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PB1623-Decision Making Handbook for Insect & Mite Pests of Ornamental Plants

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Introduction

Attractive, vital landscape plants contribute significantly to real estate values. On the other hand, poorly maintained landscapes may become a liability, especially if trees or their parts fall and cause property or bodily injury. This realization, coupled with increased leisure time to enjoy our yards and more discretionary income for landscaping and landscape maintenance, has contributed to dramatic increases in the demand for nursery products and competent service personnel. At the same time, concerns for environmental quality and safe use of pesticides require that plant health care activities, including pest control, provide quality plants without creating adverse side effects. This is the challenge for anyone dealing with plant propagation, production or maintenance.

The nursery industry produces a diverse array of plant materials for landscape use. In many cases, these plants are native to North America and are not seriously damaged by insects or mites on native sites. However, when these same plants are grown under nursery conditions or in a landscape, native arthropods sometimes become pests. Although we do not know precisely why this occurs, it is undoubtedly related to site factors that create instability in plant-insect relationships. Either the effectiveness of natural enemies, including other arthropods and microorganisms, that normally minimize reproductive success is reduced, or the plants become stressed so they are more attractive or susceptible to opportunistic colonizers. Perhaps both regulating mechanisms commonly break down when plants are grown on non-native sites, especially under stressful conditions like those found in the urban forest.

Of course, many pests that damage landscape plants were introduced in the absence of natural enemies that normally limit their exploitation. Japanese beetle, black vine weevil and gypsy moth are examples of exotic insects that have become extremely common and damaging in North America. Although major efforts have been made to introduce parasites and predators of some introduced pests, they must usually be controlled with pesticidal sprays when their density threatens plant vitality. In any case, potentially damaging arthropods are common on landscape plants.

Since most of us take plants for granted or at least fail to inspect them periodically, insects and mites commonly cause damage before their presence is detected. This chronic lack of vigilance often results in plant damage and causes unnecessary use of large amounts of pesticides. Scheduled plant inspections and use of spot-spraying to control small but building infestations of pest species are superior ways to minimize damage from arthropods.

This publication has been prepared to inform users about the insect and mite pests that commonly attack landscape plants, when these pests are most vulnerable to control measures and currently available control options. The following narrative is included to help plant producers and landscape management practitioners understand the basic principles involved in making responsible and effective pest control decisions.

Making Decisions about Pest Control

Arthropod presence on a valuable plant does not necessarily mean that an effort should be made to eliminate it. If the plants are in nursery production and if the organism is an acknowledged pest species, then it should be controlled as soon as it becomes vulnerable to an efficient control tactic. However, the arthropod might be a beneficial species or a pest species at a low enough density on a landscape plant that control is not necessary. Several factors are considered sequentially to determine the need for indirect or direct action.

Accurate Identification

The first step when an arthropod is detected is to determine its identity. Many insects found on landscape plants are transients or beneficials, part of the natural community that helps keep pest species at low levels. It is extremely important to conserve beneficial arthropods like lady beetles, green lacewings and parasitic wasps by using pesticides only when they are needed. Extension agents, specialists and landscape maintenance personnel can help identify common arthropods, both pests and non-pests.

Once an insect or mite has been identified as a pest species, its biology and seasonal life history can be obtained to determine how and where it feeds, damage symptoms, number of generations it completes each year, the kind of plants it infests, stage(s) and time(s) when it is vulnerable to control tactics and current control options. All of this information is then used to determine the best strategy for dealing with the pest.

Degree of Infestation

Until a certain number of insects is present on a plant, control measures are not needed. It is not always easy to know when there are enough insects present to justify control mesures. One thousand caterpillars eating leaves might completely defoliate a tree in two weeks, but that same number of aphids would hardly be noted. Yet 1,000 aphids today may become 100,000 in a month. This may be more than a plant could tolerate.

It is especially difficult to say how many insects should be present on ornamental plants before we should spray. Plants established and growing well in the landscape may be able to tolerate more pests than poorly growing plants. Likewise, some homeowners expect no pests, while others do not even notice anything until extreme damage has already been done. Of course, nurseries are a different problem. State and federal regulations, as well as purchaser demands, require that plant stock for sale be "pest free." This places rather difficult standards for the final product to be sold. Experience tells us that certain pests must be controlled at the first sign of their presence because they will likely increase in numbers and cause considerable damage. With some pests and on certain plants, we will watch the infestation closely and treat only if the injury gets progressively worse.

What Happens If Nothing Is Done?

In some cases, doing nothing is the best course of action because predators, parasites and other factors take over and the pests soon disappear. Most established deciduous trees can be completely defoliated without any apparent permanent harm to them, but defoliation may weaken younger or newly transplanted trees and most shrubs until they die or become susceptible and attractive to other injurious pests.

Doing nothing may result in the beauty of a plant being destroyed or a pest becoming numerous enough to make a general nuisance of itself. In the case of a heavy borer or scale infestation, doing nothing could result in the death of a plant, regardless of its age or size.

Is Spraying Cost Effective?

The cost of having a tree or shrub sprayed one or more times may help a person to make up his/her mind quickly about what to do. It often requires at least two applications of an insecticide/miticide to clean up an infestation. Small trees and shrubs can be sprayed by the homeowner at much less expense. Tall trees may require a sprayer capable of developing as much as 500 pounds of pressure to force the spray to the top of the trees. This undoubtedly must be done by a commercial operator.

From what has been said so far, you probably realize that a person confronted with a pest problem may need some help to know just how serious the problem is and what needs to be done about it.

Where to Get Help

The University of Tennessee Agricultural Extension Service has offices throughout the state. In these offices, personnel are available to help you with your pest problems. Take the specimen to your county UT Extension office where faculty can determine if the sample needs to be submitted to the Plant and Pest Diagnostic Center in Nashville, TN. Be sure to provide as much information about the problem as possible on the forms provided. This helps specialists evaluate the problem and prescribe a recommendation.

Importance of Early Pest Detection

Because the number and kinds of ornamental pests vary from year to year and even from month to month in any one year, you never know what pest problems you can expect or how severe they will be. So, to prevent a pest from slipping in and becoming established on a plant without being noticed, visually inspect plants at least two or three times during the growing season. This may only involve a general inspection of the plants to see that there is not a loss of color or that the leaves are not being eaten. Turn over a few leaves to see if there are any pests on them. Remember, some insects feed only at night and hide during the daytime. Early detection of a pest provides time to get the problem corrected before the plant suffers permanent injury.

Insect and Mite Management Alternatives

Integrated Pest Management: Pest Management versus Pest Eradication

Managing insects and mites that attack our urban ornamental plants has generally relied on the use of pesticides. Whether this is good or bad is beyond the scope of this discussion, but we must ask whether alternative controls are available. Before we can consider the alternatives, we should review our current concept of pest management. Pest management as opposed to "eradication" implies that some pests will always be around. It is the goal of pest management to keep the pest populations down to a level where damage is not overly evident. In field crops, this has generally been termed an economic threshold level. In urban ornamentals, the aesthetic threshold level (the population of a pest that causes noticeable, unacceptable visual damage) is the term to be used.

Integrated Pest Management (IPM) - a Definition

Another common term used is **integrated pest management** (IPM), which is the selection, integration and implementation of pest control (biological, chemical or cultural) based on predicted economic, ecological and sociological consequences. In other words, when we use a pest control we must consider the cost both to the ecosystem and human society. Using the IPM approach, three important concepts must be accepted:

1. No **single** pest control method is always used. All of the control options — biological, chemical and cultural — must be considered. Chemical control is used only when needed.

2. **Monitoring** (sampling) of the pest is constantly needed to evaluate the status (not present, present but not causing aesthetic damage, present and causing aesthetic damage, etc.) of a pest population.

3. Therefore, **mere presence** of a pest is not a reason to justify action for control.

There has been considerable misunderstanding about IPM, IPM control options and the underlying concepts. Perhaps a look at what **IPM is** or **IPM is not** will aid our understanding of these concepts.

What IPM Is Not:

1. IPM is not a biological control program, though biological control is a useful option. However, biological control is only **one** of the options. We also have to consider chemical, cultural and other controls.

2. IPM is not an organic program, though organic materials can certainly be used if they do not cause economic, environmental or sociological problems.

3. IPM is not a pesticide-free program, because the chemical control tactic may be warranted. Generally, IPM programs have reduced chemical controls (pesticides) but not eliminated them. It is not necessarily the **goal** of an IPM program to reduce or eliminate pesticides.

4. IPM is not the least or most expensive method of pest management. Usually, the cost of pest control remains close to original costs. Monitoring and sampling costs are traded for scheduled pesticide applications.

What IPM Is:

1. IPM is a decision-making **process**. Each plant, each year and each habitat are slightly different and programmed controls will not address these differences. Thus, monitoring must be performed and decisions must be made.

2. IPM is a system of pest management decisions based on ecological, economic and sociological values.

3. IPM is a process of pest monitoring and sampling. We must know the status of a pest and whether it really needs a control action or not.

4. IPM is a process that considers **all** of the control options.

Monitoring

Monitoring pest activity and population levels is the key to successful IPM. Unfortunately, most feel that monitoring must be a complicated and time-consuming process where someone must constantly watch each and every plant. This is simply not true. Monitoring of pests in nurseries and landscapes can be done in a multitude of ways — from visual inspection to using temperature-dependent (degree-day) developmental models. Another method of solving the seemingly impossible task of monitoring pests in complex settings is the concept of **KEY PLANTS** and **KEY PESTS**:

1. **Key plants** are trees, shrubs and flowers that are known to have perennial pest problems. As an example, birch trees often get leafminers, aphids and borers, while red oaks rarely get significant pests.

2. **Key pests** are those that cause significant damage or may kill trees, shrubs or perennial flowers. These key pests often have special times (windows of opportunity) that they are susceptible to controls. Aphids or galls in oaks are rarely significant enough to warrant controls, while peach tree borers in ornamental plums need special attention.

The Control Options

IPM uses a variety of control options — biological, chemical, cultural and other controls. These are our alternatives and we must understand the benefits and limitations of each option. Since we are dealing with ornamental landscape plants, most of the pest problems are a direct result of poor horticultural maintenance. In other words, plants placed in urban habitats or pushed during nursery production that are not suitably adapted are the ones most likely to be severely attacked by pests. Therefore, let us look at the cultural control option first.

Cultural Controls

The cultural control option should be our **first** consideration as an alternative in landscape tree and shrub IPM. Cultural controls in field crops have generally included sanitation, crop rotation, tillage, host plant resistance/tolerance, regulatory control and mechanical/ physical destruction. If we look at these techniques, we may wonder how these relate to ornamentals in nurseries or landscapes. Though we use different terms, these techniques are commonly used and need to be emphasized more.

