AN INTRODUCTION TO TREE HEALTH PROBLEMS

Historical Impact of Tree Health Problems

Trees and woody ornamentals in landscapes, woodlots, and forests are subject to a wide variety of problems that threaten their health. These problems can affect the aesthetics of the tree or can pose more serious consequences such as disfigurement, economic loss due to reductions in yield and quality, and tree death. Diseases have also changed the composition of the forest and landscape. Until the early 1900’s, the American chestnut was one of the most dominant and important hardwood tree species in the forests of the eastern United States. It was prized for its commercial value as a source of lumber, pulpwod, poles, tannins, railroad ties, and edible nuts. With the introduction of the fungus *Cryphonectria parasitica*, a species that was not native to the U.S., chestnut trees became infected with the chestnut blight fungus and the tree was almost completely eliminated from the forest. Today, sprouts continue to grow from old stumps although they usually succumb to disease.

Dutch Elm Disease is another example of a disease that changed our city and town streets and greens. The fungus *Ophiostoma ulmi*, along with one of the insects that transmits it, were introduced to the U.S. on logs imported from Europe. The American elm (*Ulmus americana*) was highly susceptible to these exotic pests and quickly succumbed to infection. Since many of the elm trees were planted in rows along city streets and parks, the fungus easily spread from tree to tree through root grafts and feeding activities of the beetle.

Because of the diversity of tree health problems and causal factors, it is important to learn to recognize them, understand what causes them, and why and when they occur. It is also helpful to understand their importance or relative impact. This information is helpful in order to prevent the problems from occurring or, if they do occur, to properly manage them.

What is Disease?

Plant disease can be defined in many ways but one of the simplest definitions describes disease as any condition in a plant caused by living or nonliving agents that interferes with its normal growth and development. Diseases or plant health problems can impact plants in many ways since all parts of a plant can be affected including flowers, leaves, fruits, seeds, stems, branches, growing tips, and roots.

Many different factors can cause plant health problems. These factors can be divided into two groups based on whether they are living or nonliving. Nonliving disease agents, often called abiotic agents, include factors such as environmental stress or cultural care. Living disease agents, called biotic agents or plant pathogens, include microorganisms such as fungi and bacteria. Both abiotic and biotic agents will be described in greater detail in the section “Types of Disease Agents.”
How Does Disease Occur?

In order for disease to occur, three factors must be present. Because of this, disease is often pictured as a triangle having three equal sides. Each side of the triangle is necessary in order for disease to occur. One side of the triangle represents the host plant, the second side represents the causal agent or factor, and the third side represents the environmental conditions that are necessary in order for the other two sides to interact (Figure 1). When one or more sides of the triangle are missing, the triangle collapses and disease will not occur (Figure 2). For example, scab of crabapple is a very common disease in the Connecticut landscape. The “disease triangle” for this disease consists of the host plant, a susceptible variety of crabapple; the causal factor, the fungus *Venturia inaequalis*; and the proper environment, typically a cool, wet spring during which the young, emerging leaves stay wet for extended periods of time. When all three of these factors are present, scab will develop. If one component is missing, perhaps the spring weather is hot and dry and not favorable for disease development, disease will not occur since one side of the triangle is not present and the triangle collapses.

![Figure 1. The Disease Triangle: All components are present and disease occurs.](image1)

![Figure 2. The Disease Triangle: One of the components is missing (Causal Agent) so disease does not occur.](image2)

Types of Disease Agents

As previously mentioned, the two main categories of agents capable of causing plant disease are abiotic (nonliving) and biotic (living) factors. In natural settings, it is not uncommon for plants to be affected by both abiotic and biotic problems and it is often difficult to determine which came first. However, in many cases, plants that are initially stressed by abiotic factors will be weakened and therefore predisposed to biotic problems. For example, rhododendrons whose roots have been weakened by drought
stress are more susceptible to the fungal root rot caused by *Armillaria* than their healthy counterparts.

**Biotic Agents**
Unlike abiotic agents, biotic agents are able to spread from plant to plant. This is an important attribute since the number of diseased plants can increase over time as a direct result of the growth, multiplication, and movement of the causal agent.

