COURSE CODE:	CPT 505
COURSE TITLE:	Plant Disease Evaluation
NUMBER OF UNITS:	2 Units
COURSE DURATION:	1 hr. theory + 2 hrs. practical

COURSE DETAILS:

Course Coordinator: **Prof. A. Y. A. Adeoti**
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Other Lecturers: **Dr. A.R. Popoola**
Dr. A.A. Fajinmi
Dr. C. G. Afolabi

COURSE CONTENT:

Description of plant diseases under three major sections – bacterial, viral and mycological plant diseases. Development of plant diseases in relation to such factors in the environment-temperature, soil, relatives humidity and moisture. Basic methods for isolation of the various pathogens causing diseases-bacteria, virus and fungi. The ecology of various pathogens and their severity. Identification of various symptoms and organisms causing fungal, bacterial and viral diseases of arable and tree crops. Isolation of the various pathogens that could cause a disease. Determination of minimum inoculum load of the pathogens. Determination of various factors favouring disease development.

COURSE REQUIREMENTS:

This is an elective course. Students are expected to participate in all the course activities and have minimum of 75% attendance to be able to write the final examination.

READING LIST:

1. Plant pathology by Mehrotra, R.S and Ashok Aggarwal Tata McGraw-Hill Publishing Co.Ltd New Delhi.

2. An Introduction to plant Disease by Wheeler B. E. J. John Wiley and Sous Ltd, Chichester.

LECTURE NOTES

PLAND DISEASE EVALUATION : Bacterial Plant Disease Component

We shall explain:-

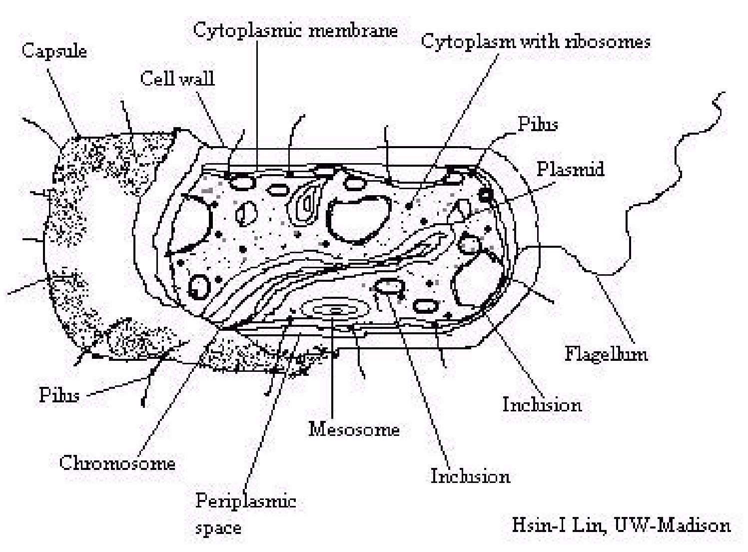
1. Morphology of Bacteria
2. Classification and taxonomy of plant pathogenic bacteria
3. Some economically important plant pathogenic bacteria
4. Control of bacterial plant diseases
5. Practical Considerations

1. Morphology of Bacteria.

- Bacteria - a group of single-cell microorganisms with procaryotic cellular configuration.
- The genetic material (DNA) of procaryotic cells exists unbound in the cytoplasm of the cells.
- No nuclear membrane, which is the definitive characteristic of eukaryotic cells such as those that make up plants and animals.
- Until recently, bacteria were the only known type of procaryotic cell, and the discipline of biology related to their study is called bacteriology.
- In the 1980's, with the outbreak of molecular techniques applied to phylogeny of life, another group of procaryotes was defined and informally named "archaebacteria".
- This group of procaryotes has since been renamed Archaea and has been awarded biological Domain status on the level with Bacteria and Eukarya.
- The current science of bacteriology includes the study of both Domains of procaryotic cells, but the name "bacteriology" is not likely to change to reflect the inclusion of archaea in the discipline. Actually, many archaea have been studied as intensively and as long as their bacterial counterparts, but with the notion that they were bacteria.

STRUCTURE

- Three architectural regions (See figure below)
  - appendages (proteins attached to the cell surface) in the form of flagella and pili;
  - cell envelope consisting of a capsule, cell wall and plasma membrane;
  - cytoplasmic region that contains the cell genome (DNA) and ribosomes and various sorts of inclusions.



Schematic drawing of a typical bacterium.

- ✓ Flagella are filamentous protein structures attached to the cell surface that provide swimming movement for most motile procaryotic cells.
- ✓ Fimbriae and Pili are interchangeable terms used to designate short, hair-like structures on the surfaces of procaryotic cells. Fimbriae are shorter and stiffer than flagella, and slightly smaller in diameter. Like flagella, they are composed of protein.
    - o A specialized type of pilus the F or sex pilus, mediates the transfer of DNA between mating bacteria, but the function of the smaller, more numerous common pili is quite different.
    - o Common pili (almost always called fimbriae) are usually involved in adherence (attachment) of procaryotes to surfaces in nature.

