum	Golden Pothos	
Epipremnum aureum 'Marble Queen'	Marble Queen Pothos	
Monstera deliciosa	Split-Leaf Philodendron	Warm
Sansevieria trifasciata	Snake Plant.	Warm
Sansevieria trifasciata 'Laurentii'	Goldband Sansevieria	Warm
MEDIUM LIGHT (75-150 FC)		
Aechmea fasciata	Silver Vase	Warm
Aglaonema commutatum 'White Rajah'	White Rajah Aglaonema	Warm
Asparagus densiflorus 'Myers'	Plume Asparagus	Temperate
Asparagus densiflorus 'Sprengeri'	Sprengeri Asparagus	Temperate
Asparagus setaceus	Fern Asparagus	Warm
Aucuba japonica 'Variegata'	Gold-Dust Plant	Cool
*Brassaia actinophylla**	Schefflera	Warm
*Brassaia arboricola**	Dwarf Schefflera	
*Chamaedorea erumpens**	Bamboo Palm	Warm
Chlorophytum comosum 'Variegatum'	Spider Plant	Temperate
Cissus rhombifolia	Grape Ivy	Warm
Dieffenbachia amoena	Giant Dumbcane	Warm
Dieffenbachia amoena 'Exotic'	Exotica Dumbcane	Warm
Dieffenbachia maculate	Spotted Dumbcane	Warm
Dieffenbachia maculata 'Rudolph Roehrs'	Gold Dieffenbachia.	Warm
Dizygotheca elegantissima	False Aralia	Warm
Dracaena deremensis 'Warneckii'*	Striped Dracaena	Warm
Dracaena fragrans 'Massangeana'*	Corn Plant	Warm
*Dracaena godseffiana**	Gold-Dust Dracaena	Warm
*Dracaena marginata**	Red-Margined Dracaena	Warm
*Dracaena sanderana**	Ribbon Plant	Warm
Fatsia japonica	Japanese Fatsia	Cool
Ficus benjamina	Weeping Fig	Warm

Ficus elastica 'Decora'	India Rubber Plant	Warm
Ficus lyrata	Fiddle-Leaf Fig	Warm
Ficus retusa	Indian Laurel	Warm
Gynura aurantiaca	Velvet Plant	Warm
Hedera helix & cvs	English Ivy	Cool
Howea forsterana	Kentia Palm	Temperate
Maranta leuconeura erythroneura	Red-Veined Prayer Plant	Warm
Nephrolepis exaltata 'Bostoniensis'	Boston Fern	Temperate
Pandanus veitchii	Variegated Screw Pine	Warm
*Peperomia caperata**	Emerald-Ripple Peperomia	Warm
Peperomia obtusifolia	Oval-Leaf Peperomia.	Warm
Peperomia obtusifolia 'Variegata'	Variegated Peperomia	Warm
*Philodendron bipennifolium**	Fiddle-Leaf Philodendron	
*Philodendron scandens oxycardium**	Heart-Leaf Philodendron	Warm
Philodendron selloum	Tree Philodendron	Warm
Pilea cadierei	Aluminum Plant	Warm
Pilea involucrate	Friendship Plant	Warm
Plectranthus australis	Swedish Ivy	Temperate
Polyscias balfouriana 'Marginata'	Variegated Balfour Aralia	Warm
Saintpaulia spp., hybrids & cvs	African Violet	Warm
Spathiphyllum 'Clevelandii'	Cleveland Peace Lily	Warm
Spathiphyllum 'Mauna Loa'	Mauna Loa Peace Lily	Warm
Syngonium podophyllum 'Trileaf Wonder'*	Trileaf Wonder Nephthytis	Warm
Tradescantia fluminensis	Inch Plant	Temperate
Zebrina pendula	Wandering Jew	Temperate
HIGH LIGHT (150-1000 FC)		
Aloe barbadensis	Aloe Vera	Warm
Alternanthera ficoidea	Joseph's Coat	
Araucaria heterophylla	Norfolk Island Pine	Temperate
Beaucarnea recurvata	Ponytail Palm	
*Cissus antarctica***	Kangaroo Vine	Temperate
Coleus blumei	Coleus	Warm
Crassula argentea	Jade Plant	Temperate
*Fatshedera lizei***	Botanical Wonder	Temperate
Hibiscus rosa-sinensis	Chinese Hibiscus	Warm
*Hoya carnosa** *	Wax Plant	Temperate
Iresine lindenii	Blood Leaf	Temperate

Podocarpus gracilior	Weeping Podocarpus	Warm
Rhoeo spathacea	Moses-in-the-Cradle	Temperate
Sedum morganianum	Burro's Tail	Temperate

(a)Warm ± 62 (night) to 85° F (daytime); Temperate ± 50 (night) to 70° F (daytime); Cool ±40 (night) to 60° F (daytime).

*May also be conditioned to grow in low light.

**May also be conditioned to grow in medium light.

PURCHASE HIGH QUALITY PLANT MATERIAL

How the plant is produced greatly influences its long-term survival in the interior plantscape. Because approximately 70 percent of the keeping quality of a plant is determined by production practices, plant buyers should develop good working relationships with suppliers and learn about their production practices in order to assure procurement of prime plant material. Price alone should not guide purchase decisions. Ask growers about the light levels used during production, fertilization programs, and pest control practices. Examine plants closely upon arrival—are they free of pests and diseases? The interior environment is tough even on healthy, properly grown plants; poorly handled, low quality material is almost certain to fail.

Most of the plants used in interiorscapes on the east coast are grown in Florida. These plants are often grown in native Florida soil, dug and placed in containers for three to four months, and then sold to interior plantscapers. Plants are available in three grades: A, B, and C. Grade "A" is the best, the most expensive, and has the best chance of surviving the interior plantscape conditions. Grade "C" plants are often sold from the back end of trucks labeled "Florida Foliage Plants" in mall parking lots. Starting with low-grade plants will lead to more problems than using high-grade plants.

ACCLIMATING PLANTS PRIOR TO PLANTING

Not only must plants be properly grown, they must be prepared for the change from the production environment to the interior environment.

Large foliage plants are grown in optimum environments outdoors in southern Florida primarily for outdoor landscaping there. Small sizes are grown in greenhouses or set outdoors in desirable growing conditions for the summer. When placed in offices, malls, or hotel lobbies, the plants usually must adjust to lower levels of light, relative humidity, and nutrients, longer intervals between irrigations, and drier growing medium. Long-term survival in the interior environment depends on the plant's condition and its tolerance for interior conditions. Tolerance can be improved by gradually acclimating the plant to the new environment.

Acclimation depends on adequate light to support the growth processes while the plants adjust to lower light environments. The minimum time required for acclimation varies by plant species but the

recommended light levels for most plants are 12 hours of 2000 foot-candles. During the acclimation period plants should also be leached thoroughly to reduce the salt and nutrient levels in the growth medium. Watering should be gradually reduced to one or two times per week, and fertilizer should be withheld. Acclimated plants have a more extensive root system (a smaller shoot to root ratio), and resist drying damage to the foliage.

The need for acclimation is greatest when plants have been grown in high light conditions. Large specimen trees, for example, require full light during production to generate adequate stem caliper and strength, and they require acclimation before going into an interior setting. In addition to preparing plants for the interior, acclimatization causes a more desirable, darker green color in palms and *Brassaia* spp.

Not all foliage plants need acclimation. Transition to the interior environment without acclimation is most successful if the plants have been produced in shade or when interior light levels are high with skylights, glass walls, or actual greenhouse-like architecture.

In general, acclimation is needed:

- When the interior has low light levels.
- Acclimation is always needed for *Brassaia, Codiaeum* and *Ficus* spp., which are produced in high light;
- For plants such as *Araucaria, Chrysalidocarpus, Dracaena*, and *Sansevieria* spp., which are produced in high shade, acclimation is seldom necessary.

MAINTENANCE IN THE INTERIOR PLANTSCAPE

Once plants have been properly placed in the interior plantscape, their appearance needs to be sustained through proper maintenance and care. Usually, this is limited to watering, fertilizing, cleaning, and pruning.

Watering

Watering indoor plants is a widely misunderstood practice. Water content in the container and plant-water needs are difficult to measure accurately. As a result, improper watering is the underlying cause of many plant problems. There are several basic points to consider when deciding when to water:

- Plants with large or very thin leaves and those with fine surface roots usually require more frequent watering than succulent plants, with fleshy leaves and stems that are able to store water internally.
- In a warm, dry, sunny location, plants need more frequent watering than they do in cool, low-light situations.
- A large plant in a small pot will need water more often than a small plant in a large pot.
- Flowering plants and rapidly growing plants dry out more quickly than plants with slow growth rates.
- Different soil mixes require different watering schedules. Heavy, fine- textured potting media and those that contain a lot of peat moss hold more moisture than loose, porous mixtures of bark, sand, and perlite.

- Water evaporates rapidly from the sides of an untreated porous clay pot, but not at all from plastic or glazed ceramic containers. Water scheduling should take container type into consideration.

In a routine maintenance program, most plant installations will be watered once every 7 to l0 days. Generally, when the top half-inch of the soil in containers up to 8 to 10 inches in diameter feels dry, the plant probably needs watering. The plants on one job site might be from five different growers and in five different media, therefore, some plants will be under watered and some will be over watered. Over watering actually excludes oxygen from the root zone. This prevents active water uptake and effectively shuts down the supply of water to the leaves, resulting in the same symptoms as under watering. Such symptoms include: wilting, loss of older leaves, brown foliage tips or margins, small new leaves, and lack of new growth.

Correct watering practices can reduce many cultural problems of indoor plants; conversely, poor watering practices may aggravate plant problems.

To minimize water-related problems:

- **Water thoroughly**. Apply enough water to moisten the entire soil volume, plus a little extra to leach soluble salts out of the container. Excess water left standing in the pot will result in root rot, salt injury, and generally poor plant performance.
- **Water early in the day**. Watering late in the day or late at night can cause the plant to take up the water faster than it is lost, causing swelling and rupture of the leaf cells (edema), generally on the underside of the leaf. The plant heals these wounds with a corky layer, which might be mistaken for a brown scale. Watering earlier in the day will prevent further problems, but it will not restore the already damaged leaves. This problem is most often seen on plants like Schefflera and Spathiphyllum.
- To preserve leaf appearance, it is best to **apply water to the soil** rather than the foliage. Watering by hand is labor intensive, but essential. Usually watering cans, watering carts, or hoses on taps no more than 100 feet away are used. It is possible to use tubes on the top of the soil or subirrigation. Sub-irrigated plants will accumulate salts and must be leached every 4 to 5 weeks. If water quality is high and the crop is free of foliar disease, overhead sprinkler watering is all right.
- **Evaluate water quality**. Sometimes it is very inconvenient or impossible to water plants without wetting the leaves. If water quality is poor, a water conditioning system must be installed. De-ionized or softened water usually causes no problem as long as routine leaching from the soil is provided. Adjusting water pH to about 6 also reduces leaf spotting, and producers typically inject phosphoric acid into their water supply to lower the pH. Chlorinated municipal water should not cause problems when good soil management practices are employed. Much of the gaseous chlorine evolves from the soil soon after watering. In many cities there are relatively high concentrations of salts in available groundwater which can actually damage salt-sensitive plants such as ferns and bromeliads.

  Check with your local county extension office if a high water-salt level is suspected. A water analysis can be requested from a qualified laboratory.

Fertilizing

Fertilization is necessary for growth and maintenance of plants. A plant's need for fertilizer depends on its growth rate, the amount of leaching that occurs during watering, soil volume, and other factors. Fertilizer levels that were ideal during production can severely damage plants in interiorscapes. Soluble

salts in the media can cause root burn when too much fertilizer is applied, when the medium dries out, and when water quality is poor.

Generally, when a plant leaves the production area there will be no further net increase in root-ball size. Any condition or practice that reduces root numbers will stress the plant and reduce plant longevity. Stress may be caused by high soluble salts, over watering, under watering, or poor water quality. At best, the rate of root replacement indoors will be very slow.

"Nutrient acclimation" of growing media is crucial for best plant performance in the interior environment. Media must be leached and the plant acclimated to reduced nutrient and salt levels before the plant is installed indoors.

One of the most devastating problems facing an interior plantscaper is "Tiny Feet." Foliage plants react very strongly to high levels of fertilizer in production. They produce very large tops, but do not develop a similar root mass. This results in "Tiny Feet". While in production under high humidity, the plants look fine and finish sooner than plants grown under lower fertility. However, when moved indoors under low humidity, the demand for water by the leaves will be greater than the roots can supply, so the plant becomes water stressed and begins to drop leaves, turn yellow, and may eventually die. Nothing can be done to correct this problem. It is prevented by purchasing plants from growers who use proper fertility in production.

Nutrient monitoring is very important in maintaining the interior plantscape. It is highly recommended that growth media be tested prior to planting. Test results will indicate whether adjustments should be made to the medium to reach optimum nutrient levels. Once optimum nutrient levels are established, they can be maintained by carefully planned fertilization practices. For a small fee, NCDA also does tissue analysis.

Generally, interior plantings should be fertilized a **maximum** of four times per year. As a rule, applications should be more frequent during the spring and summer when sunlight intensity increases and days are longer. During the short days of winter, many indoor plants that receive little or no artificial light enter a resting stage. If plants go into a winter rest period, it's best to give them little, if any, fertilizer. Plants that have just been transplanted or repotted will obtain sufficient nutrients from the fresh potting soil for at least 4 to 8 weeks. They do not require supplemental fertilizer during this time.

Triple super phosphate is a common source of phosphorus for container soils. It should not be routinely used for foliage plants because it also contains toxic fluoride ions. Thus to avoid fluoride and salt residues, a balanced fertilizer should be composed of salt combinations such as KNO_3 and $(NH_4)_2HPO_4$ or $(NH_4)_3\ PO_4$.

Slow release fertilizers such as dry, garden formulations provide nutrients over several months. Formulations that contain nitrogen only in the ammonium form are not used because toxic levels of ammonium commonly develop. The "membrane types" of slow release fertilizers are expensive per unit nutrient applied, but are less labor intensive because they are applied less frequently.

As the medium dries out, the soluble salt concentration goes up. If the plants are allowed to dry out, high salts may damage roots. Groundwater with relatively high concentrations of salts may also be a source of damage to salt-sensitive plants.

Cleaning

Plant cleaning includes dust and water-spot removal, leaf shining, and removal of senescent leaves. The leaves of indoor plants can become coated with a heavy layer of dust in a surprisingly short time. This dust and grime interferes with normal leaf functions and makes the plant less attractive. Accumulated dust will shade the leaves and may so drastically reduce light that the plant will eventually die. Dust with a soft brush or cloth moistened with warm water to clean both upper and lower leaf surfaces at least every two or three months.

Cleaning frequency and method depends, in part, on leaf characteristics. For example, hairy leaves (such as on Velvet Plant) will collect dust and require occasional brushing. Shiny, waxy leaves (as in Peperomia) readily show dust and must be wiped periodically with a damp cloth. If the upper side of the leaf is concave or has an uneven rippled surface, it will collect dust that should be removed with a gentle mist spraying or brushing. Finally, if the plant leaves grow more horizontally than at an angle, they will collect dust more easily.

