Chapter 13

PLANT DISEASE DIAGNOSIS AND MANAGEMENT

Chapter 13
Plant Disease Diagnosis and Management

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I. Introduction to Plant Diseases

Plant pathology or phytopathology is the science dealing with plant diseases and their control. Plant pathologists study plant diseases caused by fungi, bacteria, viruses, nematodes, and parasitic plants. They also study plant disorders caused by nutrient imbalances, air pollution, and other unfavorable growing conditions.

A. History of Plant Diseases

Plant diseases have had profound effects on mankind through the centuries as evidenced by Biblical references to the blasting and mildew of plants. The Greek philosopher Theophrastus (370-286 B.C.) was the first to describe maladies of trees, cereals, and legumes that we currently classify as leaf scorch, rots, scab, and cereal rust. The Romans were also aware of rust diseases of their grain crops. They celebrated the holiday of Robigalia when sacrifices of reddish-colored dogs and cattle were made in an attempt to appease the rust god Robigo.

With the invention of the microscope in the 17th century, fungi and bacteria associated with plants were investigated. In 1665, Robert Hooke published the first illustration of rust on a rose leaf. Advances in the study of diseases were hampered by the widely held belief in the theory of spontaneous generation. This theory, held by most people in the mid-18th century, considered pathogenic or disease causing microorganisms as products of disease rather than causes of disease.

Epidemics of late blight of potato devastated Ireland in 1845 and 1846. These epidemics dramatized the effect of plant diseases on mankind. Tragically, these epidemics caused famine and death for over a million people. Between 1845 and 1860, death and migration accounted for the loss of nearly one-third of Ireland's population.

In 1861, a German botanist, Anton De Bary, proved that a fungus (*Phytophthora infestans*) was the causal agent of late blight of potato. This was a milestone in the study of plant diseases since it showed that a fungus was indeed the cause of a plant disease rather than an organism simply associated with the disease. Two years later, Louis Pasteur proposed his germ theory of disease that finally disproved the theory of spontaneous generation and changed the way modern science investigated the diseases of all living organisms.

B. Significance of Plant Diseases in the United States

A few examples of plant disease epidemics that have resulted in devastating plant losses in the United States include: chestnut blight, introduced in 1904, virtually eliminated chestnut trees from North America; citrus canker, introduced in 1910, and a closely related bacterium called citrus bacterial spot discovered in 1984, resulted in the destruction of millions of citrus trees; white pine blister rust, introduced in 1912, caused large economic losses in the timber industry; and Dutch elm disease, introduced in 1930, continues to destroy large numbers of elm trees from the East Coast to the Pacific Northwest.

As a direct result of severe disease losses from imported diseased plant material, plant quarantine laws were passed by the United States Congress in 1912. The Agricultural Plant Health Inspection Service (APHIS) has quarantine inspectors stationed at points of entry into the country as well as at certain interstate points to intercept produce likely to carry new plant pathogens.

II. Disease Concepts

A. What Is a Disease?

There are many ways to define what a plant disease is. However, simply put, plant diseases involve profound changes within the host that cause a disruption of normal plant function. A good working definition of a healthy plant is one that can carry out its physiological functions to the best of its genetic ability.

Diseases are among the most important factors that can significantly diminish growth and yield, or reduce the usefulness of a plant or plant product. Healthy or normal plants develop and function to the maximum of their genetic potential. However, when plants are adversely affected by continuous irritation by a disease-causing agent, which interferes with normal development and functioning, plants are considered to be diseased. This broad definition excludes injury or damage such as mechancial injury (e.g., lawn mower or weed-eater injury to trees); deer, rodent, and bird damage; hail damage; and lightning injury.

In addition to reduction in growth, yield, and economic or aesthetic value of a plant or plant product, diseases may lead to the death of the whole plant or destruction of the entire crop under conditions favorable for the disease. Diseases may interfere with absorption and translocation of water and nutrients from the soil to the various parts of the plant, may reduce the photosynthetic efficiency of the plant parts, may interrupt the translocation of photosynthetic products through the plant, or may interfere with the reproduction and storage of food reserves in the plant.

Diseases in plants are caused by either living (biotic, parasitic, or infectious) agents called pathogens, or nonliving (abiotic, nonparasitic, or noninfectious) environmental factors. Plant diseases may also be grouped by the causal agent involved (fungal diseases, bacterial diseases, viral diseases, nematode diseases, etc.), the plant part affected (root diseases, seedling diseases, leaf diseases, stem diseases, flower diseases, fruit diseases, tuber diseases, etc.), or the types of symptoms (damping-off, wilts, leaf spots, cankers, blights, galls, root knots, mosaics, storage rots, etc.).