- ✓ A rigid cell wall protects the delicate cell protoplast from osmotic lysis.
- ✓ The cell wall of Bacteria consists of a polymer of disaccharides cross-linked by short chains of amino acids (peptides). This molecule is a type of peptidoglycan, called murein.
- ✓ In the Gram-positive bacteria (those that retain the purple crystal violet dye when subjected to the Gram-staining procedure) the cell wall is a thick layer of murein.
- ✓ In the Gram-negative bacteria (which do not retain the crystal violet) the cell wall is relatively thin and is composed of a thin layer of murein surrounded by a membranous structure called the outer membrane. Murein is a substance unique in nature to bacterial cell walls.
- ✓ Also, the outer membrane of Gram-negative bacteria invariably contains a unique component, lipopolysaccharide (LPS or endotoxin), which is toxic to animals. The cell walls of Archaea may be composed of protein, polysaccharides, or peptidgolycan-like molecules, but never do they contain murein. This feature distinguishes the Bacteria from the Archaea.
- ✓ Cytoplasmic Constituents:-
    - o Include chromosome and ribosomes. The chromosome is typically one large circular molecule of DNA, more or less free in the cytoplasm.
    - o Procaryotes sometimes possess smaller extrachromosomal pieces of DNA called plasmids.
    - o The total DNA content of a cell is referred to as the cell genome.

- The ribosomes of procaryotes are smaller than cytoplasmic ribosomes of eukaryotes. Procaryotic ribosomes are 70S in size, being composed of 30S and 50S subunits. The 80S ribosomes of eukaryotes are made up of 40S and 60S subunits.
- Ribosomes are involved in the process of translation (protein synthesis), but some details of their activities differ in eukaryotes, Bacteria and Archaea. Protein synthesis using 70S ribosomes occurs in eukaryotic mitochondria and chloroplasts, and this is taken as a major line of evidence that these organelles are descended from procaryotes.
- Cytoplasmic inclusions.
  - are distinct granules that may occupy a substantial part of the cytoplasm.
    - E.g. carbon and energy reserves may be stored as glycogen (a polymer of glucose) or as polybetahydroxybutyric acid (a type of fat) granules.
    - Polyphosphate inclusions are reserves of PO_4 and possibly energy; elemental sulfur (sulfur globules) are stored by some phototrophic and some lithotrophic procaryotes as reserves of energy or electrons. Some inclusion bodies are actually membranous vesicles or intrusions into the cytoplasm which contain photosynthetic pigments or enzymes.

2. Classification and taxonomy of plant pathogenic bacteria

Species of bacterial plant pathogens come from seven genera:

1. Agrobacterium
   a. Rhizosphere and soil inhabitants
   b. mostly cause galls and deformations on roots or stems,
   c. short rods, motile,

2. Clavibacter (Corynebacterium)
   a. only gram-positive genus,
   b. cause systemic infections producing galls and wilts,
   c. slender rods, non-motile,

3. Erwinia
   a. some cause necrotic or wilt diseases,
   b. others cause soft rots,
   c. motile rods,

4. Pseudomonas
    a. localized rots, e.g. leaf spots and blights,
    b. many produce a greenish, water-soluble pigment in culture,
    c. motile rods,

5. Xanthomonas
    a. leaf spots and blights
    b. small, motile rods,

6. Streptomyces
    a. the only one that produces hyphae, no crosswalls,
    b. all are soil inhabitants,
    c. many produce antibiotics,

7. Xyllela
    a. xylem inhabiting, fastidious bacteria.

3. Some Economically Important Plant Pathogenic Bacteria.

1. *Xanthomonas oryzae*: bacterial blight of rice
2. *Pseudomonas (Ralstonia) solanacearum*: bacterial wilt.
   Wide host range including tobacco, tomatoes, potatoes, banana.
3. Xanthomonas campestris pv. campestris: Black Rot of Cabbage
4. *Erwinia amylovora*: Fire Blight of Pear
5. *Xanthomonas campestris* pv. *vesicatoria*: bacterial spot, vegetables, peppers, tomato.
6. *Erwinia carotovora*: soft rot of vegetables and potatoes
7. *Clavibacter sepedonicum*: ring rot of potatoes
8. *Pseudomonas syringae*: bacterial blight
9. *Agrobacterium tumefaciens*: crown gall
10. Mycoplasmalikeorganisms, MPLO: Aster yellows
11. *Xylella fastidiosa*: Pierce's Disease of Grapes
12. *Xanthomonas campestris* pv. *citri*: Citrus Canker

4. **Control of bacterial plant diseases**
   A. Host Resistance: (main mechanism)
      -resistance is often unstable as pathogens can evolve quickly.
   B. Sanitation

   C. Crop Rotation

   D. Vector Control

   E. Seed Sterilization: bacteria can enter seed during flowering.

   F. Chemical Control: antibiotics -not widely applied.

   G. Biological Control.

PLANT DISEASE EVALUATION

The study of disease in plants; it is an integration of many biological disciplines and bridges the basic and applied sciences. As a science, plant pathology encompasses the theory and general concepts of the nature and cause of disease, and yet it also involves disease control strategies, with the ultimate goal being reduction of damage to the quantity and quality of food and fiber essential for human existence.

