AGC 3342: Crop Protection - Plant Pathology Component

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INTRODUCTION

Man has always been aware of plant diseases ever since he became a "farmer". In earlier times, plant diseases were attributed to both natural and supernatural causes. It was not until the mid 19th Century that the science of Plant pathology came into being.

What is Plant Pathology?

Greek - Pathos (suffering) + Logos (study) = The study of the suffering plant

Plant Pathology has two parts;

- Science - the theoretical consideration of the suffering plant.
    - i.e. How do plants defend themselves?
    - How do pathogens invade?
    - What causes symptoms?
    - Why don't all plants die?
- Art - The application of the Science
    - i.e. Diagnosis
    - Control

Plant Pathology is the study of;

1. the living entities and the environmental conditions that cause disease in plants;
2. the mechanisms by which these factors produce disease in plants;
3. the interactions between the disease-causing agents and the diseased plant; and
4. the methods of preventing or controlling disease and alleviating the damage it causes."

Hence it is a scientific study of plant diseases, their causal organisms, diagnosis and control.

Modern Plant Pathology has resulted from the accumulation of several techniques, such as Electron microscopy, experimental methods and now more recent molecular tools. In 1683, Anton von Leeuwenhoek was able to view micro-organisms, including protozoa and bacteria, which were not previously visible to the naked eye. Around mid 18th century: Duhumel de Conceal described a fungus disease and demonstrated that it could be passed from plant to plant, but his discovery was largely ignored due to existing theory of spontaneous regeneration. Around the same time, nematodes were described by several English

scientists. In 1755: the treatment of seeds to prevent a wheat disease became known. Heinrich Anton DeBary, known as the father of modern plant pathology, publishes a book identifying fungi as the cause of a variety of plant diseases. In 1876: Robert Koch publishes a set of rules known as Koch's postulates that provides the experimental proof of disease causation (pathogenicity)

Plant diseases in history

The Holy Bible: there are references in the Old Testament to blights, blasts, and mildews (Deuteronomy 28:22; 2 Chronicles 6:28). Early Romans worshipped "a god of rust" called "Robigus" in the hope to prevent from getting rust problems in their cereals. **372 BC:** Theophrastus (372-287 B.C.) theorized about cereal and other plant diseases. **350 BC:** Aristotle writes about plant diseases. **During the Middle Ages** in Europe, ergot fungus infected grain. Ergot of rye grain causes hallucinations and sometimes deadly illness (including what was then called St Anthony's fire). The hallucinations resulted in witch hunts, with suspected witches killed (Salem Witch Trials from 1692-1693. 19 people were found guilty and hanged). Massive European epidemics caused by ergot of rye occurred frequently during medieval times. **In 17th Century,** Shakespeare mentions wheat mildew in one of his plays. **1845 – 1849:** The Great Irish potato famine kills 1.5 million people, one fourth of Ireland's total population. The crop was lost to late blight of potato, a fungal disease. Great Irish Potato Famine of 19th Century is viewed by many as the start of modern plant pathology. **Mid 19th century:** Downy mildew grape disease is accidentally introduced in Europe. Downy mildew of grape destroys the vineyards in France, Germany and Italy. **Early 20th century**: the American chestnut tree is wiped out by an Asian blight disease. The chestnut was at that time the major source of timber.

Other Important landmarks in Plant Pathology

- Development of first really effective fungicide "Bordeaux mixture" by Millardet in 1885
- Breeding of the host resistant crop using Mendelian Principles at the start of the 20th Century
- By 1939, virus particles could be seen under the new electron microscope.
- During the 1940s, fungicides were developed and in the 1950s, nematicides were produced.
- In the 1960s, Japanese scientist Y. Doi discovered mycoplasmas (Phytoplasma), organisms that resemble bacteria but lack a rigid cell wall, and,
- In 1971, T. O. Diener discovered viroids, organisms smaller than viruses.

Whilst appreciating that plant pathology is an applied science with the majority of the work (research) being directed towards control, in the recent past there has been a resurgence in the interest in this field with the new important developments being made especially in Plant physiology processes, host-pathogen interactions, disease epidemiology, genetics - etc. that could be harnessed for sustainable control of Plant diseases. It must be noted that whilst all these studies are important, the primary objective in so far as the farmer (primary client) is concern is to manage the Plant diseases.