1. **Sanitation** helps remove inoculum or hiding areas of pests. Pruning, raking of leaves and destruction of heavily infested plant stock are sanitation techniques useful on our urban landscapes and nurseries.

2. **Crop Rotation** is generally used in field crops (i.e., corn rotated with soybeans), but should be considered for ornamental tree and shrub production. Many nursery producers rotate growing areas by planting different types of stock after a rotation. This seems to help reduce attacks by borers and root-infesting diseases. We also need to realize that most trees and shrubs in urban landscapes are limited by space, which reduces their vigor with time. Therefore, if a plant has begun to reach its limitations, it should be replaced with a smaller, better-suited one.

3. **Tillage** in field crops exposes resting pests and breaks up the soil for better air and water movement. In ornamental trees and shrubs, aeration and mulching are analogous.

4. **Host Plant Resistance** uses plants that are less susceptible to pest attack (tolerance), nonpreference (antixenosis) or produce actual toxins (antibiosis) that kill or stop pest growth. Trees and shrubs with resistance properties are well known though poorly utilized. In fact, damage can be reduced with the use of resistant plants. For people concerned with the use of pesticides, this is a major option to be considered.

5. **Mechanical/Physical** techniques are as simple as crushing the pest under foot to using large industrial vacuum sweepers to suck up pests. In our landscape plantings, we need to constantly remind ourselves that simple pruning or crushing of pests is preferable to chemical spraying. We are all guilty of spraying an entire juniper hedge for bagworms when only three or four bags were seen, which could have been easily picked off and crushed. Likewise, we tend to “Rambo” spray tent caterpillars in the spring when we could just reach in, roll up the nest with the caterpillars inside and dispose of the mess in a bag.

6. **Regulatory Control** is a legal method of restricting movement of contaminated plant material. Unfortunately, this technique is rarely effective, even though we know that most pest problems arrive on infested plant material. Therefore, we should pay special attention to new plantings that may have pests and plant stresses developed from the transplanting process.

7. **Good Horticulture** is one of the simple but commonly ignored methods of pest management. In other words, a “healthy” plant can generally fend for itself against insects, mites and diseases. Therefore, one of the most important control alternatives that we can use is tending to the proper needs of landscape plants. We need to match the correct trees and shrubs to the typical alkaline, hardpan clay soils of our landscapes. Not to do so causes plant stress, which allows pests to gain the upper hand.

Chemical Controls

Probably our second most useful control option in ornamental plant IPM is chemical control. Unfortunately, we have overused and misused this option, so most citizens are beginning to cast a weary eye to its use. Chemical control to most people means pesticides, though other chemicals such as attractants and pheromones are increasingly important in our IPM practice. Even if pesticides are our principal weapon, we need to understand that not all pesticides are created equal. In IPM, we want to use the ideal pesticide — a material that only kills the target pest. Unfortunately, we do not have these “silver bullets.” Most of the pesticides that are currently used have short residual life spans (this reduces accumulation in the environment), are more selective (this reduces the chance of killing nontarget animals) and are used at lower rates (this reduces the total chemical “load” used). Because of these characteristics, we need to be able to better target our applications to achieve satisfactory control.

Another general public misconception about pesticides is that “natural” pesticides are better than “synthetic” pesticides. IPM does not make this distinction. Using pesticides in IPM is evaluated on economic, ecological and sociological impacts together. In other words, there are “natural” botanical insecticides (i.e. nicotine sulfate with an LD_{50}=55 and a known carcinogen) that are much more toxic and have more adverse effects than some “synthetic” organic insecticides (i.e. acephate with an LD_{50}=866). In short, chemical controls used in IPM should be selected on their total attributes.

By knowing that we do not have “ideal” pesticides, whether natural or synthetic, we must use great caution to limit their adverse effects. Generally, this means that we should only **target sprays** to those individual plants or blocks that need it — **not cover sprays**. General cover sprays (spraying everything in the landscape or nursery whether needed or not) tend to cause several problems.

Cover sprays often tip the balance of control in favor of the pest. As incredible as this seems, cover sprays usually kill beneficial insects and mites (predators and parasites) better than they kill pests! Since pests usually have good reproductive ability, they "rebound" faster than their natural controls. This causes what we call **pest resurgence** and **secondary pest outbreak**.

Cover sprays tend to cause development of resistance. Pests and potential pests often develop resistance to pesticides when they are under constant pressure from a specific pesticide. In other words, a few insects on a plant may not cause significant damage, but if we constantly spray these insects, we force them to develop resistance. Then, when they reach damaging levels, our pesticide is no longer effective.

A more recently identified problem with general cover sprays of pesticides has been identified to be enhanced degradation. Because most of our current pesticides are organic compounds (i.e., containing carbon, hydrogen and oxygen), microbes are able to use the chemicals as foods or nutrients. Generally, these microbes are beneficial in aiding in the removal of pesticides from the environment. However, when constantly "fed" through general cover sprays, these microbes gain the ability to degrade pesticides more rapidly than normal. In summary, if the chemical control option, is to be used, we need to **use target sprays only when needed**.

The chemical control option should be considered a **limited resource**. As with all limited or scarce resources, we need to conserve what we have. Many of the chemical companies are no longer developing traditional pesticides. The cost of discovery, development and registration is simply too high. Therefore, we must conserve what we have and guard carefully the few new products that become available.

Most people believe that chemical control merely means pesticides. The chemical control option also contains repellents, attractants and pheromones, and desiccants. It is easiest to discuss these by their chemistry and activity:

A. **Chemical Pesticides** - are chemicals that directly kill the pest.

1. **Inorganics** are pesticides without carbon, which can be natural earth minerals or synthetic compounds. Examples are:

   a. **Diatomaceous Earth** — glass-like remains of single-celled organisms, diatoms, which scratch insect cuticle or puncture gut cells. Acts mainly as a desiccant and is rarely useful in landscapes unless combined with an insecticide like pyrethrin.

   b. **Sulfur** — an ancient control for insects and mites.

   c. **Sodium Fluoaluminate** (=Kryocide, Cryolite) — an earth mineral (or synthetic) that forms sharp, glass-like particles that puncture insect gut cells if ingested. Since it is a stomach poison, it does not adversely affect beneficial predators and parasites. Good only against leaf-feeding caterpillars, sawflies and beetles.

2. **Oils** are petroleum- or plant-based hydrocarbon chains that have insecticidal activity. Toxicity appears to be caused by suffocation and/or membrane disruption. Examples are:

   a. **Summer Oil** — a highly refined mineral oil used on green plants at a 0.5-2.0 percent rate.

   b. **Dormant Oil** — a slightly less refined mineral oil or summer oil used at a 2.0-4.0 percent rate when plants are in winter dormancy. When used in winter, it has a minimal adverse affect on beneficial insects.

   c. **Citrus Oil** — raw oil or separate constituents (e.g, d-Limonene) that have insecticidal properties at low dosages. Usually combined with other insecticides such as soaps.

3. **Fatty Acid Salts** or **Soaps** are synthetic hydrocarbons using an ion, usually potassium or sodium, to join together fatty acid chains. Fatty acid chains containing six to 10 carbons have insecticidal properties. Insecticidal soaps apparently disrupt cell membranes. Soaps tend to be good at controlling soft-bodied insects such as aphids, mealybugs, soft scales, caterpillars, beetle larvae and spider mites.

4. **Microbial Toxins** are molecules produced by bacteria, fungi, protozoa and other microbes that are toxic. Toxins like Bt endotoxin are relatively low in toxicity to mammals, while botulism toxin is one of the most toxic molecules known. These toxins are used by extracting the microbe or using whole organisms. Examples are:

   a. ***Bacillus thuringiensis*** (Bt) — a bacterial product containing both endotoxins and spores that are active on a variety of insects. See Biological Control below.

   b. **Avermectin-B** (=Abamectins, Avid) — a powerful toxin derived from *Streptomyces* fermentation.

   c. **Chitin** (=Clandosan) — the chemical that makes up the exoskeleton of arthropods (insects, crustaceans, etc.) and nematodes. By adding chitin to the soil, microbes produce toxins (ammonia) and/or produce digestive enzymes that destroy the cuticle of insect and nematode pests. Field results in landscapes have not been consistent in efficacy.

5. **Botanicals** are plant extracts, usually alkaloids, that have insecticidal properties. Most people believe that since these are "natural" products, they are "safer" than other pesticides. Many of these chemicals have not been fully tested and many have striking adverse affects on mammals. Many cause severe allergic reactions (i.e. pyrethrin and sabadilla), have high toxicity (nicotine) or are even suspected carcinogens (nicotine). Examples are:

   a. **Pyrethrin** is derived from a specific species of chrysanthemum originally grown in Iran. The natural product is mainly an irritant to insects and is usually mixed with piperonyl butoxide (PBO) or rotenone to provide better kill of insects. Some people are allergic to the compounds.

   b. **Nicotine** is an alkaloid derived from tobacco that has high toxicity and is a suspected carcinogen.

   c. **Neem** or azadirachtin (Bioneem, Azatin, Neemazad, Neemix) is an interesting botanical derived from an Asian tree grown in India. Neem is used as a general cleaning chemical and is found in toothpaste. It seems to act as a systemic with repellent and growth-regulator effects on insects and mites.

6. **Synthetic Organics** are synthetic compounds containing carbon and are usually synthesized from petroleum products. This is the group most people refer to when they mention pesticides. Because of the diversity and number of materials in this group, no attempt will be made to cover these compounds.

   a. **Organochlorines** (=Chlorinated hydrocarbons) usually have long residual life spans in the environment. This quality has caused most to be banned because they end up in the food chain or cause damage to non-target organisms.

   b. **Organophosphates** usually have short residual life spans. They are often stated as being related to nerve gas. Compounds in this group range from category I to III in toxicity and are generally neurotoxins. The EPA toxicity categories and accompanying hazard signal words for pesticide labels are toxicity category I, "Danger" and "Poison"; toxicity category II, "Warning"; toxicity category III, "Caution"; and toxicity category IV, "Caution." EPA toxicity category I is the most toxic, while IV is the least toxic.

   c. **Carbamates** may have long or short residual life spans and range from category I to III in toxicity. Most are neurotoxins.

   d. **Pyrethroids** are synthetics that look and act like the botanical pyrethrins. They range from category I to III in toxicity, though most are in categories II and III.

   e. **Insect Growth Regulators** (IGR) are synthetic chemicals that look and act like insect hormones. They are often metabolism-modifying organo phosphates and carbamates with very low toxicities to mammals or other non-target animals.

   f. **Spinosyns** are fermentation derived metabolites from a newly discovered species of bacteria. The only commercially available insecticide in this class is considered a "reduced risk" product by the EPA ("Caution" hazard signal word on label) because of its low levels of toxicity to mammals, beneficial and other non-target species. The mode of action is a unique mechanism that is active on the insect's nervous system nicotinic acetylcholine receptors. Exposure may occur by either ingestion or contact.

   g. **Chloronicotinyls** are a new class of insecticides. Imidacloprid is the only commercially available active ingredient in this class. It is a broad-spectrum systemic insecticide that is effective at very low use rates. The "Caution" hazard signal word appears on the labels. The mode of action is similar to that of nicotine in which nicotinic receptors at certain nerve endings are stimulated. The difference is that the chloronicotinyls are extremely selective at stimulating nicotinic receptors in insects but not those in vertebrates. Also, very little imidacloprid is absorbed through the skin into potentially sensitive tissues of vertebrates.

