BASIC CONCEPTS IN PLANT PATHOLOGY

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INTRODUCTION

Plant diseases in the landscape and garden are very important and can be a significant source of frustration and loss to the gardener. There are about 30,000 diseases of economic importance in the U.S. Plant pathology is the study of the biotic and abiotic agents that cause disease in plants; of the mechanisms by which these causal agents induce disease in pants and of the methods of preventing or controlling disease and reducing the damage caused.

PLANT DISEASES IN HISTORY

Certain diseases have had tremendous impacts on our society. Perhaps foremost among these is *Phytophthora* late blight which caused the potato famine (1845) in Ireland. It is estimated that 1.5 million Irish died from starvation and just as many immigrated to the United States.

Two forest tree diseases which caused great economic losses in America are Dutch elm disease and chestnut blight. Both were introduced accidentally to the United States and while the former continues its destruction, the latter completely destroyed valuable trees in the Appalachians.

These examples are prominent because they caused so much damage. In reality, total crop loss due to plant disease is rare. Most disease loss in the garden is due to endemic diseases.

DISEASE DEFINED

Diseases result from more or less continuous irritation of the plant tissues by a primary causal agent. Disease is a process that takes time, is physiological in nature, abnormal, and detrimental. Diseases cause damage by reducing yield and/or quality of plants and/or plant products.

TYPES OF PLANT DISEASES

There are two types of plant diseases: those whose primary causal agents are biotic (infectious), and those that are abiotic (not infectious). The causal agent of infectious diseases is called the pathogen, and the susceptible plant the suscept. Diseases caused by microorganisms or microbes, are infectious. Diseases caused by parasitic plants are also infectious. Diseases may involve more than one causal agent and often involve secondary causal agents.

Noninfectious (Abiotic) Diseases

Examples of abiotic diseases include:

- *Nutrient Deficiencies* -- A lack of essential elements such as iron or zinc may cause plant foliage to yellow.
- *Lack of or Excess Soil Moisture* -- A plant can become dehydrated during drought periods, and may suffocate when poor drainage cuts out oxygen around the roots.
- *Too Low or Too High Temperature* -- Plants grown out of their adapted habitat can be injured or killed by extremes in temperature.
- *Air Pollution* -- Ozone, sulfur dioxide and automobile exhaust fumes can injure plants.
- *Soil Acidity or Alkalinity* -- Adverse soil pH can injure plants
- *Mechanical Damage* - Girdling from roots, nylon twine or wire; injury from construction

Biotic Diseases

Biotic (infectious) diseases occur when a host plant is invaded by a living organism. Most of these organisms are microbes, and can also be referred to as parasites that attack plants. A **host** is a plant that has been invaded

by a parasite.

A parasite is an organism which obtains its nutrients from living organisms, often plants. In the process of feeding, the parasite not only consumes plant tissue, which weakens the host, but also produces toxins, enzymes, and growth regulating substances which disturb the normal metabolic processes in the plant. In some cases the parasite actually blocks the movement of food and water in the plant's conducting tissue. Any of these disorders caused by a parasite will result in a diseased plant.

Microbes are the major biotic pathogens of plants. The four major groups of microbial plant pathogens are fungi, bacteria, nematodes, and viruses. Less commonly, phytoplasmas (bacteria-like) and viroids (virus-like) also cause diseases. Parasitic flowering plants are also pathogens.

Much can be learned by studying the pathogens as groups, and a working knowledge of those groups is needed for an understanding of plant pathology. Knowing how a pathogen obtains nourishment is important to understanding the disease process and developing control strategies.

Most microbial pathogens are primarily parasites, but some are mainly saprophytes and can sometimes cause disease. Saprophytes usually feed on non-living organic matter. Most microbial pathogens have some saprophytic abilities, which are important in survival and in the disease process. Pathogens with saprophytic ability can be cultured away from their host plant.

Some pathogens can only grow in nature on their live host, (e.g. powdery mildew and rust fungi) and are called obligate parasites. Obligate parasites feed and reproduce on living plant material.