B. Symptoms of Diseases

Symptoms are the visible reactions of a plant to a disease and may suggest a causal agent. A sampling of disease symptoms might include wilting, necrosis, abnormal coloration, defoliation, fruit drop, abnormal cellular growth, or stunting of the infected plant. However, it is important to remember that different disease agents can cause similar symptoms on the same host. An equally important point to remember is that insect feeding can also cause disease-like symptoms on plants.

C. Signs of Diseases

Signs are the visible parts of the pathogen or its products seen on the host that can be used to identify the pathogen. Examples of common disease signs include: the white coating of mycelium visible on powdery mildew-infected leaves, mushroom growth on a tree limb, droplets of bacterial ooze running down a fruit tree twig, nematode cysts on plant roots, or dark fungal fruiting bodies visible in leaf lesions.

D. Causal Agents of Disease

A pathogen is any organism that can cause a disease. Pathogens cause infectious diseases that can spread from an infected plant to a healthy plant. Pathogens that cause infectious diseases include bacteria, fungi, viruses, nematodes, and parasitic plants. Plant disease can also be caused by noninfectious or nonliving factors. Causes of disease by nonliving factors include unfavorable growing conditions, mineral deficiencies, and air pollution.

Pathogens that cannot be cultured apart from their host are classified as obligate parasites. Pathogens that can be cultured apart from their hosts on artificial media are called nonobligate parasites. In general, obligate parasites only attack very specific host plants, whereas nonobligate parasites typically have a wider range of plants they can infect. Some pathogens are restricted to a single plant species, while others infect a single plant genus. Still others attack a large number of hosts from many plant genera.

There are also several levels of parasitism that pathogens can have with their hosts. When a pathogen is capable of infecting a plant, the plant is considered susceptible to that pathogen. If a pathogen cannot infect a plant, then the plant is considered immune to that pathogen. Plants can vary in their response to pathogens from high resistance (very little disease development), to partial resistance (moderate disease development), or high susceptibility (severe disease development). Pathogens can vary in their degree of virulence on a susceptible plant ranging from highly virulent (causing severe disease symptoms) to weakly virulent (causing less disease).

E. Inoculum and Pathogen Dissemination

Inoculum is any part of the pathogen that can cause infection. Examples of inoculum include fungal spores, bacterial cells, virus particles, or nematode eggs. Inoculum that survives the winter and causes the original or primary infection in the spring is called primary inoculum. Secondary inoculum causes additional infections throughout the growing season.

Inoculum is sometimes present at the site where a plant is grown and can also be introduced from an outside source. Inoculum already present at a plant site includes soil pathogens or pathogens that overwinter on perennial weeds. Introduced inoculum includes infected plant material such as infected seeds, wind-blown fungal spores, and inoculum transmitted by insects.

Inoculum can be disseminated passively by wind, rain, and man. Inoculum can also be disseminated actively by insects and nematodes or fungal zoospores swimming through water in the soil toward plant roots. Only a fraction of any pathogen's inoculum will ever land on a susceptible host. The vast majority of inoculum lands on material that cannot be infected. Most pathogens produce a tremendous surplus of inoculum.

F. Pathogen Survival

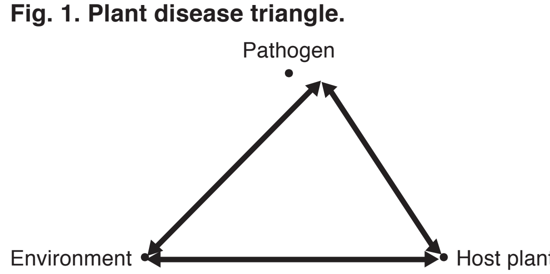
Pathogens in temperate climates must have a way of overwintering when their host plants are dormant or absent. In perennial plants, pathogens can survive in infected plant parts such as roots, bulbs, stems, and bud scales. Annual plants, however, die at the end of the growing season and pathogens must survive in insects, seeds, or as resistant spores.

G. Factors Affecting Disease Occurrence

Diseases in plants are an exception rather than a rule. Three factors, called the disease triangle (Fig. 1), must coincide for a plant to become diseased: the host, the pathogen, and the environment. The interaction between these three factors with time determines the occurrence and severity of a disease. For the disease to occur, the following conditions must be met:

1 The host plant must be of a susceptible species or cultivar at the right stage of development (susceptible host).
2. The pathogen must be of a virulent race or strain and must be present in sufficient numbers (inoculum potential). The presence of appropriate vectors or other agents of dispersal is also necessary.
3. The environmental (atmospheric and soil) conditions such as temperature, humidity, rainfall, wind, moisture, light, soil type, texture and pH, density of planting, aeration, and nutritional status (mineral deficiency or excess) must be favorable for disease development.