Plant disease

Several definitions exist and include those proposed by renowned scientists:

> "a malfunctioning process that is caused by continuous irritation. Of course, this process must result in some suffering, and produce symptoms"

Agrios GN

“Disease is a condition involving abnormal changes in the form, physiology, integrity or behaviour of a plant. Such changes may result in partial impairment or death of the plant or its parts.”

Horsfall and Cowling

"The term plant disease is properly applied to any deviation from normal growth or structure of plants that is sufficiently pronounced and permanent to produce visible symptoms or to impair quality and economic value."

Stakman and Harrar

"Any disturbance of a plant that interferes with its normal growth and development, economic value, or aesthetic quality; a continuously, often progressively affected condition in contrast to injury, which results from momentary damage."

Schumann

“Any disturbance brought about by a pathogen or a consistent environmental factor which interferes with manufacture, translocation, or utilization of nutrients “

A plant is said to be diseased when there is a harmful deviation from the normal functioning of the plant physiological processes. In other words, It is a harmful deviation from the normal healthy state.

Disease is not a Condition

In agreement with Horsfall and Cowling, a condition is a symptom complex. A disease is much more than just the symptom. A disease is the totality of the biological activity of all

interactants both overt and covert. The term "pathodeme" is used to express the altered metabolic result of the contributing interactants, but the pathodeme is not disease.

Disease is not the Pathogen

Pathogens are the causal agents of disease. Imprecise usage of terms has lead to the careless application. It's wrong to say "*Phytophthora infestans* is Late Blight of Potato". This creates failure to recognize that the organism is not the disease and that disease cannot occur in the absence of a host.

Disease is not infectious

Following the above logic, because **disease is the result of host and parasite interaction**; only the parasite/pathogenic partner is infectious but there also exists what is referred to as **non-infectious disease** caused by environmental factors (abiotic agents).

Disease is not mobile, is not disseminated

Propagules and inoculum are disseminated and the disease host may be transported; but the disease is not equal to inoculum when speaking of epidemiology or dissemination. In *strictu sensu* only inoculums (e.g. fungal spores) are disseminated.

Disease and injury are not the same

Mowing a lawn may remove as much a 60% of the biomass of the grass and may cause wounding by the mower; but it is a single nonrecurring event that does not cause constant irritation. As such disease is not the result of tissue removal. But such wounding sites produced by tissue removal are potentially for entry sites for opportunistic parasites that may lead to disease.

N**oninfectious diseases** are caused by environmental stress and damage by weather and other environmental factors. Indirectly, environmental factors that cause a plant to be stressed may result in the plant's gradual decline. The decline may result in the plant being more susceptible to disease organisms. In this case, the real cause of a problem may be the stress factors, with the disease simply being a secondary factor.

As a study, plant pathology involves the study of pathogen identification, disease aetiology, disease cycles, economic impact, plant disease epidemiology, plant disease resistance, how plant diseases affect humans and animals, pathosystem genetics, and management of plant diseases.

Nowadays Plant Pathology comprises about four main disciplines/fields

Mycology - deals with fungi and fungi related organism

Bacteriology – Dealing with Bacteria

Virology - Deals with Viruses and viroids

Nematology – Deals with nematodes

Molecular Plant Pathology – Using Molecular tools in diagnosis of plant disease

Why are Plant Disease Important?

- All of our food, much of our clothing, building materials, and much of the beauty in nature is provided by plants. Hence Plant diseases are a constant threat to the world's food and fibre crops, forests, and landscape plants. They affect the plant's performance in particular yield, causes famines (history has records to that effect), loss of farmer's income affecting the social welfare of the farmers household e.g. no money for school fees.

Some definitions/ Plant Pathology terms

Aggressiveness: Capacity to invade, grow and reproduce in the host

Appressorium (pl. Appressoria): an enlarged fungal filament that adheres to the surface of the host, prior to penetration.

Avirulent: unable to cause disease on a host which has resistance

Biotroph: (syn. obligate parasite) an organism that can live and multiply only on another living organism

Causal Agent: The biotic or abiotic agent which, through prolonged irritation, causes the disease. While causal organism refers only to the living entity (biotic) of the disease tetrahedron that causes the disease. Some are parasite. The casual organism (factor or agent) may be present for the whole duration of the disease.