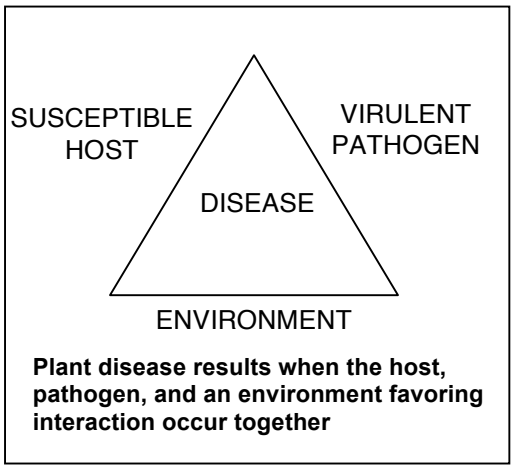
CONDITIONS NECESSARY FOR DISEASE

In order for disease to occur, three conditions must be met. First it is necessary to have a susceptible host plant. Each species of plant can be infected by only some pathogens. The plant must also be in a stage of development susceptible to infection by the disease agent.

The second requirement is the presence of an active pathogen. If there is no pathogen present, there can be no disease. Also, the pathogen must be in a stage of development conducive to infecting or affecting the host plant.

The third condition is an environment suitable for the pathogen to cause disease of the plant.

The interaction of host, pathogen, and environment can sometimes be represented by a triangle. The "disease triangle" cannot be constructed unless all 3 legs are present simultaneously. (See accompanying diagrams.) Break any leg of the triangle, and there is no disease. Disease control strategies can be based on breaking a leg of the triangle.



Plant disease results when the host, pathogen, and an environment favoring interaction occur together

DISEASES CAUSED BY FUNGI

A fungus is a multi-cellular organism made of thread-like material known as mycelium. Fungi cannot make their own food, so in the process of obtaining food from higher plants, fungi injure roots, stems, leaves, and fruit. This action causes what we know as plant diseases. Not all fungi, however, cause disease.

<u>Types of Fungi</u>

There are many types of fungi.

Many saprophytic fungi are beneficial to mankind. Beneficial fungi rot leaves, cause fermentation in the manufacture of alcohol and cheese, and produce antibiotics used to treat

human infections. Yeasts, which are used in fermentation, and *Penicillium*, an important antibiotic producer, are fungi.

Thousands of species of parasitic or pathogenic fungi cause plant diseases. Some species attack only one plant; others attack many different plants. Some plants are susceptible to more than 50 fungal diseases.

Fungi are mainly composed of mycelia. Mycelial threads resemble spider webs in appearance. Bread mold is a fungus and is typical of the vegetative structures fungi produce.

How Do Fungi Reproduce?

Fungi reproduce by forming spores, sclerotia and mycelial fragments. These fungal parts provide a means for the fungus to be moved from diseased to healthy plants and for the fungus to survive from one season to the next.

Spores: Fungus spores can be compared to seed in higher plants. A fungus can produce millions of spores which are too small to be seen with the naked eye. Each fungus species produces a spore or group of spores which is different from that of all other species. A fungus can be identified by the spore it produces, just as an individual can be identified by finger prints. Spores come in a variety of shapes or colors and can have one cell or be multi-cellular. Some types of fungi mate and form sexual spores, but most fungi are asexual, and fertilization is not necessary for reproduction. Some fungal spores are short-lived, and some are resting spores which can last many years even under adverse conditions.

Sclerotia: The mycelium of some fungi becomes hard and forms reproductive structures known as sclerotia. These sclerotia or hard bodies will remain dormant in the soil for several years or until a susceptible crop is planted. *Sclerotium rolfsii*, which causes crown rot of vegetables, is a good example of a fungus with this kind of reproduction.

Mycelial Fragments: Some fungi are spread from one area to another by fragments of their mycelium. This form of reproduction is similar to vegetative reproduction in higher plants. *Rhizoctonia*, which causes damping off of seedlings, is spread by mycelial fragments.

Where Are Spores Produced?

In Soil Water: Some fungal-like organisms (Oomycota) produce motile spores with flagella, known as a zoospores, that move from root to root in soil water. Other members of the Oomycota which form motile spores such as *Pythium* and *Phytophthora* thrive in low wet areas and cause such diseases as root rots and stem rots.

Special Structures: Some fungi produce spores in special structures inside the infected plant tissue. Numerous spores are produced inside these fruiting bodies, and upon maturity the spores are discharged on the surface of the diseased plant where they can be carried away by air currents or splashed into the air by raindrops.