Fig. 1. Plant disease triangle.



4. Understanding the various aspects of the host, the pathogen, the environment, as well as their interaction is essential to implement an effective disease management strategy.

III. Diseases Caused by Living (Biotic, Parasitic, or Infectious) Agents

A. Fungi

Commonly known as molds, fungi (singular = fungus) are mostly microscopic organisms that have bodies (mycelium) composed of multi-cellular, thread-like, branched filaments (hyphae) and reproductive structures called spores. Since they do not possess chlorophyll, fungi depend on either dead organic matter or living plants for their growth and reproduction. Some fungi produce vitamins and antibiotics that are useful to us.

A few fungi, like some types of mushrooms and morels, are edible. On the other hand, some fungi thrive on living plants, drawing their nutrition from them and sometimes producing toxins that cause disease and death of the plants they infect. These are called plant pathogenic fungi.

A majority of diseases in plants are caused by fungi. Some examples commonly encountered in home gardens and landscape trees are: brown rot of cherries, apple scab, black spot of rose, snapdragon rust, corn smut, powdery mildew of rose, peach leaf curl, sycamore anthracnose, early blight of potato, Verticillium wilt of tomato, damping-off, and root rot of vegetables.

B. Bacteria and Phytoplasmas

Bacteria (singular = bacterium) and phytoplasmas (formerly known as mycoplasmas or mycoplasma-like organisms) are microscopic, single-celled organisms that cause some of the most destructive diseases in plants. Some bacteria, like those that induce nodulation in leguminous plants, are beneficial to plants because they fix nitrogen from the air into the root nodules in a form that the host plant can utilize for its growth.

Phytoplasmas are a type of bacteria that lack distinct cell walls. Under favorable conditions, bacteria reproduce very rapidly and can cause serious damage in a short period of time. Bacterial pathogens are spread by wind-splashed rain, insects, contaminated seed, or implements. Bacterial diseases are relatively difficult to control because there are very few chemicals that are effective against them.

Some commonly encountered bacterial diseases are: crown gall of rose, grape, apple, cherry, and other ornamental plants; fire blight of apple and pear; soft rot of potato; ring rot of potato; and aster yellows phytoplasma on carrots, tomatoes, onions, lettuce, etc.

C. Viruses

Viruses are infectious agents so small they must be observed through an electron microscope. Particles of these viruses may be in the form of rods, spheres, or threads. They are composed mainly of a nucleic acid core surrounded by a protein coat. Viruses can multiply only in a living host cell and can often spread systemically throughout the infected plant.

Viruses can be transmitted from infected to healthy plants mechanically, through grafts, and by contaminated propagating material. Viruses can also be transmitted by certain organisms, referred to as vectors. In addition to insects (primarily aphids, white flies, leafhoppers, and beetles), virus vectors include mites, nematodes, and fungi in the soil.

Viral diseases are not controlled by pesticide chemicals. Examples of viral diseases are: curly top of tomato, bean, cucurbits, etc.; potato leaf roll; bean common mosaic; and rose mosaic.

D. Nematodes

Nematodes are microscopic roundworms that live in soil as well as water, and survive as eggs or cysts. Most of them are saprophytes, but some infect living plants and cause diseases. Most plant parasitic nematodes feed on the underground parts of the plants (roots, tubers, bulbs, etc.) causing lesions or root knots. However, a few nematodes also affect the buds, leaves, flowers, and stems of plants. Nematodes spread through contaminated planting material (tubers, seedlings, etc.), manure, soil, water, machinery, and implements. Some nematodes are vectors of plant viruses.

Some examples of plant parasitic nematodes are: root knot nematodes of tomato, potato, beans, and many other plants; root lesion nematodes of corn and potatoes, cyst nematode of sugarbeets; stubby root nematode of corn; stem and bulb nematodes of onion; and foliar nematode of chrysanthemum.

E. Parasitic Higher (Flowering) Plants

Several flower- and seed-producing plants live as parasites on other plants (host plants), deriving their nutrition from them and adversely affecting the host plant's growth and yield. Dodder (also know as strangleweed and devil's hair), for example, parasitizes several garden plants such as potatoes and carrots. It produces orange or yellow vine strands that entwine the stems and other plant parts from which it draws its nutrition through tube-like structures it introduces into the host tissue. Dodder produces abundant seeds that ensure its propagation and spread. Another example of a parasitic plant is dwarf mistletoes on pines.

