Plant pathology: Terms and definitions

- **Plant pathology**

The study of the diseases of plants, its causes, processes of development, consequences and the structural and functional changes caused by the disease.

In Greek, '*Phyto*' means plant, 'Pathos' means suffering and '*Logos*' means knowledge.

- **Disease**

A disease may the defined as sustained physiological or structural unbalance in the plant as a whole or a part of it, caused by certain external agencies.

Any abnormal condition of the body that causes discomfort, dysfunction or distress to the affected plant is called disease.

Agrios (1997) defined disease in plants as a series of invisible and visible responses of plant cells and tissues to a pathogenic micro-organism or environmental factor that result in adverse changes in the form, function or integrity of the plant and may lead to partial impairment or death of the plant or its parts.

Agencies that cause disease may be unfavourable environmental conditions (non-pathogenic) or it may be a pathogen like bacteria, fungi, virus, etc.

- **Pathogen**

An agency which generates a disease is referred to as a pathogen.

A pathogen is an organism or virus capable of causing disease in a particular host or ranges of host.

The word 'pathogen' has been derived from the Greek word 'pathos' meaning suffering.

Though the causal organisms of diseases are generally parasitic, a parasite is not synonymous to pathogen. In some cases, organisms are parasitic without causing any disease to its host.

Thus all pathogens are parasites but all parasites are not pathogens!

- **Parasites**

Parasites are defined as organisms or viruses existing in an intimate association with another living organism from which they derive an essential part of the materials required for their nutrition.

- **Pathogenecity**

The ability of a pathogen to cause or incite disease is called pathogenecity. It may also be defined as the ability of the pathogenic parasite to interfere with one or more of the essential physiological functions of the plant and cause disease development.

- **Pathogenesis**

The process or chain of events leading to the development of disease is called pathogenesis.

In other words, pathogenesis is the sequence of progress of different biochemical steps that are involved in disease development starting from the initial contact between a pathogen and its host to the completion of the syndrome.

- **Vector**

An organism, especially an insect, which carries a disease-producing microorganism (pathogen) from one host to another, either within or on the surface of its body is called a vector.

- **Biotrophs**

These are organisms which obtain their food from living tissues on which they thrive and complete their life cycle. They are called living-feeders.

Ex: *Pseudomonas syringae* is a model biotrophic pathogen.

Rust and smut fungi are also biotrophs

- **Necrotrophs**

These are organisms which derive their nutrition from host cells that they have already killed. They rapidly kill host tissues and then live saprophytically on the dead tissue. They are called dead-feeders.

Ex: *Botrytis cinerea* is a model necrotrophic pathogen

- **Inoculum**

Inoculum is the infectious material that can cause disease and it is that portion of individual pathogen that is brought into contact with the host plant.

Primary inoculum: The overwintering or oversummering dormant stage which causes the original infection in the spring or autumn is called primary inoculum. The infection it causes is called primary infection.

Primary inoculum may reside:

- In or on the seed of the host plant
- In the debris of infected plant of the previous season
- In perennial wild alternate host
- As dormant endospore in soil

Secondary inoculum: An inoculum produced from the primary inoculum in the active stage at the diseased area is called secondary inoculum. The infection it causes is called secondary infection.

When the plant becomes diseased after primary infection, it produces another round of spores or infective bodies called the secondary inocula. These secondary inocula cause secondary infection and further spread the disease.

- **Inoculation**

The process of coming in contact of the inoculum of the pathogen with the host plant is called inoculation.

In most cases, inoculum is carried to the host plant passively by wind, water or by insects. Zoospores and nematodes may be attracted to the host plant by sucking substances like sugars and amino acids. In some cases vectors mediate inoculation.

- **Inoculum density**

It is the number of inoculum per unit area.

Minimum inoculum density required for disease development is called numerical threshold of inoculum density.

- **Inoculum potential**

It is the degree of infectivity of the inoculum.

Garrett (1956) defines inoculum potential as the energy of a pathogen available for infection of a host at the surface of the host organ to be affected.

- **Propagule**

A single unit of the inoculum of any pathogen is called a propagule.