B. **Attractants** and **Pheromones** are compounds that attract a pest in search of food or another of the species (aggregation and sex pheromones). Most of the compounds in this group have not been used effectively to reduce pests but are used in traps to sample pest activity. Examples are:

1. **Geraniol/Eugenol** is the attractant "floral scent" used in Japanese beetle traps. These traps do not reduce beetle damage or grub populations. In fact, evidence exists that plants near traps may sustain more damage.

2. **Disparlure** is the sex pheromone attractant for gypsy moth males. It is a powerful sampling tool but has not been successful in disrupting mating.

3. **Clearwing Moth Borer Pheromones** is a mix of sex pheromones attractive to several borers such as the dogwood, lilac/ash, rhododendron and peach tree borers. These traps allow for precise timing of larval controls.

4. **Pine Tip Moth Pheromones** are sex pheromones for various pine tip moths. These traps determine the starting point for degree-day models for predicting larval control windows.

C. **Desiccants** are materials that cause the insect pests to lose water faster than they can replace it. Since insects are very small, this water loss is rapidly lethal. Unfortunately, most desiccants must be kept dry, so outside usage is limited. Examples are:

1. **Silica Gel** is the same drying agent used in packing or flower drying and can be ground to a powder to dust onto insects.

2. **Diatomaceous Earth** acts like a desiccant when dusted on the exterior of insects. The sharp edges of this product abrade away the thin wax waterproofing coat on the exoskeleton of insects.

Biological Controls

Biological control is the use of **parasites**, **predators** and **pathogens** (diseases) to control pests. We have to realize that in the urban landscape and nursery, there are a multitude of beneficial insects and mites that can prey on pests. In many cases, these naturally-occurring beneficials will do a good job of controlling the pests if we do not disturb the system too much. As stated above, we usually disrupt this system by overusing pesticides that kill the beneficials better than the pests. On the other hand, there are occasions where we can actually increase these biological controls. The classical way to implement biological controls is through introductions, conservation and augmentation.

A. **Introductions** of exotic parasites, predators or diseases are made when foreign pests become established. This is an attempt to establish some of the checks and balances found where these pests are naturally controlled. Occasionally, foreign biological controls are found that may better control native pests.

B. **Conservation** is the use of other control tactics, usually pesticides, so they have the least adverse affect on predators and parasites. It can also be the providing of habitat or food needed by the biological control organisms to improve their survival. In the urban landscape or nursery, we can use targeted sprays on those specific plants where pests are getting the upper hand. We can also plant flowers that provide nectar and pollen to feed the adults of many of the parasitic insects.

C. **Augmentation** is usually the rearing and release of biological control agents. Unfortunately, this technique is usually expensive and we must use those biological controls that fit into the definition of a “good” biological control.

What is meant by a “good” biological control? Not all predators, parasites and pathogens are useful in their ability to be used in pest management. Useful ones have the following characteristics:

A. **High Reproductive Potential** — they must be able to keep up with the high reproduction of the pests.

B. **Good Mobility** — they must be able to search out the pests or come into contact with the pests.

C. **Host-specific** — they should not be generalists that may adversely affect other, sometimes beneficial, organisms.

D. **Persistent**— they should have the ability to exist when pest populations become low and remain from season to season.

E. **Easily Reared or Encouraged** — this will allow them to be inexpensive and competitive with other controls.

F. **Tolerant of Other Controls** — to fit into a true IPM system, they need to be tolerant of cultural and chemical controls.

To illustrate these concepts, let us look at a praying mantis versus a lady beetle. The praying mantis has one generation per year; eats anything in sight (including each other and other beneficials); usually ignores small insects such as aphids, mites and scales; often does not survive the summer to lay another egg case; and is sensitive to any pesticide. Therefore, praying mantids **do not** qualify as a useful biological control. On the other hand, lady beetles have many generations per year, they only eat a narrow range of pests (usually they are aphid, mite or scale specialists), usually overwinter well and can often withstand some of the softer pesticides, especially soaps and oils. Therefore, lady beetles easily qualify as a useful biological control.

Unfortunately, we often think that we have to actively introduce predators and parasites in our urban landscapes. Because most of these animals already exist, we merely have to be able to recognize them and avoid using cover sprays of pesticides.

Predators you should learn about are:

A. Lady Beetles are commonly sold as adults and are useful control agents if properly handled. The adults need to be fed honey (resembling aphid honeydew) in a cage (to suppress a strong urge to fly away) before release in the garden. Larvae are often mistaken for pests because they look like leaf beetle larvae or some other pests (e.g., the “mealybug destroyer” lady beetle larva looks like a mealybug).

B. Green Lacewings are not to be confused with the lace bug pest. The larvae feed on aphids, scales and mites. Eggs are purchased and sprinkled where small pests are noted to be active. The larvae must search for the pests because they do not have wings.

C. Ground and Rove Beetles are active predators present in most soil/turf habitats. Both the adults and larvae feed on a wide variety of pests, but are highly intolerant of pesticides.

D. Syrphid Flies (=Hover Flies) are common yellow and black flies that have voracious larvae (maggots) that eat aphids.

Parasites are insects (often called parasitoids) with larvae that feed on the inside or outside of their host, usually killing or sterilizing it. Some common parasites you should learn about are:

A. Trichogramma Wasps (=Egg Parasite Wasps) are microscopic (usually less than 0.02 inch long) and lay their eggs in the eggs of other insects. They are usually very host-specific and generally limited to butterfly or moth (caterpillar) pests.

B. Ichneumonid and Braconid Wasps are small wasps that commonly attack caterpillars and aphids. The larvae usually emerge from the dying host and spin small-white or yellow cocoons.

C. Tachiniid Flies are generally medium-to-large flies that lay eggs on caterpillars or various leaf-feeding beetles. The eggs hatch into maggots, which feed on and eventually kill the host insect.

Pathogens can cause diseases that kill insects. They are usually bacteria, virus, fungi and protozoa. Insect pathogens are fairly ideal in that they are host-specific. They are also non-infective to vertebrates. Examples are:

A. Bacteria have been the easiest of the pathogens to use because they can often be reared “in vitro” (in artificial culture) and form spores fairly resistant to adverse environments. Examples are:

1. ***Bacillus thuringiensis*** (Bt) - has several strains that produce toxins lethal to various insect groups (and are thus technically a chemical control). The most common types are:

a. **Bt ‘kurstaki’** — that affects only young caterpillars.
b. **Bt ‘israelensis’** — that affects aquatic fly larvae such as mosquitos and black flies.
c. **Bt ‘tenebrionis’** — that affects some leaf-feeding beetles.

2. ***Bacillus popilliae*** (= white grub milky disease) — has one strain available that kills Japanese beetle grubs.

B. **Fungi** have been identified, but are difficult to use because the spores are easily dried out or need high moisture and/or water to germinate. An example is:

Beauveria spp. have been identified infecting a wide variety of insects including bugs and beetles. A commercial strain, Naturalis - O™, is available for indoor and outdoor use on a variety of ornamental plants.

C. **Viruses** are common pathogens of insects, but are one of the most difficult to use because they require living insects to grow. Recent development of insect tissue culture has allowed for rearing of some of the virus strains, but the only commercial product is **Nuclearpolyhedrosis Virus** (NPV) — for gypsy moth control under the trade name of Gypcheck™.

D. **Entomopathogenic Nematodes** are a group of tiny parasitic roundworms that carry a bacterium lethal to insects. Once the nematode gains entry into an insect, it regurgitates the bacterium, which paralyzes and kills the insect. The nematode then feeds on the reproducing bacteria. The most commonly mentioned species are:

1. ***Steinernema carpocapsae,*** which has several strains good at attacking insects that live in the upper soil or on the soil surface. Biosafe™, Vector TL™ and Scanmask™ are commercial preparations.

2. ***Heterorhabditis*** spp. are better at attacking insects that live deeper in the soil. This group can also bore through the insect cuticle.

In summary, there are multiple alternative control methods that can be used in the urban landscape. Integrated pest management provides a framework in which to use all of the alternatives in a systematic fashion. Of most importance is the idea that we must monitor for pest problems and then select the best targeted control available.

Factors Critical To Pesticide Performance

Application Timing

Pest control should be initiated only after the pest has been identified accurately and its presence threatens either the aesthetic quality or the vitality of the plant. If a decision has been made to use a pesticide, timing of the application must coincide with a stage of the pest that is vulnerable to the application.

Many pests, including borers, armored scales and gall formers, can be contacted with pesticidal sprays for only a short time during the growing season. For example, armored scales can best be controlled by attacking the newly-hatched nymphs (called crawlers) when they are active or have recently settled on their host. Borer sprays must be applied either before egg laying begins (e.g., bronze birch borer and other flatheaded borers) or before egg hatch (e.g., dogwood borer and other clearwing moth borers). Pesticide applications at any other time during the life cycle of these pests will be ineffective and should not be used.

Understanding Pest Life Cycles and Movement

Many insects and mites complete only one life cycle (=generation) each year. A single, well-timed, thorough cover spray with an effective pesticide should provide season-long control. Other pests, including aphids, mites and some scales and bark beetles, complete two or more generations each year. These pests may require more than one spray during the growing season.

Most adult insects have wings and can fly. After spraying, new insects may fly in and reinfest a plant, making it appear that the insecticide applied did not perform well. For this reason, repeated applications are needed to protect some plants from incoming insects.