IV. Diseases Caused by Abiotic (Nonliving, Nonparasitic, or Noninfectious) Agents

A variety of environmental and cultural factors can cause diseases in plants. Since these diseases occur in the absence of pathogens, they do not spread from a diseased plant to a healthy plant.

A. High or Low Temperatures

When plants or plant parts are exposed to high temperatures for prolonged periods, symptoms of scorching or scalding may develop. Some examples are: sunburn or scorching of leaves and sunscald of fruits (e.g., apples, tomatoes, peppers, and melons). Similarly, low temperatures, like frost or freeze, can damage the exposed or sensitive organs (buds, flowers, young fruits, etc.) or may kill the entire plant. Examples include: southwest-side damage to trunks of apple trees; frost damage to blossoms and young apple fruits; russet ring (caused by frost) on apple and pear fruits; winter injury to trees; and frost damage to tomatoes, beans, potatoes, etc.

B. High or Low Soil Moisture

Too much moisture due to excessive watering, poor drainage, ponding, or flooding may cause plants to turn yellow and be stunted. Potted indoor plants, for example, may show poor development or root rots. Seedlings are vulnerable to damping-off caused by soilborne pathogens under these conditions.

In some indoor or greenhouse plants (e.g., geraniums, begonias) growing under warm, humid atmospheric conditions and excessive soil moisture, a condition known as edema (small, wart-like rusty, corky bumps) can develop on the underside of the leaves, and on the stems. At the other extreme, low moisture or drought conditions can lead to poor development, wilting, and death of plants.

C. High or Low Light Intensity

High light intensity is usually not a problem but low light conditions, especially for indoor plants, can lead to etiolation (spindly or lanky plant growth with chlorotic yellow foliage).

D. Lack of Aeration or Low Oxygen Supply

Low aeration can deprive plant roots of adequate oxygen and can adversely affect their development or even kill the plant. Inadequate oxygen supply during the storage of potato tubers can lead to the development of a condition called blackheart, the browning and death of internal tuber tissue.

E. Air Pollution

Certain chemcals, such as ozone, sulfur dioxide, and nitrogen dioxide are released into the air from factories, power plants, and automobile exhausts. These chemicals can accumulate in the atmosphere in sufficient concentration to cause damage to plants.

Ozone damage appears in the form of mottling, chlorosis, spots, and bleaching of young leaves. This is common in certain regions of the country where there is a high ozone concentration in smog. For example, ozone damage is frequently found on the leaves of beans, petunias, and grapes. Some of the air pollutants responsible for acid rain cause damage to vegetation in certain regions. In Idaho, however, plant damage due to air pollution is not common.

F. Nutrient Deficiencies

Plants require several major (nitrogen, phosphorus, potassium, calcium, magnesium, and sulfur) and minor (iron, boron, copper, zinc, etc.) elements for normal growth. Deficiency or lack of any of these essential nutrients results in disease symptoms in the plant. Specific symptoms depend on the plant species and the deficient nutrient. If not corrected, a prolonged acute deficiency of essential nutrients can lead to death of the plant.

Common examples of nutrient deficiencies are: nitrogen deficiency in beans, iron deficiency in peaches, zinc deficiency in apple trees, and calcium deficiency in apple fruit (bitter pit). In the home garden, the common blossom-end rot of tomato fruit is caused, in part, by calcium deficiency.

G. Mineral Toxicity

Presence of excessive available amounts of certain minerals in the soil can lead to mineral toxicity to the plants. The extent of injury depends on the mineral, its concentration, and the species of the plant. Excessive amounts of sodium salts in the soil can lead to high pH and to alkali injury (e.g., alkali injury to apple). Plants growing in acidic soils can be injured by aluminum or manganese toxicity.

H. Unfavorable Soil pH

Although many plants can grow in a rather wide range of soil pH, plants growing in soils with unfavorable pH usually show poor growth and mineral deficiency or toxicity symptoms.

For example, iron deficiency symptoms are very common in plants growing in high pH soils in Idaho. Under conditions of high soil pH, iron in the soil becomes unavailable to the plant, thus inducing interveinal chlorosis and yellowing of leaves. The plant may die if the condition remains uncorrected for a prolonged time.

I. Pesticide Toxicity

Some pesticides, if improperly used, can cause serious damage to plants. For example, if wettable sulfur is sprayed (for powdery-mildew control) on a very hot day (above 90°F), it will result in injury to the plant phytotoxicity). However, the most common type of chemical injury to plants is due to soil residues or spray drift of herbicides.

Examples of pesticide toxicity are: 2,4-D damage to beans and tomatoes, dicamba (Banvel) damage to vegetables and trees, and glyphosate (Roundup) damage to fruit trees. Some herbicides used as soil sterilants may leave the soil unsuitable for any plant growth for several years.