- **Infection**

Infection implies the establishment of the pathogen inside the host following penetration in which a parasitic relationship between the host and the pathogen is established.

The word infection is derives from the Latin word '*Ínficere*' meaning 'to taint'.

Two concurrent sub-stages of infection:

- Invasion of the host tissue by the pathogen
- Growth and reproduction of the pathogen in the infected tissue

Successful infection results in the appearance of symptoms.

During infection a number of biologically active substances like enzymes, toxins and growth regulators that may affect the structural integrity of the host cells and their physiological processes.

Visible and invisible infection

The infection when visible externally on the host surface is known as visible infection. It is commonly called appearance of the disease.

When infection is established in the host tissue but is not visible from outside the host it is known as invisible infection.

Conditions for successful infection

For a successful infection to occur it is not sufficient for a pathogen to come in contact with the host; rather, several other conditions must also be satisfied:

- Host must be susceptible and the pathogen must be virulent
- Pathogen must be in the pathogenic stage, not in dormant stage
- Environmental conditions must favour infection
- Inoculum density must be higher than the numerical threshold

➢ **Causal complex**

A combination of several factors, both external and internal, becomes the cause of the disease when it alters the physiological processes and morphological development of a particular part or the plant as a whole. This is called causal complex.

It may also be necessary for a plant first to be weakened by unfavourable environmental conditions before it can be attacked by a pathogen. The entire plant or only a portion of it may be affected and disease may or may not necessarily be significantly injurious. Environmental conditions as well as the organism inciting the disease are also part of the causal complex.

- Host -----Susceptible ----
    - Genetic susceptibility
    - Biochemical susceptibility
    - Morphological susceptibility
- Pathogen -----Inoculum ----
    - Inoculum potential -----Virulence
    - Inoculum density and numerical threshold
- Environmental factors -----
    - Microclimate
    - Macroclimate

➢ **Disease cycle**

A series of events involved in disease development, including the stages of development of the pathogen and the effects of the disease on the host, is called the disease cycle.

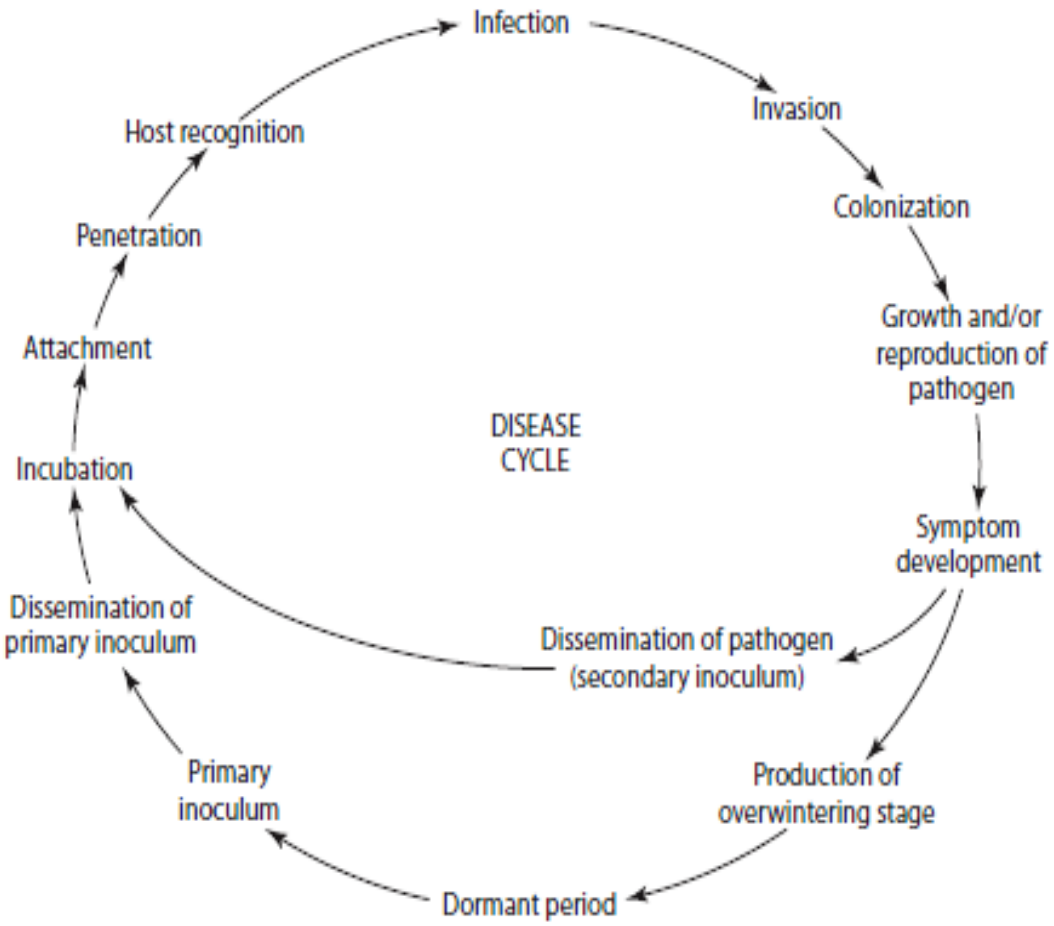
When a pathogen is involved the disease cycle is intimately associated with the organism. It is distinct from the life cycle of the organism.