Dust can be a tremendous maintenance problem in large-scale plantings. Ease of maintenance should be a consideration in selecting plants for a particular location. More dust is likely to accumulate where the ventilation system is open than in air-conditioned locations where it is closed. Accessibility of installed plants for cleaning is a further consideration. If plants are not easily accessible, only the most dust-resistant ones should be chosen. Dusting will not present as much of a problem in homes, but in commercial installations, accessibility of plants and the availability of maintenance staff are additional considerations. In some instances, large plant material is best cleaned by washing off the foliage.

Several leaf-cleaning compounds have been tested on *Philodendron scandens* subsp. *oxycardium*. All products seem adequate. However, reductions of plant growth probably are caused both by the product as well as the degree of leaf abrasion during application.

Plants that are small enough to move into the shower or outdoors, for a mild soapy wash and rinse, in warm weather will be more attractive and less prone to insect problems. Plant leaf-shine materials should be avoided. They attract dust and can slow plant growth.

Pruning

Interior plants often grow at a slow rate, but to the extent that they increase in size, they will require maintenance. Plants with mechanical damage or those under environmental stress will also require maintenance. Pinching, disbranching, and shaping-from removing a shoot tip to encourage branching to removing an entire section of the plant to maintain its intended design size-may be necessary occasionally. Another reason for pruning may be the removal of insect pests such as scales that may accumulate on specific branches.

If light comes from one direction, plants should be turned regularly if possible to expose all sides to light. This encourages a more uniform shape. Remove yellow or discolored foliage as it develops. Dried brown leaf tips and margins may be trimmed back to green tissue with scissors. Follow the shape of the leaf when making these cuts to maintain the natural appearance.

CHAPTER THREE

DISEASES OF INDOOR PLANTS

The occurrence of diseases on indoor landscape plants is typically a result of adverse environmental conditions or the presence of infectious agents. Diseases solely caused by microorganisms (fungi, bacteria, viruses or nematodes) are not common in the indoor landscape setting if the landscape was established using disease-free plant material and conditions conducive to disease development are avoided. It is critical to identify the causal agent or the type of disease that arises in the interior landscape in order to take appropriate corrective measures. Plants are subject to two types of disorders:

- **Abiotic or non-infectious disorders;** caused by environmental, cultural, and non-living things. Things causing abiotic or non-infectious diseases do not grow, reproduce, or spread from plant to plant; they are not contagious.
- **Biotic, infectious or pathogenic diseases;** caused by living pathogenic microorganisms such as fungi, bacteria, viruses, or nematodes. These microorganisms can spread from plant to plant.

To manage plant diseases and disorders successfully, plant maintenance technicians must be able to:

- Recognize symptoms and signs that indicate the presence of a disease or disorder.
- Accurately identify the cause and type of problem (abiotic or pathogenic or a combination of the two).

Select the best method(s) for correcting conditions that contributed to the disease development.

ABIOTIC DISORDERS

Abiotic disorders produce a wide range of symptoms such as reduced vigor, yellowing leaves, leaf drop, or rapid death of plants. The abiotic conditions causing severe damage are easiest to recognize and correct. Less obvious symptoms may go unnoticed and therefore the unfavorable condition or cultural practices may persist for a long period of time. During this time plants are stressed and become

more susceptible to pathogenic diseases. For example, if powdery mildew develops on a plant that is usually resistant to this disease, an investigation may reveal that the plant was consistently over watered, resulting in high moisture and humidity (abiotic conditions) in the planting area. In this case, correcting the cultural practice that allowed the pathogen to become established may be the only corrective measure necessary for managing the powdery mildew.

Many cultural and environmental conditions that lead to poor plant health are mentioned throughout this manual. This section will focus on some of the most likely abiotic disorders found in an interior landscape.

Environmental Conditions Contributing to Abiotic Disorders

There are certain ranges of temperature, light and humidity that provide for optimal plant health. The importance of these factors is considered here in relation to the development of abiotic disorders.

Typically interior spaces utilized for living or work environments provide temperatures adequate for growing foliage plants. A temperature range between 50 and 90° Fahrenheit can be tolerated by most foliage plants. Attention must be given to temperatures during times when interior spaces are not occupied by people. With a more energy-conscious society, the thermostat may be set to temperatures that may injure plants when they are exposed over a period of time. Foliage plants can suffer cold damage without freezing. This is referred to as chilling injury. A few plants that are injured by exposure to chilling temperatures between 35 and 50° F for short periods of time include *Aglaonema* X 'Silver Queen', *Dieffenbachia maculata*, *Dracaena* spp. and *Polyscias fruiticosa*. Symptoms of chilling injury include yellowing or brown water-soaked areas on leaves, loss of foliage, poor growth, and wilting.

Plants exposed to hot temperatures for prolonged periods of time can also suffer injury. Wilting, marginal burn on foliage, and leaf drop may occur. Since most foliage plants can tolerate temperatures as high as 95°F, provided they receive adequate water, the problem is not related entirely to maximum temperature but to utilization of stored food reserves due to elevated respiration levels. When a plant depletes its stored carbohydrates, it may become weak and predisposed to other stresses including invasion by pathogens.

Light affects numerous physiological conditions and processes in plants. When plants are subjected to inadequate light levels, disruptions of these functions may cause stress. Plants may exhibit poor growth and color. These symptoms are easily mistaken for something other than poor environmental conditions.

If plants haven't been adequately acclimatized to the conditions of an interior plantscape (lower light levels, lower temperatures and humidity), they may experience yellowing and leaf drop and possible death following installation.

Many growers are producing acclimatized plants which require more time to grow, but are more tolerant of environmental stress at the job site. Be familiar with the growing practices of your supplier and symptoms associated with an inadequately acclimatized plant. If the grower doesn't acclimatize the plants, establish a method and facility to do so before installing the plants directly into an interior landscape.

Cultural Practices Contributing to Plant Disorders
Most plant replacements result from a combination of poor environmental conditions and poor cultural practices. Abiotic disorders symptoms, resulting from poor environmental conditions and cultural practices, are extremely variable and are often misdiagnosed. Pesticide applications will not correct an abiotic disorder. It is vital that plant technicians understand the impact of their cultural practices on the plants they maintain.

The misapplication of water is the leading source of problems related to cultural practices. Do not wet foliage or splash water when performing routine care. Wetting foliage may promote the growth of leaf-spot organisms. Moisture and warm temperatures are required for most diseases to develop on healthy plants.

Water drops on leaf surfaces magnify the intensity of light as it passes through the drop. Plants in direct sunlight can develop burned spots beneath water drops.

Plants with hairy (pubescent) leaf surfaces (i.e. African violets, gloxinia) are easily damaged by cold water on their leaves. Damage from water that is 10 degrees cooler than the leaf surface will appear as distinct "fairy rings."

Misting plants is not recommended because this added moisture on leaf surfaces can spread disease organisms or create conditions favorable for disease development. Foliage should only be wetted when dislodging insects or when removing dust.

Damage from the application of pesticides (phytotoxicity) occurs for several reasons. Products used for shining leaf surfaces should be avoided since they leave heavy residues and clog plant pores.

The misapplication of fertilizers is also a common cultural practice that causes abiotic disorders. Under fertilization can lead to nutrient-starved plants which appear sickly and may be more susceptible to biotic diseases. Over fertilization can led to nutrient imbalances and high levels of salt in the soil. High levels of salts in the growing media can cause damage to plant roots which makes them more susceptible to attack by soil-borne pathogens. The use of water high in minerals may also lead to soil-salt problems.

Soil pH may change over time. Maintaining a proper pH will minimize nutritional problems. When diagnosing plant problems, always check the soil pH to be sure it is in a range adequate for foliage plant growth.

Plant Problems Due to Miscellaneous Activities
Environmental factors and cultural practices can be monitored and adjusted to provide the best possible conditions for plants. Yet there may be harmful activities that occur in the interior landscape that are beyond the control of the plant technician. When symptoms seem to have no other explanation, the following possibilities should be considered:

- Fumes from cleaning agents can be harmful to plants. Commercial strength ammonia fumes can blacken foliage and cause plant death. Other symptoms produced by exposure to toxic fumes include loss of foliage or curled leaves.
- Air pollutants can harm plants, even at levels that are not a threat to human health. Many plants (especially orchids and ferns) are sensitive to small amounts of ethylene in the air. Symptoms of

ethylene injury include leaves bending down at the stems, yellowing and dropping of older leaves, and slowed growth.
- Plants installed near indoor pools can be damaged by chlorine released into the air. Symptoms include bleaching of leaves and dying of plant tissues.
- Heavy tobacco smoke can harm plants by settling on leaf surfaces and blocking the pores used for gas exchange. Routine washing prevents this from being a problem.

BIOTIC DISORDERS

It is helpful to understand which conditions influence biotic disease (also known as infectious disease) development when managing the health of plants. The disease triangle illustrates the primary factors that must be present and favorable for a biotic disease to occur. These are:

- **Pathogen**: the abundance, aggressiveness, and other characteristics of the agent causing the disease influence the disease development. Some pathogens are widespread and attack many plants; others are not.
- **Host Plant**: the genetic susceptibility and general condition of the plant influence disease development. Healthy, stress-free plants are less susceptible to pathogens than weakened plants. Different species or cultivars of plants may be more or less susceptible to attack.
- **Environment**: certain environmental conditions favor the infection of the plant by a pathogen. These include temperature, moisture, humidity, soil conditions, light, density of the planting, and location of the plant.
- **Time** is another factor that influences disease development. Time and the three components of the disease triangle all interact with one another. While one factor may be most important in a particular disease and less important in another, no single factor acts alone.

The goal of a plant pest manager is to recognize and manipulate these primary factors to promote stress-free plants and eliminate conditions favorable to disease development. Remember, problems on plants generally do not arise from one isolated cause.

INFECTIOUS DISEASES ON INDOOR PLANTS

The disease triangle reminds us of the factors necessary for a pathogen to infect a plant. A susceptible host plant and a pathogen must be present along with the proper environmental conditions in order for a disease to occur. Conditions that favor the development of pathogenic diseases can be avoided in the interior landscape setting. Overhead irrigation, splashing water, prolonged leaf wetness, high humidity, crowded blocks of similar plants, and propagation of infected stock are conditions more likely to occur in a greenhouse production setting.

Typically, diseases in the interior landscape result as a secondary infection after a plant has been stressed by adverse cultural or environmental conditions. Correcting the stress often prevents the development of diseases.

Pathogenic organisms can be widespread. A plant technician should be aware of the sources of infectious plant pathogens which include:

- Use of infected plant materials.
- Established plants harboring disease.
- Debris left after removing diseased plants.
- Infested soil used in the soil mix, or reused pots.
- Dust.
- Water dripping or splashing from infected plants overhead.
- Air currents carrying spores.
- Insects or mites carrying diseases from infected plants to healthy plants.
- Contaminated pruning or maintenance equipment spreading disease from infected plants to healthy plants.

When a disease appears in the interior landscape, it is possible that it is a continuation of a situation that began in the greenhouse. The goal of plant growers is to produce high-quality plants as free of pests as possible. Greenhouse growers commonly use pesticides to suppress the development of diseases. The suppressed diseases may become prominent in an interior plantscape where fungicide applications are not routine.

Interior landscapers are responsible for maintaining plants under favorable conditions before, during, and after installation to avoid disease development. Prevention is always the preferred method of disease management. Otherwise, once diseases develop, more costly or hazardous methods must be used. Attention to maintenance practices reduces the opportunity for pathogens to become established. Best management practices include:

- Using pasteurized potting media and sterile containers.
- Using only disease-free plants.
- Maintaining proper environmental conditions.
- Trimming out all damaged and infected plant parts prior to installation and as they develop on the job site.
- Not crowding plants; allowing air to circulate freely around foliage.
- Watering without splashing soil or wetting leaves.
- Not over watering or allowing water to stand in bottom of containers.

- Routinely disinfecting tools, implements and hands.
- Managing insect and mite populations.
- Completely removing infected plants and contaminated materials.

The use of fungicides is not always possible in an interior landscape setting due to the need for repeated treatments and the limited number of fungicides registered for use in interior landscapes. The only fungicides currently labeled for use in the interior landscape are those that are applied to the soil, typically as a soil drench. If a fungicide is labeled for use on the plant(s) and for the pathogen you need to treat, but is not labeled for use in an interior landscape setting, you may temporarily relocate the plant to a location that is on the label (such as outdoors or in a greenhouse) and then make the treatment. By removing a plant from its interior landscape, the options for fungicide applications are expanded, although temporarily relocating plants may not always be practical. Prevention is the most practical and effective way to manage disease.

Most pathogenic diseases of foliage plants are caused by fungi, bacteria and viruses. Observing symptoms and signs provides clues to the type of pathogen causing a disease but may not indicate the specific agent. Accurately diagnosing the specific pathogen causing the problem is critical for selecting appropriate corrective measures.

Any fungicide will only be effective in controlling those specific pathogens listed on its label. Knowing the exact pathogen causing your problem is important. Accurate diagnosis of plant pathogens may require laboratory analysis. A fresh, representative sample produces the most accurate diagnosis. It is best to collect and submit samples early in the week so that the sample does not arrive during a weekend or holiday when there will be time for it to deteriorate. Large samples will generally enable a quick correct diagnoses. Send a whole plant if feasible. Otherwise, collect leaves, stems, and roots from plants showing the symptoms. Include the full range of symptoms. Remember that leaf symptoms may be the result of a stem or root problem. Also include a small sample of soil from the roots. Diagnostic assistance can be obtained from your local County Extension Service.

Disease symptoms on foliage or stems are the most likely to be noticed. A quick response can stop the spread of a pathogen on the host and to other plants. If plant damage is not severe and has been checked by your management procedure the plant may still be attractive enough to remain on site. Root diseases are less likely to be noticed until damage is severe. When an infection becomes severe, the best alternative is removal of the plant and infested growing media.

Fungi

Fungi are the most prevalent plant pathogen of indoor ornamental plants. They cause a number of leaf spot, stem, and root rot diseases. Most foliage diseases caused by fungi develop circular, dead spots or lesions on leaves, stems and flowers. The gray-to- brown center is dry and papery, with a darker edge. As surrounding tissue is invaded, lesions may exhibit a concentric ring which gives the affected tissue a "target-like" appearance with a faded green halo forming the outermost ring. These circular lesions can overlap, forming larger lesions, producing a blotchy appearance. Also, look for black, pinpoint-like pustules within the lesion. These black specks are the reproductive structures of the fungus which develop on or in diseased tissue. (Not all fungi produce these structures.) Inside these structures are millions of spores that are easily carried by air currents, water or soil movement, and human activity. After reaching a host plant, spores can remain inactive for long periods until conditions are favorable for growth and infection of plants. Temperatures from 60 to 80°F and high moisture levels encourage fungus growth.

There are many different fungal pathogens found on foliage plants. They produce different sizes, shapes, and colors of lesions. Refer to Table 1 for an overview of common fungal leaf-spot diseases of foliage plants.