J. Improper Cultural Practices

Any cultural practice done in the wrong way or at the wrong time can result in significant damage to plants. Injury can result from improper amounts of chemical fertilizer or pesticide or improper chemical mixes in the spray tank. Root pruning can result from excessively deep cultivation; distorted and twisted roots can result from pot-bound conditions of a plant. African violet leaves sprinkled with very cold water develop rings and ring-like patterns that resemble symptoms caused by some viruses.

V. Diagnosing Plant Disease Problems

A. Why Is Diagnosis Important?

Whether in an effort to save existing plants or to prevent problems from recurring, it is important to know “What went wrong?” Diagnosis is the process of gathering information about a plant problem and determining the cause. Once the cause has been determined, it is then possible to recommend a solution or remedy.

Diagnosing plant problems can involve considerable detective work. Sometimes there is insufficient information and other times, the primary cause of a problem is hidden by more obvious, but less-important, problems. Success in diagnosing plant problems depends on how much we know about the host plant, about the plant problems in general, and the quality of information obtained from the client.

For example, 10 tomato plants all similarly damaged, are brought to you. All have yellow leaves, stunted growth, and very few feeder roots. You learn from questioning the grower that he applied one-half of a 20-pound bag of 10-10-10 fertilizer to a tomato plot that measures 60 square feet. The grower put 10 pounds of fertilizer on 60 square feet, which translates to a rate of 166 pounds per 1,000 square feet. This is almost 10 times the normal rate of 20 pounds per 1,000 square feet of a 10-10-10 fertilizer. The grower's fertilization rate is enough to kill fine feeder roots. The diagnosis is damage to the roots caused by overfertilization.

B. Basic Steps in Reaching a Diagnosis

1. Identify the plant—The better your plant identification skills the faster you will be able to diagnose a problem. Most references on plant pests and diseases are organized by plant, so knowing the plant is the essential first step in using many reference books.
2. What is normal? Your familiarity with the normal appearance and cultural requirements of the plant will enable you to differentiate normal changes from symptoms of a problem.
3. What is the problem? To make a disease diagnosis, you need to know: the pattern of distribution of the diseased plants or plant parts, the plant species or cultivar involved, the site where the plant is growing (field, orchard, garden, greenhouse, inside the house, etc.), and previous crop history of the site.

   For example, uniform damage to many species in an area, to all plants on one side of the field or garden, or to all shoots on one side of the tree indicates that the cause may be an abiotic factor. Also, if the damage is well demarcated in a garden or in a plant, it may suggest that some abiotic factor is involved. On the other hand, if there is evidence of progressive spread of the disease from an initial focus to other plants of the same cultivar or species or to different parts of the plant, it may indicate that an infectious agent is involved.
4. Examine the plant and note symptoms and signs —For a presumptive diagnosis of diseases in plants, look for the symptoms and signs of the disease. The characteristic internal or external alterations of a plant in response to a disease-causing agent are called symptoms (leaf spot, necrosis, blight, canker, wilt, lesion, gall, witches' broom, rot, chlorosis, mosaic, etc.). Sometimes, the pathogen that causes the disease produces its own characteristic growth or structures on the diseased plant that are of diagnostic value. These are referred to as signs of the disease (mold, mildew, sclerotia, mushrooms, conks, etc.).
5. Tentative diagnosis—Based on your knowledge of the plant and information from reference books, formulate a tentative diagnosis. This will help you focus your examination of the plant and assist in collecting relevant information.
6. Double-check the diagnosis—Once you have arrived at a diagnosis, unless it is an obvious diagnosis, double-check it. Ask other master gardeners or extension educators for their opinions. Read through the reference books about your diagnosis to make certain everything matches. Additional laboratory work may be needed to confirm your diagnosis.
7. Types of plant disease diagnosis—Verbal descriptions by a telephone call or evaluation of a sample provide the most common diagnostic opportunities. However, a site visit provides more complete information.

   To make a telephone diagnosis, you must completely rely on information provided by the caller in order to make your diagnosis. There will be common, familiar problems, such as powdery mildew of apples, when a little information easily leads to a correct diagnosis. In other cases, it will be very difficult to make a diagnosis over the telephone and it may be necessary to evaluate a sample.

   Much of your diagnositic work as a master gardener will be done with plant samples. Usually, the sample will provide the clues necessary to solve the problem. But when the sample only confirms the identification of the plant, you must concentrate on acquiring information to reach a diagnosis. Your job will be to learn about the plant's cultural and environmental conditions, the care the plant has received, and whether the sample is representative of the problem affecting the plant.