Stalks or Conidiophores: Many fungi produce their asexual spores on exposed stalks known as conidiophores. Fungi on the surface of the plant tissue form stalk-like structures which produce numerous spores known as conidia. A conidiophore resembles a small plant with fruit hanging on it. This type of spore is usually carried away by air currents since it is produced on the surface of plant tissue.

Penetration of Plant Tissue

In order for infection to occur, the spore must germinate and penetrate the plant tissue. When a spore germinates on moist tissue, it enters the tissue by direct penetration, through natural openings such as stomata or lenticels, or via wounds.

Direct Penetration: In direct penetration, the spore forms a germ tube which penetrates using enzymes and physical pressure. Young, tender leaves, roots, and blooms are more likely to be invaded by direct penetration. Many foliage infections occur in early spring while the new growth is tender. Some fungi penetrate only the cuticle layer (outer layer) of leaves or fruit. The disease apple scab is a good example of a subcuticular infection. Other fungi such as powdery mildew penetrate only the epidermal layers.

Penetration Through Stomata: Some

fungi penetrate through stomata (natural openings). Fungi which enter through stomata can attack older and tougher leaves. Rust fungi such as cedar apple rust or bean rust penetrate via stomata.

Penetration Through Wounds: Some fungi enter plant tissue only through wounds. Pruning wounds make an excellent avenue of penetration. Many fruit rots occur when fungal spores come in contact with bruised areas.

Factors Necessary for Infection

There are millions of fungus spores in our environment but infection does not occur every time the spores are deposited on plant tissue. Certain favorable factors are necessary before infection can occur.

Moisture: In order for most fungus spores to germinate and penetrate plant tissue, free water must be available on the plant surface. If the leaf is dry, infection will not occur. A dry spring can reduce disease development for the entire season since the dry weather protects the young tender tissue from fungus infection. If sufficient moisture is available later in the season, the foliage may be tough and spores less numerous. Thus, free moisture especially early in the season favors most diseases.

Temperature: Some crops grow at a temperature below which fungi can infect, but most crops grow at temperatures most suitable for fungal reproduction. Most fungi grow well at temperatures between 70^{o} and 90^{o} F and are dormant in winter. Diseases are more common, and more damaging, in tropical climates than the temperate climates.

Stage of Plant Growth: Fungi infect susceptible plant tissue. Some fungi attack any young, tender leaves. Others prefer new shoot growth, young feeder roots, or ripe fruit. If the plant passes through this susceptible stage before spores are available or during unfavorable weather conditions, then it might escape injury for the entire season.

Disseminating Agents: Fungus spores must be carried from infected to non-infected tissue by some agent such as wind, insects, man, transplants, or seed. A disease spread by wind or blowing rain might not reach epidemic proportions during calm, dry periods. The spores of downy mildew can be spread all the way across the continent by wind currents. Dutch elm disease is spread from tree to tree by insects.

Duration of Spore Release: Some fungi produce spores during the entire spring or summer, but others produce only one crop of spores during a short period in early spring. A fungus which produces spores for only a few days can be more easily controlled since the infection period is very short and the plant might not be in a susceptible stage of growth when spores are available. Dispersal of fungal spores frequently occurs daily and corresponds closely to current critical environmental events that favor infection or pathogen reproduction, e.g., moisture, temperature, etc.

DISEASES CAUSED BY BACTERIA

Bacteria are minute one-celled microbes closely related to fungi. Plant pathogenic bacteria do not produce spores. They reproduce by simple cell division. The tiny rod-shaped cells reproduce very rapidly. Cells may divide every 20 to 30 minutes. At this rate, one cell will give rise to 17 million cells in 12 hours. This rapid growth rate accounts for the seemingly explosive nature of bacterial diseases. Large cell numbers confer great bacterial cell surface area for release of enzymes, toxins, or slime. These bacterial products are responsible for much of the damage caused by bacterial infection.

How Are Bacteria Spread?

Blowing Rain: Bacteria ooze out of infected tissue and form a mass of sticky material on the plant surface. Rain drops hit the bacteria and splatter them to new infection sites.

Insects: In the process of pollinating plants, bees crawl through the bacterial ooze and then deposit the organism in blooms. This is the primary means of spreading fire blight of apple and pear from tree to tree. Some bacteria live inside insect vectors and are spread from plant to plant.

People: While picking beans or suckering tomatoes, people can come in contact with bacteria and transfer them from plant to plant on their hands. Never work in the garden

when plants are wet.