Primary disease cycle: The disease cycle that is produced from primary infection.

Secondary infection: The disease cycle that is produced from secondary infection.

Primary events of disease cycle:

- Inoculation
- Penetration
- Establishment of infection
- Colonization (invasion)
- Growth and reproduction
- of the pathogen in the host
- Overseasoning of the pathogen



- **Disease triangle**

A plant becomes diseased in most cases when it is attacked by a pathogen, or less commonly, when it is affected by an abiotic agent.

So, 3 components must be present simultaneously to cause a disease. These are:

- Susceptible host
- Virulent pathogen in the active stage
- Suitable environment

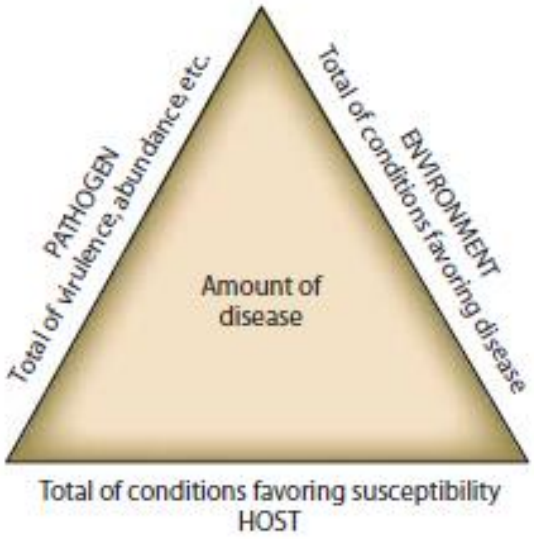
The interaction of these 3 components have been often visualised as a triangle, referred to as ‘disease triangle’. Each side of the triangle represents one of the 3 components.

The length of each side is proportional to the sum total of the characteristics of each component that favours disease. The area of the triangle represents the potential amount of the disease.

If the plant is resistant, wrong age or widely spaced, the host side is small or zero and amount of disease is less or zero. If the plant is susceptible, at right age or closely planted, the host side is long and amount of disease will be more.

Similarly, more virulent, abundant and active the pathogen, the longer the pathogen side would be and the amount of disease would be greater.

And, the more favourable the environmental factors that help infection, the longer the pathogen side would be and the amount of disease would be greater



- **Etiology**

Study of pathogens in their natural condition is called etiology.

In a broader sense, it includes the study of the causal organisms, their nature and their relations with the host.

Thus etiology is the study of causal organism and predisposing factors (favourable environmental conditions that are essential for disease development) and the pathogen.

Thus the sum total of the etiology and susceptible host represents the disease triangle.

Etiology+Susceptible host=Disease triangle

- **Microclimate**

It refers to the environmental condition existing immediately around the inoculum.

Ex- *Puccinia graminis* requires the presence of free water at the point of contact for germination of the spores.