Bacteria

Bacteria are microscopic organisms. They enter the host through wounds, natural openings or direct penetration. Once inside the host bacteria begin to multiply rapidly by increasing cell division. Although plant diseases caused by bacteria are less common than fungal diseases, bacterial pathogens can cause some of the most economically damaging diseases. There are no chemical controls available for managing bacterial infections in indoor landscapes. Prevention is directed at reducing the number of bacterial sources and avoiding conditions that are favorable for growth of bacteria. Cultural control and sanitation are important aspects of prevention.

Moist conditions and high humidity from splashing or misting contribute to the spread of bacterial disease. Bacteria are single-celled, microscopic organisms. There are two types of bacterial plant diseases:

> **Systemic infections** which occur in the plant's vascular tissues (water- and nutrient-conducting tissue), and
> **Localized infections** which appear as leaf and/or stem lesions.

Systemic infections are limited to the vascular tissues of stems, crowns, and sometimes roots. They cause wilting and general yellowing of plants. Occasionally systemic bacterial diseases may cause rotting or cankering of the stem tissue. These cankers or rots will be soft and mushy in appearance and may have an unpleasant odor. Early stages are almost impossible to diagnose. Later stages are easier to diagnose, however, the disease is so extensive by this point that treatment is impossible. If bacterial diseases are diagnosed, the best action to take is to remove the infected plant from the site and destroy it.

Localized bacterial disease symptoms can be in the form of leaf spots and/or stem rots. Bacterial leaf spots may be distinctly different from fungal leaf spots. They are dark green with a greasy, water-soaked appearance when viewed from the underside of the leaf. Eventually these areas turn tan, dark brown, or black depending on the plant species and the bacterium involved. A distinct yellow band (referred to as a halo) often surrounds the periphery of infected tissues. The yellow region can also be described as chlorotic, meaning the tissue becomes yellow because the chlorophyll has been destroyed. A small slice of the lesion placed in a drop of water may emit a stream of bacteria from the tissue. The water will appear cloudy. Early detection will allow you to prune out infected plant parts and possibly save the aesthetic value of the plant. Clean hands with soap and water and disinfect pruning tools in 70 percent alcohol after such removal actions.

The spots or lesions of localized infections can enlarge rapidly and consume the entire leaf within a short time. Such fast-moving infections often spread into leaf petioles and stems. Plant tissue becomes soft and mushy, often with a foul odor. In advanced stages, brown ooze is found in veins throughout the plant. Control of these diseases generally involves prompt removal of infested plant parts. Refer to Table 2 for examples of bacterial leaf spot and stem rots.

Viruses

Viruses are much smaller than bacteria. They enter the cells of a plant and are multiplied by the host. Viruses live and multiply only within living cells. Viral diseases are usually introduced into interior

landscapes by the use of infected plants or Vectors such as insects. They can be spread to healthy plants by the feeding activity of sucking insects such as aphids and leafhoppers, or on the hands and tools of maintenance workers. Currently there is no chemical control for a virus once it infects a plant. Although most viruses are specific to only a few types of plants, prompt and complete removal to prevent its potential spread is recommended when a virus is discovered.

Symptoms of viral diseases are very diverse. Some viral diseases have symptoms similar to fungal diseases. Symptoms of viral infection include:

- Mosaic patterns on leaves (a mixture of irregularly shaped dark- and light-green areas on the leaf).
- Yellow streaking of leaves, especially monocots.
- Yellow ringspots or lines on leaves.
- Veins becoming distinctly yellow.
- Uniform yellowing, bronzing or reddening of leaves.
- Cup-shaped leaves.
- Crinkling or curling of leaf margins.
- Distortion of leaves and growing points.
- Stunting of growth.

Refer to Table 3 for examples of viruses on indoor plants.

Diagnosing a viral disease should not be based only on symptoms. If you suspect a virus, isolate the diseased plant and obtain assistance from your local County Extension office.

Root Diseases

Root rots are the most common disease problem with indoor ornamental plants. Most root rot diseases are caused by fungi. See Table 4 for examples of fungal root rots.

Infectious root rots can be diagnosed to some extent by direct observation of the root system. Healthy roots of herbaceous plants should appear white and firm. Off-color or brownish- to-blackish, limp roots often indicate that root rot is present. Being able to pull off outer root tissue with your fingers (leaving the string-like center of the root behind) is a good sign that root rot is present. In order to determine the health of a root system, you should know what a healthy root system looks like. Conditions of the above-ground portions of the plant that indicate a root problem include smaller and less vigorous growth, new leaves that may be smaller and fewer than normal, and old leaves that turn yellow and fall beginning at the base of the stem. Also, the plant may droop and new shoots may emerge from the lower stem.

Two of the most common root rot fungi involved in root rot disease are the water molds, *Pythium* spp. and *Phytophthora* spp. These organisms are called water molds because of a spore stage that is adapted to spread by swimming in water. These organisms, even if present, are not a problem unless plants have been subjected to poor environmental conditions or cultural practices. High moisture levels in potting soil due to over watering, poorly drained media, or water standing in the bottom of the containers induce infection of roots by these fungi. Root damage caused by over fertilization, build up of salts in the soil, chilling or freezing temperatures, or phytotoxicity caused by improper soil drenches can also lead to root rots.

Drainage of the media and establishing proper irrigation, fertilization and good sanitation practices help avoid and/or correct root rot diseases in general. Be aware of the changes in the physical structure of the rooting media. As media ages it may settle and pack in the bottom of containers and hinder drainage.

Rhizoctonia solani is a soil-borne organism which is especially damaging to roots and lower stems. Under high humidity and cool weather conditions this organism, as well as the water molds, can cause serious aerial blights (diseases of above-ground plant parts). Only occasionally is this a problem for indoor plants. *R. solani* has a wide host range and needs only minimal environmental requirements for disease development. Therefore, this organism poses a serious threat where poor horticultural practices exist or when this organism has contaminated the potting media.

Other pathogenic organisms which can be equally detrimental under the right conditions are *Fusarium* spp., *Cylindrocladium* spp., *Sclerotinia* spp., and *Thielaviopsis basicola*. These organisms are soil borne and persist in soil or artificial media for quite a while. Therefore, the best management of these pathogens, as all the others, is prevention: Use only disease-free plants, avoid stressed plants or those with discolored roots or stems, monitor watering practices closely, and practice good sanitation measures.

Nematodes

Several types of tiny roundworms cause plant diseases on plants used indoors. Lesion nematodes (*Pratylenchus* spp.) and spiral nematodes (*Helicotylenchus* spp.) cause plant stunting and poor growth because their feeding weakens the root system. The root knot nematode (*Meloidogyne* spp.) causes nodules to form on roots, thus impairing root function. This causes stunting. The foliar or spring-crimp nematode (*Aphelenchoides* spp.) lives within the leaf tissues of many indoor plants. It causes death of the leaf tissue, resulting in brown lesions on older leaves. Nematode diseases tend to be rare on indoor plants.

Good sanitation is the primary means of controlling these pathogens. Soil sterilization prior to planting will kill adults as well as eggs of root nematodes. Fumigants are as effective as steam for this purpose. Fumigants can be used as a nematode management tool in a production setting but are not registered for use in interior landscapes.

Material adapted from Michigan State University Extension Bulletin E-2308 Interiorscape Pest Management. A Training Manual for Commercial Pesticide Applicators. Julie Stahecki, Editor.

Table 1. Examples of Common Fungal Leaf Spots

DISEASES	PATHOGEN	HOST	SYMPTOMS
Anthracnose	*Gloeosporium* spp. *Colletotrichum* spp., *Glomerella* spp.	*Dracaena* spp., *Ficus* spp., Brassaia sp., *Philodendron* spp., *Dieffenbachia* spp., *Sansevieria* spp., ivy, palms, and others.	Lesions form on leaf or stem, limited in size. Spots often have a raised edge.
Cephalosporium Leaf Spot	*Cephalosporium dieffenbachiae*	*Dieffenbachia* spp.	Young leaves develop small red spots with dark edges. Spots may merge before leaf yellows and falls.

			Fungus enters insect-feeding wounds.
Cercospora Leaf Spot	*Cercospora* spp.	*Brassaia actinophylla*, *Cordyline* spp., *Ficus* spp., *Peperomia* spp., palms, and others.	Pinpoint lesion on underside of leaves that resemble edema. Some hosts have many small red-to-brown lesions with pale edges. Affected leaves yellow and fall.
Fusarium Leaf Spot	*Fusarium moniliforme*	*Dracaena* spp., *Pleomele* spp.	Attacks growing point, which may be totally rotted away. Yellow-to-red rounded or oval leaf spots may appear. Cream-colored spores may appear.
Gray Mold or Botrytis Blight	*Botrytis cinerea*	Wide range of hosts, including many flowering plants.	Quick rot of flowers, buds, stems, and leaves. Gray-colored hyphae and spores easily seen in severe cases.
Phyllosticta Leaf Spot	*Phyllosticta dracaenae*	*Dracaena* spp., *Cordyline* spp.	Irregular spots with brown centers and yellow halos merge to destroy large areas of leaf.
Powdery Mildew	*Erysiphe cichoracearum* *Odium* spp. *Sphaerotheca humuli* and other fungi.	*Begonia* spp., *Kalanchoe* spp., African violets, and many others.	Usually affects leaves, but all above-ground parts can be affected. Gray-white spots or patches. Leaves may discolor before drying out, turning brown and falling. Infected buds fail.

Table 2. Examples of Bacterial Leaf Spots and Stem Rots

DISEASE	PATHOGEN	HOSTS	SYMPTOMS
Bacterial Leaf Spot	*Xanthomonas dieffenbachie*	*Anthurium* spp. *Dieffenbachia* spp., *Philodendron* spp.,and others.	Spots from pinpoint size up to 3/8"develop and merge to cover large areas, except for midrib of leaf. Spots round to oval, yellow or yellow orange with a dull green center.
Erwinia	*Erwinia chrysanthemi*	*Agleonema* spp., *Dieffenbachia* spp., *Philodendron* spp., *Syngonium* spp., and others.	Symptoms range from distinct spots on blighted leaves to mushy, foul-smelling rot of main stem. New leaves can yellow and wilt. Also rapid, mushy leaf collapse.

Table 3. Examples of Viruses of Indoor Plants.

VIRUS	HOSTS
Cactus Virus X	*Cacti* spp.
Cucumber Mosaic Virus	*Maranta* spp.
Dasheen Mosaic Virus	*Aglaonema* spp., *Caladium* spp., *Dieffenbachia* spp., *Philodendron* spp.

Fig Mosaic Virus	*Ficus* spp.
Tobacco Mosaic Virus	*Rhoeo* spp. , *Columnea* spp.
Tradescantia Mosiac Virus	Wandering Jew

Table 4. Examples of Fungal Root Rots

DISEASE	PATHOGEN	HOSTS	SYMPTOMS
Wet Rots	*Pythium* spp. *Phytophthora* spp.	*Diffenbachia* spp. *Maranta* spp., *Aglaonema* spp., *Philodendron* spp., *Brassaia* spp., and many others.	Begin at root tips, move toward stem. Roots turn brown to black, outer layer is mushy and may slip off, leaving center of root intact.
Dry Rots	*Rhizoctonia solani* *Rhizoctonia* spp.	*Aglaonema* spp. *Dieffenbachia* spp., and many others.	Source of damping off in seedlings. Older plants develop dry, reddish-brown lesions at the soil line. Leaves can be affected if they are near soil level.

Table 5. Susceptibility of Various Plants Used Indoors To Various Diseases*

Host Plants	Systemic Bacterial Infection	Bacterial Leaf Spots	Nematode Diseases	Virus Diseases	Powdery Mildew	Water Mold and Crown Rots	Root and Stem Rots	Fungal Leaf Spots And Blights
Aglaonema spp.	X	X					X	X
Aloe spp.						X	X	X
Aphelandra spp.	X	X					X	X
Aralias		X				X	X	X
Araucaria spp.							X	X
Ardisia spp.						X	X	X
Areca spp. (See Palms)								
Asparagus spp.	X							X
Begonia spp.	X	X			X	X		X
Brassaia spp.		X	X	X		X	X	X
Caladium spp.			X	X			X	
Clathea spp.								X
Cacti	X		X	X		X	X	X
Chamaedorea spp. (see Palms)								
Chlorophytum spp.	X					X	X	

Chrysalidocarpus spp. (see Palms)								
Cissus spp.							X	X
Codiaeum spp.						X	X	X
Cordyline spp.	X					X	X	X
Crassula spp.	X						X	X
Dieffenbachia spp.	X	X		X		X	X	X
Dizygotheca spp. (see Aralias)								
Dracaena spp.	X					X	X	X
Epipremnum spp.	X	X	X			X	X	X
Fatshedera spp. (see Aralias)								
Fatsia spp. (see Aralias)								
Ferns		X	X				X	X
Ficus spp.				X			X	
Hedera helix		X				X	X	X
Howea spp. (see Palms)								
Hoya spp.						X	X	X
Ivies				X			X	X
Maranta spp.	X		X	X		X	X	X
Nephrolepis spp. (see Ferns)								
Palms			X				X	X
Peperomia spp.				X		X	X	X
Philodendron spp.	X	X	X	X		X	X	X
Phoenix spp. (see Palms)								
Pittosporum spp.							X	X
Pleomele spp.							X	X
Podocarpus spp.						X	X	X
Polyscias spp. (see Aralias)								
Raphis spp. (see Palms)								
Sansevieria spp.	X		X			X	X	X
Schefflera spp.		X						X

Sedum spp.								X
Spathiphyllum spp.		X		X		X	X	X
Yucca spp.								X
Zebrina spp.			X	X			X	

* Disease occurrences are noted from the articles Nematode Pests of Tropical Foliage Plants and Leatherleaf Fern by A. R. Chase, D. T. Koplan, and L. S. Osborne (**Foliage Digest** July 1983, pp. 3-6) and Guide to Diseases of Foliage Plants 1983 by A. R. Chase (**Foliage Digest**, June 1983, pp. 7-9), and as listed in **Index of Plant Diseases in Florida**, Bulletin 11, Div. of Pit. Ind, Fl. Dept. of Ag and Consumer Services.

** Includes *Erwinia carotovora*.

*** Includes anthracnose diseases.

This is not intended to be a comprehensive table

Resources

This material was adapted from the following resources:

Bailey, Douglas. 1994. Indoor plant selection and care. North Carolina Cooperative Extension Service. Horticulture Information Leaflet 554.

Bailey, Douglas. 1983. Selection and care of foliage plants. Proceeding of the North Carolina Interior Plantscape Symposium.

Fonteno, William. 1993. Stress Physiology: What is your plant telling you? Proceedings of the North Carolina Interior Plantscape Symposium.

Thanks to Dr. Alice Russell, Extension Specialist, Consumer Horticulture for reviewing this chapter.