Selecting the Correct Insecticide/Miticide

Although many insecticides/miticides are effective against a number of different kinds of pests, it is always important to choose a product that has been proven to provide excellent results against the pest you are trying to control. General-purpose sprays and pesticides are not the best approach to pest control. Instead, consult the tables in this bulletin and choose a product that has been rigorously evaluated for its effectiveness against your target pest. Then, use it according to directions on the container label, using only the amount specified. Do not use adjuvants (i.e. spreaders and stickers) unless specified on the label.

Weather-Related Problems

Sprays should always be applied to dry foliage and bark when rain is not expected for several hours. However, as long as sprayed surfaces dry before rainfall occurs, reapplication is usually unnecessary. Sprayed plants should be monitored in five to seven days to determine treatment effects, especially if rain occurs soon after the application. If the treatment was not effective, and if the pest is still in a vulnerable stage, the application should be repeated. It is a good policy to spray when the temperature is between 50 and 90F (10-32C). Many pesticides are less effective below this range, and some products may cause plant damage above the upper limit.

Storage Life of Pesticides

Many insecticides/miticides may tend to lose their killing power over a period of time, once they have been opened. This process may be speeded up with improper handling and improper storage. Therefore, it is always best to buy only the amount of insecticide/miticide you expect to use in one season.

Many pesticides however, can be used from one year to the next. The remaining product should be stored in a safe, dry place that does not experience freezing or extremely high temperatures. Refer to the label for specific instructions on long-term storage.

Pest Resistance

Resistance is a general term which, in the broad sense, means pests that were previously killed by a pesticide have produced offspring that are no longer killed by it. To illustrate, let us suppose that an insecticide is applied and that it kills 95 percent of the insects in a population that contact it, but there are 5 percent of the insects that received the same dosage but survived the treatment. This 5 percent is considered resistant to the insecticide. They live to produce another generation, and this generation, having had resistant parents, passes on to its offspring the resistance factor. Most likely there will be a greater number of the new individuals carrying resistance to the insecticide compared to the first-treated population. As repeated insecticide applications are made and more generations produced, it is only a matter of time before the majority of the insects in question will survive the insecticidal application. A possible explanation is that the insecticide has acted as a selecting agent, killing those members of a population that are susceptible to the chemical and leaving those that are resistant. Survivors breed and produce subsequent resistant generations. Resistance develops fastest in insects with high rates of reproduction. This is another reason why pesticides should be used only when and where necessary to prevent damage to valuable landscape plants.

Understand Insecticides/ Miticides Before Using Them

Most people know little about pesticides, yet they play an important role in food production and personal well-being. Even though they are important products, we must not forget that they are poisons and may present serious dangers if not stored and used properly. The best place to learn about a pesticide that you intend to buy and use is the label printed on the container. This is a legal document that contains information developed by scientists, government regulators and suppliers over a period of several years. By following timing recommendations listed in this publication and on the pesticide label, you can achieve results equally good as those of the scientists who rigorously tested the product.

How Poisonous Are Insecticides/Miticides?

All insecticides and miticides are poisons. However, some are much more toxic than others. The pesticide container lists a precautionary statement that indicates the toxicity of the product. For example, a skull and crossbones indicates the most highly toxic materials. In most cases, these products should not be purchased, stored or used by those untrained in pesticide usage. Most of these products also will state "RESTRICTED USE PRODUCT," which means that only certified applicators may purchase or apply these products. University of Tennessee county Extension offices can supply pesticide certification information.

The toxicity of all pesticides is measured by a term called LD_{50}. LD stands for Lethal Dose, or the amount of material that causes mortality of, in this case 50 percent of the pest population tested. Most LD_{50} studies are conducted with mice, rats or rabbits under laboratory conditions. Since these animals and humans are warm-blooded mammals that share biochemical processes, scientists extrapolate from these tests to predict just how toxic products might be to humans. In any case, LD_{50} is a relative measure of toxicity. We must remember that many individuals in a population will be sensitive to the product at a level well below the LD_{50}.

Pesticide Formulations

Insecticides and miticides may be purchased in forms such as dusts, wettable powders, liquid concentrates, flowables, granules, oil emulsions, aerosol sprays, baits and fumigants. Here are some good and bad points of these formulations.

Dusts are dry mixtures of insecticides with inert powders such as organic flours, minerals, talc or clay. The dusts are composed of fine particles, about 250 to 350 mesh. They are usually sold in strengths of 0.5-10 percent and are applied in the form purchased. Dusts can be used on almost any surface without harming it, but visible dust will usually create an unsightly appearance. Due to their small particle size, dusts will float in air and are easily blown away during application. They generally leave an effective residue as long as they remain dry, but when they get moist, they may cake and become ineffective. However, a slight amount of moisture on a plant may actually aid in the distribution and adherence of the dust to the treated surface. Dusts are of little use in treating large trees.

Liquid concentrates are high concentrations of the "pure" pesticide dissolved in a solvent. Other materials are added to the concentrate to make the pesticide mix with water. Liquid concentrates are sold in strengths of about 18 to 75 percent. Because they are concentrates, it takes only a small amount mixed in water to make an effective spray. A disadvantage of liquid concentrates is that they may cause plant injury under certain weather conditions because of the solvents they contain.

Wettable powders are usually made by impregnating an inert powder with an insecticide or by grinding a dry pesticide into a powder and then adding a wetting agent so that the powder particles can be suspended in water. Sprays made with wettable powders must be constantly agitated to prevent the large particles from settling to the bottom of the sprayer. Because the water used as a carrier of the powder during application evaporates, most of the insecticide is left as a residue. However, the powder itself is quite visible and this residue may be undesireable. Wettable powders are sold in strengths from 15 to 80 percent. As they are not formulated with solvents, they are preferred over liquid concentrates for use on plants that may be injured by solvents. However, during mixing, wettable powders have a tendency to drift or blow about. This problem is often addressed by bagging in water-dispursable packets or granulating into dry flowables.

Flowables are finely ground pesticide particles suspended in a liquid, usually water-based, carrier. They have the same characteristics as wettable powders but are easier to handle during mixing.

Granules commonly contain from 1 to 20 percent of the insecticide impregnated onto highly absorptive materials like clays, limestone, corn cob or nut hull pieces or even fertilizer particles ranging in size from 30 to 60 mesh. Granules are heavy. This minimizes drift and prevents undue loss of insecticide and undesirable contamination of areas bordering those being treated. Granules are used mainly for ground treatment and not on foliage.

Oil emulsions contain an insecticide mixed in a highly refined oil and are used primarily for the control of household pests like cockroaches or wood borers. These formulations are sold in strengths from 4 to 5 percent in low-pressure, atomizer-type applicators. These oil solutions should never be used on plants because the oil will kill living plant tissue.

Aerosol sprays usually contain a mixture of several insecticides in a pressurized can. Most of them contain only a small percentage of insecticide and are designed for small jobs. Until recently, aerosol sprays were used mainly for killing flying pests in the house. Today, many of the aerosols can be applied to rose bushes and other outdoor plants. They are not practical for large scale use on ornamental plants because they are rather expensive for the amount of insecticide contained.

Baits contain a food substance attractive to the insects, along with an effective stomach poison. Formulations are available for use both inside and outside the house. In general, they need to be applied at several intervals to be most effective.

Fumigants may be purchased in solid or aerosol forms and are generally used in closed areas where a lethal concentration of the poison can be built up in the air. Fumigants are of limited value for use on ornamental plants, unless they are grown in enclosed greenhouses or polyhouses.

Systemic Insecticides/Miticides

A systemic insecticide/miticide is one that is absorbed by plant tissue and translocated by the movement of sap from the area treated to additional parts of the plant. Systemics are effective against many different kinds of sucking and chewing insects as well as mites. When absorbed by the plant, they actually become a temporary part of it, and as the plant grows, the systemic is distributed to foliage and other growing areas. This built-in poison may continue to be a toxic meal to various pests for several weeks.

One of the advantages of systemics is that when a plant is growing rapidly, even the new growth is being protected by the insecticide. Depending on application method, another good aspect of systemics is that they have little or no direct affect on beneficial insects that prey on the destructive pests feeding on the plant tissue. Also, systemics in a plant are not subject to breakdown by environmental factors such as rain, wind, temperature and sunlight, at least not as readily as externally applied materials. Systemics cannot be used on all kinds of plants because they may burn foliage.

Systemics are available in granular and liquid concentrate formulations. Granules may be broadcast, used as a side-dressing or incorporated in the soil at planting time. Liquids may be injected into the soil, watered onto the surface of the ground, painted or sprayed on the bark, sprayed on the foliage or injected into tree trunks.

How to Protect Yourself When Using Pesticides

Many pest problems cannot be solved without using pesticides. These materials are poisons and must be used accordingly. If we must use pesticides, let us acquaint ourselves with some general precautions that will help us to use them safely.

General Precautions

1. Read the label. This is the first rule of safety in using any pesticide — **read the label and follow the directions and precautions printed on it**.
2. Store pesticides in closed, well-labeled containers where children or pets cannot reach them. Do not store them under the sink, in the pantry or in the medicine cabinet. Do not store them near food of any kind.
3. Store application equipment as you do pesticides — out of the reach of children or pets.
4. Do not save or reuse empty pesticide containers. Dispose of containers promptly as directed on the label.
5. Do not apply more pesticide than the label recommends. Overdosage is wasteful and may be dangerous.
6. If you use poisoned bait to control rats, mice or other pests, either indoors or outdoors, place it where children or pets cannot find it.
7. When opening a container of liquid pesticide, keep your face away from, and to one side of, the cap or lid.
8. Mix or prepare dusts or sprays outdoors or in a well-ventilated room.
9. In handling **any** pesticide, avoid contact with the skin. Do not get pesticide near your mouth, eyes or nose.
10. If pesticide gets in your eyes, flush the eyes with water for five minutes; get medical attention.
11. Never smoke, eat or drink while handling a pesticide. After finishing the work, wash exposed skin surfaces with soap and water.
12. If you spill pesticide on your clothing, launder the clothing separate from family laundry before wearing it again.
13. If you become ill during or shortly after using a pesticide, call a physician immediately. From the container label, read to him or her the names of the active chemical ingredients; follow instructions for first-aid treatment.
14. Poison information centers are located throughout the state and are on call 24 hours a day. In an emergency, you could call the center closest to you, but it is preferable to let your doctor consult the center. Most telephone 911 systems can contact poison information centers directly.

Honey Bee Protection

Honey bees are important pollinators of plants. Every possible effort should be made to reduce bee losses from pesticide poisoning. Do not apply pesticides during the bloom period when bees are likely to be most active on the plants.