A site visit provides the greatest opportunity to gather information, but a successful plant diagnosis also depends on a combination of factors: your knowledge of the plant involved, your understanding of the plant's basic cultural requirements, and your recognition of the potential problems that might affect it. It also depends on your ability to gather information, both through observation of the plant and discussion with the client.

VI. Principles of Plant Disease Control

Plant disease control aims at preventing or reducing the amount of damage or economic loss. Most plant disease-control measures are aimed at preventing or protecting plants from the disease rather than curing the plant after it is diseased. By the time the disease symptoms appear, it is often too late to reverse the damage caused by the disease agent. In some cases, acceptable control measures are not available to halt the disease, short of plant removal. Correct diagnosis of the disease is important in order to implement a control strategy to prevent or reduce the incidence of the disease in the next crop cycle.

The various controls for diseases can be classified as exclusion strategies, inoculum reduction methods, use of disease-resistant cultivars, chemical control, and biological controls. Integrated disease-management strategies may utilize any or all of these methods.

A. Exclusion of the Pathogen

Some destructive plant diseases do not occur in our country, state, or region. To prevent import and introduction of these pathogens national, regional, or state regulations, known as quarantines, are put into force. Some examples are the customs and plant health inspection services at airports and check points on highways. In addition, national and state laws regulate the conditions under which certain crops may be grown and distributed between states and countries. We cannot import several types of plant material from abroad without specific permission and inspection by the appropriate quarantine authority.

An example of a state quarantine is in relation to white rot of onion and garlic. White rot is a very destructive disease of onion and garlic. Once introduced in the soil, the pathogen can survive for over 20 years and there are no satisfactory chemical control measures. At present, our commercial onion growing areas in southern Idaho are free from this disease. Therefore, the State Department of Agriculture in Idaho restricts the importation of onion and garlic bulbs and other related plants for planting in southern Idaho.

Restriction of bean seed from outside of Idaho prevents the introduction of two serious bacterial diseases: halo blight and common blight.

Homeowners can keep some serious plant pathogens out of their yards and gardens by planting only certified, disease-free planting material (seeds, tubers, bulbs, seedlings, nursery stock, etc.). For example, a homeowner can avoid several virus diseases and ring rot of potato by planting certified disease-free tubers.

B. Eradication or Reduction of the Pathogen Population

Serious disease damage to a crop or garden patch can be prevented or reduced by pulling out and destroying the first plant or the first few plants that show the disease symptoms (roguing). This prevents the spread of the pathogen to other healthy plants (e.g., elimination of the first bean plants with mosaic symptoms).

Since some of the root-infecting pathogens remain viable in the soil even after the crop is harvested, avoid planting the same or similar susceptible crop in that part of the garden for the next 2 to 3 years. An appropriate crop rotation in the garden is very essential to reduce the damage caused by root rot and wilt-causing pathogens and nematodes (e.g., Fusarium root rot and wilt, Verticillium wilt, and nematodes on tomato).

Eliminating the infected leaves and diseased or dead branches, as well as using clean garden tools and similar methods of sanitation, will prevent the spread and build up of disease-causing organisms.

Other cultural practices, such as growing plants on raised beds and using composted tree bark in the planting medium for containerized nursery stock, help reduce the damage caused by certain soilborne pathogens (e.g., damping-off, root rots, and wilts).

Proper irrigation management can prevent some diseases (e.g., collar rot of apple).

Using the sun's heat during the summer months to reduce some of the soilborne pathogens can be successful in certain regions. In this process, called soil solarization, the soil is cultivated to a fine texture and deeply watered.The moist soil is covered with a clear polyethylene sheet. The sheet's edges are buried to create an airtight environment. The moist soil below the polyethylene mulch heats up and is slowly "cooked." Under sunny weather conditions for at least 4 weeks, this process reduces or eliminates several soilborne pathogens.

Marigolds interplanted with nematode-susceptible crops produce substances in the soil that are toxic to plant parasitic nematodes and thereby reduce the nematode damage to the crop plant.

Controlling insects with insecticides can reduce the spread of some of the diseases caused by viruses that are transmitted by insects (e.g., potato leaf roll virus spread by aphids).

C. Use of Disease-Resistant Cultivars

Where available, use of disease-resistant cultivars is the most cost-effective, safe, easy, and environmentally desirable option for the gardener. In fact, for some diseases (such as curly top of tomato), resistant cultivars offer the only practical control option available. Varieties resistant to one or more diseases are available in several vegetables and fruits (e.g., tomato cultivars with resistance to Fusarium wilt, Verticillium wilt, nematodes, and tomato mosaic virus; and apple cultivars resistant to fire blight).