Interior Plantscape Integrated Pest Management

CHAPTER FOUR
INSECT MANAGEMENT IN THE INTERIOR PLANTSCAPE ENVIRONMENT

Commercial indoor landscape accounts are perhaps the most difficult areas in which to attempt pest control. Interior plantscapes extend from public conservatories to extensive plantings in homes, hotels, office buildings, restaurants, shopping malls, hospitals, schools, and other environmentally sensitive areas. The use of insecticides in many of these areas is often greatly restricted because of the sensitivity of the surroundings. In addition, few chemicals are cleared for ornamental plant use in public areas, and public prejudice against pesticide odors can prevent application of pesticides in many situations.

An amazing variety of insects feed on flowering and foliage plants. The routine use of insecticides usually eliminates predaceous insects and mites. However, pests remaining after treatment sometimes tolerate commonly used insecticides. To stay in business, most commercial flower and foliage plant growers must become fairly sophisticated in using various types of pest management practices, insecticide formulations, application equipment, and in rotating insecticides from one chemical group to another.

COMPONENTS OF INTEGRATED PEST MANAGEMENT

The first line of defense against ornamental plant pests is sanitation and quarantine. Taking steps to prevent pest problems is well worth the effort. Inspect plants thoroughly and only place insect-free plants into an indoor landscape. If possible, when insect infestations are first found, isolate infested plants to prevent spread of the infestation.

Monitoring
Constant vigilance for insects, mites, and diseases is required for effective pest management. An employee or certain employees should be assigned the responsibility of scouting for insects and other

pests on a regular basis (perhaps weekly during the winter and twice weekly during the summer). Written records of where various pests are found should be kept. Pests can be monitored by using yellow and blue sticky cards, by using yellow pan traps, and by examining the foliage, flowers, and occasionally the roots.

For proper management, it is important to be able to recognize the various kinds of pests in their various stages of development.

Probably the most frequently misidentified pests are shore flies and dark-winged fungus gnats. Shore flies are of little economic consequence in the greenhouse but are very resistant to pesticides. Thus a grower can waste effort and pesticides trying to chemically control shore flies rather than trying to control algae the shore flies are breeding in. Another example of misidentification is the assumption that parasitized green peach aphids are some sort of new "tan" aphid. Parasitized aphids adhere to the plant fairly tightly, so in spite of repeated applications, these "tan" aphids seem to be impossible to kill.

Biological Control
Interest in biological control in indoor landscapes has expanded in recent years because of restrictions placed on interior plantscape pesticide applications, pesticide costs, poor control with pesticide products, phytotoxicity, and potential human health hazards. To be successful at managing pest problems with biological control agents requires a knowledge of the biology of the pest species, the biological control agent(s), and a great deal of time and commitment. Biological control systems do not look after themselves.

Pesticides
Thorough, timely applications of properly labeled pesticides are another important aspect of an integrated pest control program. Rotating infested plants back into a greenhouse where they can be treated thoroughly and revived in vigor before being returned to the indoor landscape is a sound practice but is often not practical. Treat commercial landscape areas at night, on weekends, or when a minimum number of people are present. The public should not be allowed in the vicinity of treated plants until the pesticide residue on the foliage has dried completely.

Record Keeping
A written log should be kept of pest type, locality, abundance, and all pesticides applied. Such records can be of long-term benefit as many pests tend to appear at about the same time each year. However, the short-term benefits of written records may be greater. Knowing what pests survive a pesticide application alerts the grower to the possibility of poor timing, poor application, or pesticide resistance in the pest population. A change in strategy, application technology, or type of pesticide can be made before the crops are significantly damaged.

APHIDS

KEY TO APHIDS MOST COMMONLY FOUND IN GREENHOUSES

1. CHRYSANTHEMUM APHID- Aphid dark mahogany brown; found exclusively on chrysanthemum.

1.' Aphid pale yellow, green, pink, or red; may be found on chrysanthemum but occur on other plants as well.

2. GREEN PEACH APHID- Cornicles long, slender, and pale in color but sometimes dark at the tip; body 2.0 millimeters long.

2.' MELON OR COTTON APHID- Cornicles shorter and uniformly dark; body 1 to 1.8 millimeters long.

CHRYSANTHEMUM APHID

SCIENTIFIC NAME: ***Macrosiphoniella sanborni*****(Gillette)**
ORDER: HOMOPTERA
FAMILY: Aphididae

Adult

Older Nymph

DESCRIPTION

Adult: The winged adults are about 2 to 2.5 millimeters long; soft bodied; and dark, shining mahogany brown. Due to their dark color they were once called "black flies." Wingless adults are only 1.5 millimeters long. Small, black, sturdy cornicles are found on the end of the body.

Nymph: Nymphs resemble smaller versions of the adult aphids (0.6 to 1 millimeters). Nymphs have dull, brick-red bodies with relatively long legs and antennae. The cornicles are short and dark. The outer two-thirds of the legs and antennae are gray (young nymphs) to dark gray. Older nymphs have proportionally longer cornicles. Those destined to be winged adults have wing buds in the later instars.

BIOLOGY

Host Plants: Chrysanthemum is the only known host for this aphid in North America, but it has been reported on a few related plants in Asia.

Damage: The chrysanthemum aphid feeds by piercing the plant surface with its threadlike mouthparts to suck out plant juices. They gather about the terminal buds and feed on the new growth. This feeding causes distorted growth and the leaves may be covered by the feeding aphids' honeydew and cast skins. Sooty mold may grow on the honeydew giving the leaves and stems a black appearance. Chrysanthemum aphids are able to transmit chrysanthemum vein mottle virus and chrysanthemum virus B.

Life Cycle: Only female chrysanthemum aphids are known. They reproduce by giving live birth to more females, without mating. Chrysanthemum aphids overwinter in greenhouses where they feed throughout the winter. During the warmer months they leave the greenhouses in search of new plants. They also may be moved about as plants are shipped or sold. When the winged female stage infests new plants, it usually starts feeding and producing live nymphs. Each female can produce four to eight young aphids per day.

Within about a week the new nymphs mature into wingless females which begin to bear young of their own. One aphid on a plant in a short time may build the population up to hundreds of individuals. As the plant becomes crowded, more and more of the offspring develop into winged females which in turn migrate to other plants to begin new infestations.

MANAGEMENT STRATEGIES
Infested plants in the greenhouse should be sprayed thoroughly when aphids are first noticed. On outdoor plantings, natural enemies may control minor infestations. For specific chemical controls, consult your local County Extension Service.

GREEN PEACH APHID

SCIENTIFIC NAME: *Myzus persicae* (Sulzer); **ORDER: HOMOPTERA** **FAMILY: Aphididae**	

DESCRIPTION
Adult: The small adult green peach aphid is light to dark green or pink, with red eyes. Three dark lines run down its back. Wings may or may not be present. The tobacco aphid is similar and can be either red or green.

Egg: Found only in the northern United States, the egg is black and shiny for the green peach aphid. The tobacco aphid has not been found to have an egg stage.

Nymph: The wingless nymph resembles the larger adult.

BIOLOGY
Host Plants: Green peach aphids have been collected from over 100 plants, including a wide variety of vegetable and ornamental crops. Spinach, potatoes, and peaches (the host on which eggs are laid) seem to be especially favored hosts. Tobacco aphids will be pests primarily on tobacco and closely related plants such as flowering tobacco and Nicotiana. It is probably not a major pest, but will feed on pepper and eggplant as well as cole crops such as turnips, kale, and collards.

Damage: Aphids suck plant sap and contaminate the host with honeydew and cast skins. Some hospitals refuse to allow cut flowers in patients' rooms because of the mess by aphids. They are also the

vectors of a number of plant viruses including tobacco, tomato, lettuce, dahlia, canna, and bee mosaics as well as tuber spindle, rugose mosaic, and leaf roll diseases of potato.

Life Cycle: In the northern United States, green peach aphids overwinter as eggs, but in the Southeast, no eggs are laid. Instead, female aphids give birth to young females during the growing season. The reproductive capacity of green peach aphids has been described as "fantastic." High reproductive rates- and resistance to pesticides make the green peach aphid a formidable pest in the greenhouse. Up to 30 generations per year may take place in this pest's southernmost range.

The tobacco aphid probably over-winters on weed hosts or on cole crops that remain alive through the winter. Tobacco aphids are not known to have an egg stage, and they reproduce by giving birth to live young female aphids without mating. Their young are able to produce young as well without mating. If the plant becomes too crowded or if it becomes late in the season and the aphids need to find a winter host, the aphids give birth to young that will grow up to have wings and can move to other plants. Differences on reproductive rates exist between the red and green forms of the tobacco aphids. The red form is able to reproduce much faster during extremely hot weather than the green form.

On chrysanthemums, green peach aphids feed on all parts of the plant (melon aphids feed only on the buds and leaves, and chrysanthemum aphids feed only on the stems and leaves). Green peach aphids will not become established in the presence of the other two aphids unless pesticides are applied. In that case, green peach aphids outlive both melon aphids and chrysanthemum aphids.

MANAGEMENT STRATEGIES

Because green peach aphids overwinter on weed hosts, infestations can occur in the greenhouse any time of year. Green peach aphids readily infest bedding plants and can be introduced into greenhouses whenever bedding plants are brought in from another grower. Although damage per aphid is often not serious, these aphids reproduce so rapidly that serious harm can be done in a short time.

Biological Control: Ladybugs, lacewings, syrphid flies, damsel bugs, wasps, and parasitic fungi tend to regulate green peach aphid populations outdoors.

Pesticides: These aphids' resistance to pesticides calls -for thorough applications whenever a new infestation is found. Tobacco aphids can be controlled in the same manner as green peach aphids. For specific chemical controls, consult your local County Extension Service.

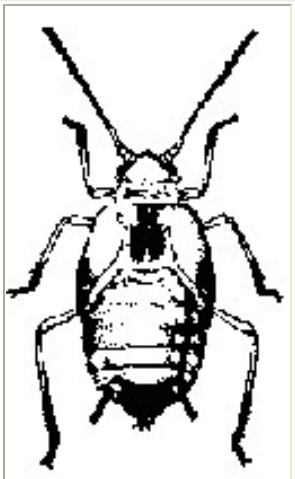
MELON OR COTTON APHID

SCIENTIFIC NAME: *Aphis gossypii* Glover
ORDER: HOMOPTERA
FAMILY: Aphididae

Winged Adult

Winged Adult

Wingless Adult



Nymph

DESCRIPTION

Adult: This is a small aphid, smaller than most other aphids. The winged adults are about 1.25 millimeters long, soft bodied, and yellow to dark green with a black head and thorax. The wings are held roof like over the abdomen at rest. Wingless adults tend to be 1.0 to 1.5 millimeters long, uniform in color, and yellow to dark green. The antennae and cornicles are shorter than those of winged adults. Cornicles are small, tail-pipe-like structures on the end of the body. Pale individuals tend to be smaller and to have fewer antennal segments than dark individuals.

Nymphs: Nymphs resemble adult aphids except for size (about 0.5 to 1.0 millimeter long). Those destined to be winged adults have wing buds in the later instars.

BIOLOGY

Host Plants: Melons and other cucurbits, okra, hops, strawberries, beans, spinach, tomatoes, clover, asparagus, citrus, catalpa, violet, hydrangea, begonia, ground ivy, and weeds are some melon aphid hosts. They have been discovered feeding on plants in 25 plant families. The melon aphid is an important pest of cotton and is also called the cotton aphid.

Damage: The melon aphid feeds by piercing the plant surface with its threadlike mouthparts to suck out plant juices. This feeding causes distorted growth, decreased yield, reduced quality of yield, and prematurely ripened fruit. The fruit may be covered by the feeding aphids' honeydew and by cast skins.

The melon aphid transmits several important plant viruses including cucumber mosaic, onion yellow dwarf, citrus quick decline, lily symptom-less diseases, and lily rosette.

Life Cycle: The melon aphid is an important pest of both agricultural and ornamental plants. Being practically omnipresent, it feeds upon many host plants. The melon aphid spends the winter on weed hosts and on cold-tolerant plants probably both as nymphs and adult females in the south. During warm periods of winter they start feeding until cold weather inactivates them again. In the spring the adult females move to new hosts and start feeding and rapidly reproducing. In northern climates the aphid over winters in the egg stage. Indoors and in greenhouses the aphids feed and reproduce throughout the winter. Melon aphids commonly start out on one plant and spread out from that point. On woody ornamentals such as gardenias, feeding is confined to new growth in the spring.

For the melon aphid there are two kinds of hosts, primary and secondary. In late fall, aphids feed upon primary plants mate and lay overwintering eggs. Melon aphids feeding on secondary plants always give birth to live young. In spring, winged forms usually infest new plants, both primary and secondary, and the females produce live nymphs. Within about a week the new nymphs mature into wingless females that begin to bear young of their own. As the plant becomes crowded, more and more of the offspring develop into winged females which in turn migrate to other plants to begin new infestations. Wingless forms usually predominate in low aphid populations.

MANAGEMENT STRATEGIES

Biological Control: Natural enemies may control minor infestations on outdoor ornamentals. Syrphid fly maggots and ladybird beetles and their larvae feed upon melon aphids. Braconid wasps parasitize the aphids, and ants feed on the honeydew excreted by feeding aphids.

Pesticides: Because the winged forms are 2 to 3.7 times more resistant to organophosphate pesticides than are wingless forms, infested plants in the greenhouse should be sprayed thoroughly when aphids are first noticed. For specific chemical controls, consult your local County Extension Service.

FLIES

KEY TO MOST COMMON FLY PESTS FOUND ON FLOWERS AND FOLIAGE PLANTS

1. Narcissus bulb fly: Larger flies, 10 to 12 millimeters long; dense covering of long hairs that gives a furry look, resembling that of bees.

1.' Smaller flies, 6 millimeters long or shorter; hairs scattered or very short, flies not bee-like..... 2

2. Lesser bulb fly: Flies about the size of a housefly, 5 to 6 millimeters long; body shiny under a dense covering of short hairs.

2.' Flies smaller, 3 millimeters long or less; body either dull colored or with scattered long hairs 3

3. Dark-winged fungus gnats: Antennae elongate, as long as head and thorax; flies dull black with uniformly dark-colored wings.

3.' Antennae no longer than head; pattern usually present on body or wings 4

4. *Liriomyza* spp: Flies shiny black and yellow; wings clear.

4.' Shore flies. Flies dull; some species have patterned body or wings.

KEY TO MOST COMMON MAGGOTS FOUND ON FLOWERS AND FOLIAGE PLANTS

1. Dark-winged fungus gnats: Larva with shiny black head capsule; body slender, white, smooth; found in decaying roots or stems or soil around them, rarely even on terminals; mostly in greenhouses.

1.' Without head capsule, with a pair of downward curving mouth hooks; body a typical maggot, wider in middle and tapering to one or both ends, may have roughened skin or fleshy filaments protruding from body.....2

2. *Liriomyza* spp.: Tiny yellow maggots, smooth; mining in leaves of plants.

2.'Not yellow and not leafminers.....3

3. Larvae found in roots, rhizomes or bulbs 4

3.' Shore flies: Larvae found among algae or on wet surfaces, in hydroponic operations, filters, wet benches, etc.