Precautions for Avoiding Plant Injury

1. Do not apply liquid concentrates when the temperature is above 85F (30C). [Do not apply any spray when the temperature is above 90F (32C).] Wettable powder formulations are less likely to cause injury.
2. Do not apply dormant oil sprays if the temperature is below 40F (4C) or where there is danger of the temperature falling much below this in the 24-hour period.
3. Do not apply horticultural, summer oils when the temperature is 80F (27C) or above and high humidity reduces the chance of the spray drying within an hour after the application.
4. Use only the amounts of insecticide/miticide indicated on the current pesticide label.
5. Continuous agitation of the spray tank is necessary to prevent spray materials from settling out. Recycle contents of long spray hoses into the spray tank if enough time has elapsed between sprayings for the mix to separate.
6. Clean out sprayer after use.
7. Never use a sprayer that has contained a weed killer (herbicide) to perform other pest control activities.

Insecticide/Miticide Application Equipment

Small Trees and Shrubs

Much of the success or failure of an insecticide/miticide application depends on the kind of equipment used.

Hose-end sprayers are small sprayers that are screwed onto the end of an ordinary garden hose. The spray container varies in size from a half pint to one quart and will deliver from one to 15 gallons of spray when the contents are emptied. Insecticide is added to the sprayer on the basis of so many tablespoonfuls per gallon of spray delivered. The sprayers are put in operation by turning on the water and placing a thumb or other device over a small hole in the top of the lid. The insecticide is drawn from the container and mixed with the hose water as the water flows out the nozzle. One of the major disadvantages of this type sprayer is that wettable powder often plugs the nozzles. A big advantage is the constant pressure is that you need no pumping to maintain pressure in delivering the spray.

Compressed air sprayers include metal or plastic tanks that vary in size from one to three gallons. Air is pumped inside the sprayer with a plunger on the tank. The spray is delivered through an attached hose with a hand shut-off valve and a nozzle tip. Disadvantages of this type sprayer are that it must be pumped frequently to maintain pressure, the tank must be transported, the nozzle tips are of the low-volume type, a relatively long time is required to empty the tank and tanks rust unless they are made of stainless steel or plastic. In spite of these disadvantages, compressed air sprayers are useful for many smaller pest control jobs in and around the landscape.

Knap-Sac sprayers are compressed air sprayers that vary in size from three to five gallons and are strapped onto one's back. A handle pump is attached and is pumped continuously at a slow pace. The pumping builds up a pressure in the tank and allows the spray to be delivered through a hose and nozzle tip at an even, steady rate. It, too, is equipped with a hand shut-off valve. This type of sprayer is suited for spraying fairly large areas. Disadvantages are that the sprayers are expensive; loaded with water, they are quite heavy; and they must be pumped-up to maintain pressure. However, a stainless steel knap-sac sprayer should last many years and handle any spray job in the garden and around the landscape, except large tree spraying.

Wheelbarrow sprayers are manually or motor operated hydraulic sprayers mounted on a frame with one or two wheels. They generally have a capacity of 12 or more gallons. The motorless type sprayer usually requires one person to operate the pump and another to direct the spray stream. Wheelbarrow sprayers are more expensive, but are suited for bigger jobs.

Large Trees

The equipment mentioned so far is used primarily for small jobs and would not be practical for large tree spraying. The following equipment is for large tree spraying.

Mist blowers deliver concentrated insecticide to trees by means of a high-volume, high-velocity air stream. The insecticide is diluted primarily in air rather than in water. Spraying with a mist blower requires an experienced operator. Plant injury or poor distribution of the spray on the tree may result from an improperly operated machine.

Hydraulic sprayers are satisfactory for tree and shrub spraying and have been in use for a long time. Hydraulic machines deliver high-gallonage, high-pressure sprays. The spray is delivered through a specialized spray gun attached to a pressure hose. This is one of the most common types of sprayer used in controlling pests of shade trees.

Buying Equipment

Before buying a piece of spray equipment, keep in mind the size of the job to be done, kind of performance desired, kinds and amounts of insecticides to be used, amount of water needed per spraying, the size of the plants to be treated and amount of money to be spent. If you explain these facts to a spray equipment dealer, he or she will be able to recommend the correct piece of equipment for the job. Remember that a piece of equipment is no better than what it costs or the person who uses it, and all equipment must be serviced and cleaned frequently.

Accessory Equipment — Measuring equipment is necessary to accurately measure the required amounts of insecticides, thus ensuring better pest control results and less plant injury. This equipment includes a 1-quart measuring cup and a set of measuring spoons. They should be kept separate from those used in the home or work place and should be marked in some way to indicate they are for pesticide measurements only.

Alternative Products

Their Selection and Use for Insect and Mite Control on Ornamentals

Introduction

In the previous chapter, we discussed the integrated pest management process and the control options available. Recent interest in alternatives to traditional synthetic pesticides has resulted in numerous products containing botanicals, oils, soaps and microbial materials.

These alternative products often do not act in the same manner as traditional pesticides. The user must understand when these products can be used effectively and what special conditions must be met to be successful.

Oils

Oils are petroleum-or plant-based hydrocarbon chains that have insecticidal/miticidal activity.

The use of oil to kill insects and mites has been known to work since the 1700s. However, the early use of oil usually resulted in killing the plants as well as the insects. Oil came into widespread use to control insects and mites after oil-refining techniques were developed that would free the petroleum oils of unsaturated hydrocarbons, acids and highly volatile elements. Oil is effective against insects and mites because it suffocates or causes cell membrane destruction of the pests that it hits, as well as their eggs. Another advantage of oil is that no pest has been known to become resistant to its killing action.

At least three different types of oil are used for pest control: petroleum, summer or horticultural oil, petroleum dormant oil and citrus oil.

Petroleum, summer or **horticultural oil** is a lighter weight oil applied during the active growth of a plant, when green plant foliage is present.

The **dormant oil** is usually defined as a heavier weight oil applied in spring prior to bud break or in the fall after leaf drop.

Citrus oil is usually added to other pesticide formulations such as soaps and botanical pesticides.

What makes the identification of oils confusing is that summer oils can be used as dormant oils. However, do not use a dormant oil as a summer oil. The simplest method for identifying oils is to **READ THE LABEL**. If the label only mentions usage on dormant plants, it is a dormant oil. On the other hand, if the label mentions using the oil on green, leafy plants during the growing season, it is a summer oil.

If you do not want to rely only on the label instructions, there are three oil factors that you need to evaluate: oil volatility, oil viscosity and the unsulfonated residue rating.

Volatility is measured by the distillation temperature. This is the temperature that the oil comes out of heated crude oil at the refinery. A low distillation temperature produces a light oil. A high distillation temperature produces a heavy oil. The lighter oils evaporate faster and thus have less of a chance to cause plant damage (phytotoxicity). The heavy oils may coat the plant and either smother the leaves or destroy some of the cells. The result is phytotoxicity. The distillation temperature is probably the most important number to look for on the label.

Volatility and Oil Usage

Distillation Temperature	Primary Use	Dosage per 100 Gallons
412F	Summer	1.5-3 gal.
435F	Summer/Dormant	1.5-2 gal./Summer 3-4 gal./Dormant
438F	Dormant	2-4 gal.

Viscosity is the flow rate or thickness of an oil. It is measured by the time it takes a volume of the oil to flow through a small funnel opening. The label may say that the oil is a 60-second or 100-second oil. In the past, a lot of emphasis was placed on getting an 80-second oil or better. We feel that the volatility rating is more important.

The **unsulfonated residue** (UR) rating is an index of the quantity of oil free from unsaturated hydrocarbons. Look for oils with a minimum UR of 92 percent. Some oils are as high as 99 percent free.

Some of the better oils, especially summer oils, have distillation temperatures of 412F and UR = 96 percent.

Even with the best oils, phytotoxicity is always possible. However, this is the same as with standard insecticides! The following guidelines are recommended by most users and manufacturers of dormant and summer oils:

1. Do not apply the oils when the temperature is below 40F (4.4C) or above 100F (37.8C). If low humidity is accompanying the high temperature, oils have less of a chance of causing damage.

2. Do not apply oils if rain is a possibility or if the plant tissues are wet. The leaves must be dry and the oil must have a chance to evaporate.

3. Avoid spraying or getting drift on oil-sensitive plants.

4. Apply the oil according to the label rates. Always go light, not heavy.

5. When using dormant oils or high rates of horticultural oils, do not spray when plant buds are fully open and shoot elongation is occurring.

6. Do not spray plants when the humidity is expected to remain above 90 percent for 36 to 48 hours.

7. Leaf drop in the fall is not a reliable method for determining plant dormancy. It is better to wait until after several light frosts.

8. Oil-sensitive plants are: maple, hickory, black walnut, cryptomera, smoketree and many azalea.

9. Plants tending towards oil sensitivity are: beech, Japanese holly, redbud, Savin junipers, Photinia, spruce and Douglas fir.

Most oil labels contain a list of plants that are sensitive or tend towards sensitivity. Read them carefully. Most problems occur when oils are simply sprayed on everything in the landscape.

As with all pesticides, use oils only where needed. They do not need to be used as general cover sprays. Plants with a history of aphid, scale and mite problems are the best ones to target.

Soaps - Fatty Acid Salts

Soaps are made from fats reacted with a strong lye to form potassium or sodium salts of the fatty acid components. Fatty acid chains containing 6-10 carbon atoms have insecticidal/miticidal activity. These soaps, often called insecticidal soaps, apparently disrupt the respiratory systems and cell membranes.

Currently available soap products usually contain soaps derived from plant fats and oils. These are often considered "organic" in origin and are used by most organic gardeners.

Mammalian toxicity: Insecticidal soaps have the same general mammalian toxicity traits of any soap or detergent. Contact with mucus membranes, such as eyes or mouth, may cause temporary irritation or a burning sensation. Ingestion may cause vomiting and general gastric upset, but this normally results in no serious consequences. Some insecticidal soap concentrates contain up to 30 percent ethyl alcohol, which can cause intoxication at doses above several ounces; however, vomiting is likely to clear most of the alcohol from the system before it is fully absorbed.

Some insecticidal soap products contain additional insecticidal compounds such as pyrethrins or citrus oils. These alterations change the overall toxicity levels.

Uses: Insecticidal soaps are used as contact pesticides to control a wide variety of insects and mites. Generally, soft-bodied insects such as aphids, caterpillars, scale crawlers, leafhopper nymphs, mealybugs, thrips and whiteflies are the best targets. However, some products claim efficacy against Japanese beetle and flea beetle adults.

Soaps are commonly used in more environmentally sensitive areas such as around houses, in interiorscapes and where organic pesticides are requested.