Plant disease - a disease that affects plants
Disease - an impairment of health or a condition of abnormal functioning

Throughout history, loss of crop yields from disease has had severe effects on the human race.

There are at least 50,000 diseases of crop plants. New diseases are discovered every year. About 15% of the total U.S. crop production is lost annually to infectious diseases despite improved cultivars and disease control techniques. Damage from disease has not been eliminated. Disease-causing organisms (pathogens) multiply and mutate rapidly. They develop genetic resistance to chemical controls and have the ability to infect new hybrids. Good gardening practices and an understanding of plant pathology are the first line of defense against disease.

DEFINITION OF PLANT PATHOLOGY

The study of plant diseases is known as plant pathology. Infectious diseases are caused by living organisms called pathogens. Noninfectious diseases caused by environmental stress and damage by weather and other environmental factors also will be covered.

Indirectly, environmental factors that cause a plant to be stressed may result in the plant's gradual decline. Decline results in the plant being more susceptible to disease organisms. Because of this, diagnosing plant diseases can be tricky. The real cause of a problem may be the stress factors, with the disease simply being a secondary factor.

DISEASE TRIANGLE FOR VIRUS INFECTION

Three critical factors or conditions must exist for virus disease to occur: a SUSCEPTIBLE HOST PLANT, a VIRULENT PATHOGEN, an active VECTOR and the right mix of ENVIRONMENTAL CONDITIONS. The relationship of these factors is called the disease triangle.

If only a part of the triangle exists, disease will not occur. Understanding the disease triangle helps us understand why most plants are not affected by the many thousands of diseases that exist.

VIRUS PATHOGEN

Viruses are very small (submicroscopic) infectious particles (virions) composed of a protein coat and a nucleic acid core. They carry genetic information encoded in their nucleic acid, which typically specifies two or more proteins. Translation of the genome (to produce proteins) or transcription and replication (to produce more nucleic acid) takes place within the host cell and uses some of the host's biochemical "machinery". Viruses do not capture or store free energy and are not functionally active outside their host. They are therefore parasites (and usually pathogens) but are not usually regarded as genuine microorganisms.

Most virus pathogens are host-specific to a particular plant species, genus or family. Viruses also cause many important plant diseases and are responsible for huge losses in crop production and quality in all parts of the world. Infected plants may show a range of symptoms depending on the disease but often there is leaf yellowing (either of the whole leaf or in a pattern of stripes or blotches), leaf distortion (e.g. curling) and/or other growth distortions (e.g. stunting of the whole plant, abnormalities in flower or fruit formation).

VECTOR

Some important animal and human viruses can be spread through aerosols. The viruses have the "machinery" to enter the animal cells directly by fusing with the cell membrane (e.g. in the nasal lining or gut).

By contrast, plant cells have a robust cell wall and viruses cannot penetrate them unaided. Most plant viruses are therefore transmitted by a vector organism that feeds on the plant or (in some diseases) are introduced through wounds made, for example, during cultural operations (e.g. pruning). A small number of viruses can be transmitted through pollen to the seed (e.g. *Barley stripe mosaic virus*, genus *Hordeivirus*) while many that cause systemic infections accumulate in vegetatively-propagated crops.

SUSCEPTIBLE HOST

A susceptible host has a genetic makeup that permits the development of a particular disease. The genetic defense against a disease is called disease resistance. This resistance can be physical characteristics of the plant (fuzzy or waxy leaf surfaces), chemical characteristics (enzymes that kill pathogens and lack of enzymes) and growth patterns (ability to block off diseased tissue or outgrow damage).

Plants also may be disease-tolerant. Even though infected with a disease, they can grow and produce a good crop or maintain an acceptable appearance. The plant outgrows the disease and symptoms are not apparent or at a damaging level.

It is important to remember that plants labeled as disease-resistant are resistant only to a particular disease. They are not resistant to all diseases. Resistance does not mean immunity. Under extreme circumstances, resistant plants may be infected by the disease to which they have resistance.

For disease to occur, the host plant must be at a stage of development that allows it to be susceptible to infection. For example, damping-off only affects seedlings. Botrytis is primarily a disease of buds, although it also can occur on flowers and leaves. Also, it is important that the pathogen be in a proper stage of its development to infect host plants.

ENVIRONMENTAL CONDITIONS

Certain environmental conditions must exist for disease pathogens to cause infection. The specific conditions vary for different pathogens. High moisture and specific temperature ranges are necessary for many virus diseases. These conditions must continue for a critical period of time while the pathogen is in contact with the host for infection to occur.