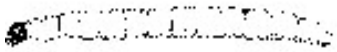
4. Narcissus bulb fly. Mature larva large, more than 10 millimeters long; with only 1 pair of very short fleshy filaments under the spiracular tube at end of body; spiracular tube about as long as wide.

4.' Lesser bulb fly. Mature larva small, less than 10 millimeters long; with 3 pairs of fleshy filaments around the spiracular tube; spiracular tube about twice as long as wide.

FUNGUS GNATS

SCIENTIFIC NAME: *Lycoriella* spp. and *Bradysia* spp.
ORDER: DIPTERA
FAMILY: Sciaridae

Adult



Larva

Pupa

DESCRIPTION

Adult: The flies are slender with comparatively long legs and antennae. They are grayish-black and about 2.5 millimeters long.

Egg: The yellowish-white tiny eggs are 0.2 millimeter long and 0.1 millimeter wide.

Larva: Dark-winged fungus gnat maggots have shiny black head capsules and white bodies. The last body segment is lobed and helps push the insect along. Mature larvae are about 5.5 millimeters long.

Pupa: Initially white, pupae become dark shortly before the adult emerges.

BIOLOGY

Host Plants: Dark-winged fungus gnat maggots feed on the roots of alfalfa, carnations, clover, corn, cucumbers, Easter lilies, geraniums, lettuce, nasturtium, peppers, rape, poinsettias, potatoes, soybeans, wheat, and organic matter.

Damage: Damage first becomes apparent when plants lose their healthy appearance and wilt. Dark-winged fungus gnat adults are usually noticed before injury caused by the maggots is apparent.

Life Cycle: Dark-winged fungus gnat maggots have only recently been recognized as important pests in greenhouses and mushroom cellars. They are also pests of house plants. Several of these flies are of economic concern. Generally, dark-winged fungus gnats are most abundant in greenhouses in the winter and spring. Adults and larvae inhabit moist, shady areas. Adults live about 1week, during which time each female deposits 100 to 150 eggs. They are laid in strings of 3 to 40 in the top of the soil, usually near stems of plants. They hatch within 4 days in the greenhouse. There is a tendency for the progeny of each female to be all one sex.

The larvae begin feeding on the root hairs and roots usually in the upper centimeter of medium, working their way up the plant and into the stem; however, they also feed on any organic matter in the soil. Being somewhat gregarious, the larvae often form clusters in the soil. They mature in about 14 days, after which they construct a pupal case, made of silk and debris, in the soil. The pupal stage lasts about 3.5 days. Adults are weak fliers, but they run rapidly on the soil surface or may remain motionless.

MANAGEMENT STRATEGIES

Cultural Controls: Clean cultural practices and lack of excessive watering usually will prevent fungus gnat infestations. Since fungus gnats prefer potting mixes containing peat moss and abundant moisture, consider using bark mixes and avoid over watering ornamental plants. Decoy pots of sprouting grain are attractive to females that lay eggs in these pots. Afterwards, the pots should be submerged in boiling water or the contents destroyed in some manner every 2 weeks to destroy the eggs and maggots.

Biological Control: Fungus gnats have few efficient natural enemies. The predaceous nematode, *Steinernema bibionis*, has reduced fungus gnats in mushroom houses 85 percent when applied at a rate of 600 per square meter. Another nematode, *Steinernema carpocapsae*---, is now on the market for fungus gnat control in greenhouses.

Pesticides: Some species of fungus gnats in mushroom houses have developed up to 47-fold resistance to pyrethroid insecticides. For chemical control recommendations, consult your local County Extension Service.

INTRODUCTION TO MEALYBUGS

One of the more common groups of scale insects attacking ornamental plants are called mealybugs. There are about 275 species of mealybugs known to occur in the continental United States. Mealybugs are prevalent pests in greenhouses and interior plantscapes such as shopping malls, conservatories, hotels, and office buildings. Mealybugs cost growers and retailers millions of dollars per year in control costs and crop damage or loss. Damage is caused by mealybugs feeding on host tissues and injecting

toxins or plant pathogens into host plants. In addition, mealybugs secrete a waste product, honeydew, which is a syrupy, sugary liquid that falls on the leaves, coating them with a shiny, sticky film. Honeydew serves as a medium for the growth of sooty mold fungus that reduces the plant's photosynthetic abilities and ruins the plant's appearance. Feeding by mealybugs can cause premature leaf drop, dieback, and may even kill plants if left unchecked.

Mealybugs are one of the more active groups of scale insects as most of them retain well-developed legs and remain mobile throughout their life. However, they generally move little once a suitable feeding site is found.

They are small insects (1 to 4 millimeters long) and the body is usually covered with a white cottony or mealy wax secretion. This makes them appear like small spots of cotton on the plant, particularly when the female is laying eggs and producing an ovisac to cover and protect the eggs. Mealybugs generally have an oval body outline. Many of them produce marginal filaments of wax that may be wedge-shaped or spine-like, but others lack marginal filaments entirely. As immatures, male and female mealybugs look alike, but as adults they are quite different. The adult male looks more like a small two-winged fly.

The life history of mealybugs varies depending on the species. Basically female mealybugs go through four developmental stages or instars and as adults may lay up to 600 eggs, usually in a cottony-like ovisac beneath her body. The eggs hatch in 6 to 14 days and the first instars or "crawlers", as they are commonly called, disperse to suitable feeding sites on new plant parts or hosts. They can survive only about a day without feeding, and once they insert their stylets to feed they generally remain anchored permanently. The crawler stage is the most fragile and easily controlled stage in a mealybug’s life history. Some mealybugs, like the long-tailed mealybug, do not lay eggs, but bear their young as active crawlers. Male mealybugs go through five instars and feed only in the first two instars.

Adult males have no functional mouthparts, live only a day or two, and exist solely to fertilize the females.

Outdoors most mealybugs go through one or two synchronized generations and over winter as second instars. Indoors, there may be a continuous overlapping of generations and all stages can be found on the host at a given time. The citrus mealybug may have as many as eight generations indoors. The overlapping of generations makes control difficult. One of the first methods of control is to purchase plants that are not infested with mealybugs. Commercial flower growers sometimes discard plants infested with mealybugs rather than try to rescue them with insecticidal treatments.

Common mealybugs occurring indoors include: the citrus mealybug, the long-tailed mealybug, the Mexican mealybug, and Pritchard's ground mealybug. Citrus mealybug is by far the most common and widespread mealybug pest. It attacks nearly every flowering species grown in the greenhouse.

KEY TO THE MOST COMMON MEALYBUGS FOUND ON FLOWERS AND FOLIAGE PLANTS

1. **Long-tailed Mealybug.** Adult females with long, white filaments at the rear; females apparently giving birth to live young.

1.' Adult females without long, white filament at the rear; females lay eggs in a dense, white fluffy

ovisac.... 2

2. Female feeding on above ground portion of plant.....3

2.' **Pritchard's Mealybug and other root mealybugs.** Female never feeding on above ground portions of plant; white mealybug feeding on roots.

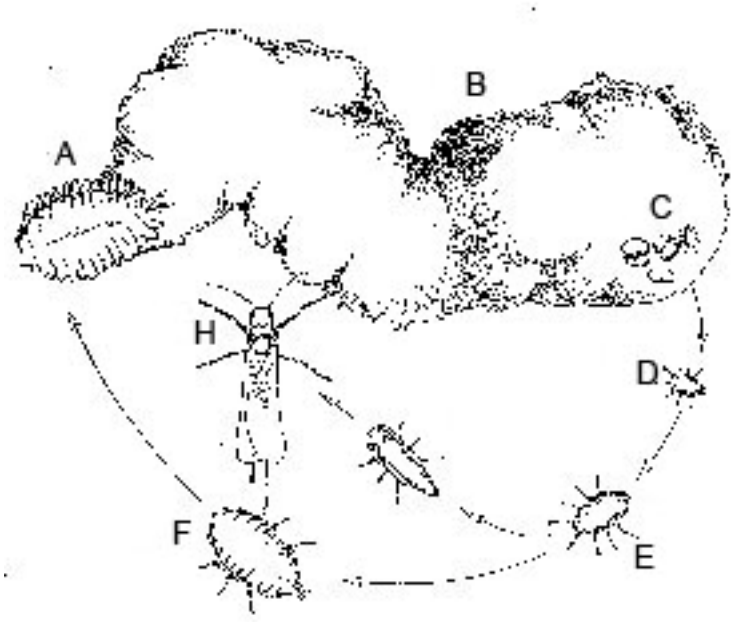
3. **Citrus Mealybug.** Body orangish or purplish and covered with white bloom; a darker line down the middle of the back; mealybug very damaging to the health of many plants.

3.' **Mexican Mealybug.** Body purplish and covered with white bloom; three rows of white tufts down the back; may occur in high numbers with little effect on the health of the plant.

CITRUS MEALYBUG

Scientific Name: ***Planococcus citri*****(Risso)**
ORDER: HOMOPTERA
FAMILY: Pseudococcidae

A. Adult Female
B. Egg Mass
C. Nymphs
F. Female Crawler
H. Adult Male



DESCRIPTION

Adult: The female citrus mealybug is wingless and appears to have been rolled in flour (hence the name). It grows to 3 millimeters long and 1.5 millimeters wide. A fringe of small waxy filaments protrudes from the periphery. The male is small, but with its wings and tail filaments, it appears to be 4.5 millimeters long.

Egg: The oblong, yellow eggs are enmeshed in a dense, fluffy, white ovisac.

Crawler: The tiny crawler is oval and yellow, with red eyes. The antennae are rather distinct.

Nymph: Female nymphs resemble the larger adult females. Male nymphs are narrower and often occur in a loose cocoon.

BIOLOGY

Host Plants: Citrus mealybugs have been collected from at least 27 host plant families. Many ornamental plants grown in greenhouses are susceptible to attack including begonia, coleus, amaryllis, cyclamen, and dahlia. Citrus mealybug has been collected on canna, narcissus, and tulip outdoors.

Damage: Citrus mealybugs damage hosts by sucking out plant sap, by excreting honeydew in which sooty mold can grow, and by causing distorted growth and premature leaf drop with their toxic saliva. They further disfigure plants by secreting cottony wax. Infested plants usually die unless the pest is controlled.

Life Cycle: The citrus mealybug has been recognized as a pest of citrus and ornamental plants in Europe since 1813 (where it is called the greenhouse mealybug) and in the United States since 1879. Because female citrus mealybugs have no wings, they must be transported to the proximity of the next host plant. They can, however, travel short distances by crawling. The immatures can be blown about. Males are small, winged insects. After mating, each female lays up to hundreds of eggs in a dense, fluffy secretion called the egg sac or ovisac. Within a few days, new mealybugs (crawlers) hatch and begin to squirm out of the ovisac. Light infestations are easily overlooked because the mealybugs tend to wedge into crevices on the host plant. As their numbers increase, mealybugs of all sizes can be seen crawling around or feeding on all exposed plant surfaces.

MANAGEMENT STRATEGIES

Control of citrus mealybugs is amazingly difficult. Some commercial flower growers merely discard infested plants rather than trying to rescue them from citrus mealybugs. Horticultural oils may damage amaryllis. For specific chemical controls, consult your local County Extension Service.

LONGTAILED MEALYBUG

SCIENTIFIC NAME: *Pseudococcus longispinus* (Targioni-Tozzetti)
ORDER: HOMOPTERA
FAMILY: Pseudococcodae

A. Adult

B. Nymphs

DESCRIPTION

Adult Female: Up to 3 millimeters long, female long-tailed mealybugs have 17 pairs of waxy filaments around the periphery. On mature specimens, the caudal (tail) filaments are as long as or longer than the

yellowish to grayish body (unless the tail filaments have broken off). Overall length maybe 6 to 7 millimeters.

Egg: There is no external egg stage of the long-tailed mealybug.

Nymphs: The nymph is similar to the larger adult female except that the filaments around the edges are shorter.

BIOLOGY

Host Plants: Long-tailed mealybugs have been found on at least 26 plant families. Dracaena appears to be the favored host, but most flowering and ornamental foliage plants are susceptible.

Damage: Long-tailed mealybugs feed by sucking out plant sap from leaves and stems. Honeydew and sooty mold further disfigure infested plants, which may eventually be killed. These pests also secrete a fluffy white wax which also detracts from the appearance of infested plants.

Life Cycle: Although long-tailed mealybugs were first described in 1867, not much has been published on their biology. Females give birth to live young on a shallow pile of white waxy secretions. Because the females are wingless, they must be brought into proximity of a host plant before it can be infested.

MANAGEMENT STRATEGIES

Biological Control: A small wasp, *Anagyrus nigricornis*, parasitizes longtailed mealybugs, and a small, predaceous, brown lacewing insect feeds on them. Ants sometimes protect long-tailed mealybugs from parasites and predators and feed upon the honeydew excreted by these mealybugs.

Pesticides: Long-tailed mealybugs are sometimes difficult to control, even though there is no egg stage protected by a dense ovisac. If many plants are infested, they should be dipped or sprayed thoroughly with a pesticide mixture or the entire greenhouse treated with an aerosol. It is best to retreat two or more times at weekly intervals. Retreatment will control mealybugs that were missed by earlier control efforts. For specific chemical control recommendations, consult your local County Extension Service.

ROOT MEALYBUGS

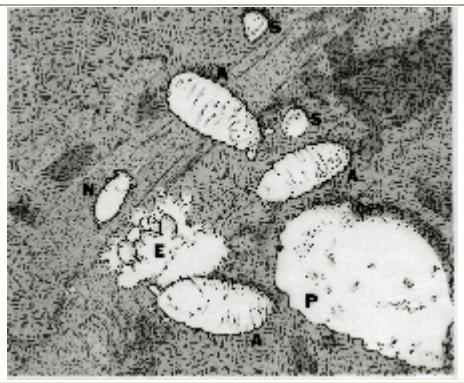
SCIENTIFIC NAME: Ground Mealybug: *Rhizoecus falcifer* Kunckel d'Hercularis
Pritchard's Mealybug *Rhizoecus pritchardi* McKenzie
ORDER: HOMOPTERA
FAMILY: Pseudococcidae

A. Adults

E. Eggs

N. Nymph

P. Particle of perlite



DESCRIPTION

Adult Female: The ground mealybug is white and 2.4 to 3.9 millimeters long. It resembles a springtail, but moves much more slowly and cannot jump. The ground mealybug has slender waxy filaments that form a sort of netting over some individuals. The ground mealybug also secretes a small amount of wax, which can give the soil a somewhat bluish appearance when the mealybugs are abundant. Pritchard's mealybug is snow white and 1.6 to 2.1 millimeters long and oval. It has small- to non-existent eyes.

BIOLOGY

Host Plants: The ground mealybug feeds on the roots of anemone, chrysanthemum, gladiolus, iris, and numerous other flowers, shrubs, and ornamental grasses. Pritchard's mealybug has become a serious pest of African violet, although it also infests Achillea, Arctostaphylos, Geum, and Polygala.