Seed: Bacteria can live from year to year inside seeds. When infected seeds are shared between gardeners, bacterial diseases can spread. This is why seeds grown in a dry western climate are clean. Avoid saving seeds from your garden unless you are preserving a unique variety.

DISEASES CAUSED BY VIRUSES

Viruses are very tiny particles of nucleic acid and protein which can multiply only inside living cells. Virus particles in the cell disrupt normal cell functions and can affect the production of chlorophyll and starch. Infected plants may become yellow or be distorted due to malfunctioning cells. Other symptoms include mottled or puckered leaves, streaks on the leaves or, in some cases, distorted fruit.

How Are Viruses Spread?

Mechanically: Virus diseases can be spread from plant to plant on tools or hands. Some tobacco products may contain tobacco mosaic virus. Gardeners who use tobacco should wash their hands with soap and water, or in milk, before handling plants.

Insects: Insects remove virus particles from infected crop or weed plants when they suck out plant material. The insect can later inject the virus into another plant nearby or some distance away.

Seed: A few viruses are seedborne and are spread when infected seeds are planted.

DISEASES CAUSED BY NEMATODES

Nematodes are very tiny, eel-shaped worms which live mainly in the soil. These tiny worms cannot be seen by the naked eye. Many nematodes feed on plant roots, causing root injury which interferes with the movement of food and water in the plant. Other nematodes may not feed on roots. The pine wilt nematode mainly inhabits and feeds in the resin canals of pine stems and branches. Most nematodes go through several life stages including egg, larva, and adult.

How Do Nematodes Feed?

Nematodes have a spear-like mouth part that works like a hypodermic needle. The nematode inserts this spear or stylet into the root tissue, injects a chemical substance, and then withdraws plant material as it feeds. Root feeding sometimes causes root galls. Root knot and cyst nematodes are examples of root gall forming nematodes. Root feeding by nematodes causes plant tops to be stunted, yellowed, or wilted.

Where Are Nematodes Found?

Nematodes are found in many garden soils. Nematodes can be brought into the garden in the roots of transplants. Once garden soil is infested, the nematodes will generally remain there year after year for the life of the garden since most vegetables make ideal hosts.

PLANT DISEASE SYMPTOMS AND SIGNS

Symptoms are the plant's expression of being diseased. Examples of symptoms include: blights, cankers, galls, rots, necrosis, and spots. Symptoms are expressed either locally or systemically, and they frequently reflect the structural, functional, or physiological systems disturbed. Diseases that produce few noticeable symptoms are termed "symptomless".

Signs are the physical evidence of the pathogen (primary or secondary, vegetative and/or reproductive structures). Some examples include: conks, mildew, mycelium, ooze, pycnidia, and rhizomorphs. Diagnosis of plant disease is based on looking for symptoms and signs.

A DICTIONARY OF PLANT DISEASE SYMPTOMS AND SIGNS

blight: sudden death of twigs, foliage, and/or flowers

blotch: large and irregular-shaped spots or blots on leaves, shoots, and stems

canker: dead places on bark and cortex of twigs or stems; often discolored and raised or sunken

chlorosis: yellowing of normally green tissue due to reduced chlorophyll content, such tissue is *chlorotic*

conks: fungal fruiting structures formed on rotting woody plants (shelf or bracket fungi)

damping-off: destruction of seeds in the soil, or seedlings near the soil line, resulting in reduced stand, or the seedling falling over on the ground

decline: progressive, gradual weakening and death of a plant or population of plants

dieback: progressive, gradual weakening and death of individual branches of a plant, often leading to decline

distortion: malformed plant tissues

flagging: the loss of rigidity and drooping of leaves and tender shoots preceding the wilting of a plant

fleck: a minute spot

galls: abnormal, localized swellings or tumors, on leaf, stem or root tissue

gum: complex of sugary substances formed by cells in reaction to wounding or infection

gummosis: production of gum by or in a plant tissue

inoculum: amount of pathogen available for infection

leaf spot: a self-limiting lesion on a leaf

lesion: a localized area of discolored, diseased tissue

malignant: tissue that divides and enlarges autonomously, forming a tumor or gall

masked symptoms: virus-induced plant symptoms that are normally, but appear when the host is exposed to certain environmental conditions of light and temperature