Disease cycle: A series of events a pathogen in its development in its association with the host

Disease development: Series of event between infection till the occurrence of the syndrome

Disease Incidence: the number of plants affected by a disease within a population.

Disease Severity: the measure of damage done by a disease.

Disorder: a harmful non-pathogenic deviation from normal growth

Epidemiology: The study of the factors affecting outbreak of disease and spread of infection

Facultative parasite: organism that is normally saprophytic but is capable of being parasitic

Facultative Saprophyte: organism that is normally parasitic but is capable of being saprophytic

Horizontal resistance: Polygenic – conferred by several minor genes. It's very difficult to breakdown. Evenly spread out against all races of the pathogen.

Incubation: The time period between penetration and beginning of symptoms. It relates to how the disease spreads. E.g. with smut it can take to a year thus initial inoculums is important

Infection: Establishment of the pathogen in the host and describes the beginning of the parasitic relationship

Infectious Disease: Disease caused by infectious organism (or biotic organisms), which a transmissible organism is part of the causal complex of the disease

Infectious Organism: Transmissible organism from a diseased host to a susceptible host and capable inciting the disease under favourable conditions

Inoculum (pl. Inocula): a pathogen or its parts which can cause infection when transferred to a favourable location; the population of microorganisms introduced in an inoculation.Inoculum could either be **primary** – initial or **secondary-** inoculums from previous infection.

Inoculation: coming together of host and parasite, to introduce a microorganism or virus into host plant or into a culture medium

Inoculum potential: Energy of growth of a fungus (or other microorganism) available for colonization of a substratum at the surface of substratum to be colonized.

Mycelium (pl. Mycelia): a mass of hyphae that forms the body (thallus) of a fungus.

Obligate parasite: organism that can grow only as a parasite in association with its host plant and cannot be grown in artificial culture media

Necrotroph: an organism (parasite) that causes the death of host tissues as it grows through them, obtaining its energy from the dead cells.

Perthotrophs: Kill the living tissue in advance though they need it. They produce enzyme which pre-digest the host tissue. Saprophytic lifestyle but have an advantage over saprophytes in that the latter have to attack cell wall but the former uses sap.

Hemitroph: an organism with a mode of attack and nutrition are like biotroph but once it kills the tissue, continue getting their nutrient from it.

Heterotroph: an organism that obtains nourishment from outside sources and must obtain its carbon from organic carbon compounds.

Parasite: organism that lives in intimate association with another organism on which it depends for its nutrition; not necessarily a pathogen

Pathogen: a parasite able to cause disease in a particular host or range of hosts

Pathogenesis: the sequence of processes in disease development from initial contact between pathogen and host to completion of syndrome

Pathotype/pathovar: a subdivision of a species distinguished by common characters of pathogenicity, particular in relation to host range. In bacteriology, where pathovar is the preferred term, pathotype is used to described the type (or reference) culture of a pathovar

Penetration: Initial invasion of a host by a pathogen.

Penetration Peg: a structure found in some plant parasitic fungi. The penetration peg is a specialised, narrow, hyphal strand located on the underside of an appressorium that penetrates the epidermal cell wall.

Predisposition: Any or number of factors which increases the vulnerability of the plant

Resistance: Inherent ability to resist or restrict establishment of subsequent stages of a pathogen in a host to cause disease

Saprophyte: organism that obtains nourishment from non-living organic matter

Sporangiophore: Sporangium-bearing body of a fungus.

Sporangium (pl. Sporangia): A unicellular or multicellular sac-like structure in fungi that produces asexual spores.

Spore: a specialised reproductive body in fungi (and some other organisms), containing one or more cells, capable of developing into an adult.

Susceptibility: Inability of the host to resist the effects of the pathogen. It is quite variable due to a wide range of factors which are introduced to express it.

Symbosis: Mutual association resulting from coexistence of two organisms

Vertical resistance: The gene for gene resistance. It is conferred by a major gene. Effective against some races of the pathogen. Easy to incorporate in plants due to the number of gene but does break down easily.

Virulence: the degree or measure of pathogenicity of a given pathogen; relative capacity to cause disease.