Caution: Common household soaps and detergents have insecticidal properties when applied as 1-2 percent solutions in water. However, these compounds are **not registered for this purpose and plant injury may occur.**

Botanical Insecticides

These are pesticides derived or extracted from plants or plant parts. For control of ornamental insects and mites, pyrethrins, rotenone and neem (azadiractins) products are currently registered.

Pyrethrins

Pyrethrins are six related compounds extracted from dried flowers of the pyrethrum daisy, *Chrysanthemum cinerariaefolium*. When the ground-up flower itself is used, the product is called a pyrethrum. Most products use pyrethrins combined with synthetic synergists, usually PBO or MGK 264. These synergistic compounds increase the killing power of pyrethrins. Natural pyrethrum and pyrethrins are highly irritating to insect nervous systems and they cause quick "knock-down." However, many insects are able to break down the pyrethrins before death occurs and soon recover. The synergists help stop this break down.

Mammalian Toxicity: Pyrethrins are low in mammalian toxicity, with the oral LD_{50} between 1,200 and 1,500. However, cats are highly susceptible to poisoning from pyrethrins. When ingested, pyrethrins are usually broken down by stomach acids before absorption can occur. Pyrethrins are general irritants and repeated contact may cause skin irritation or allergic reactions.

Uses: Pyrethrins are contact poisons with extremely short residual activity. Exposure to sunlight, air and moisture will degrade them within hours. Pyrethrins are generally mixed with a synergist and rotenone to provide better action against a wider variety of pests.

Rotenone

Rotenone is an alkaloid toxin extracted from the roots of two tropical legumes, *Lonchocarpus* from South America and *Derris* from Asia. Most of the current rotenone comes from Peru, where it is often referred to as cubé root. "Cubé extracts" may appear on the label.

Rotenone is extracted with acetone or ether and the concentrate is used to make products. Some products simply use the powdered root.

Rotenone disrupts cellular respiration and death is relatively slow compared to most nerve toxins. Rotenone is extremely toxic to fish and is used as a fish poison by South American Indians or in water management programs. It is also synergized by PBO or MGK 264.

Mammalian Toxicity: Rotenone varies considerably in mammalian LD_{50} values (60-1,500), depending on the carrier used. Most ingested rotenone is detoxified efficiently via liver enzymes. Rotenone is more toxic by inhalation than by ingestion. High exposure may cause nausea, vomiting, muscle tremors and rapid breathing. Contact with rotenone may cause skin irritation and inflammation of mucous membranes.

Uses: Rotenone is a broad-spectrum contact and stomach poison that is most useful against leaf-feeding beetles and caterpillars. Rotenone degrades rapidly when exposed to air and sunlight. Alkaline materials, such as soaps, also speed rotenone degradation. Rotenone is usually mixed with pyrethrins to provide longer lasting residual and better killing power.

Neem

Neem oil is an extract from the neem tree, *Azadirachta indica*, which is grown in tropical and subtropical climates. The most commonly used compound is azadirachtin, a complex chemical that acts as an insect feeding deterrent and growth regulator.

Azadirachtin can be extracted from much of the neem tree, but most comes from oil pressed from seeds and seed kernels.

When neem is applied to a plant, it serves as a repellent, but if it is ingested, the compound affects insect egg laying and growth.

Mammalian Toxicity: Neem is low in toxicity and has an LD_{50} near 13,000. It rarely causes any irritation to the skin or mucous membranes. It has been used in India and Asia as a cleaner, disinfectant and medicine.

Uses: Currently registered products for ornamental pest control claim activity against a variety of sucking and chewing insects. Recent field trials have not confirmed significant repellency activity. However, good control of insects can be achieved if the insects are exposed while they are actively growing immatures - nymphs and larvae. Action can be slow because the insect often has to go through one or two molts.

Microbial Insecticides

Microbial insecticides are toxins derived from various bacteria and fungi. The most highly developed group of compounds are derived from the common bacterium, *Bacillus thuringiensis*, or "Bt" for short. The many different strains of this bacterium produce a variety of crystalline protein-like toxins that commonly have toxic activity against certain insect groups.

A second group of compounds have been derived from the soil fungal actinomycete, *Streptomyces avermitilis*. This fungus produces a variety of toxins called avermectins. Commercial pesticides derived from this group include ivermectin and abamectin.

BTs

Bacillus thuringiensis is found in soils around the world. Scientists have known for a long time that strains of this bacterium produced crystalline protein toxins that had insecticidal activity. However, it was not until the late 1960s that fermentation technology was developed that allowed for the large-scale rearing of this bacterium and extraction of the toxin.

Though several strains of the bacterium were known to be toxic to insects, the most widely developed materials were derived from *Bt.* var. *'kurstaki'*. The toxins derived from this variety are toxic only to the larvae (caterpillars) of butterflies and moths. Products with ornamental labels are: Biobit™, Caterpillar Attack™, Dipel™, Larvo-Bt™, Javelin™ and others.

In the early 1980s, another strain, *Bt.* var. '*israelensis,*' was developed that has activity against the larvae of certain flies, especially mosquitoes. These products are not effective against the dipterous leafminers of ornamentals.

In the late 1980s, the third strain, *Bt.* var. '*tenebrionis*' (=*Bt.* var. '*san diego*'), was developed that has activity against certain beetle larvae. The elm leaf beetle has been the most common ornamental pest target. product with the ornamental label are: M-Trak™ and Novodor™.

Apparently, Bt crystalline toxins attack the cell membranes of the gut lining. This causes the insect to stop feeding as soon as it ingests the Bt product and death often occurs several days after gut bacteria have invaded the insect body cavity. To get maximum efficacy out of Bt products, it should be targeted towards the younger larvae that have less- developed gut linings.

Mammalian Toxicity: Bt toxins are considered relatively non-toxic to mammals and other animals. Some formulations may have carriers that can cause eye irritation, but this is not caused by the Bt toxin.

Uses: Bt products are useful alternatives to standard pesticides where caterpillars and beetle larvae are a problem. Unfortunately, most of the Bt products are not effective once the larvae have exceeded half of their growth. Therefore, continuous monitoring of caterpillar or elm leaf beetle populations must be performed to target applications correctly. Where reinfestations regularly occur, as in the elm leaf beetle, several applications may be necessary to achieve satisfactory control.

Entomopathogenic Nematodes

Nematodes are commonly called roundworms. They comprise a very large and diverse group that includes general scavengers, predators, plant-infesting and animal-infesting species. A certain group of nematodes attacks insects by entering the insect gut or body, regurgitating a lethal bacterium and reproducing in the insect cadaver. These are called entomopathogenic. These nematodes have a mobile, infective juvenile (the J3 stage) that is microscopic and can be sprayed through conventional equipment. These infective juveniles are quite resistant to many chemicals, but they can not withstand rapid drying or prolonged contact with sunlight.

Numerous species belong to the genera *Steinernema* or *Heterorhabditis.* Both steinernemid and heterorhabditid nematodes have been found in native soils. However, many of the strains currently marketed and under development have come from foreign countries.

Up to the early 1980s, attempts to use these nematodes as biological controls were rarely successful. The nematodes are weakly persistent and rearing sufficient numbers was costly.

In the 1980s, several companies developed large-scale rearing techniques, often using large-scale fermentation technology. This allowed for the production of nematodes in sufficient quantity to be commercially useful.

Because the nematodes are considered animals rather than microbial agents, they are not required to be regulated as pesticides by the U.S. EPA.

Mammalian Toxicity: Entomopathogenic nematodes are noninfective to mammals, birds, fish or other animals except certain insect groups. Some of the residues from nematode production or formulation materials may cause eye irritation, so eye protection during mixing may be required. Field studies also have indicated that thenematodes rarely come into contact with beneficial insects and mites.

Uses: Since entomopathogenic nematodes are exempt from U.S. EPA registration, caution must be taken when evaluating supplier claims of efficacy. Current research indicates that the nematodes have been useful in reducing black vine weevil larval populations, especially in containerized plants. Other studies have indicated activity against certain borers (when the J3s are applied to borer holes or frass), leafminers and soil-inhabiting pests.

The infective juveniles are applied at $1x10^6$ to $2x10^9$ J3s to the acre. Because they are living organisms, they must be applied so as not to expose them to direct sunlight for any length of time, and they must be allowed to contact moist surfaces so as not to dry rapidly.

Detection and Monitoring of Insects and Mites

on Woody Ornamentals and Herbaceous Perennials

Introduction

Integrated pest management usually has an emphasis on the selection and use of the three control options — chemical, biological and cultural. However, even though a control option may be selected, one still has to determine when to use the control. Therefore, **monitoring** pest populations (as well as the biological controls) becomes central to determining when controls are to be used.

Pest monitoring is simply using those techniques and tools that allow the pest manager to determine **when** and **if** control action is needed.

Preventive Pesticide Applications

Unfortunately, many pest managers simply apply a pesticide for control of anticipated insect and mite pests through regularly scheduled "programs." These applications may be called "preventive-," "round-" or "calendar-" timed applications.

Though there are numerous reasons stated for making preventive applications that seem appropriate, there are certain problems associated with this strategy:

1. A damaging pest population may not have occurred, so the pesticide application was not needed, leading to questions of environmental concern;
2. Unnecessary pesticide applications may encourage development of pest resistance or accelerated pesticide degradation, and the usefulness of the pesticide may be lost;
3. Merely having the pesticide in the tank or on the fertilizer granule increases the chance of pesticide misapplication;
4. Making a pesticide application, whether needed or not, reduces the professional status of the manager/applicator because no effort was made to see if the pest was actually present.

Occasionally, preventive pesticide applications are warranted. Where pests are certain to occur (because of previous monitoring or predictive models indicate that a major pest outbreak will occur) or where pests under quarantine are present, preventive pesticide applications may be more effective than applications made after the pest has become active. Some pests, like borers and leafminers, are more difficult to manage after the larvae have entered the host plant. Therefore, preventive applications of pesticides to "protect" the plant from invasion are preferable. Some recently developed insecticides with sustained residual ability or those with insect growth regulator action are often more effective when used as preventives.

Reactive Pesticide Applications

On the other hand, many pests are not expected and applications are made after some damage has been detected.

These applications are best termed "reactive" treatments. These applications are usually made because a damaging pest population was missed. Problems associated with making reactive applications are:

1. Since poor sampling or monitoring was used, damage has occurred and people are upset;
2. Damaging or noticeable pest populations may be more difficult to control;
3. If the preventive application did not work, additional applications may be necessary to control the pest.