**Fungi**
The majority of plant diseases are caused by fungi. There are well over 100,000 different species of fungi and only a surprisingly small portion of them are capable of causing plant diseases. Fungi are similar to plants but lack chlorophyll and the conductive or vascular tissues that are found in ferns and seed plants. Fungi are small (usually microscopic) organisms that consist of a mass of filaments or threadlike strands called hyphae. The primary means of reproduction and spread of fungi is by spores. Many fungi produce more than one type of spore during their life span and this often influences how diseases are spread.

The primary way that fungi infect plants is through direct penetration of tissues, although they also infect through natural openings such as stomates, hydathodes, and lenticels, or through wounds. In most cases, fungi require free water on plant surfaces in order to infect. Because of this environmental criterion, fungal diseases are frequently more common after periods of wet weather or when overhead irrigation is used. Fungi are primarily spread by wind, splashing water (from rain or irrigation), insects, and through cultural practices (e.g., on pruning shears, on pots, or in contaminated soil).

**Bacteria**
Bacteria are very different from fungi and are single-celled microorganisms that do not have an organized nucleus. As with fungi, only a small percentage of bacteria found in nature are capable of invading living plants and causing plant disease. Bacteria have cell walls and most plant-pathogenic bacteria are rod-shaped. Bacteria reproduce primarily by cell division. This can occur in a short period of time and their initial presence or growth within a plant is usually not visible.

Unlike fungi, bacteria cannot invade plant tissues that are intact and healthy. As a consequence, most infections occur through wounds. Bacteria also infect through wounds made by insects during their feeding activities and through natural openings in a plant such as nectaries or stomates. Bacteria are spread from plant to plant by splashing water (from rain or irrigation), by insects, and through a variety of cultural practices (e.g., as contaminants on pruning shears, in plant or soil debris in pots). Bacteria can also be transmitted by seeds from infected plants.

**Phytoplasmas**
Phytoplasmas are a relatively new type of disease agent that are closely related to bacteria but lack a rigid cell wall. These organisms used to be called mycoplasma-like organisms or MLO’s. As with bacteria, phytoplasmas have no organized nucleus and
are microscopic and unicellular. They can be irregular and amoeba-like or spiral in shape. Phytoplasmas are tissue-specific and only live in the phloem or the nutrient-transport system of their plant hosts. Most phytoplasmas are incapable of living outside of their plant host or insect vectors.

Since phytoplasmas cannot survive as free-living microorganisms, they are incapable of infecting plants without “outside” assistance from insect vectors or by mechanical means of transmission. As a consequence, the primary way that phytoplasmas are spread is by phloem-feeding insects such as leafhoppers. Phytoplasmas can also be spread mechanically by grafting infected plant parts onto healthy plants.

**Viruses and Viroids**

Viruses are unique plant pathogens since they consist of nucleic acid and a protein coat and have no cellular structures. Additionally, viruses are unable to replicate or reproduce without the aid of the components of the plant host cell. Viroids are even more simplistic than viruses since they lack a protein coat and only consist of nucleic acid.

Because of the nature of these disease agents, wounds are necessary in order for viruses and viroids to infect. Therefore, the primary means of spread is through the feeding activities of a number of insects, predominantly aphids, whiteflies, and leafhoppers. Viruses can also be spread by nematodes and in infected pollen. Human activities are also very important for spread of these disease agents. Included among these are grafting and mechanical transmission associated with the handling of infected plant material.

**Nematodes**

Nematodes are tiny, translucent roundworms, oftentimes just barely visible to the naked eye. As with fungi and bacteria, only a small portion of nematodes found in nature are parasitic to plants. Most nematodes have three life stages: egg, larva, and adult. The latter two stages are most damaging to plants. Plant-parasitic nematodes are obligate pathogens and have developed specialized structures called stylets, which allow them to pierce plant cells and extract cell contents.

Nematodes can infect plants through direct penetration. This usually occurs at the tip of a root. They also infect through wounds, through natural openings, and through the activities of certain insects that serve as vectors. Nematodes are also spread by infected plant material and by contaminated soil and plant debris.

**Abiotic Agents**

Plant health problems attributed to abiotic agents can also be referred to as disorders rather than diseases. Both terms are used to describe the same types of abnormalities in a plant although disorder usually implies the causal factor is nonliving whereas disease usually implies the causal factor is a living agent. Abiotic disease agents can be categorized as being cultural or environmental. These types of agents are often overlooked as probable causes of plant health problems because they are very difficult...
to identify since they cannot be cultured or viewed microscopically. As a consequence, the ability to pinpoint the causal factor requires close review and examination of the cultural and environmental history of the plant in question.