Moisture, temperature, wind, sunlight, nutrition and soil quality affect plant growth. If one of these factors is out of balance for the culture of a specific plant, that plant may have a greater tendency to become diseased. Environmental conditions also affect the growth and spread of disease pathogens. Very dry or wet weather will have an accompanying set of virus diseases that thrive under these conditions.

MOISTURE

Moisture in the plant environment can include humidity, dew, rainfall or water from irrigation. Moisture is critical to the spread of most plant virus diseases. Constantly wet foliage from overhead watering is a condition that promotes disease development.

TEMPERATURE

Each disease pathogen has a specific temperature range for growth and activity. There are warm-weather and cool-weather diseases. Temperature affects how rapidly pathogens multiply.

Soil temperature can also be critical for disease infection. Cool, wet soils promote virus diseases transmitted by nematodes in root diseases. Temperature extremes can cause stress in host plants, increasing susceptibility.

WIND AND SUN

The combination of wind and sun affects how quickly plant surfaces dry. Faster drying generally reduces the opportunity for infection. Wind can facilitate vector movement from one area to another, even many miles. Wind and rain together can be a deadly combination. Sunlight is very important to plant health. Plants that do not receive the right amount of sunlight to meet their cultural requirements become stressed. This may make them more susceptible to infection.

SOIL AND FERTILITY

Soil type can affect plant growth and also development of some pathogens. Light sandy soil low in organic matter favors growth of many types of nematodes. Soil pH affects pathogen development in some diseases. Fertility affects a plant's growth rate and ability to defend against disease. Excessive nitrogen fertilization can increase susceptibility to pathogen attack. It causes formation of SUCCULENT tissue and delays maturity. Nitrogen deficiency results in limited growth and plant stress which may cause greater disease susceptibility.

DISEASE CYCLE

There are five stages in disease development: inoculation, incubation, penetration, infection and symptoms.

INOCULATION

The viral pathogen must be introduced (inoculated) to the host plant. This is done by insects, birds, animals and people.

Working in the garden when plants are wet is a common way to spread disease. Disinfesting tools requires a 9-to-1 solution of water and bleach and takes a minimum of ten minutes. Smokers can transmit tobacco mosaic virus from a cigarette to tomato plants.

Seeds or cuttings from infected plants will also transmit disease. Certified seed guarantees that at the time of sale the seeds are free of all diseases.

Disease-free stock guarantees that the plant is not infected with disease. This is particularly important with perennial plants, such as roses, raspberries and other small fruits.

INCUBATION

The second stage of disease development is incubation. The pathogen changes or grows into a form that can enter the new host plant.

PENETRATION

The third stage is penetration or the point at which the pathogen actually enters the host plant. Wounding roots of bedding plants during transplanting provides entry for viral pathogen. The mouthparts of an insect also result in openings for penetration.

INFECTION

The fourth stage is infection. The pathogen multiplies within the plant using some of the host's biochemical "machinery" and begins damaging the plant tissue.

SYMPTOMS

As the pathogen consumes nutrients, the plant reacts by showing symptoms. Symptoms are evidence of the pathogens causing damage to the plant. Symptoms include mottling, dwarfing, distortion, discoloration, wilting, and shriveling of any plant part.

PATHOGEN SURVIVAL

Many pathogens can survive without a susceptible host even under the most unfavorable conditions. Many plant diseases survive from one growing season to the next on plant debris, seeds, and alternate hosts or in soil.

Because of pathogen survival, it is important to remove and properly dispose of any infected plant materials. It is also important for the gardener to know about the diseases that affect each plant throughout the home landscape, as well as the conditions needed for proper culture.

Symptoms of plant virus diseases

Symptoms are expressions of pathological activity in plants. They are visible manifestations of changes in color, form, and structure: leaves may become spotted, turn yellow, and die; fruits may rot on the plants or in storage; cankers may form on stems; and plants may blight and wilt. Diagnosticians learn how to associate certain symptoms with specific diseases, and they use this knowledge in the identification and control of pathogens responsible for the diseases.

Those symptoms that are external and readily visible are considered morphological. Others are internal and primarily histological, for example, vascular discoloration of the xylem of wilting plants. Microscopic examination of diseased plants may reveal additional symptoms at the cytological level, such as the formation of tyloses (extrusion of living parenchyma cells of the xylem of wilted tissues into vessel elements).

It is important to make a distinction between the visible expression of the diseased condition in the plant, the symptom, and the visible manifestation of the agent which is responsible for that condition, the sign. The sign is the structure of the pathogen, and when present it is most helpful in diagnosis of the disease.

All symptoms may be conveniently classified into three major types because of the manner in which pathogens affect plants. Most pathogens produce dead and dying tissues, and the symptoms expressed are categorized as necroses. Early stages of necrosis are evident in such conditions as hydrosis, wilting, and yellowing. As cells and tissues die, the appearance of the plant or plant part is changed, and is recognizable in such common conditions as blight, canker, rot, and spot.