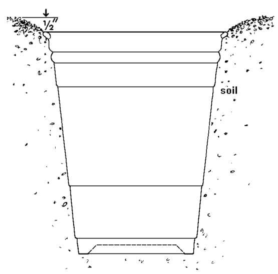
Alternative Tools and Strategies for Timing of Controls

Alternative strategies for timing of controls are available and should be used to reduce the problems associated with preventive and reactive pesticide applications. Active sampling of pest populations is the heart of all integrated pest management programs. Before proper controls can be applied, you need to know if a pest is present and if its population or potential population will cause significant damage. Unfortunately, in plant nurseries where no pests can be allowed on the plants before sale, the mere presence of pests warrant pest management.

The single best sampling device is the traditional **visual inspection**. However, because many of the pests or their eggs can be small, a 10-15X magnification hand lens is essential when performing visual inspections. In fact, low cost dissecting microscopes (15-45X) should be obtained by anyone making many inspections. These microscopes can also help determine if small mites or scales have been killed after a pesticide application. To assist in visual inspections, you should also have a strong, non-folding utility knife (for checking under loose bark or splitting stems), good pruning shears (to remove pieces of branches or splitting stems), a spade (for digging around plant roots) and several plastic bags (for taking samples back to the microscope or for mailing to a laboratory for identification).

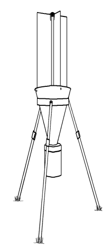
In addition to visual inspection, several other trapping and sampling tools are useful for detecting insects and mites on trees, shrubs and perennials:

1. **Beating Trays** (=Beating Boards) are cloth sheets stretched on a frame, cardboard or plastic boards (often 10 to 20 inches square) that are held under plant foliage. The plant branch or foliage is struck sharply with a stick or hand to dislodge any insects or mites onto the tray. The number of pests are counted to determine if a treatment is needed.

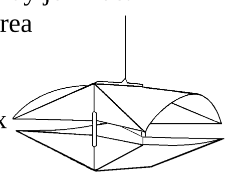


Pitfaff Trap in Ground

2. **Pitfall Traps** are cups or cans sunk into the soil or turf near ornamental plants to capture crawling insects such as black vine weevil adults. The 16 to 20 oz. plastic cups used for cold drinks make ideal pitfall traps. These are easily installed in the ground using a 4.25-inch golf course cup cutter. Pull a soil or turf plug to the depth of the plastic cup. Obviously, a pitfall trap should not be used in areas where people may twist an ankle, but they can be us next to flower beds or under a tree.


Insect Light Trap

3. **Light Traps** that use "black lights" attract and capture the adults of many moth, beetle and true bug pests. Use of black light traps is not for the novice, since hundreds of different species of insects can be caught in one night. However, nursery and landscape managers may join local IPM groups that run a light trap in an area and report insect activity.


Pheromone Trap

4. **Pheromone Traps** contain the sex and/or attractant chemicals used by clearwing moth borers, pine tip moths, Japanese beetles and other pests. These can be used, like light traps, to determine specific insect activity periods.

5. **Trap Logs** are often used to capture the adults of various wood-boring beetles, especially bark beetles. Freshly cut pieces of host tree trunks or limbs are placed in plantations where the pest is suspected to be active. The trap logs are inspected periodically to see if the adults have moved to their oviposition sites so treatments can be properly timed. Occasionally enough trap logs are used to attract the majority of pest insects for egg laying. After egg laying but before the larvae mature, these trap logs are burned or chipped, thereby destroying the pests.

Host Phenology Models are developed by monitoring *plant* (the host) activity compared to various *pest* activities. The flowering times of various trees and shrubs are commonly used to time applications of various insecticides. This technique is best used by keeping a yearly record of plant and pest activities. For example, if you find that pine needle scale crawlers appear at the same time that horse chestnuts bloom, then horse chestnut bloom can be your "trigger" for applying controls for the pine needle scale in your area.

Weather-Mediated Predictive (Degree-Day) Models are developed by monitoring weather parameters [usually temperature, as Degree-Days (DD)] and comparing these to insect or mite activity. Though these models help determine better timing of controls, they still do not answer the question of whether the pests are present in sufficient numbers to cause damage or warrant controls. Models have been developed and published for a variety of ornamental insect and mite pests. However, you should carefully keep local records of temperature and pest activity to better calibrate published targets. For example, a published DD target for pine needle scale first generation of crawlers is 298-488 DD base 50F. If you find that the local pine needle scale crawlers are active from 350-500 DD, then you should modify the chart to reflect this later emergence pattern. See information on the next page.

Pest Mapping is simply good record- keeping. Most insect and mite pests require specific plants and weather or habitat conditions to build to damaging populations. Generally, trees, shrubs or perennials that have had insect or mite problems in the recent past are most likely in need of attention. In short, if a damaging pest population occurred last year, the probability is much higher that the same thing will occur again. Keeping a useful record of pest occurrence is pest mapping.

Likewise, certain plants appear to be prone to certain pests. Little-leaf lindens will certainly be defoliated if Japanese beetles are in the area. European birch is usually attacked by birch leafminers every year and, eventually, will come under lethal attack by the bronze birch borer. These plants are **KEY PLANTS**. Pest mapping for landscape management firms should be performed by making a plant survey of the customer's property to determine what key plants are present. These plants should then be placed on a master routing schedule for inspection and treatment at the appropriate time. Likewise, nursery producers should highlight the plantings of key plants on their nursery production maps.

Degree-Days:

Their Calculation and Use in Management of Turf and Tree/Shrub Pests

Reason for Using Degree-Days

Degree-Days (DD) are a method of accounting for heat units. Power companies use cooling degree-days and heating degree-days to calculate how much energy a customer needs to cool or heat a house. Plants and animals that do not regulate internal temperatures (often called "cold-blooded") vary in their physiological development, or metabolism according to what temperature they are subjected to. In short, these organisms develop rapidly at warm temperatures and slowly at cool temperatures. Therefore, we can treat plants and animals like a house — the more energy (heat) added, the faster things happen. Conversely, the cooler (less energy) the organism, the slower it develops. If this rate of development related to temperature can be determined, a prediction of insect and/or plant development or activity can be made.

Using DD as a predictor takes into account cool vs. warm weather. Calendar scheduling of controls will usually be too early or too late unless the year is an "average year."

Temperature Thresholds

Fortunately, most plants and animals develop within a specific range of temperatures. If the organism drops below a certain temperature, called the **lower threshold**, no development occurs (see Figure 1). Above this lower threshold, the rate of development increases with temperature in an almost straight-line fashion.

Most organisms also have an **upper threshold** temperature at which development begins to deteriorate because of heat shock. If the organism's temperature rises too far above this threshold, it will die. In nature, most insects and plants find habitats that have temperatures above the lower threshold for sufficient time to complete a generation of development, but rarely exceed the upper threshold temperature.

Several field crops and ornamental plants are occasionally grown outside their original habitats. Corn plants shut down their development above 86F and Balsam fir tends to stop development above 90F. Unfortunately, most state crop-reporting services are based on corn DD models that have the relatively low upper threshold of 86F. Most insect pests and other trees and shrubs do not stop development until temperatures reach 100-110F.

In reviewing DD thresholds for many insects and plants, several lower thresholds seem to be common. Most soil-dwelling insects and some cool-season plants (i.e. conifers, maples) seem to have lower thresholds of 40F (5C) or 45F (7C). Most above ground feeding insects (turfgrass surface feeders and most tree/shrub scales and caterpillars) seem to have a lower threshold of 50F (10C).

For all practical purposes, associating insect activity and plant phenology with 50F degree-days (DD_{50}) is generally satisfactory.

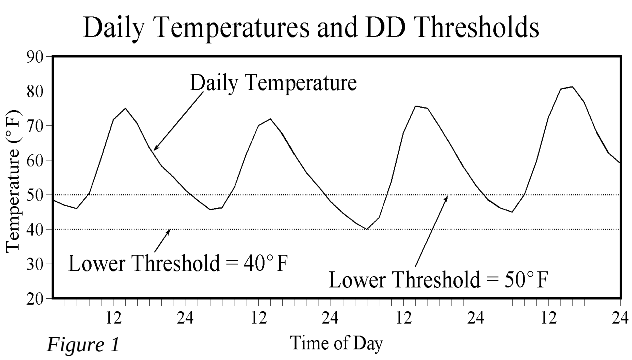


Figure 1

Methods of DD Calculation

There are many methods for calculating DD. The easiest method is to use the average temperature method (see Figure 2). This method calculates the day's DD units by subtracting the lower threshold from the average daily temperature. Ave T minus lower threshold (50) equals DD50.

Table 1 illustrates this technique with several daily temperatures.

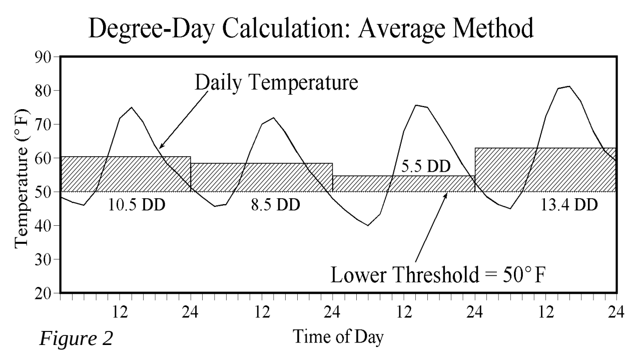


Figure 2

Table 1. DD_{50} units for days with varying maximum and minimum temperatures

Example	*Max T*	*Min T*	*Ave T*	*DD_{50}*
1	50	30	40	0[1]
2	60	40	50	0[2]
3	70	40	55	5
4	75	55	65	15

[1]/ If the average temperature is below the threshold, a "0" is used instead of negative units.

[2]/ If the average temperature is equal to the threshold, a "0" is used.

Many state reporting services use a **sine wave calculation** (see Figure 3) or a small time-unit calculation. The sine wave method assumes that the rise and fall of daily temperatures approximates a sine wave pattern. This method also allows for the accumulation of those units of heat energy in a day when the temperature was above the threshold. In example 2 from Table 1, the temperature was above 50F for part of the day and the insects were developing. The average method estimated that no activity occurred while the sine method would have estimated about 0.3 DD_{50} units for that day.