Environmental Factors
Many types of environmental factors cause plant diseases. Among these are unusual precipitation patterns resulting in drought or waterlogged soils, limited snow cover, excessive winds, lightning, hail, late spring or early autumn frosts, and extreme temperature fluctuations, especially during the winter. Air pollution is another important factor. Among the pollutants encountered in Connecticut are ozone, hydrogen fluoride, sulfur dioxide, ethylene, and peroxyacyl nitrate. Some of these compounds are more problematic in glasshouses and others primarily occur outdoors.

Environmental disease agents result in a wide variety of symptoms. For example, drought or dry soil conditions result in root damage and death. Non-woody feeder roots, usually located in the top 15 inches of soil, are particularly sensitive and are the first ones affected. Without moisture, these roots shrivel and die. When these roots become nonfunctional, a water deficit develops since the roots cannot provide water to the top of the plant. Symptoms of drought vary with the plant species and the severity of the water deficit but are often not evident until sometime after the event has occurred—even as much as one or two years later. Symptoms include loss of turgor in needles and leaves, drooping, wilting, yellowing, premature leaf or needle drop, bark cracks, and twig and branch dieback. Leaves on deciduous trees often develop marginal scorch and interveinal necrosis whereas needles on evergreens turn brown. Drought-stressed trees and shrubs can also exhibit general thinning of the canopy, poor growth, and stunting. In extreme cases, drought can result in plant death.

Cultural Factors
Cultural factors associated with plant health problems are quite diverse. Among the common factors are site and soil attributes (e.g., pH, organic matter, drainage, soil type), planting practices (e.g., preparation of the rootball and planting hole, planting too deep or too shallow), plant hardiness, construction activities resulting in soil compaction or severing of roots, and mechanical injuries from lawn mowers and string trimmers. Other types of problems result from incorrect or improperly timed pruning, incorrect mulching, fertilizing practices (e.g., incorrect timing, inappropriate applications resulting in toxicities or deficiencies), and watering practices (e.g., too late in the day, too much or too little, and frequent, shallow watering).

Another type of cultural agent that can result in plant damage and death involves chemicals. Included in this category are de-icing salts and misapplied pesticides, particularly herbicides. For example, misapplied herbicides can result in damage that varies with the particular compound and plant species. Symptoms can develop several days to weeks after exposure or, in some cases, not until the following spring. Symptoms include chlorosis, necrotic spotting, marginal scorch, twisting, growth abnormalities, leaf/needle drop, dieback, general decline, and plant death.
As with environmental factors, cultural factors can affect plant health in many ways and result in a wide range of symptoms. For example, when mulches are applied too close to the base of a plant and too thick, they can result in root and crown rots and asphyxiation of roots, respectively. This can cause plant decline and death.

For more detailed information on many of these abiotic disease agents, please refer to the Fact Sheets portion of this guide or the CAES website (http://www.caes.state.ct.us/).

**Disease Cycles**

Disease cycles help in understanding how the components of the disease triangle fit together in a dynamic framework. They help to describe when infections occur, how disease agents are carried over the winter, and how to determine when a fungicide application would be most effective. Knowledge of the type of cycle for a particular disease will assist in determining the strategies for managing that disease.

There are several types of disease cycles but the three most prevalent ones for diseases of ornamental and shade trees are simple, complex, and multiple host cycles.