D. Chemical Protection of Plant

The most common method of direct protection of plants against plant pathogens is through the use of chemicals. Chemicals used for control of fungal diseases are called fungicides, those that control bacterial diseases are called bactericides, and those that control nematodes are called nematicides. No chemicals at this time are effective against diseases caused by viruses.

Certain chemicals, used to control soilborne pathogens, are called fumigants. These are highly volatile chemicals that are toxic to all the living organisms (biocides), including insects, weed seeds, fungi, bacteria, and nematodes. An example of a soil fumigant is methyl bromide. Fumigants need extreme care in handling and application, and therefore, can only be used by certified pesticide applicators.

Based on the mode of action, pesticide chemicals can be classified as follows:

Protectants: These chemicals, when applied to the plants, remain on the plant surface and prevent spore germination and infection of the plant by the pathogen (e.g., sulfur, captan).

Systemics: These chemicals are absorbed by plants and are translocated to other plant parts (e.g., Benlate, Ridomil).

Eradicants: These chemicals can eradicate the pathogen from plant tissue after the infection has occurred; that is, after the penetration by and establishment of the pathogen inside the host tissue (e.g., Rally).

Based on the type of chemical (active ingredient), these pesticides can also be classified as copper compounds, sulfur compounds, dithiocarbamates, benzimidazoles, antibiotics, etc. Disease-control chemicals can be applied as seed treatments, foliar sprays, dusts, fumigants, wound paints, dips, or through irrigation water (chemigation).

The effectiveness of chemical control measures is dependent upon our understanding of the disease cycle, host susceptibility, timing, mode of application, coverage, and choice of the appropriate product. Timing of the application and thorough coverage of the plant surface are very important for effective disease control. For best results, most chemicals are applied before the pathogen infects the host. Also, most chemical sprays have to be applied several times at regular intervals for best disease control.

Always follow the label directions and precautions. Development of pathogen strains resistant to chemicals or antibiotics (e.g., streptomycin-resistant strains of apple fire blight pathogen) can lead to these products becoming ineffective in disease control.

E. Biological Control

The strategy for biological control of plant diseases involves the use of antagonistic microorganisms before or after infection takes place. There has been successful control of crown gall with strain K84 of *Agrobacterium radiobacter,* which produces an antibiotic specific against crown gall bacterium. Commercial biological control agents are available as seed treatments and soil amendments to protect plants against soilborne pathogens.

Currently, the bacteria *Bacillus subtilis* and *Pseudomonas* spp. and the fungi *Gliocladium virens* and *Trichoderma* spp. are the organisms with the most applications in biological control strategies. There is tremendous research interest in developing new biological tools for plant disease control, but research-based options are limited at this time. Genetic engineering of biocontrol microorganisms has sparked wider environmental concerns, which will limit the speed of this new technology's use in plant disease control.

F. Integrated Disease Management

An effective, economical, and sustainable disease management strategy should incorporate all the available approaches of a disease management program. It should include the relevant preventive and control measures appropriate for the crop, such as selection of planting site, selection of the most adapted and disease-resistant variety, crop rotation, pathogen-free planting material, seed treatment, appropriate planting date, planting depth and density, irrigation and fertilizer use, weed control, sanitation, timely pesticide applications, proper harvesting, and handling and storage of the produce. The integrated disease management measures selected should be effective (should control the disease), economical (should result in an economic return), and sustainable (should be environmentally sound).

VII. Plant Disease Terms

Anthracnose—Black or brown dead areas on leaves, stems, or fruits (anthracnose of sycamore, maple).

Blackleg—Darkening at the base of a stem (blackleg of potato).

Blight—Rapid death of leaves and other plant parts (fire blight of apple, early blight of tomato).

Brown rot—Soft rot of fruit covered by gray to brown mold (brown rot of cherries, peaches, nectarines).

Canker—Sunken, discolored, dead areas on twigs and branches, usually starting from an injury or wound (Cytospora canker of trees, common canker of rose, fire blight cankers).

Chlorosis—Yellowing or whitening of normally green tissue (iron chlorosis of trees).

Crown gall—Excessive, undifferentiated growth that may girdle roots, stems, or branches (crown gall of grapes, rose, apple, cherry).

Curly top/leaf curl/leaf roll—Rolling and curling of leaves and growing point (curly top of sugarbeet, tomato, bean, etc.; peach leaf curl; potato leaf roll).

Damping-off—Stem rot near the soil surface leading to either failed seed emergence or falling over after emergence.

Epidemic—A widespread and severe outbreak of a disease.