Modern farming practices and plant diseases

Under natural conditions, plants occur in mixed stands. Plant types compete for space, light, moisture and nutrients. Under these conditions there is minimal attack of infectious disease agents on one plant type. There's no clear evidence of disease readily being found within natural plant communities though pathogens can be isolated from wild plants. There is a balanced relationship of coexistence between the host plants and pathogen.

However, modern farming that began to develop in America and Europe from the 1920's, is typified by a more intensive use of land and buildings, mechanisation and the use of artificial chemical fertilizers and weed and pest control.

It is characterized by

1. **High plant density**
2. **Monoculture**
3. **High fertilizer inputs**
4. **Heavy use of pesticides**

High plant density: Individual plants that are nearly identical planted in large numbers and very close together, creating favorable micro and macro-environments ideal for disease development. With high plant density, there's increase in humidity levels due to plant respiration. In addition there's prolonged leaf wetness in a high plant density canopy than in low-density canopy (because there is limited air circulation). Leaf wetness is a key factor in the initiation and developing of many diseases. The incidence and severity has also been shown to increase with high plant density as the latter provides unlimited number of disease hosts. High plant density also bring plants in close physical proximity allowing pathogens to easily move from one plant to the next.

Monoculture: Monoculture is the agricultural practice of producing or growing one single crop over a wide area. The dependence on monoculture crops can lead to large scale failures when the single genetic variant or cultivar becomes susceptible to a pathogen or when changes in weather patterns occur. Genetic variation in the host is the key to improved disease resistance. Monoculture implies that there is reduced barrier to pathogens that can affect a certain host. When a pathogen arises capable of causing disease on a plant variety planted in monoculture, such a pathogen will easily move to the next susceptible plant, unlike mixed planting where the neighboring plant may be of different species and thus act as a barrier to spread of the pathogen. The Great Irish Famine (1845-1849) was caused by susceptibility of the potato to *Phytophthora infestans*. The wine industry in Europe was devastated by susceptibility to *Phylloxera* during the late 19th century. Each crop then had to be replaced by a new cultivar imported from another country that had used a different genetic variant that was not susceptible to the pathogen. In Brazil for example, monoculture plantations of Eucalyptus have been widely planted, and diseases are wide spread.

High fertilizer inputs: High rates of nitrogen fertilizer will provide more plant nutrition, resulting in higher yield. However, high nitrogen fertilizer rates also: increase weed

populations in the current and subsequent crops (weeds may act as reservoirs for plant pathogens), the incidence of fungal and bacterial diseases by increasing tissue susceptibility and tiller density. The tissues become more succulent and softer and thus prone to pathogen attack. In rice, for example the use of excessive N fertilizer has been observed to increase sheaths blight though the actual mechanism are unknown.

High pesticides: Heavy reliance on pesticides or chemical application gives detrimental effect to the plant. Once we spray the chemical to control the pest or disease over period of time it will cause the pest particularly to become resistant to that chemical. In the case of Tungro virus disease in paddy rice field, the vector of the disease which is *Nephotettix virescens,* became resistant when too much chemicals were applied. This caused the Tungro virus disease to be difficult to control. This is especially so in pathogens and also in arthropods with high fecundity. In both cases the genetic variation is high and this makes them to re-adapt with constant excessive pesticide applications. Pathogens (fungi, bacteria, nematodes) may also develop resistance to pesticides and lead to increase disease epidemics. Furthermore, the use of chemicals may kill natural enemies of several vectors of disease-causing organisms.