**Simple Cycle**
A simple disease cycle is characteristic of diseases that have one infection period per year. Because there is only one infection period per year, there is only one opportunity for control using fungicides. An example of a disease with a simple cycle is oak leaf blister (Figure 1). In this disease, there is only one spore stage of the fungus that is capable of infecting newly developing leaves. The fungus overwinters in buds and bud scales. As temperatures increase in spring, the fungus produces ascospores that infect buds as they begin to swell. Symptoms develop on infected leaves during the summer but no new infections can occur. Since there is only one infection period per year, the only opportunity to control the disease would be fungicide applications targeted to inhibit primary infections during bud swell (note dotted line intersecting the disease cycle). Although fungicide applications at this time are effective, this disease is not serious enough to warrant chemical controls in most situations.
Complex Cycle
A complex cycle is characteristic of diseases that have multiple cycles each year. These types of diseases typically have two cycles, a primary cycle and a repeating, secondary cycle. Since secondary cycles are embedded in primary cycles, they are dependent upon primary cycles in order to exist. If the primary cycle is stopped, the secondary cycle can’t begin. An example of a disease with a complex cycle is scab on crabapple (Figure 2). Because there are two cycles, there are two opportunities for disease control. In the case of scab, there are two types of spores produced by the causal fungus. The spores responsible for the primary cycle overwinter in fallen leaves. In spring, spores are produced in the fallen leaves that initiate the primary cycle of disease as these spores infect newly emerging leaves, flowers, and young fruit. The primary cycle is completed when symptoms develop on leaves and fruitlets. Another type of spore is produced in the infected tissues, which in turn initiate secondary cycles. Multiple secondary cycles can occur as new lesions occur and more spores are produced to initiate new secondary infections. The first opportunity for controlling this disease would be fungicide applications aimed at stopping the primary cycle. These would be applied to protect newly emerging tissues in spring (note dotted line intersecting the primary cycle). This is the most effective and important way to control this disease with fungicides since breaking the primary cycle eliminates the existence of the secondary cycle. In cases where the primary cycle is not properly controlled, the
second opportunity to stop this disease is to target additional sprays to protect tissues from infection by the spores initiating the secondary cycle. This type of control is much more difficult than controlling primary infections since repeating cycles can occur.

**SCAB ON CRABAPPLE**

*Figure 2. Complex disease cycle of scab on crabapple.*

**Multiple Host Cycle**

A multiple host cycle is characteristic of diseases caused by pathogens that require more than one host (and in some cases require more than one year) to complete their life cycles. An example of a disease with a multiple host cycle is cedar-apple rust (Figure 3). This pathogen requires two distinctly different hosts: primary hosts are apple and crabapple and secondary or alternate hosts are junipers, including eastern red cedar. The most effective way to manage this disease is to separate the two types of hosts. Imagine breaking the circle into two pieces right down the middle and separating the crabapple and juniper hosts. Unfortunately this is not feasible in most landscape situations since the two hosts need to be separated by one mile in order to be effective. The most commonly used strategy to manage this disease in the landscape is to prevent infections from occurring by protecting tissues with fungicides. The fungus overwinters in galls on the juniper hosts. In spring, gelatinous, orange telial horns containing spores develop on overwintering galls. These spores are only able to infect the apple or crabapple hosts and initiate infections as the newly emerging leaves...
Reddish to orange spots develop on infected leaves in which other types of spores are produced. These spores can only infect juniper and infections occur as the spores are wind- or rain-driven to the junipers. The most effective way to break this cycle is to apply fungicides to protect the newly emerging crabapple leaves from infection (note dotted line intersecting the crabapple portion of the cycle). If crabapple infections don’t occur, the disease is stopped since the spores that infect junipers are not produced on those crabapple hosts.

CEDAR-APPLE RUST

In spring, gelatinous, orange telial horns containing spores develop on overwintering galls.

Spores infect newly emerging leaves and other tissues.

Juniper

Spores lands on twigs and develop into galls.

Crabapple

Reddish to orange spots develop on infected leaves and produce spores.

Figure 3. Multiple host cycle of cedar-apple rust.

Types of Plant Health Problems

A significant factor that influences the ability to manage plant health problems lies with the ability to recognize a problem when it occurs. One of the most important ways to identify a problem is by the symptoms that are produced by the affected plant. A symptom is defined as the response of a plant to the presence of a disease agent, regardless of whether it is nonliving (abiotic) or living (biotic). Symptoms are the external and internal reactions of a plant as a result of disease. The presence of a symptom on a plant distinguishes the diseased plant from its healthy counterparts.
Plants can exhibit a variety of symptoms, some of which are associated with a specific causal factor, but more commonly, can be associated with many different factors. Symptoms can also occur on many different parts of a plant. Additionally, it is not uncommon for a diseased plant to exhibit more than one type of symptom. For example, the initial symptoms of dogwood anthracnose appear as distinct spots approximately ¼-½ inch in diameter with dark purple margins. These spots are usually scattered over the surface of the leaf. However, when the number of spots increases, they coalesce and the leaves develop a blighted appearance as they turn completely brown and shrivel.

Some of the common symptoms that we encounter on diseased plants are listed and defined in this section. These terms provide the vocabulary or terminology to describe what we see when a plant does not appear healthy or normal.