Damage: At times the ground mealybug becomes abundant enough to damage its host. Pritchard's mealybug causes devitalization, foliage deterioration, and even death of its host plant.

Life Cycle: Little has been published on the life history of root mealybugs. When infested African violets are irrigated, Pritchard's mealybugs crawl out of the drainage holes and spread throughout the greenhouse. Eggs are laid in a loose ovisac in clusters of at least six eggs. All stages can be found on the roots and potting mix of African violets where they resemble slow moving, snowy white collembola.

MANAGEMENT STRATEGIES

Pesticides: Pesticides applied as dips, drenches, or granular are more effective for root mealybug control than are foliar sprays. For specific chemical control recommendations, consult your local County Extension Service.

INTRODUCTION TO MITES

Although mites differ from insects in several ways, their damage to ornamental plants resembles that of thrips and lace bugs. Most mites have eight legs as adults (adult insects usually have six). Mites do not have wings (some adult insects have wings) but can be aerially dispersed by breezes and winds more or less like aerial plankton, particularly in hot, dry weather. It is thought the mouthparts (chelae) of mites evolved from legs with a prehensile joint, (the digitus mobilus) which allows the mite to chew with a vertical, scissors like action. In spider mites, broad mites, and cyclamen mites, the chelae have evolved into sharp mouthparts that mites use to pierce the surface of the plants they feed on in order to suck out the contents of the plant cells. Mites evidently inject saliva as they feed for one of the first symptoms of broad mite and cyclamen mite feeding is failure of the host plant to blossom. Infested plants then exhibit a variety of plant growth regulator symptoms including twisted and distorted growth, and shortened internodes and petioles.

KEY TO THE MOST COMMON MITES FOUND ON FLOWERS AND FOLIAGE PLANTS

1. Mites visible to the naked eye; infested plant may be discolored but usually not distorted by feeding.....2

1.' Mites not visible without at least a 10 X hand lens; infested plants usually cease blooming and have shortened internodes, distorted leaves and stems, and blasted buds.....3

2. **Twospotted spider mite.** Mites feeding on foliage and causing tiny chlorotic spots, mites sometimes accompanied by fine silk webbing.

2.' **Bulb mites.** Mites feeding primarily in the bulbs of Easter lilies.

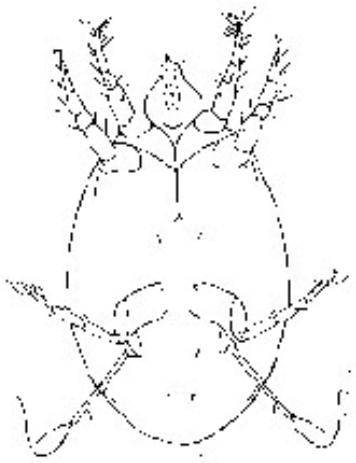
3. **Broad mite.** Egg oval, about 0.08 millimeters long, covered with minute white bumps; female translucent brown and about 0.2 millimeter long, shaped like a fat football.

3.' **Cyclamen mite**. Egg oval, about 0.1 millimeters long, without minute bumps; female translucent brown, about 0.3 millimeters long, shaped like a skinny football.

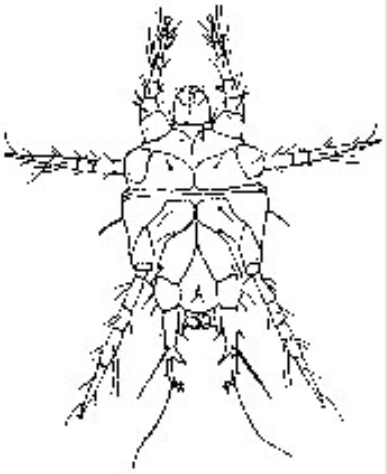
BROAD MITES

SCIENTIFIC NAME: ***Polyhagotarsonemus latus*** **(Banks)**
ORDER: PROSTIGMATA
FAMILY: Tarsonemidae

Egg



Adult Female



Adult Male

Nymph

DESCRIPTION

Adult: Broad mites are almost microscopic (less than 0.2 millimeters long). They are translucent and colorless to pale brown. There are four pairs of legs; the last pair in the female ends in a long hair; the last pair on the male ends in a strong claw.

Egg: The egg is elliptical, translucent, colorless, about 0.08 millimeters long, and is covered by 29 to 37 whitish bumps.

Larva: The young broad mite has three pairs of legs and is whitish due to minute ridges on the skin. It is about 0.1 millimeter long.

BIOLOGY

Host Plants: Broad mites infest African violet, ageratum, azalea, begonia, dahlia, gerbera, gloxinia, ivy, jasmine, impatiens, lantana, marigold, peperomia, snapdragon, verbena, and zinnia.

Damage: Infested plants become unthrifty. Leaves curl downward and turn coppery or purplish. Internodes shorten and lateral buds break more than normal. This new growth may also be stunted or killed, which forces out additional shoots. Flowers are distorted and fail to open normally. Unless controlled, broad mites usually destroy the commercial value of infested ornamental corps. Broad mites damage flowers and foliage of begonia and cyclamen, and bronze the lower leaf surfaces. Broad mites are so small that they are virtually invisible on the host plant even with a good hand lens.

Also the mites tend to crowd into crevices and buds and feed on the growing tips. Their toxic saliva causes twisted, hardened and distorted growth in the terminal of the plant. The effects of their feeding may persist long after the mites have been eradicated.

Life Cycle: Female broad mites lay 30 to 76 eggs on the leaf surface over an 8- to 13-day oviposition period. Unmated females lay male eggs; mated females usually lay four female eggs for every male egg. The larvae hatch in 2 or 3 days and emerge from the egg shell to feed. Larvae are slow moving and do not disperse far. In 2 or 3 days, the larvae develop into a quiescent larval stage. Quiescent female larvae become attractive to the males which pick them up and carry them to the new foliage. Males and females are very active, but the males apparently account for much of the dispersal of a broad mite population in their frenzy to carry the quiescent female larvae to new leaves. When females emerge from the quiescent stage, males immediately mate with them. Males live 5 to 9 days; females live 8 to 13 days.

MANAGEMENT STRATEGIES

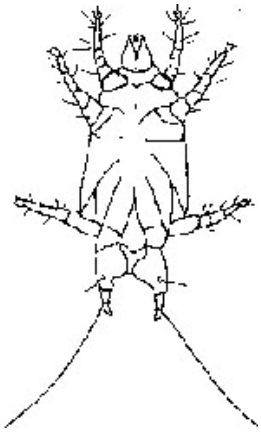
Cultural control: Broad mites are very sensitive to heat. Lowering infested plants into water held at 43 to 49°C for 15 minutes will destroy broad mites without damaging the plants.

Pesticides: Broad mites are susceptible to various miticides. However, they are more difficult to control in winter than in summer due to lower greenhouse temperatures. For specific chemical control recommendations, consult your local County Extension Service.

CYCLAMEN MITES

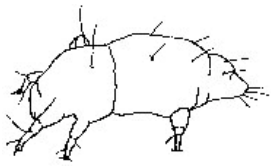
SCIENTIFIC NAME: ***Stenotarsonemus pallidus*****(Banks)**
ORDER: ACARINA
FAMILY: Tarsonemidae

Female



Male

Egg



Larva

DESCRIPTION

Adult: These mites are tiny animals, less than 0.3 millimeters long. Colorless or brown tinted and waxy looking, they have four pairs of legs. The fourth pair of the female is slender with a long, hair extending from the tip. The fourth pair of legs of the males ends in a strong claw.

Egg: The elliptical egg is 0.1 millimeter long and smooth.

Larva: The young mites are about 0.2 millimeter long and are whitish and have three pairs of legs. The legs have microscopic claws and suction cups.

Quiescent Stage: This stage appears as an immobile, engorged larva.

BIOLOGY

Host Plants: African violets are most often damaged by cyclamen mites. They also have been found on ivy, snapdragon, chrysanthemum, larkspur, geranium, fuschia, begonia, petunia, daisy, and azalea.

Damage: Cyclamen mites cause tuberous begonia and cyclamen flowers to be discolored or to shrivel or wilt. Infested flowers may not open properly or may not open at all. The mites also cause puckering, crinkling, and curling of leaves; infested leaves become brittle. Infested cyclamen buds fail to open or the flowers are distorted.

Life Cycle: Cyclamen mites were first reported in the United States about 1900. It has since become famous as a harmful plant pest. Cyclamen mites seem to avoid the light; they occur in hidden areas on plants (buds and between the calyx and corolla and the stamens and ovaries of flowers). This mite also prefers high humidity. The eggs have delicate shells that can often be found collapsed among masses of unhatched eggs and mites. Deposited in moist, dark places and in small groups, the eggs require about 11 days to hatch. The mites molt only once.

New larvae have wrinkled skin that stretches as they grow. They are highly active for about one week, after which they enter a quiescent stage for a few days and then molt to the adult stage. Each day the female lays two or three eggs. Eggs are relatively large in comparison to the adults. Cyclamen mites often exist wherever old cyclamen corms are preserved in the greenhouse. If a suitable host is not present year-round, female mites may semi-hibernate in the soil until a host becomes available. Females are usually more abundant than males in the winter months, and they live longer than males.

MANAGEMENT STRATEGIES
Cultural Control: Immersing infested plants (pot and all) into water heated to 43° C for 15 minutes kills cyclamen mites without harming most plants.

Pesticides: If chemical control is desired, spray or dip the plant thoroughly with a miticide. For specific chemical control recommendations, consult your local County Extension Service.

TWOSPOTTED SPIDER MITE

SCIENTIFIC NAME: ***Tetranychus urticae*** **Koch**
ORDER: PROSTIGMATA
FAMILY: Tetranychidae

DESCRIPTION
Adult: The eight-legged adult can be pale green, greenish amber, or yellowish. Usually having two (sometimes four) black spots on top, the two spotted spider mite is about 0.4 millimeters long.

Egg: The spherical egg ranges from transparent and colorless to opaque straw yellow.

Larva: The six-legged larva is colorless, pale green, or yellow.

Nymph: Similar to the adult except in size, the nymph has eight legs and is pale green to brownish green. Large black spots may develop on each side.

BIOLOGY
Host Plants: Twospotted spider mites have been reported on over 300 host plants, which include over 100 cultivated species. Violets, chickweed, pokeweed, wild mustard, henbit, vetch, and blackberry are common foci from which infestations develop on nearby crops.

Damage: Twospotted spider mites pierce the epidermis of the host plant leaf with their sharp, slender mouthparts. When they extract the sap, the mesophyll tissue of the leaf collapses in the area of the

puncture. Soon a chlorotic spot forms at each feeding site. After a heavy attack, an entire plant may become yellowed, bronzed, or killed completely. The mites may completely web over entire plants.

Life Cycle: Twospotted spider mites are important pests on more crops than any other arthropod in the Southeast. Though insects and mites are in a group called the Arthropoda (meaning jointed foot) because jointed legs are common to both, spider mites are not actually insects. They are more closely related to spiders, and they derive their name from the thin web which some species spin.

In North Carolina, two-spotted spider mites overwinter as adults in the soil or on weed hosts such as violets, henbit, and hollyhocks. In mild winter weather, two spotted spider mites continue to feed and lay eggs, although development in the winter is much slower than in the summer. From the eggs hatch six-legged larvae. They develop into eight-legged nymphs which pass through two nymphal stages. After each larval and nymphal stage, there is a resting stage. The adults mate soon after emerging from the last resting stage, and in warm weather the females soon lay eggs. Each female may lay over 100 eggs in her life and up to 19 eggs per day. Development is rapid in hot, dry weather. Each generation may take as many as 20 or as few as 5 days to mature.

They often damage one species of plant quite heavily and then disperse to other hosts. When a plant is heavily damaged, the mites migrate to the outer periphery of the plant. From here, even the gentlest of breezes can carry them a significant distance to attack new hosts.

MANAGEMENT STRATEGIES

Cultural Control: If spider mite infestations are detected early enough, a daily misting or spraying with water can be an effective control.

Pesticides: The use of foliar insecticides in hot, dry weather can induce spider mite outbreaks by killing the beneficial arthropods that would normally feed on the mites. In addition, a fungal pathogen attacks spider mites following short periods of cool, damp weather. Certain fungicides can eliminate this fungus and should be avoided for several weeks if plants are infested and such conditions occur.

The resting stages and eggs of the two-spotted spider mite are more tolerant to pesticides than the motile forms. Consequently, a second application of pesticide may be necessary at 4- or 5-day intervals in hot weather (7 to 10 days in cool weather) to kill those mites that may have survived the first application. For specific chemical control recommendations, consult your local County Extension Service.

INTRODUCTION TO SCALE INSECTS

Scale insects are a diverse group of insects in the order HOMOPTERA. There are about 6,000 species of scale insects in 21 families worldwide. About 1,000 species occur in North America. The three most common families of scale insects are the armored scale, the soft scale, and the mealybugs. Most of the pest species belong to one of these three families.

Armored Scale Insects: Armored scales are the smallest of scale insects, ranging in size from 1 to 3 millimeters. The body of the scale insect is protected by a cover (the armor) made from wax secreted by the insect and cast skins (exuviae) of previous growth stages. One must remove the hardened wax cover to expose the body of the insect. The exposed body usually is yellow or orange, but may have a pink or red color to it. This cover also protects the eggs laid by the female. Armored scale insect covers vary from circular to elongate or oyster shell-shaped. Male and female covers may differ in size and

shape for the same species. The cover of the female is generally largest. Boisduval scale and fern scale are common armored scale insects attacking flowers and foliage plants.

Most armored scale insects reproduce sexually. The eggs hatch beneath the protective scale cover and the first instars, commonly called "crawlers", migrate to the new growth to settle and feed. Armored scale females lose their legs at the first molt and are sessile for the rest of their lives. Females develop through three instars and males develop through five. Armored scales may overwinter as eggs, nymphs, or adult females. Adult males are usually present about two weeks in each generation. Some armored scales have four generations per year.

Soft Scale Insects: Soft scales differ from armored scales in that they do not secrete a waxy covering that is separate from the body. If wax is present, it adheres tightly to the body of the female and cannot be easily separated from it. Most soft scales produce a thin, glassy wax that does not obscure the color or form of the female soft scale. Soft scales are fairly large (2 to 6 millimeters long) and can be distinguished by their larger size, round or oval body outline, and convex or hemispherical profile. Soft scale females vary from flat to almost spherical. Often different host plants will alter the body form of a single species so much that taxonomists have described the different forms as separate species. If one turns the adult soft scale over, legs, antennae and thread-like mouthparts are readily visible with the aid of a microscope. Three common soft scales found in greenhouses and interior plantscapes are the brown soft scale, hemispherical scale, and tessellated scale.

Soft scales may reproduce sexually or parthenogenetically and every female may be capable of producing progeny without fertilization. Tremendous populations can develop during a single growing season. Most outdoor species have one generation per year. Females either lay eggs or give live birth, depending on the species. There are three instars in the females and five instars in the males. In warmer climates and in greenhouses, species with multiple generations may have all stages present simultaneously throughout the year.