mildew: a plant disease in which the pathogen is seen as a growth on the surface of the host; e.g., downy mildew, powdery mildew, caused by very different fungi, but both having the name mildew

mosaic: symptom of certain viral diseases of plants characterized by intermingling patches of normal green and light green or yellowish colors

mottle: an irregular pattern of indistinct light and dark green areas

mummy: a dried shriveled fruit

mycelium: masses of fungal threads (hyphae) which compose the vegetative body of the fungus

necrosis: death of tissue

necrotic: dead or discolored brown to black

ooze: a mass of bacterial cells usually embedded in a slimy matrix appearing on the diseased plant surface, often as a droplet; or, a flux, a viscid mass of juices composed of host and parasite substances occasionally found exuding from a diseased plant

pycnidia: minute, usually globose and black, fungal asexual fruiting structures formed on plant surfaces

rhizomorphs: string-like strands of fungal mycelia sometimes found under bark of trees

ring spot: a circular area of chlorosis with a green center; a symptom of many virus diseases

rot: the softening, discoloration, and disintegration of succulent plant tissue as the result of fungal or bacterial infection

russet: brownish roughened areas on skin of fruit as a result of cork formation

rust: a type of disease caused by a specific group of fungi, often producing orange-red "rust" colored spores

scab: a roughened crust-like diseased area on the surface of a plant organ; a disease in which such areas form

sclerotia: tough structures produced by fungi for long-term survival.

scorch: burning of leaf margins as a result of infection or unfavorable environmental conditions

shot-hole: a symptom in which small diseased fragments of leaves fall off and leave small holes in their place

signs: visible evidence of the pathogen; signs are not the same as symptoms

spots: circular or irregular lesions on above ground tissue
tip blight: death of shoot tips

tumor: a malignant overgrowth of tissue

vein banding: retention of bands of green tissue along the veins while the tissue between veins has become chlorotic

vein clearing: destruction of chlorophyll adjacent or in the vein tissue as a result of infection by a virus or other pathogen

wilt: loss of rigidity and drooping of plant parts generally caused by insufficient water in the plant

witches' broom: broom-like growth or massed proliferation caused by the dense clustering of branches in woody plants

yellows: a group of systemic mycooplasma-caused diseases often resulting in wilt, witches broom, or decline

CONTROLLING DISEASES

Control of a disease is basically aimed at suppressing the pathogen by altering one or more sides of the disease triangle. This requires knowing as much as possible about a disease. Disease forecasting would be of great value for disease control, but it requires greater knowledge of the disease situation than is available in most cases. Biological, environmental, cultural and chemical controls are all useful, but have their limitations. Thus, it is often necessary to integrate several practices to get good disease control. Plant disease control in the garden is practiced on the population level as well as on the individual plant level.

All production practices have some influence on the disease situation, and the disease situation often can be changed dramatically through changes in cultural practices. People are the hardest factors to manipulate in most disease situations. Disease control is a cost to consider in gardening: financially and ecologically.

The importance of understanding the disease development process becomes obvious when considering control options. By the time symptoms are expressed, the pathogen (with few exceptions) is already inside the host plant and is relatively safe. Therefore, control efforts in most cases must occur before penetration has taken place. The overall principle in effective disease control is to keep the inoculum density of the pathogen at very low levels.

Success in controlling plant disease will occur when a combination of the following methods of control are used:

- **avoidance** -- A grower can avoid certain diseases by choice of geographic area or by choice of planting site in a local area. Diseases can be avoided by planting at a time that does not favor disease development. Using disease-free planting stock or modifying cultural practices also helps to avoid disease.

- **exclusion** -- A grower can inspect planting stock for signs of disease and reject or treat any which is suspect. Plant quarantines are designed to exclude certain pests from areas that are free of that pest. Elimination of insect vectors can exclude a disease.

- **eradication** -- Once a disease is established in an area, eradication is unlikely. However, significant reduction in disease inoculum can be attained by destroying diseased plants or alternate hosts, by rotating crops, or by certain soil treatments.

- **protection** -- Spraying or dusting plants with fungicides or bactericides is done to protect them from disease. Sometimes modifying the environment or cultural practices may protect the crop. Control of insect vectors will also protect plants.

- **resistance** -- Breeding and selection are used to develop resistant crops, and resistance can be enhanced through proper culture of a crop. Resistance is not immunity. Improper culture of a resistant variety may negate that resistance.