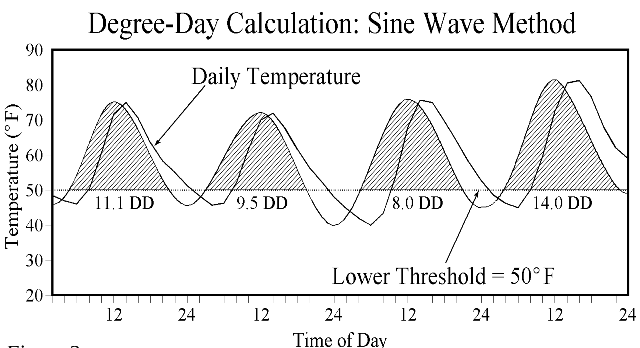


Figure 3

The **small time-unit calculations** are continuous temperature monitors that read the temperature every few minutes and use that fraction of a day to calculate the DD.

In retrospect, use caution when looking at DD reports. You need to know what thresholds were used (especially if a low upper threshold is in effect) and the method of calculation (ave, sine, etc.).

Conversion of Degree-Day Units

Changing from DD-Centigrade (%C) to DD-Fahrenheit (%F) is very easy using the following formulae:

DD%C = DD%F x 5/9

DD%F = DD%C x 9/5

Note that (± 32%) is not used in this conversion.

Converting between Ave-DD and Sine-DD is a bit more complicated and should be done with care. Each geographic location usually has a constant that can be added or subtracted for this conversion. This constant is determined by calculating Ave-DD and Sine-DD using 30-year average temperatures.

If you need to convert between average and sine DDs, you should probably seek the assistance of a crop consultant or Extension agent.

Determining Degree-Day Targets for Pests

There are four methods generally used to determine DD- pest activity association:

1. growth chamber studies;
2. field data using regression analysis;
3. field data using lowest coefficient of variation (CV) analysis;
4. experienced guess-trial and error using average yearly temperatures.

The first three methods generally require special equipment, complicated calculations and detailed data bases. The "experienced guess" technique makes use of past experience to form a rough target DD. This target is then modified yearly ("trial and error") as new information is gathered using actual DD calculations.

To use the experienced guess technique, obtain an annual weather summary from NOAA (National Oceanic and Atmospheric Administration, National Climatic Data Center, Federal Building, Asheville, NC 28801) and calculate the $AveDD_{50}$ using the normal maximum and minimum temperatures.

Chart the cumulative DD_{50} for each day from January 1 through August. See the following example:

Charting Cumulative Degree-Days (DD) — Pest Activity, an example.

Date	DD_{50}	Pest Activity		
.	.			
.	.			
May 1	143			
May 2	150			
May 3	158			
May 4	166			
May 5	175			Lilac Borer
May 6	183			Adults
May 7	192		Holly Leaf Miner	
May 8	201		Adults	
May 9	210			
May 10	220			
May 11	230			
May 12	240			
May 13	250	Pine Needle Scale		
May 14	261	Crawlers		
May 15	272			
May 16	284			
May 17	296			
May 18	308			
May 19	320			
May 20	332			
May 21	341			
May 22	353			
.	.			
.	.			

Let us say that you remember that you usually see pine needle scale crawlers in the third week of May, holly leaf miner adults in the first and second week of May and lilac borers in your pheromone traps in the first three weeks of May. Your target DDs would then be 250-332, 143-261 and 143 to 332, respectively.

The next season you accumulate actual DDs_{50} and you notice that the pine needle scale crawlers were active from 290 to 340 DDs. This indicates that the prediction should be shifted slightly to more DD_{50} units.

Degree-Day Targets for Ornamental Plant Pests

In 1988, Warren Johnson of Cornell University produced one of the most comprehensive lists of insects and mites that attack trees and shrubs and associated Degree-day (DD) activity periods. These DD periods were not developed using rigorous observations and model development. They were developed by taking yearly notes of insect and mite activities.

These notes were then compared to DD charts for those same years and a range of DDs (base 50F) were recorded.

The original list of insects and mites has been reduced to those that are of importance to Tennessee operations (see Table 2).

Table 2. Common names, scientific names of insects and degree days (DD_{50}) affecting ornamental plants.

		Growing Degree Days					
Common Name	Scientific Name	min1	max1	min2	max2	min3	max3
Aphids		7	120	135	250		
Elm bark beetles	*Scolytus* sp., *Hylurgopinus* sp.	7	120				
Elongate hemlock scale	*Fiorinia externa*	7	120	360	700	2515	2625
European red mite	*Panonychus ulmi*	7	58	240	810		
Golden oak scale	*Asterolecanium variolosum*	7	121	802	1266		
Kermes oak scales	*Allokermes* sp.	7	91	298	912		
Oak leaftier	*Croesia semipurpurana*	7	35				
Oystershell scale	*Lepidosaphes ulmi*	7	91	363	707		
Spruce spider mite	*Oligonychus ununguis*	7	121	192	363	2375	2806
Taxus mealybug	*Dysmicoccus wistariae*	7	91	246	618		
White pine aphid	*Cinara strobi*	7	121	121	246	1917	2271
Tuliptree scale	*Toumeyella liriodendri*	12	121	2032	2629		
Cooley spruce gall adelgid	*Adelges cooleyi* - on spruce	22	92	1500	1775		
Juniper scale	*Carulaspis juniperi*	22	148	707	1260		
Magnolia scale	*Neolecanium cornuparvum*	22	91	246	448	2155	2800
Pine bark adelgid	*Pineus strobi*	22	58	58	618		
Spruce bud scale	*Physokermes piceae*	22	12	1	912		1388
European pine shoot moth	*Rhyacionia buoliana*	34	121				
Euonymus scale	*Unaspis euonymi*	35	120	533	820		
European fruit lecanium	*Parthenolecanium corni*	35	145	1266	1645		
Fletcher scale	*Parthenolecanium fletcheri*	35	148	1029	1388	2515	2800
Hemlock scale	*Abgrallaspis ithacae*	35	121	1388	2154		
Balsam twig aphid	*Mindarus abietinus*	58	120				
Honeylocust plant bug	*Diaphnocoris chlorionis*	58	246				
Maple bladdergall mite	*Vasates quadripedes*	58	148	98	155		
Pine tortoise scale	*Toumeyella parvicornis*	58	148	618	1050		
Eastern tent caterpillar	*Malacosoma americanum*	90	190				
Gypsy moth	*Lymantria dispar*	90	448				
Cooley spruce gall adelgid	*Adelges cooleyi* - on fir	120	190	1500	1775		
Nantucket pine tip moth	*Rhyacionia frustrana*	121	448	1514	1917		
Woolly larch adelgid	*Adelges laricis*	121	192				

Table 2 continued. Common names, scientific names of insects and degree-days (DD_{50}) affecting ornamental plants.

Common Name	Scientific Name	Growing Degree Days min1	max1	min2	max2	min3	max3
Zimmerman pine moth	*Dioryctria zimmermani*	121	246	912	1917	1917	2154
Black vine weevil	*Otiorhynchus sulcatus*	148	400				
Cankerworms (inch worms)		148	290				
Dogwood borer	*Synanthedon scitula*	148	700				
Lilac borer	*Podosesia syringae*	148	299				
Birch leafminer	*Fenusa pusilla*	190	290	530	700		
Holly leafminer	*Phytomyza ilicis*	192	290	246	448		
Honeylocust pod gall midge	*Dasineura gleditschiae*	192	229				
Imported willow leaf beetle	*Plagiodera versicolora*	192	448				
Larch sawfly	*Pristophora erichsonii*	192	299				
Linden looper	*Erannis tiliaris*	192	363				
Native holly leafminer	*Phytomyza ilicicola*	192	298	1029	1266		
Rhododendron borer	*Synanthedon rhododendri*	192	298	533	707		
Rhododendron gall midge	*Clinodiplosis rhododendri*	192	363				
Lace bugs	*Corythuca* sp.	239	363	1266	1544		
Arborvitae leafminers	*Argyresthia* sp.	245	360	533	700	1700	2100
Boxwood psyllid	*Cacopsylla (=Psylla) buxi*	290	440				
Locust leafminer	*Odontota dorsalis*	298	533	1029	1388		
Pine needle scale	*Chionaspis pinifoliae*	298	448	1388	1917		
Elm leaf beetle	*Xanthogaleruca luteola*	363	912				
Elm leaf miner	*Fenusa ulmi*	363	530				
Larch casebearer	*Coleophora laricella*	363	618	2375	2805		
Twospotted spider mite	*Tetranychus urticae*	363	618				
Bronze birch borer	*Agrilus anxius*	440	800				
Azalea whitefly	*Pealius azaleae*	448	700	1250	1500	2032	2150
Boxwood leafminer	*Monarthropalpus buxi*	448	700				
Lace bugs	*Stephanitis* sp.	448	618	802	1029		
Mountain ash sawfly	*Pristiphora geniculata*	448	707				
Oak skeletonizer	*Bucculatrix ainsliella*	448	707	1798	2155		
Spruce needle miner	*Endothenia albolineane*	448	802				
Greenstriped mapleworm	*Dryocampa rubicunda*	533	1645				
Bagworm	*Thyridopteryx ephemeraeformis*	600	900				
Cottony maple scale	*Pulvinaria innumerabilis*	802	1265				
Oak spider mite	*Oligonychus bicolor*	802	1266				
Roundheaded apple tree borer	*Saperda candida*	802	1029	1514	1798		
Honeylocust mite	*Eotetranychus multidigituli*	912	1514				
European elm scale	*Gossyparia spuria*	1029	1388				
Japanese beetle	*Popillia japonica*	1029	2154				
Walnut caterpillar	*Datana integerrima*	1029	1514				
Dogwood sawfly	*Macremphytus tarsatus*	1151	1500				
Tuliptree aphid	*Macrosiphum liriodendri*	1151	1514	1917	2033		
Fall webworm	*Hyphantria cunea*	1266	1795				
Maple trumpet skeletonizer	*Epinotia aceriella*	1388	2032				
Twobanded Japanese weevil	*Callirhopalus bifasciatus*	1644	2271				
Locust borer	*Megacyllene robiniae*	2271	2805				

Growing Degree Days (GDD) = average cumulative degree days with a threshold of 50F.

Min1-Max1, etc. = range of GDD during which pest is susceptible to control. If more than one range of numbers appears, multiple generations and/or control periods are expected.

Degree-Day Accumulation Chart

Year_______

Date	Max Temp	Min Temp	Max T + Min T 2	DD50[1] (Ave T)-50	Cumulative DD50

[1] Remember, a negative number should be changed to a 0 for the day.

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COOPERATIVE EXTENSION WORK IN AGRICULTURE AND HOME ECONOMICS
The University of Tennessee Institute of Agriculture, U.S. Department of Agriculture,
and county governments cooperating in furtherance of Acts of May 8 and June 30, 1914.
Agricultural Extension Service
Billy G. Hicks, Dean