Many pathogens do not cause necrosis, but interfere with cell growth or development. Plants thus affected may eventually become necrotic, but the activity of the pathogen is primarily inhibitory or stimulatory. If there is a decrease in cell number or size, the expressions of pathological activity are classified as hypoplases; if cell number or size is increased, the symptoms are grouped as hyperplases. These activities are very specific and most helpful in diagnosis. In the former group are such symptoms as mosaic, rosetting, and stunting, with obvious reduction in plant color, structure, and size. In the latter group are gall, scab, and witches'-broom, all visible evidence of stimulation of growth and development of plant tissues.

dieback - a disease of plants characterized by the gradual dying of the young shoots starting at the tips and progressing to the larger branches
mosaic - viral disease in solanaceous plants (tomatoes, potatoes, tobacco) resulting in mottling and often shriveling of the leaves
yellow dwarf - any of several virus diseases of plants characterized by stunting and yellowing of the leaves

yellow spot - viral diseases characterized by yellow spotting on the leaves

Kinds of plant diseases

MYCOPLASMAS

Mycoplasmas are disease agents that were not accurately identified until the 1960's. Previously many mycoplasma-caused diseases were thought to be caused by viruses. A group of diseases caused by mycoplasmas is called YELLOWS diseases. Yellows disease is usually spread from one host plant to another by an insect vector. Leafhoppers are common vectors for mycoplasmas.

Viruses and viroids

Viruses are organisms so small that they can only be seen under an electron microscope, magnified 2,000 to 3,000 times. Viruses multiply only within living cells of host plants. Viruses are spread by insects, nematodes and humans. Symptoms include vein banding, mosaic, flecking or spotting on foliage and abnormal growth, similar to herbicide damage. Tobacco mosaic virus on tomatoes and leaf mosaic on dahlias are common viral diseases. Control is limited to removing and destroying infected plants.

Viruses and viroids are the simplest of the various causative agents of plant disease. The essential element of each of these two pathogens is an infective nucleic acid. The nucleic acid of viruses is covered by an exterior shell (coat) of protein, but that of viroids is not. *See also* Plant viruses and viroids.

Approximately 400 plant viruses and about 10 viroids are known. The nucleic acid of most plant viruses is a single-stranded RNA; a number of isometric viruses have a double-stranded RNA. A few viruses contain double-stranded DNA, and several containing single-stranded DNA have been reported. The nucleic acid of viroids is a single-stranded RNA, but its molecular weight is much lower than that of viruses.

Some viruses, such as tobacco mosaic virus (TMV) and cucumber mosaic virus, are found in many plant species; others, such as wheat streak mosaic virus, occur only in a few grasses. Viruses are transmitted from plant to plant in several ways. The majority are transmitted by vectors such as insects, mites, nematodes, and fungi which acquire viruses during feeding upon infected plants. Some viruses are transmitted to succeeding generations by infected seed. Viroids are spread mainly by contact between healthy and diseased plants or by the use of contaminated cutting tools.

The control or prevention of virus diseases involves breeding for resistance, propagation of virus-free plants, use of virus-free seed, practices designed to reduce the spread by vectors, and, in some cases, the deliberate inoculation of plants with mild strains of a virus to protect them from the deleterious effects of severe strains..

Noninfectious agents of disease

Plants with symptoms caused by noninfectious agents cannot serve as sources of further spread of the same disorder. Such noninfectious agents may be deficiencies or excesses of nutrients, anthropogenic pollutants, or biological effects by organisms external to the affected plants. On the farm, plant-damaging pollution may be caused by careless use of pesticides. Mishandled herbicides are by far the most damaging to plants. Off the farm, anthropogenic air pollutants are generated by industrial processes, and by any heating or transportation method that uses fossil fuels. The most common air pollutants that damage plants are sulfur oxides and ozone. Sulfur oxides are produced when sulfur-containing fossil fuels are burned or metallic sulfides are refined. Human-generated ozone is produced by sunlight acting on clouds of nitrogen oxides and hydrocarbons that come primarily from automobile exhausts.

Epidemiology of plant disease

Knowledge of these components, the outbreak of disease may be forecast in advance, the speed at which the epidemic will intensify may be determined, control measures can be applied at critical periods, and any yield loss to disease can be projected. The maximum amount of disease occurs when the host plant is susceptible, the pathogen is aggressive, and the environment is favorable.

Epidemiologically, there are two main types of diseases: monocyclic, those that have but a single infection cycle (with the rare possibility of a second or even third cycle) per crop season; and polycyclic, those that have many, overlapping, concatenated cycles of infection per crop season. For both epidemiological types, the increase of disease slows as the proportion of disease approaches saturation or 100%.

Control of plant disease is defined as the maintenance of disease severity below a certain threshold, which is determined by economic losses. Diseases may be high in incidence but low in severity, or low in incidence but high in severity, and are kept in check by preventing the development of epidemics. The principles of plant disease control form the basis for preventing epidemics. However, the practicing agriculturist uses three approaches to the control of plant disease: cultural practices affecting the environmental requirement of the susceptible host -pathogen-environment triangle necessary for disease development, disease resistance, and chemical pesticides.