KEY TO SCALE INSECTS

1. Body of insect protected with a wax or vanish-like covering that is not attached to the body of the insect; the insect can be seen by lifting off this covering. **Armored scale insects.....2**

1.' Body of insect oval in top view, bare or covered with a clear glassy-type wax that adheres to the insect's body; infested plants often sticky with honeydew excreted by the insect. **Soft scale insects. 3**

2. Fern Scale. Scale covering of female brownish and oyster shell shaped; male cover snow-white with three ridges down the back.

2.' Boisduval scale. Scale covering circular or oval, thin, flat, white to light yellow, semitransparent, and exuviae-central or sub-central; male cover oblong oval, white, also with three ridges down the back.

3. Hemispherical scale. Mature individuals noticeably convex or hemispherical in side view, shiny brown in color; sometimes hundreds of eggs found under the body.

3.' Mature individuals flat or only slightly convex in side view; yellowish-green to black in color; no eggs found under body although a few crawlers may be present under the female 4

4. Brown soft scale. Body yellowish-green to yellowish-brown in color; often mottled with brown spots.

4.' Tessellated scale. Body oval, opaque, reddish-brown, and 4 to 5 millimeters in length; the dorsal surface appears checkered or cellular in pattern when examined with a magnifying glass.

BOISDUVAL SCALE

SCIENTIFIC NAME: ***Diaspis boisduvali*** **Signoret**
ORDER: HOMOPTERA
FAMILY: Diaspididae

DESCRIPTION
Adult Female: Cover of the adult female boisduval scale is circular or oval, thin, flat, white to light yellow, semitransparent, and 1.2 to 2.25 millimeters in diameter. Exuviae central to subcentral in position.

Other Stages: The male cover is somewhat rectangular in shape, elongate, about 1 millimeter in length, and snow white with three ridges down the back.

Eggs: Boisduval scale eggs are oval and pale yellow to pale orange.

Nymphs: Newly settled nymphs are pale orange.

BIOLOGY

Host Plants: Cattleya and Cymbidium orchids are the most common hosts, but this scale insect thrives on the leaves and bark of other orchids, palms, banana, and cacti.

Damage: New growth is frequently attacked prior to opening, and leaves may be killed if the infestation is dense. Lighter infestations produce irregular chlorotic spots that mark feeding sites and spoil the appearance of the leaves.

Life Cycle: Under greenhouse conditions, boisduval scale can complete its life cycle in about 50 days. Females may produce up to 200 eggs in a lifetime.

Eggs hatch in 5 to 7 days and most of the crawlers settle to feed within 24 hours after hatching. The first stage lasts about 10 days, the second about 8 to 10 days for females and 15 for males. After mating, females retain their eggs for a short period, and then oviposit. Because females produce eggs over a long period, generations overlap, and usually all stages can be found at any one time. Crawlers can settle anywhere on the leaf, but seem to prefer the midrib and major veins.

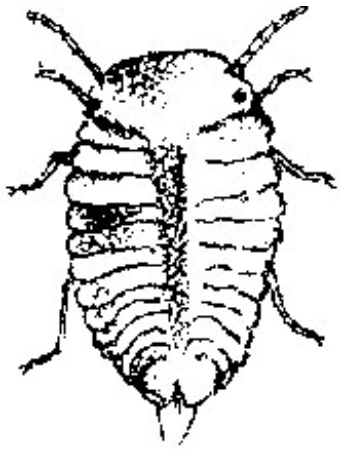
MANAGEMENT STRATEGIES

Try to purchase plants from a supplier who does not have a scale infestation.

Pesticides: When scales are encountered, horticultural oils give adequate control without excessive phytotoxicity. Two thorough treatments 2 weeks apart should give good control. Boisduval scale crawlers often establish themselves near the base of the plant and in leaf sheaths making control difficult. Also, both upper and lower leaf surfaces are attacked, so thorough coverage of any treatment is essential. For specific control recommendations, consult your local County Extension Service.

BROWN SOFT SCALE

SCIENTIFIC NAME: *Coccus hesperidium* Linnaeus
ORDER: HOMOPTERA
FAMILY: Coccidae



Crawler

Mature Female

DESCRIPTION

Adult: Living adult female brown soft scales are pale yellowish green to yellowish brown, often mottled with brown spots. Older females are brown. The body is usually oval in outline, 2.5 to 4 millimeters in length and slightly convex in profile. The shape tends to vary according to position on the host plant. Males look like tiny two-winged wasps or flies and are rare.

Other Stages: Crawlers and young nymphs are yellow and almost flat in profile. Parasitized nymphs are dark brown to black and convex. Crawlers have well-developed legs and antennae and are quite active until settling. Older nymphs are sessile.

BIOLOGY

Host Plants: Brown soft scale has been reported feeding on hundreds of different plants. It can survive on most greenhouse plants, but seems to prefer perennials over annuals. Ferns are a favored host.

Damage: Brown soft scale is probably the most frequently encountered scale on plants indoors. Infestations of brown soft scale can become so heavy as to encrust the stems and petioles of their host plant. They also settle on leaves, usually along midribs and occasionally on the fruit. Large colonies remove large quantities of plant fluids and can cause wilting, but they seldom kill their host. Immatures and adults produce much honey dew that serves as a medium for the growth of sooty molds. These fungi inhibit photosynthesis and make infested plants unsightly. Obnoxious insects such as ants and wasps are also attracted to feed on the honeydew.

Life Cycle: Females are ovoviviparous and retain the eggs in the body until hatching. Brown soft scales are born as active crawlers but remain under the body of the female for a short time before emerging and selecting a feeding site to settle and complete their development. Females molt twice before reaching maturity. Males undergo four molts before emerging as winged adults, but are rarely seen. All stages are found throughout the year in warmer regions and in greenhouses. Brown soft scales can complete three to seven generations per year depending on temperature. It takes about 60 days to complete a generation.

MANAGEMENT STRATEGIES

Brown soft scales are surprisingly difficult to control even though there is an external egg stage and only a few very young nymphs are protected by the body of the mother.

Biological Control: Although reported as a pest species of many host plants in many countries, outdoors it may be suppressed by natural enemies in many areas. *Scutellista cyanea* Motschulsky is a common parasite and *Metaphyous luteolus* Timberlake controls brown soft scale in California.

Pesticides: For specific chemical control recommendations, consult your local County Extension Service.

FERN SCALE

SCIENTIFIC NAME: *Pinnaspis aspidistrae* (Signoret)
ORDER: HOMOPTERA
FAMILY: Diaspididae

DESCRIPTION

Adult: Female fern scale armor is oyster shell or pear shaped, flat, light brown with the crawler cast skin a paler brown. Sometimes the second stage armor is also paler than the adult armor. They are 1.5 to 2.5 millimeters long. The male armor is white felted, three-ridged, and the crawler cast skin is beige to yellowish brown. Adult males are tiny, two-winged, gnat-like insects that are easily overlooked.

Egg: Eggs of armored scales are usually oval and about 0.2 millimeter long. They are laid in groups under the female armor.

Crawler: Fern scale crawlers are about 0.2 millimeter long, flat, and yellow with red eyes. The legs and antennae are well developed.

Nymph: Female second-stage nymphs secrete an oval, pale brown armor about 0.8 millimeters long. Male second stage nymphs secrete a white armor which has three long ridges. Mature male second stage nymphs are about 1 millimeter long.

BIOLOGY

Host Plant: Fern scales mainly infest true ferns (not asparagus ferns) and liriope. This pest has been recorded from numerous foliage plants, citrus, and other woody ornamental trees and shrubs in Florida.

Damage: Infested ferns are disfigured by the presence of male second stage armor which is conspicuous against the dark green foliage. Ferns in commercial production sometimes tolerate a tremendous scale population with little noticeable reduction in vigor or color. Feeding by female scales causes yellow spots on some fern varieties and on liriope. Males do not feed beyond the second stage of development.

Life Cycle: Little specific information is known about the biology of fern scales. Female scales lay their eggs under the armor. The female dies after the last egg is laid. Tiny crawlers hatch from the eggs and eventually emerge from under the mother's armor. The crawlers move about until they begin to

feed by inserting their long, thread-like mouthparts into the leaf and sucking out nutrients. The insect molts into a second stage which begins to secrete a waxy material from under the rear of the first stage (crawler) cast skin. Eventually these insects molt into the adult stage. Female scales begin to secrete the adult armor at the rear of the second stage armor. Males emerge from their second stage armor as tiny, gnat-like insects that crawl or fly to female scales to mate. The armor remains fastened to the plant long after the scale insect leaves (male) or dies inside (female). When populations become dense, females tend to lay male eggs so that heavily infested plants become conspicuously spotted by second stage male armor.

MANAGEMENT STRATEGIES
Try to purchase plants from a supplier who does not have a fern scale infestation.

Pesticides: When fern scales are encountered, horticultural oils give adequate control without excessive phytotoxicity to ferns. Two thorough treatments 2 weeks apart should give good control. Ferns are notoriously sensitive to pesticides. Whenever treating ferns and other sensitive plants, treat at a time that the pesticide will be dry on the foliage before the plants are exposed to full sunlight. For specific chemical control recommendations, consult your local County Extension Service.

Biological control is a tool to be considered in constructing an integrated pest management scheme for an interior environment. Biological control is a method of pest management in which a naturally occurring disease, parasite, or predatory organism is manipulated to control a pest.

A **parasitic insect** grows on or feeds off another organism. Adult parasitic insects lay eggs inside or on the surface of a host insect. As the egg develops, it consumes the host. These parasitic organisms are typically limited to a very narrow range of insect pest, and results are not quickly apparent; pests may live much of their lives before dying.

The life cycle of a parasitic insect must coincide closely with that of their host to achieve optimum suppression of the pest. Timing the release of parasites to coincide with increasing damage levels may be tricky, but successful establishment consistently results in pest death. Braconid wasps are parasitic insects that have been used successfully in interior plantscape environments.

Predatory insects consume a large number of both adult and immature stages of a pest. These organisms feed on a wide range of prey. When the population of one prey declines, they will shift to feeding on an alternate prey species present in the area. Predatory organisms can consume a large number of pests daily and may act quite rapidly. In many instances a significant proportion of pest populations may be controlled by parasites and predators.

The life cycles of predatory insects do not have to coincide with their prey for successful establishment, but unless a population of prey exists, the beneficial organisms will disperse to find prey elsewhere. If predators are released before the pest population builds up, the beneficial insect or mite will starve or disperse.

Examples of predatory insects that have been used in the interior plantscape environment include: mealybug destroyers, and predaceous mites. Natural enemies can be manipulated in many ways to control pest insects. Three definitions that are used to describe the manipulation of natural enemies are listed below. All three manipulation techniques can be used in interior plantscape biological control programs.

Biological Control Definitions	**Biological Control Implementation**
Augmentation: The periodic release of artificially produced natural enemies to supplement those that occur naturally. **Conservation:** Managing an environment so that it provides the necessary requirements for natural enemies to survive and reproduce. **Importation:** Introduction and permanent establishment of a naturally occurring enemy into	Biological control can be an effective, environmentally sound method of managing pests. However, when using natural enemies it may be helpful to consider the following suggestions: • Make sure you identify the pest correctly. All insect pests found in interiorscapes undergo metamorphosis. Larval and pupal forms of insects that undergo complete metamorphosis look entirely different from adult forms. • Determine whether releases of natural enemies are appropriate for your specific situation. For example, if pest populations are already causing damage to plants, it may be advisable to use a pesticide. • Any biological control products should be chosen carefully. The introduction of a beneficial insect, method of release,

an environment occupied by an insect pest.	timing of the release, and number to release should be determined through consultation with a reliable source. Table 1 outlines natural enemies and their release rates for the top five insect pests found by North Carolina interior plantscape managers. Beneficial insects and other living control agents need to be handled and released in careful and specific ways.

- Monitor the population of undesirable insects after a release to assess the success of the release. Augmentation may be necessary for effective control.

- Once a decision has been made to use biological controls, conservation measures must be followed. Most predators and parasites are susceptible to many pesticides. Once the decision has been reached to use beneficial insects, the use of synthetic pesticides should be used with caution. Likewise, caution must be used when using non-synthetic pesticides. If you will be supplementing releases with the use of least-toxic chemicals such as insecticidal soaps, horticultural oils, pyrethrums, rotenone, or neem extract, you need to be aware of the effect these chemicals may have on specific beneficial populations. Steiner and Elliott report on the toxicity of pesticides to various biocontrol agents in the publication **Biological Pest Management For Interior Plantscapes.**

Table 1. Natural Enemies for the Top 5 Ohio Interior Plantscape Insect Pests

PEST	NATURAL ENEMY	RATE	UNIQUE CHARACTERS
Citrus Mealybug	**Mealybug Destroyer** *(Cryptolaemus montrouzieri)* ladybeetle	2-8/yard of foliage every 3-2 weeks, 2-4 times to maintain control	Mealybug destroyer larvae can be confused with mealybug larvae
Long-tailed **AND** Citrus Mealybug	**Mealybug Destroyer** *(Cryptolaemus montrouzieri)* ladybeetle	As above.	Mealybug destroyers need cottony egg mass to lay their eggs in. Long-tailed mealybugs don't produce a cottony mass.
Long-tailed Mealybug	**Green Lacewing** *(Chrysoperla spp.)* aphid lions	2-5/yard every 2 weeks, 2-3 times	Need to release lacewing **larvae.**
Spider Mite	**Anblyseius Mites**	10-32/yd, every 3-2	Effective under a variety of

	(Amblyseius fallacis) predatory mite	wks, 2-4 times. 3-6/yd/month to maintain	conditions. Can live on pollen as well as mites.
Scale (soft or armored)	**Harmonia** *(Harmonia axyridis)* multicolored Asian ladybeetle; halloween ladybeetle	1-4/yard of foliage every 3-2 weeks, 2-4 times to start. 1-3/yd/quarter to maintain control	Release of lab-raised Harmonia in interiorscapes will not cause pest problem associated with wild populations of this beetle.
Fungus Gnats	**Soil Dwelling Mites** *(Hypoaspis miles)* predator, scavenger mite	1-4/yard of foliage every 3-2 weeks, 2-4 times to start. 1-3/yd/quarter to maintain control	Will also feed on thrips pupae in the soil.
Aphids	**Aphidius** *(Aphidius matricarae)* parasite wasp	2-8/yd/week, 2-4 times to start. 2-3/yd monthly to maintain control	Shipping as live adults, ready to parasitize aphids.
	Aphidoletes *(Aphidoletes aphidomyza)* predatory midge	2-5/yd every 2-1 weeks, 2-5 times to start. 2-3/yd monthly to maintain control	Drop from plants into soil to pupate. If soil is not directly beneath foliage, they will die.
	Ladybeetles *Harmonia* **or** *Hippodamia*	As above.	