Etiolation—Long internodes and pale green color of plants growing under insufficient light or in complete darkness.

Fumigation—The application of a toxic gas or volatile substance to disinfect soil or a container such as a grain bin.

Fungicide—A compound toxic to fungi.

Host plant—A plant that is invaded by a parasite.

Host range—The various plants that may be attacked by a parasite.

Inoculum—The pathogen or its parts that can cause infection.

Integrated control—An approach that attempts to use all available methods for control of a pest or disease.

Isolation—The separation of a pathogen from its host by culturing on a nutrient medium or on an indicator plant.

Lesion—A localized area of discolored or dead tissue (early blight lesions on potato leaf).

Life cycle—The successive stages of growth and development of an organism.

Microscopic—Organisms so small that they can be seen only with the aid of a microscope.

Mosaic—Intermittent yellowish and green mottling of leaves (bean common mosaic, rose mosaic).

Necrosis—Death of tissue (necrotic area in black spot of rose).

Organism—A living being.

Parasite—An organism that lives in or on another organism (host) and derives its food from the latter.

Pathogen—A disease-causing agent.

Plant disease—Any lasting change in a plant's normal structure or function that deviates from its healthy state.

Plant pathology—The study of diseases in plants: what causes them, what factors influence their development and spread, and how to prevent or control them.

Powdery mildew—Fine, white to gray, powdery coating on leaves, stems, and flowers (powdery mildew of rose, grapes, lilac, and apple).

Resistance—The ability of a host plant to prevent or reduce disease development by retarding multiplication of the pathogen within the host.

Root and stem rots—Soft and disintegrated roots and lower portions of the stem, sometimes results in death of plant (root rot of pea, damping-off of seedlings, collar rot of apple).

Root knots—Swelling and deformation of roots (tomato root knot).

Rust—Raised pustules on leaves, stems, and fruits; contain yellow-orange or rust-colored spore masses (snapdragon rust, geranium rust).

Sanitation—The removal and disposal of infected plant parts; decontamination of tools, equipment, hands, etc.

Saprophyte—An organism that can subsist on nonliving matter.

Scab—Slightly raised, rough areas on fruits, tubers, leaves, or stems (common scab of potato, apple scab).

Shot-hole—Roughly circular holes in leaves resulting from the dropping out of the central dead areas of spots (Coryneum leaf spot of peach).

Sign—The part of a pathogen seen on a host plant (moldy growth, spores, etc.).

Smut—Black masses of spores in galls that may form on stems, ears, etc. (common smut of corn).

Spore—The reproductive unit of a fungus, similar to the seed of a plant.

Susceptibility—The condition of a plant in which it is prone to the damaging effects of a pathogen or other factor.

Symptom—The altered external or internal appearance of a diseased plant (spot, gall, soft rot, etc.).

Systemic—Spreading internally throughout the plant.

Vascular pathogen—A disease-causing organism that invades mainly the conductive tissues (xylem or phloem) of the plant.

Vector—A living organism that is able to transmit or spread a pathogen.

Virulent—Capable of causing severe disease.

Wilt—Drooping and drying plant parts due to interference with the plant's ability to take up water and nutrients (Verticillium wilts, Fusarium wilts).

Further Reading

Books

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Booklets and Pamphlets

University of Idaho Extension

Pesticide Safety

PNW 512	Farm Safety Series
PNW 512S	Farm Safety Series (Spanish)
PNW 278	First Aid for Pesticide Poisoning
CIS 1030	Idaho Homeowner's Commonsense Guide to Pesticides: Storage and Disposing of Home and Garden Pesticides
CIS 781	Laundering Pesticide-Contaminated Clothing and Safety Equipment
CIS 1019	Pesticides for the Home Garden and How to Use Them

Small Fruit

CIS 341	Crumbly Fruit in Raspberries
CIS 789	Diseases of Raspberries in Idaho
CIS 847	Virus and Nematode Diseases of Raspberries

Tree Fruit

CIS 866	Homeowner's Guide to Fruit Tree Fertilization
PNW 121	Nutrient Disorders in Tree Fruits (online only)
CIS 752	Phytophthora Collar-Rot of Orchard Trees

Ornamentals

CIS 869	Controlling Sunscald on Trees and Vines
CIS 1068	Fertilizing Landscape Trees

Gardening

CIS 292	Blossom-End Rot of Tomatoes
CIS 993	Management of Vegetable Diseases in Home Gardens
BUL 775	Planning an Idaho Vegetable Garden

Lawns

BUL 676	Fairy Rings in Turf
CIS 1062	Starting a Home Lawn
CIS 1063	Thatch Prevention and Control in Home Lawns

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