Concepts of health and Plant diseases

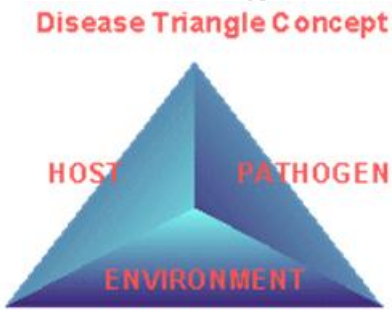
Plant diseases are typically difficult to recognize and diagnose with absolute certainty. To help understand this world of contradiction and confusion, it is instructive to compare the "healthy" to the "unhealthy.“ **Healthy plant** can be defined as a plant that is able to carry out normal physiological functions at an acceptable level consistent with its genetic potential. Normal physiological functions include: Normal cell division, differentiation and development; absorption of water and minerals from the soil and translocation; photosynthesis and translocation of photosynthates; utilization and storage of healthy plant photosynthates; metabolism of metabolites and synthates; reproduction; and storage of reserves for overwintering or reproduction. Plant disease is an impairment of the normal state of the living (plant) that interrupts, modifies, (or stresses) vital functions. Disease is a response to specific causal agents (biotic or abotic), inherent defects of the organism, or combinations of these factors". *Or in other words*: any malfunctioning of host plant cells and tissues those results from continuous irritation by a pathogenic agent or environmental factor which leads to the development of symptoms; - abnormal functioning of physiological processes of an organism.

Diseases are recognized by the resulting symptoms expressed by the host, and signs (pathogens or pathogen parts or products) of the causal agent. The causal agents, as the term is used in the above definition of disease, can be **biotic** (living or infectious), or **abiotic**

(nonliving or non-infectious). Biotic causal agents of disease are termed pathogens. Examples of biotic causal agents (pathogens) of plant disease are fungi, bacteria, mycoplasmas, spiroplasmas, viruses, viroids, nematodes, protozoans, and parasitic higher plants. Examples of abiotic causal agents of plant disease are temperature extremes, moisture extremes, nutrient extremes, light extremes, soil pH extremes, air pollution, oxygen deficiency, pesticide phytotoxicity, cultural malpractices.

Disease Triangle

The "Disease Triangle" is a central concept of Plant Pathology. It is based on the principle that disease is the result of an interaction between a host, a potential pathogen, and the environment. If any one of these factors is missing then disease will not occur. It is important to remember that all three components are necessary pre- and post- infection. Too often the importance of environment is forgotten once the host-parasite interaction is established. To do so is to limit potential disease management approaches.



That's to say: three critical factors or conditions must exist for disease to occur – a susceptible host plant, a virulent pathogen, and the right mix of environmental conditions. The relationship between these factors to cause disease is called the disease triangle. Understanding the disease triangle is critical to the understanding of why most plants are not affected by the many thousands of diseases that exist.

1. Pathogen

Pathogens are the microorganisms that cause disease. Because they are living, they are called biotic agents or causes. Examples of biotic causal agents (pathogens) are fungi, bacteria, mycoplasmas, spiroplasmas, viruses, viroids, nematodes, protozoans, and parasitic higher plants. Each has a different life cycle, which includes an infectious stage. Most pathogens are host-specific to a particular plant species, genus or family. For instance,

black spot of rose will not attack marigolds or lettuce. Some diseases, such as the powdery mildews, produce similar symptoms on different plants. However, the fungi involved are usually host-specific. The rose powdery mildew fungus will not infect cucurbits or turfgrass or vice-versa.

2. 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 labelled 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.

3. 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, for example, are necessary for many fungal diseases. These conditions must continue for a critical period of time while the pathogen is in contact with the host for infection to occur. Environmental conditions also affect the growth and spread of disease pathogens. These conditions include appropriate moisture, temperature, wind, sunlight, nutrition and soil quality. If one of these factors is out of balance for the growth and proliferation of a given pathogen, disease may not occur. In addition, an impbalance in any of these conditions may stress the plant and make less able to defend itself against pathogen attack, and that plant may have a greater tendency to become diseased. For example, lilacs growing in shade are more likely to be infected with powdery mildew than those growing in full sunlight. Very dry or wet weather will have an accompanying set of diseases that thrive under these conditions.

3.1. Moisture

Moisture in the plant environment can include humidity, dew, rainfall or water from irrigation. Moisture is critical to the spread of most plant diseases. Familiar diseases, such as black spot, fire blight and apple scab require moisture to spread to and infect new host plants. Constantly wet foliage from overhead watering is a condition that promotes disease development. Seedlings grown indoors in soggy, unsterilized potting medium and pots are more prone to damping-off, a fungal disease. This is because such mosit conditions favor the rapid growth and reproduction of the pathogen which causes damping-off.