Some Suppliers of Natural Enemies in the United States

The Green Spot	CibaBunting North America	Koppert USA
93 Priest Rd.	PO Box 2430	2856 South Main St.
Nottingham, NH 03290-6204	Oxnard, CA 93034-2430	Ann Arbor, MI 48103
Tel: 603-942-8925	Tel: 805-986-8265	Tel: 313-998-5589
Fax: 603-942-8932	Fax: 805-986-8267	Fax: 313-998-5557

Compiled by David Orr, 01/30/97

Selecting Natural Enemies

If you decide to use biological control, you should choose your product and supplies carefully, as you would any consumer product. The number and rate of natural enemies to release, as well as the timing and method of application can be determined through consultation with a reliable supplier or your local County Extension Service.

Using natural enemies in augmentative biological control will require a bit of experimentation on your part. Professional plant managers are used to experimenting with plant varieties, fertilizers, watering schedules, etc. What works and what doesn't is somewhat dependent on your situation. So, too, for natural enemies!

Table 2 summarizes the primary predators and parasites of major interior plantscape plant pests.

The booklet **Biological Pest Management for Interior Plants** contains guidelines for choosing and distributing natural enemies that will maintain pests below a visible plant damage threshold.

Fungus Gnats

Bacterial and nematode organisms can be readily integrated into a traditional pest management scheme, whereas others require a fairly high level of management. *Bacillus thuringiensis israelensis* and *Steinernema carpocapsae* nematodes suppress dark-winged fungus gnats. Except for *Bacillus thuringiensis* pesticides, the use of biological organisms is usually not compatible with the use of chemical sprays.

It is possible to integrate sprays of soaps and oils with *Encarsia Formosa* by timing pesticide applications to coincide with the "black scale stage" of the parasite's development. Also the "brown mummy" stage of aphids infected with Aphytis wasps are resistant to soaps and oils.

Purchasing Natural Enemies

The majority of natural enemies used in augmentative biological control programs are produced commercially.

One of the most common questions people ask when they purchase natural enemies is, "Am I getting the number I paid for?" This is a very important question, as the chances for control are very much related to the number of natural enemies released. Evaluation of quality control increases an end-user's confidence in the ability of natural enemies to control insect pests. Other important factors to consider when ordering from a commercial supplier include the survival, vigor, and availability of a natural enemy.

When purchasing natural enemies the first question you need to ask is, "Do I need natural enemies?" If you do not know what pest you have but you know that it is, or soon will be a problem, put your checkbook away. It is very important to order the right natural enemy to do the job. This can only be done if you have correctly identified your pest. Your local Extension service and the companies selling natural enemies are good sources of information.

Order from a reputable firm; one that either specializes in natural enemies or has been selling them for a long time. Check with your local County Extension Service. You can also call the company (most have 800 numbers) and ask them. Companies usually provide lots of free information right over the phone, so ask away. They should be able to tell you what natural enemies they have in stock, what they are used for, how many to use, and under what conditions you should use them (e.g., when and how to release).

Finally, once you receive your natural enemies, look at your order. Did it come on time? If you ordered eggs (e.g. for lacewings), do you see larvae crawling around in the shipment. If you ordered parasites,

do you see lots of "mini-wasps" flying out of the shipping container. A small magnifying glass will come in handy for observing smaller natural enemies. If you suspect you did not get what you paid for, call the company. They are usually helpful and friendly and will replace shipments. If neither, use someone else next time!

Sources of Biological Control Agents

Natural enemies are available from numerous commercial suppliers. A directory of suppliers can be obtained by contacting the following two resources.

Directory of Least-Toxic Pest Control Products
Published annually by Bio-Integral Resource Center, P.O. Box 7414, Berkley, CA 94707,
Phone: 510/524-2567

Suppliers of Beneficial Organisms in North America.
Charles D. Hunter, California Environmental Protection Agency.
Department of Pesticide Regulation, Environmental Monitoring and Pest Management Branch,
1020 North Street, Room 161,
Sacramento, CA 95814-5604

Table 2. Summary of Primary Predators and Parasites of Major Plant Pests

Pest	Predator	Parasite	Comments
Greenhouse Whitefly (*Trialeurodes vaporariorum*)	None	*Encarsia formosa*	Size of a spider mite, readily available from insectaries.
Green Peach Aphid (Myzus persicae)	Various lady beetles. Some results with *Aphidoletes aphidimyza* a predaceous midge larva.	Braconid and Chalcid wasps	The adult midge lays 100-200 tiny orange eggs near the aphid colonies which hatch in two to three days. The larva is orange or red and depending on temperature and food supply, matures in three to five days.
Soft Scales (Coccids)	*Chilocorus nigritus* and *Lindorus lophanthae* (two small lady beetles)	*Metaphycus helvolus,* a tiny black and yellow wasp.	Both beetles will control soft scale and ornamental scale. *Chilocorus nigritus* development time is approximately one month.
Twospotted Spider Mite *(Tetranychus urticae)*	*Phytoseiulus persimilis* *Typhlodromus occidentalis* *Amblyseius californicus*	.	Adults can consume 5-20 eggs or mites per day. These mites avoid bright lights. Tolerates both high and low temperatures. Effective on hairy- leaved plants. Persists at low prey densities.
Citrus Mealybug (Planococcus citri)	*Cryptolaemus montrouzieri,* Austrailian lady beetle.	*Leptomastix dactylopii*	*C. montrouzieri* will consume all species of above ground mealybugs. Will feed on aphids and immature scale insects when mealybugs are not available.

Case Study

Biological Control in the Great Indoors: At the Mall of America

When most people think of biological control, they think of experiences in the great outdoors—fields, orchards, and forests. But biological control can also be an effective management tactic indoors, and there is no greater indoors than the Mall of America in Bloomington, Minnesota. This mega mall has it all, including a seven acre amusement park at its center called Knott's Camp Snoopy. "Campers" and their parents are greeted at the entrance by a three-story tall Snoopy, and are thrilled with rides including Paul Bunyan's Log Chute, the Ripsaw Roller coaster, and the Kite Eating Tree, attractions such as Lego land, Wilderness Station, and the Ford Playhouse Theater, and several food and concession stands.

Within this urban entertainment area, lies 54,000 square ft. (1.2 acre) of a man-made forest. Over 100 temperate, subtropical, and tropical plants species grow in this arboretum, including black olive trees, Ficus trees, Norfolk Island pines, English ivy, oleanders, and ferns. Birds, reptiles, and mammals inhabiting the Wilderness Station, and Koi fish swimming in the pond near the Ford Theater, add to the forest experience.

Roxanne Rickert and Karla Richter, horticulturalists for McCaren Design, Inc., St. Paul, MN, have handled landscape design, plant maintenance, and pest control for Camp Snoopy since it opened in August of 1992. At that time, plants brought from field nurseries in Florida, Georgia, and California probably contained hitchhiking arthropod pests, therefore presenting the designers with pest management problems. Although chemical control is used in some areas (materials such as Safer's soap, 70% alcohol mixed with Ivory soap, and the insect growth regulator Enstar), one concern of Camp Snoopy officials is pesticide applications around the Wilderness Station and Koi fish pond. Ms. Rickert addresses this concern by using cultural control (washing down plants on a weekly basis) and augmentative biological control (see MBCN Vol. I, No. 4). The specialists now use inoculative releases in roughly 3/4 of the planted area (0.9 acre).

McCaren horticulturalists initially received management ideas and pest identifications from Jody Fetzer, a horticulturalist for the University of Minnesota's Landscape Arboretum. Arboretum staff have been using biological control in their greenhouses for over six years, and Ms. Fetzer worked directly with the McCaren staff in ordering and releasing beneficial arthropods. The University's Dial U Insect and Plant Clinic, the Minnesota Department of Agriculture (MDA) Biological Control Program, and interior landscape magazines also have provided information for the McCaren staff.

Pest Species

What are some of the arthropod pests in this interior forest? Pest species during the three years have included soft scales (brown soft scale, *Coccus hesperidium*, and black scale, *Saissetia oleae*), mealybugs (citrus mealybug, *Planococcus citri*, and longtailed mealybug *Pseudococcus longispinus*) , mites (spider mites, *Tetranychus urticae* and *Panonychus citri*; cyclamen mite, *Phyonemus pallidus;* and *eriophyids*), thrips (western flower thrips, *Frankliniella occidentalis*, and Cuban laurel thrips, *Gynaikothrips ficorum*), and various aphid species.

Scale and Mealybug Control

McCaren receives their beneficials from two sources, BioTactics, Inc. from Riverside, CA and IPM Laboratories, Inc. from Locke, NY (see MBCN Vol. II, No. 3). Initially, *Metaphycus helvolus*

(Encyrtidae) was released for soft scale control. Although this parasite was effective in lowering scale population densities, parasite shipments were not always available. MDA entomologists got involved in the biological control project after meeting Ms. Rickert in late 1993. Scale populations were expanding on the black olive trees and shipments of *M. helvolus* were delayed. Dr. John Luhman and Dr. Dharma Sreenivasam mentioned that another parasite, *Coccophagus lycimnia* (Aphelinidae), was found parasitizing scale in a greenhouse and was being reared at MDA. In a much publicized media event, Dr. Luhman released about 300 *C. lycimnia* pupae and adults to the treetops via a power lift in early January 1994.

During post-release sampling, Dr. Luhman recovered *M. helvolus* and *C. lycimnia,* and a third parasite species, *Diversineruis* sp. (Encyrtidae). This species apparently arrived with the scale population from the nursery. After one year, new oleander plant material was brought into Camp Snoopy. These plants apparently were infested with scale, and soon after introduction, *M. helvolus, C. lycimnia,* and *Diversineruis* sp. were all found to be colonizing the scale. Therefore, all three species became established and were able to search in a different architectural habitat for hosts.

Mealybug biological control has been accomplished through releases of the mealybug destroyer, *Cryptolaemus montrouzieri* (see MBCN Vol. II, No. 5). This predator was received from commercial insectaries and from Dr. Luhman when insectary shipments were delayed. McCaren staff have also released *Leptomastix dactylopii* (Encyrtidae) against mealybug, but indications thus far have suggested that this parasite hasn't become established.

Biological control management hasn't been effective against armored scale. The parasite *Aphytis melinus* (Aphelinidae) was released on Norfolk Island pines that were infested with armored scale, but the parasites either did not become established nor did so at very low levels. Unfortunately, the trees had to be removed and were replaced with native Northern white pines.

Mite and Thrips Control

Predatory mites have been released to control spider mites, cyclamen mites, and thrips. *Galendromus (= Metaseialus, = Typhlodromus) occidentalis*, the western predatory mite, *Phytoseiulus persimilus,* and *Neoseialus (= Amblyseius) californicus* have been successful at reducing spider mite populations. *Neoseialus (=Amblyseius) cacumeris* has been successful against western flower thrips and cyclamen mites. The generalist predator *Orius insidiosus* (Anthocoridae) (see MBCN Vol. I, No. 1) has been released against Cuban laurel thrips, and though it is still found throughout the forest, this predator hasn't been able to bring the thrips under control.

Aphid and Whitefly Control

Aphid natural enemies that have been augmented into Camp Snoopy have included both a parasite and a predator. *Aphidius matricariae* (Aphidiidae) hasn't worked well, but the cecidomyiid predator, *Aphidoletes aphidimyza* has been effective whenever aphid numbers have increased. Shipments of Hibiscus plants introduced whitefly to the forest and a parasite, *Eretmocerus californicus* (Aphelinidae) and a predator, *Delphastus pusillus* (Coccinellidae) (see MBCN Vol. I, No. 2; Vol. II, Nos. 1-3), were released to manage populations. The small, black Delphastus beetles have been very successful in maintaining whitefly populations below aesthetic levels.

Augmentation, Thresholds, and Cost Effectiveness

McCaren horticulturalists say that spring is their busiest time for predator and parasite releases. "We may make releases on a weekly or biweekly basis during spring," says Rickert. This time period coincides with an increase in pest populations and the introduction of new plants with new pests.

Camp Snoopy officials and McCaren staff seldom disagree when considering at which time pest population levels have gotten too large. "When Cuban laurel thrips ride along with blue balloons or when aphids start appearing in face painter's paint, then we know pest levels are too high," says Rickert.

The McCaren staff believe that biological control is cost effective when a predator or parasite becomes established and reduces pest populations. "Labor and application costs and worker concerns are lower with biocontrol compared to using chemicals," says Richter. "Of course, biological control is the only option in sensitive areas such as the Wilderness Station and Koi fish pond," adds Rickert.

Other Interior plantscapes

McCaren horticulturalists use biological control in other indoor landscapes. Hospitals, hotels, restaurants, office buildings, and some department stores are also common augmentation sites for beneficials. "There are sensitive areas in all these buildings, and that is where beneficials are released," states Rickert. Most of the public doesn't seem to notice the beneficials and McCaren doesn't advertise that they are using augmentative biological control, although it may be an advantage in the bidding process for future interiorscape contracts.

-Rob Meagher, University of Minnesota

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APPENDIX
INTERIOR PLANTSCAPE PEST MANAGEMENT REFERENCES

IPM REFERENCES

Common Sense Pest Control. 1991 . William Olkowski, Sheila Darr, and H. Olkowski. The Tauton Press, Newtown, CT. ISBN 0-942391-63-2

- Includes a chapter on pests of indoor plants. General management strategies, monitoring, and preparation suggestions for IPM use are discussed. Biology and treatment options for major indoor pests are also discussed.

Integrated Pest Management for North Carolina Municipalities.

- This information is available on the world-wide-web at the following address: urban/cropsci
- Includes general information about IPM principles.

HORTICULTURE REFERENCES

University of Florida Foliage Plant Production Guides.

- This information is available on the world-wide-web at the following address: http://www.ifas.ufl.edu/~apkweb/folnotes.htm
- This site contains guides that cover physiological problems, insects, and diseases common to numerous types of commercially produced foliage plants.

PLANT DISEASE REFERENCES

Ball Field Guide to Diseases of Greenhouse Ornamentals.

- Margery Daughtrey & A.R. Chase
  Ball Publishing, 1 North River Lane, Suite 206, Geneva, IL 60134-0532
  ISBN 0-9626796-3-1
  Excellent color photos of common diseases on flowering and foliage plants.

INSECT REFERENCES

Insect and Related Pests of Flowers and Foliage Plants. 1994. J. R. Baker, Editor. North Carolina Cooperative Extension Publication No. AG-136.

- This publication is also available on the world-wide-web at the following address: INSECT_ID/AG136/ncstate.html.

BIOLOGICAL CONTROL REFERENCES

Directory of Least Toxic Pest Control Products.

- Contact: Bio-Integral Resource Center
- P.O. Box 7414
- Berkeley, CA 94707
- Phone: 510/524-2567

Biological Control Virtual Information Center.

- Biocontrol information available on the world-wide-web at the following address:biocontrol/biocontrol.html
- Includes links to numerous biocontrol sites across the U.S.

Knowing and Recognizing: The Biology of Glasshouse Pests and Their Natural Enemies. 1992. M. Malais and W.J. Ravensberg. Koppert Biological Systems.

- Greenhouse pests and their natural enemies are discussed in detail. Numerous color photos.

Biolgical Pest Management for Interior Plantscapes
1987. M. Steiner and D. Elliot. Alberta Environmental Centre

- can be ordered at http://www.gov.ab.ca/qp/index.html