  Plants resist pathogens naturally by a variety of defensive measures, both active and/or passive. Resistance to a specific pathogen is the rule, while susceptibility is the exception. Disease resistance follows Mendelian genetic principles. Disease resistance can be either specific or general in nature.

- **therapy** -- Surgical removal of diseased parts of a plant will sometimes control the disease. There are a few diseases which can be treated with chemicals or heat to gain a degree of control.

Familiarity with crops and the diseases and insects that affect them is useful in planning control programs. Some diseases occur every season; others occur sporadically. Some can be controlled easily by using proper methods; others must be tolerated. Knowing which problem falls into which category comes with experience.

CONTROLLING PLANT DISEASES DURING THE RESTING STAGE

Many plant disease organisms have a dormant or overwintering stage coinciding with plant dormancy. Where the organism overwinters and how it is disseminated have a considerable influence on the kind of control developed. The following are practical suggestions for controlling disease causing microbes at rest.

Organisms Overwintering on Soil Surface

Many organisms survive on old leaves, branches, mummied fruit, and other debris on the soil surface. Certain control measures are designed specifically to handle surface organisms.

Mulch: Placing a pine needle or leaf mulch beneath shrubs or between the rows in the garden forms a barrier which prevents organisms from moving from soil to plants. Before a new mulch is laid, all diseased debris should be removed.

Cultivation: Cultivating under fruit trees destroys old, mummied fruit and prevents the organism from reproducing and infecting the new crop.

Deep Plowing: When soil is turned four to six inches deep, organisms on the soil surface are buried so deeply that they cannot come in contact with plants.

Sanitation: Removing all old leaves and stems from beneath trees and shrubs eliminates most of the disease organisms on the soil surface. Many diseases reproduce in dead tissue on the soil surface.

Organisms Living in the Soil

Certain organisms live their entire life in the soil, and practically all soil contains parasitic organisms. Most pathogens can live in the soil from 1 to 4 years in the absence of a susceptible host. However, a few pathogens can live in the soil for 30 years without feeding.

Crop rotation is a procedure in which non-host crops are used until the pathogenic organisms die out and susceptible crops can once again be grown. This works very well in areas where pathogens die within one to four years in the absence of a susceptible host. Some soil organisms attack only certain crops so these crops should not be grown in the same part of the garden each year.

Resistant varieties are the only solution to soil organisms that can live in the soil for 20 to 30 years without a susceptible host. Wilt-resistant tomatoes are a good example of this kind of disease control. Always select disease-resistant vegetable varieties.

Chemicals can be used to treat soil in cases where crop rotation is ineffective or when resistant varieties are not available.

Organisms Living in Dead Wood

Several diseases which attack apples, stone fruits, grapes, and many woody landscape plants live and reproduce in dead wood. Pruning all diseased and dead wood will destroy a major portion of this inoculum. Less spraying is necessary when this source of infection has been removed.

Organisms Disseminated by Wind

Many diseases are brought into the garden from great distances by the wind. The only means of controlling diseases spread in this way is to protect the foliage with chemicals. Since we do not know when the wind might blow spores into the garden, we should use protective chemicals on a regular basis. When spores are blown into the garden during dry weather, they do not germinate and penetrate the tissue, so less fungicide is needed during dry weather. Wind-blown spores need a wet surface in order to germinate. For this reason, it is best not to water the garden in late afternoon, allowing the foliage to remain wet during the night. Some

spores can penetrate wet tissue in 12 to 15 hours.

Organisms in Seeds

Organisms can easily live in seed and are often spread from garden to garden in this way. For this reason, unless a unique garden variety is being preserved, gardeners should not save seeds from their garden, but should purchase seeds that were produced in parts of the country where diseases do not occur. Seedborne diseases can also be greatly reduced by using a chemical seed treatment.

SUMMARY

Diseases of plants are to be expected but are the exception, rather than the rule. The truly devastating diseases cause tremendous losses; fortunately, there are few of these in most years.

For disease to occur, there must be a susceptible host, a suitable environment, and an active pathogen. When all three conditions are met, disease occurs. Severity of disease depends on the degree to which the conditions are met.

Control involves more than the use of chemicals for protection. Avoidance, eradication, exclusion, resistance, and therapy all have a role in disease control. A combination of these will give best results. Growers must manage their plants and pests to maintain an attractive and healthy landscape and garden.