**Common Symptoms of Plant Disease:**

**Leaf spot:** spots of dead tissue on the foliage; the size, shape, and color may vary with causal agent and host; usually limited to a relatively small portion of the leaf surface.

**Leaf blotch:** dead areas of tissue on foliage; irregular in shape and larger than leaf spots.

**Blight:** rapid yellowing, browning, collapse, and death of leaves, shoots, and stems, especially young, growing tissues; usually occurs very quickly and involves a major portion of a tree.

**Scorch:** browning and death of indefinite areas of tissue along the leaf margins and/or between veins.

**Wilt:** loss of turgor or drooping of leaves, shoots, or the entire tree due to apparent lack of water.

**Canker:** dead area on twigs, stems, or main trunk; can be sunken, swollen, or discolored and are usually distinguished from adjacent healthy tissues by color.

**Stunting:** reduced plant growth; failure of plant parts to grow to full size; often used to describe an entire plant.

**Gummosis:** exudation of sap or gum from wounds, cracks, or other openings in the bark.

**Gall:** a swelling or abnormal growth of plant tissues; can develop on leaves, stems, and roots; may be induced by insects, fungi, bacteria, or nematodes.

**Chlorosis:** yellowing of normally green tissues due to lack of chlorophyll.
**Necrosis:** death of plant cells or tissues; necrotic = dead.

**Dieback:** large portion of dead tissue in a tree; death of the tips of leaves, shoots, and stems; failure of branches to develop, especially in the spring.

**Vascular discoloration:** streaking or darkening of vascular tissues.

**Witches' broom:** abnormal proliferation of shoots from the same point on a plant resulting in a bushy, broom-like appearance.

### Strategies for Managing Plant Health Problems

Regardless of the plant host or particular type of disease that you encounter, the concepts of disease prevention and management are fundamentally the same. Management of plant diseases involves a two-step process that first requires accurate diagnosis and assessment of the severity of the problem. This is followed by implementing strategies to minimize the impact of the disease.

**1. Disease Diagnosis:**
The first step in disease management is knowing what you’re trying to control—is it a disease caused by a fungus or is it associated with the weather, the site, or your cultural care? Accurate diagnosis is very important since it determines two things: the need for control and the type of control. Some plant diseases are merely aesthetic and, under normal circumstances, don’t require control measures. On the other hand, there are diseases that can be fatal if left uncontrolled. For example, tar spot of maple is usually not serious enough to require control measures even though it can result in premature defoliation. In contrast, Phytophthora root rot of rhododendron is a disease that interferes with water uptake and can seriously debilitate and eventually kill the plant if left unchecked.

Another part of diagnosis involves assessing the severity of the problem. This assessment is made by gathering information about the nature of the problem: is it a foliar or a root problem, is it localized to one part of the plant or is it systemic? It is also helpful to determine the level of the disease: how many plants are involved or how long have they been symptomatic?

Disease diagnosis based solely on symptoms can sometimes be misleading and can lead to improper, ineffective controls. In circumstances where different causal agents incite the same or similar symptoms on a host plant, accurate diagnosis requires identification of the causal agent. Since most biotic agents are microscopic, accurate identification is not possible without the necessary equipment. In these cases, samples may be submitted to the Plant Disease Information Office of the Experiment Station for diagnosis. Diagnosis can involve light microscopy and histochemical staining, isolation on artificial media, soil extraction, electron microscopy, studies of host range, and indicator plants. The Office also utilizes serological tests and a variety of other
procedures as necessary. Information about the Plant Disease Information Office and about how to prepare and submit samples can be found in this Disease Management Guide or can be obtained by calling the Office or accessing the CAES website.

2. Management Options:
A common misconception to disease control is that chemical sprays, dusts, and soil drenches are the only effective means of reducing the effects of plant disease. However, chemical control is only one component of a multifaceted approach that includes culture, sanitation, resistance, and biological and chemical components.

It is important to realize that the goal of disease management is not necessarily to completely eliminate diseases but to manage them such that they remain at acceptable levels.