3.2. Temperature

Each disease pathogen has a specific temperature range for growth and activity. There are warm-weather and cool-weather diseases. Many powdery mildew diseases are late summer, warmer temperature diseases. Anthracnose and grey mold disease tend to increase in low temperature environments (about 18-22 degrees celsius). Temperature affects how rapidly pathogens multiply. Soil temperature can also be critical for disease infection. Cool, wet soils promote fungal root diseases. Temperature extremes can cause stress in host plants, increasing their susceptibility to diseases.

3.3. 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 spread pathogens from one area to another, even many miles. The action of wind and rain can lead to an epidemic. Windblown rain can spread spores from infected plant tissue, blowing them to new susceptible host plants. Sunlight is very important to plant health. Plants that do not receive the right amount of sunlight to meet their nutritional requirements become stressed. This may make them more susceptible to infection.

3.4. Soil type and fertility

Soil type can affect plant growth and development of some pathogens. Light sandy soils low in organic matter favours growth of many types of nematodes. Damping-off disease increases in heavy, cold, water-logged soils. Soil pH affects pathogen development in some diseases. Acidic condition (Low pH) favours Club root of cabbage while alkaline conditions (High soil pH) are a factor in the development of scab on potatoes. Soil 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. It has been demonstrated that high Nitrogen fertilization is responsible for certain patch diseases in lawns. Equally Nitrogen deficiency may results in limited growth and plant stress which may cause greater disease susceptibility.

Infectious diseases are caused by biotic agents. Non-infectious diseases are caused by abiotic causes. Examples of abiotic causal agents of plant disease are temperature extremes, moisture extremes, nutrient extremes, light extremes, soil pH extremes, air pollution, oxygen deficiency, pesticide phytotoxicity, cultural malpractices.

How Do Pathogens Cause Disease

1. Enzymatic degradation

In their most basic form, pathogens secrete enzymes, which catalyze the breakdown of host tissues, similar to the digestion of food in mammals. Breakdown of host tissue allows the pathogen to enter the host and to convert organic compounds into simpler forms for absorption by the pathogen. Pathogens produce enymes that help them to breakdown the cell wall and cell membranes allowing the to access cytoplasmic contents for their nutrition. Pathogens will usually degrade the cell wall and membrane by producing enymes such cellulasas and pectinases to breakdown cellulose and pectins in plant cell walls.

2. Toxins

Toxins are poisonous substances, proteins or secondary metabolites, which can be produced by prokaryotic or eukaryotic organisms and which can cause disease or even have lethal effects on other organisms after contact or uptake. Pathogens often benefit by producing toxins, which kill the tissue in advance of enzymatic degradation. In many pathogens, particularly non-obligate pathogens, toxins cause the majority of damage to the host. Necrotrophic plant pathogens often produce toxins to kill plant tissues in advance of colonizing them, whereas obligate biotrophic pathogens are dependent on living host cells and have often lost the ability to produce toxins. Toxins help pathogens to overcome the host's defense mechanisms. Examples include AAL-toxin produced by *Alternaria alternata* f.sp *lycopersici* causing stem canker of tomato, T-toxin produced by *Helminthosporium maydis* causing southern corn leaf blight, and HC-toxin produced by *Helminthosporium carbonum* causing northern leafspot and ear rot of maize

3. Growth regulators

Pathogens often find it advantageous to produce growth regulators, or cause the host to produce them, or to inhibit their production. The most common are those that cause

translocation of nutrients to host cells and/or cause host cells to enlarge or divide in the vicinity of the pathogen, or reprograming the cell to produce unique nutrients needed by the pathogen, thus providing an increase in food and shelter for the pathogen. Obligate pathogens are very good at this technique because it allows the host to go on living, but still provides extra food for the pathogen. Examples include the production of cytokinins by Corynebacterium fasciens producing “leafy” gall disease of sweet pea, Auxins produced by *Ustilago maydis* causing corn smuts, Gibberellins produced by *Gibberella fujikuroi*, the cause of the “foolish seedling” disease of rice.….e.t.c

4. Genetic manipulations

Viruses plus a few bacteria are able to force the plant to produce pathogen gene products from pathogen genetic material. This starves plant cells and disrupts their function.