DIAGNOSIS OF PLANT VIRUS DISEASES

A METHOD

To correctly diagnose plant disease problems, follow a few basic steps. View the plant and its environment from various perspectives.

CLOSE-UP VIEW

The most obvious place to look first is up close. Use a hand lens if necessary. Don't stop at the first or most obvious symptom; check for more. You want to find all of the symptoms.

Look for symptoms on leaves, stems, roots, flowers and fruits. Cut open a branch or stem to look for vascular problems. Vascular problems show as discoloration of vascular tissue, leaf or stem wilting and sudden wilting of a section or a total plant.

GENERAL VIEW

Stand back and look at the overall picture. Consider the total environment: weather, soil, stage of development for plant and pathogens, cultural practices and condition of other plants in the area. A plant growing in the wrong location may be stressed. Consider pesticide applications, recent construction or digging, and weather conditions.

TIME

Determine when the symptoms became apparent. The onset of a problem may be due to a cultural practice, the seasonal appearance of a disease or insect, or a weather-related event. Remember that long-term stress is slow to appear, taking a year or more at times.

Is the problem spreading? This may indicate it is a pathogen. Are plants of other species affected? Diseases are usually species-specific. Problems caused by environmental factors do not spread, although the symptoms may become more severe.

KNOWLEDGE AND EXPERIENCE

You must know what the plant should look like to be able to determine abnormalities. Check the references to see what problems are typical for a particular species. Gather all the information you can to help you make the diagnosis.

Remember that there is usually no single cause. There may be a primary cause; however, it may be associated with cultural or environmental conditions. Just as there is probably no single cause, there is usually no single symptom. Search for all of the symptoms. Orderly thinking and good questions are the key to accurate diagnoses.

When in doubt about a diagnosis, turn to agents, state specialists or the Pest and Plant Disease Clinic for assistance or a second opinion.

NONLIVING OR ABIOTIC AGENTS

Nonliving or abiotic agents can indirectly result in plant problems. Additionally, several factors in the plant's environment can produce disease-like symptoms: weather extremes, high winds, high or low temperatures, nutrient deficiencies, physical damage and poor cultural conditions.

Frost often damages buds and leaves in early spring. Hail can cause leaf spotting or holes. Drought and high winds result in wilting and in extreme cases, browning and curling.

Air, water and soil pollution affect plant health and can produce disease-like symptoms. Soil imbalance, resulting from construction or other dumping, or misapplied garden chemicals can cause damage and disease-like symptoms. Dumping of household, automotive and industrial chemicals can also produce plant damage.

Plant disease can result from a combination of abiotic agents and biotic agents. Plants may be initially placed under stress by nonliving agents. This creates a susceptibility in plants for attack by living agents. Drought may damage roots which then are more likely to be infected by fungal diseases.

RANDOM OR UNIFORM PATTERNS

Random distribution of symptoms on injured plants is usually caused by a biotic factor, such as infectious disease pathogens or an insect/animal. Uniform patterns are generally associated with abiotic or noninfectious agents like pesticides, fertilizers, environmental or site stress and mechanical damage.

COLLECTING SPECIMENS

Plant specimens that are to be diagnosed should be taken from the area where symptoms are showing on living tissue. Dead plants are often invaded by secondary pathogens which may hide the original problem. Collect several representative samples showing various stages of disease development. A generous sampling will assist in diagnosis. If possible, collect the entire plant, including roots.

Wrap the specimens in dry paper. Do not moisten them or seal them in plastic wrap or plastic bags. Never mix different specimens in a single bag. A fresh sample is required. Complete the diagnostic form as thoroughly as possible. This will result in better diagnosis.

Strategies for Control

Resistance: Conventional approaches

- Breeding for Resistance to Plant Viruses
- Control of Plant Virus Diseases by Cross-protection of Virus Infection in Crops Through Breeding Plants for Vector Resistance: Biochemical and molecular approaches
- Biochemistry of Resistance to Plant Viruses
- Protein and Replicase-mediated Resistance to Plant Viruses
- Antisense RNA and Ribozyme-mediated Resistance to Plant Viruses
- Satellite RNA-mediated Resistance to Plant Viruses: Are the Ecological Risks Well Assessed?
- Alternative Strategies for Engineering Virus Resistance in Plants
- Controlling Mosaic Virus Diseases Under Field Conditions by Using Multiple-gene Strategies in Transgenic Plants Special topics related to resistance
- Releasing Genetically Engineered Virus Resistant Crops - Risk Assessment
- Antiviral Substances of Plant Origin Resistance to Plant Viruses: an Overview

Control of Vectors

- Forecasting Aphid-borne Virus Diseases
- Chemical Control of Insect and Nematode Vectors of Plant Viruses
- Chemical Control of Fungal Vectors of Plant Viruses