Culture: A key opportunity for disease management focuses attention on cultural manipulations that help to minimize conditions favorable for disease development. These include numerous methods that modify the plant’s growing conditions in order to optimize growth and vigor.

a. Plant and Site Selection
- Hardiness- often an overlooked aspect of disease prevention; most of Connecticut is in USDA Zone 6 (some Zone 5); this is an important factor for consideration when trying new species;
- Plant Requirements vs. Site Characteristics- it is important to match the conditions required by a particular plant with the attributes of the intended site as closely as possible; special attention should be given to soil type and pH, drainage, and light levels.

b. Planting Practices
- Spacing- use the correct spacing for the particular plant species; too-close spacing can promote disease by compromising plant vigor and by inhibiting drying and air circulation;
- Planting- dig and prepare the planting hole correctly; check for the root flare at time of planting to make sure the tree is not planted too deep or too shallow;
- Rootball preparation- for balled and burlapped stock, the burlap and wire basket should be removed, if possible; for container-grown stock, the rootball should be thoroughly moistened, scored, and teased apart before planting;
- Plant rotation- it is helpful to purposefully alternate the species grown in a specific area, especially when the disease agent is soilborne.

c. Plant Care
- Fertilizing- appropriately timed applications of fertilizer will help to maximize growth and vigor and avoid stress due to nutrient deficiencies or toxicities; fertilizer applications should be based on a soil test and/or tissue analysis; applications of biostimulants and mycorrhizae can also be helpful;
• **Watering**- maintain adequate soil moisture for the plant species; this usually translates to approximately one inch of water per week; in the absence of natural rainfall, irrigation should be used and, depending on soil type, this is best delivered as a deep soaking; avoid overhead irrigation or water plants early in the day to allow foliage to dry before nighttime;

• **Mulching** (summer mulch)- properly applied mulch helps with weed control, soil temperature moderation, soil moisture retention, and reduces the spread of disease; summer mulches should not be applied too thick or too close to the trunk or stem;

• **Winter Protection**- winter mulches, physical barriers, and applications of anti-transpirants or anti-desiccants can be effective in protecting plants from heaving during freeze-thaw cycles and from drying winds.

An example of cultural manipulations that help to reduce disease can be illustrated for winter injury and desiccation of rhododendron, a common problem in Connecticut. Rhododendrons are more prone to this type of injury as well as to fungal leaf spots when they are not properly maintained or when stressed by root injury from drought. These problems can be minimized by maintaining an acidic soil pH, fertilizing in early spring, and watering during periods of drought and just before the ground freezes in the fall.

**Sanitation:** This option for disease management focuses on minimizing the introduction of disease agents through plant selection and by eradication of diseased plants or plant parts as a means to reduce the potential for spread of biotic agents.

• **Plant Selection**- use of healthy, pathogen-free seedlings and transplants;

• **Prune and Remove Infected Plants and Debris**- symptomatic plants or infected plant parts such as fallen leaves should be promptly removed to minimize disease spread; this practice helps to reduce the amount of overwintering inoculum;

• **Use Clean Equipment**- all tools and equipment should be thoroughly cleaned and disinfested with 10% household bleach (1 part bleach: 9 parts water), 70% alcohol, or a commercial compound such as Greenshield®; bleach can be corrosive so equipment should be thoroughly rinsed in clean water and oiled after treatment;

• **Scout**- check trees on a regular schedule in order to monitor for buildup of diseases and plant abnormalities; keep records for use in outlining management needs for the next year.

An example of sanitation as an essential component for disease control can be illustrated for brown rot, a common and destructive fungal disease of many *Prunus* species in Connecticut. This practice involves removing and destroying mummied fruit on the ground or remaining on the tree and pruning and removing dead and/or cankered twigs. These practices significantly help to reduce the amount of overwintering inoculum that will be available to infect the newly emerging tissues in the spring.

**Resistance:** This management option utilizes resistant or tolerant cultivars or species of trees to minimize or avoid disease. When available, genetic resistance is probably the most desirable and effective management tool since it circumvents the need for additional controls. It is especially important for diseases caused by viruses,
nematodes, and soilborne and wilt pathogens since these are all extremely difficult to control with other means. Although genetically resistant plants are not available for all plants and all diseases, breeding programs are underway and the availability of these types of plants is expected to increase in the near future.

Examples of effective use of genetic resistance include cultivars of crabapple with resistance to scab and rust, cultivars of rose with resistance to powdery mildew and black spot, and cultivars of elm with resistance to Dutch Elm Disease.