Disease Cycle

Both the host and the parasite have life cycles. While the life cycles of higher plants can be easily stylized and summarized, the life cycles of the organisms that cause plant disease are widely varied. The simplest is, perhaps, the viruses; which require only a vector and can reproduce nearly autonomously after infection. On the other hand, the macro-cyclic rusts with alternate hosts have not only numerous spores types, that must be developed in sequential order, but also require multiple hosts in order to complete their life cycle. There are five stages in disease development: **inoculation, incubation, penetration, infection and symptoms development**.

1. Inoculation

The pathogen must be introduced (inoculated) to the host plant. Most pathogens cannot move on their own, but must be carried to the host plant. This is done by rain, wind, insects, birds and people. Splashing rain carries spores of apple scab fungus from infected apple leaves to uninfected leaves. Wind blows fungal spores from plant to plant. The spotted cucumber beetle transmits bacterial wilt of cucumbers when feeding. Working in a crop field when plants are wet is a common way to spread disease. Disinfesting tools may require a 9 : 1 solution of water and bleach and take 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. Seeds are often coated with a fungicide to prevent the transmission of surface fungal 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.

2. Incubation

The second stage of disease development is incubation. The pathogen changes or grows into a form that can enter the new host plant. In many fungal diseases, the pathogen arrives on the plant as a spore which must germinate before it can grow into the plant.

3. Penetration

The third stage is penetration or the point at which the pathogen actually enters the host plant. Once the fungal spore germinates, it sends out thread-like tubes called hyphae. These penetrate the plant through wounds or natural pores (e.g. stomata). Wounding roots of bedding plants during transplanting provides entry for root-rotting fungi. The mouthparts of an insect also result in openings for penetration.

4. Infection/invasion/colonisation

The fourth stage is infection. The pathogen grows within the plant and begins damaging the plant tissue.

5. Symptoms development

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 shrivelling of any plant part.

<u>Plant Disease Symptoms</u>

The visible presence of the pathogen or products of the pathogen on the host plant are referred to “Signs of the pathogen”. These are physical manifestation of the causal agent maybe in the form of spores, mycelia, thallus, nema, bacterial ooze (when the bacterium is present), etc. In contrast, symptoms are the external and internal reactions or alterations of a plant as a result of disease. They are physical manifestations of the host’s response to pathogen. These are profound physiological and morphological changes that are visible in a diseased plant. The symptoms also change as the disease progresses. Symptoms may be localized (confined to a small area of the plant) or systemic (spread throughout the plant). Primary symptom: symptom proximal to the infection site produced as a direct response to the causal agent. A common primary symptom is a lesion; a well defined localized diseased area. Secondary symptom: symptoms which result from indirect or "chain of events" interactions and occur some distance from the infection point and in many cases distal to the causal agent. Symptoms of disease include death and destruction of host tissue, wilting,

abnormal growth and differentiation and discolouration of host tissue. Some parasites, called necrotrophs, secrete enzymes that kill host tissue, extract nutrients from the cells and then live in the dead tissue. The necrotic lesions caused by pathogens can be localised or extensive. Local necrotic lesions appear as discrete necrotic areas, while extensive, or spreading lesions spread until the whole organ or plant is killed. Wilting occurs when water loss is greater than water intake. It results from either: interference with water and nutrient absorption at the roots, interference with water conduction within the plant (i.e. infection of the vascular tissue), or loss of control of transpiration. Abnormal growth and differentiation results from deviation from the complex balance of interrelated reactions that take place in plants. Parasites can alter the hormonal balance in plants causing an abnormal increase in the size or number of cells, resulting in abnormal growth and differentiation, for example, and formation of galls. Discolouration of tissue is most commonly by chlorosis or mosaics of leaves, both of which can have a number of causes. Anything that interferes with the production of chlorophyll causes leaves to turn yellow, or chlorotic. Mosaicism is a symptom typical of many virus infections and is characterised by alternating light and dark green areas on the leaves. Normal tissue colours may be any of this: green, dark green, light green or multiple hues of red. While any deviation from this may be symptoms of the disease. Symptoms aid in the correct diagnosis of a plant disease

Soft versus Dry Rots: Soft rots are usually soft, usually watery and often odoriferous or produce bad smell. Dry rot, or un-watery rot, are largely firm dry decaying caused by fungal infection, e.g. Fusarium dry rot on potato tuber or Fusarium dry root rot of beans.