Quarantine and Certification

- Exclusion of Plant Viruses
- IPGRI's Role in Controlling Virus Diseases in Plant Germplasm
- Seed Certification for Viruses
- Control of Viruses Affecting Potatoes Through Seed Potato Certification Programs
- Virus Certification of Grapevines
- Virus Certification of Ornamental Plants - The European Strategy
- Virus Certification of Fruit Tree Propagative Material in Western Europe
- Virus Certification of Deciduous Fruit Trees in The United States and Canada
- Indexing for Viruses in Citrus
- Virus Certification of Strawberries
- Certification for Plant Viruses: an Overview

Elimination

- Heat Treatment of Perennial Plants to Eliminate Phytoplasmas, Viruses, and Viroids While Maintaining Plant Survival
- Virus Elimination by Meristem Tip Culture and Tip Micrografting

Detection

- Advanced Diagnostic Tools as an Aid to Controlling Plant Virus Diseases
- Identification and Detection of Recalcitrant Temperate Fruit Crop Viruses Using dsRNAs and Diffusion Antisera
- Detection and Identification of Plant Viruses and Viroids Using Polymerase Chain Reaction (PCR)
- Ultra Microscopic Detection of Plant Viruses and Their Gene Products
- Detection and Management of Plant Viroids

By the time disease symptoms appear, disease pathogens are inside the plant and usually beyond control. Therefore, it is important to prevent penetration of pathogens. Consider the following methods of disease control:

AVOID

Avoid certain diseases through choice of appropriate site and planting time, purchase of disease-free stock and cultural practices that do not favor disease infection. Insect control can be important for controlling spread of viruses, mycoplasmas, bacteria and fungi. Mulching can help control diseases by preventing the contact of foliage with soil.

REMOVE

Remove all diseased plants, including alternate hosts. Immediate removal of diseased plants or plant parts reduces the chance of the disease spreading. Selective pruning and careful sanitizing of pruning equipment can prevent spread of disease. Rotate crops to avoid soil-borne diseases.

PROMOTE VIGOROUS GROWTH

Use best cultural practices. Follow recommended cultural practices.

Plant Disease Evaluation

Parasitism and Disease development

Diseases of plants, like diseases of humans and animals, are complex phenomena. It may be difficult to provide a comprehensive definition of disease, but one important characteristic of plant diseases is that they are injurious, causing harm to plants in some way. Disease also is progressive, which helps distinguish disease development over time from an instantaneous injury such as lightning striking a tree. Plant diseases are a challenge to people interested in maintaining and producing healthy plants. Plant health can be achieved only with an understanding of plant diseases. We need to know what causes them, how they spread, and how we can prevent them or at least minimize the damage they inflict.
Diagnosis is the first step in addressing the challenge of plant diseases. We are familiar with symptoms and signs of animal and human diseases, but symptoms of plant diseases are very different from human symptoms. However, a better understanding of disease development can help minimize the problems caused by plant diseases.

Plant Disease Triangle

The disease triangle represents the three fundamental elements required for disease in plants:

(i) a susceptible plant

(ii) a pathogen capable of causing disease

(iii) a favorable environment

The Plant

Susceptibility to disease can be affected by many factors, including the growth stage of the plant, its genetic predisposition and stress. By careful observation of a diseased plant, one can begin to speculate about what basic functions of the plant are affected and, therefore, what kind of disease it may be.

Symptoms are the expression of disease by a plant as a response to the activities of the pathogen. It may be localized, such as leaf spots or systemic such as stunting that affects the entire plant. Some symptoms develop first on young and otherwise healthy tissues, other occur first on senescent tissues, such as aging flowers or lower leaves that are turning yellow. Many symptoms of plan diseases involve the death of plant tissues. Symptoms alone are not enough for accurate diagnosis of many plant diseases.

The Pathogen

The second vertex of the plant disease triangle is the pathogen. The word *pathogen* comes from the root word *pathos* ("suffering") and the suffix *–gen* ("origin" or "genesis"). Together they mean "the cause of a disease".

Most plant diseases are caused by parasites. A parasite is an organism that obtains its nutrients from another living organism. Parasites of plant include fungi, bacteria, nematodes, viruses and even other plants. Parasites become pathogens when they do not merely live on and obtain nutrients from a host organism but actually case harm to the host, resulting in disease symptoms. Pathogens that are also parasites are infectious. They can be spread (transmitted) from plant to plant, potentially causing an epidemic. These living organisms that cause diseases are sometimes called biotic pathogens. There are also abiotic (nonliving) agents that cause disease. Noninfectious factors may affect many plants in an area, but the diseases they cause are not "contagious", i.e. they are not transmitted from one plant to another.

The Environment

An environment favorable for disease development (the third vertex of the disease triangle) consists of factors affecting the plant, factors affecting the pathogen, and sometimes additional organisms, such as vectors. The environment in which plant disease occurs consists of a wide range of factors that should be investigated when a diagnosis is being made. These factors include recent temperature (such as extreme highs and lows), rainfall or irrigation (amounts, timing and source), and light intensity or shade. Characteristics of the soil, such as drainage, soil type, and pH, are also important.