**Biological:** This management tool employs living agents (fungi or bacteria) to control plant disease agents. Effective biological controls act by direct competition, by predation or parasitism, by antibiosis, or by stimulation of the natural defenses of the plant. The availability of biological controls is on the increase and is becoming a viable option for disease management for the future.

An example of biological control is the introduction of hypovirulent (“less” virulent) strains of the chestnut blight fungus. These strains compete with virulent strains and keep them from causing killing cankers on infected trees. More detailed information on this topic can be found in numerous Fact Sheets about chestnut blight on the CAES website. Several commercial biological control agents have recently become available and are registered for control of some root rot and foliar diseases. Since these products contain living organisms, the directions for storage and use of these products are different from those for conventional pesticides. Thus, careful attention to the label is particularly important.

**Chemical:** Although it is possible to successfully manage many disease problems without the use of pesticides, there are situations where pesticide usage is important and highly successful. Chemical disease control uses pesticides (fungicides, bacteriocides, and nematicides) to limit the effects of biotic agents. Fungicides are the most common chemicals used for disease control. In most cases, however, the degree of control depends on the proper selection, timing, and method of application of the compound. In this regard, selection of the appropriate fungicide is contingent on accurate diagnosis of the problem since fungicides vary in their efficacy; some fungicides are toxic to all or most kinds of fungi whereas others affect only specific types of fungi. Another way of looking at pesticides is as “plant medicines”: these are compounds used to protect or cure plants from infectious agents.

- **Categories of Pesticides:**
  - “Biorational” pesticides: these pesticides are defined as products that are considered to be environmentally friendly because they have minimal harmful effects on non-target organisms and the environment; they are frequently more “user friendly” than traditional pesticides; examples include neem oil, insecticidal soap, horticultural oil, sulfur, and potassium bicarbonate.
  - Biological pesticides: these are also called biofungicides and contain microorganisms (bacteria or fungi) that are used to control specific plant
pathogens; biocontrol agents have multiple modes of action and can act by direct competition (e.g., occupy the same niche or site or compete for the same food source), by predation or parasitism (e.g., attack or kill the pathogen), by antibiosis (e.g., secrete compounds or produce by-products that alter the environment and make it unfavorable for the growth of the pathogen), or by stimulation of the natural defenses of the plant (e.g., induce biochemical changes in the host plant that stimulate growth); examples include QST713 strain *Bacillus subtilis*, harpin protein, and *Trichoderma harzianum* T22. In many cases, biofungicides need to be rotated and/or tank-mixed with other products with different modes of action to avoid pesticide resistance.

- **“Chemical” pesticides:** these are considered “traditional” pesticides with traditional modes of action; examples include strobilurins, sterol inhibitors, benzimidazoles, coppers, and sulfurs.

**Protectant vs. Systemic Fungicides** - Many fungicides are protectants and must be present on the surface of the plant in advance of the causal agent in order to prevent infection. Their primary mode of action is to inhibit fungal spores from germinating or to kill spores after they germinate and inhibit further growth. These compounds do not stop or cure a disease after it has started since they are not absorbed or translocated within the plant. On the other hand, systemic fungicides are absorbed through the foliage or roots and are translocated within the plant. Products differ in their ability to move from the initial point of contact or absorption. Some products can move upward within the plant, others can move upward and downward. These compounds have a therapeutic (curative) or “kickback” mode of action since they can kill or inhibit growth of pathogens after they have invaded the plant host.

**Trade Name vs. Common Name** - The common name of a pesticide is the name assigned to the active ingredient of the pesticide. In contrast, the trade name of a pesticide is the name assigned by the manufacturer or distributor of a particular product. For example, chlorothalonil is the common name of a fungicide that is sold under many trade names including Daconil WeatherStik®, Echo 90DF®, and Concord DF®. Therefore, a single common name or active ingredient may be available under many different trade names.

When using pesticides for disease control, it is **very important** to thoroughly read and comply with the label. This applies to information on host plants, dosage rates, safety precautions, and days-to-harvest intervals (also called pre-harvest intervals), when applicable.

An example of effective fungicide applications can be illustrated for control of scab of crabapple, one of the most troublesome diseases of apples and crabapples in Connecticut every year. For this disease, the fungus has two distinct cycles of infection (please refer to section on Disease Cycles, Figure 2). If the pathogen is essentially controlled with properly selected and timed fungicides during the first cycle of infection
in the spring, the second cycle does not occur and fungicide sprays are unnecessary for the remainder of the season.