Determination of disease causing organism: Koch's postulate

i. The suspected pathogen must be consistently associated with diseased plants

ii. The suspected pathogen must be isolated in a pure culture and its characteristics noted

iii. The diseased must be reproduced in a healthy plant inoculated with the isolated organism

iv. The same pathogen characterized in step 2 must be isolated from the inoculated plant

Biotrophs and Necrotrophs

Plant diseases often involve the interaction of plants and parasites. Thus, diseases are greatly affected by the biology of the parasites.

Biotic pathogens can be divided into two categories (biotrophs and necrotrophs) that describe their approach to causing disease. **Biotrophs** require living plant tissues. **Necrotrophs** usually produce destructive toxins and enzymes that destroy plant tissues.

Some parasites are so dependent on their hosts that they are unable to exist without them. These parasites, called **biotrophs** or **obligate parasites**, can obtain nutrients only from plant cells. They often form some kind of survival structure in the absence of a host. In some cases, biotrophs do not form a survival structure and will perish if they do not find a way to move to another living plant before the host plant dies.

Most plant pathogens are more flexible in their adaptation and can live either as **parasites** or as **saprophytes**, organism that obtain nutrients from dead organic matter. Organisms with the flexibility to switch back and forth between the parasitic and the saprophytic life style are described as facultative. **Facultative saprophytes** are better adapted to living as parasites but can survive as saprophytes when necessary. **Facultative parasites** are primarily saprophytes but can live as parasites if given the opportunity to invade compromised or senescent plant tissues. Many other bacteria and fungi are **obligate saprophytes** living only on dead organic matter and incapable of causing plant disease. These organisms may act as secondary invaders of dead and dying tissues. They contribute to the decay of plants and other organisms.

At the other end of the spectrum of parasitism are the facultative parasites and facultative saprophytes, or **necrotrophs.** As the name suggests, they obtain nutrients from dead organic matter or from dead or dying cells of living plants. In contrast to the more delicate invasion by biotrophs, necrotrophs tend to produce toxins and enzymes that rapidly kill and degrade plant tissue and inhibit defense mechanisms by the plant. Necrotrophs commonly penetrate plants through wounds or natural openings.

The Disease Cycles

Pathogens, like their hosts plants, have life cycles. These may be as simple as that of a bacterium, in which a single cell divides into two cells. When interaction between a plant and a pathogen result in disease, the interactions are described by the **disease cycle**.

A disease cycle may be simple or complex, but all disease cycle follow a pattern of discrete steps occurring in a predictable order. Disease cycles may be completed in as little as a few days or (in some tree diseases) as long as several years. It is important to be able to identify the stages of the disease cycle of each disease, because they will suggest ways to prevent or manage the disease.

The life history of a pathogen consists of two phases: (i) pathogenesis and (ii) survival

Pathogenesis – is the chain of events whereby disease occurs

Pathogenicity - is the ability of the parasite to interfere with one or more of the essential functions of the plant, thereby causing disease.

Each cycle begin with the introduction of the pathogen into a plant environment and terminate with the cessation of its activities. Primary cycle begin only with after a period of rest or dormancy or seasonal inactivity, while secondary cycle originate during the growing season and there is neither a period of rest or dormancy.

Pathogenesis in both primary and secondary cycles proceeds in the following stages.

(i) Inoculum – Inoculation is the initial contact of a pathogen with a site of plant where infection is possible. The pathogen(s) that lands on or is otherwise brought into contact with the plant is called the **inoculum**.

(ii) Penetration – Is the entrance of the pathogen into a plant and this usually takes place through wounds, natural openings e.t.c.

(iii) Infection – Implies the establishment of the pathogen within the tissues of the plant.

(iv) Incubation – This is the interval of time between the infection by the pathogen and production of disease symptoms.

(v) Invasion – This refers to the latter stages of infection in which the pathogens invade and ramify the tissues and cells of the plant.

(vi) Reproduction – After establishing itself between the plant cells and tissues and obtaining nourishment from them, a pathogen may increase in size and number.

(vii) Dispersal – After reproduction, a plant pathogen or its propagules must be dispersed and disseminated to other plants.

(viii) Survival – After passing through its pathogenic phase during crop growth and during the growing season. A pathogen must survive until the next growing season. Many pathogens produce hardy structures with which they can survive from one growing season to another.

Measurement of Plant Disease

(i) Incidence of the disease i.e. the number or proportion of plant units that are diseased (i.e. the number or proportion of plants, leaves, stems and fruit that show any symptom) in relation to the total number of units examined. Measuring disease incidence is relatively quick and easy, and this measurement is the one that is used commonly in epidemiological studies to measure the spread of a disease through a field, region or country.

(ii) Severity of the disease i.e. the proportion of area or amount of plant tissue that is diseased. Disease severity is usually expressed as the percentage or proportion of plant area or fruit volume destroyed by a pathogen. More often, disease assessment scales from 0 to 10 or 1 to 4 are used to express the relative proportions of affected tissue at a particular point in time.