- **Symptoms**

Successful infection results in the appearance of symptoms. Symptoms are the visible changes in the morphology and physiology of the host plant that results from a successful infection.

- **Syndrome:**

Every disease in plants is expressed in a variety of symptoms and signs which constitute the clinical picture or syndrome of the disease.

Types of symptoms

- **Necrotic symptoms:** Necrosis is caused due to death of plant cells in the affected area caused by both parasitic and non-parasitic agencies. The affected plant tissue usually turns brown to black in colour. Necrotic symptoms could appear in any part of the plant such as in storage organs or in green tissues. Ex: Leaf blight
- **Atrophic symptoms**: A slowing down in the development of the affected plant or plant parts resulting from subnormal cell division (**hypoplasia**) or from degeneration of cells. Symptoms are dwarfism and nanism. This can be caused due to unfavourable environmental conditions or due to pathogen invasion.
- **Hypertrophic symptoms:** Overgrowths of all kinds resulting from an abnormal increase in the number of cells due to excessive cell division (**hyperplasia**) or from an abnormal increase in the size of cells (**hypertrophy**) or from both. Symptoms are galls, leaf curls, leaf blisters, etc.

IMPORTANT TYPES OF SYMPTOMS

- **Wilt:** A drooping condition of the leaves, shoots, or other parts is usually due to a diseased vascular system. The wilting mat be temporary, the plants recovering at night, or it may be permanent and progress to death of the affected plant part.
- **Blight:** A condition developed due to the rapid killing of foliage, blossoms, etc., by pathogens is called blight. The killed tissue is often transformed into slimy mass which emits pungent odour.

- **Spot:** A very common symptom in many diseases is the development of more or less circular diseased areas on the affected plant parts. Often the affected tissue dies, turns brown and dies out. Sometimes the central dead area is surrounded by one or more zones of reddish or yellowish tissue.

- **Blast:** The sudden death of above ground plant parts like young buds, inflorescence and young fruits is called blast.

- **Die-back:** A symptom resulting from death of twigs or branches from tip towards the base is called die-back.

- **Anthracnose:** Elongate, more or less angular spots appear on the lower side of the leaf spreading into surrounding tissue and eventually appearing on the opposite side. Petioles, stems and often fruits may be affected.

- **Canker:** This is asunken necrotic lession developed in the cortical tissues of the stem, fruits or leaves. A sharp demarcation of the area by a sharp crack separating the diseased part from the healthy part often marks a stop in canker development.

GEOGRAPHICAL DISTRIBUTION OF DISEASES

- **Endemic disease:** A disease is said to be endemic when it is constantly present in a moderate or severe form and is confined to a particular geographical region like country or district.

Ex: Wart disease of potato caused by *Synchitrium endobioticum* is endemic in Darjeeling

- **Epidemic disease:** An epidemic or epiphytic disease usually occurs widely, but periodically in a destructive form. The pathogen may be present, as in endemic disease, but the environmental.

. Ex: Powdery mildew, cereal rusts, etc.

- **Sporadic disease:** Sporadic disease in reality belongs to the epidemic group. The term is applied to those diseases which occur at very irregular intervals and locations and in relatively fewer instances.

Ex: Angular leaf spot and blotch diseases of cucumber; most of the soil borne diseases is sporadic in nature

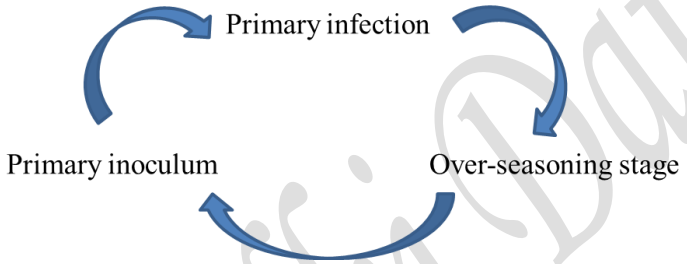
- **Pandemic disease:** Pandemic outbreak is an epidemic which occurs over vast and extensive areas causing severe loss. This occurs all over the world and result in man mortality, i.e. it has a global scenario.

Ex: Late blight of potato

TYPES OF DISEASES CYCLE

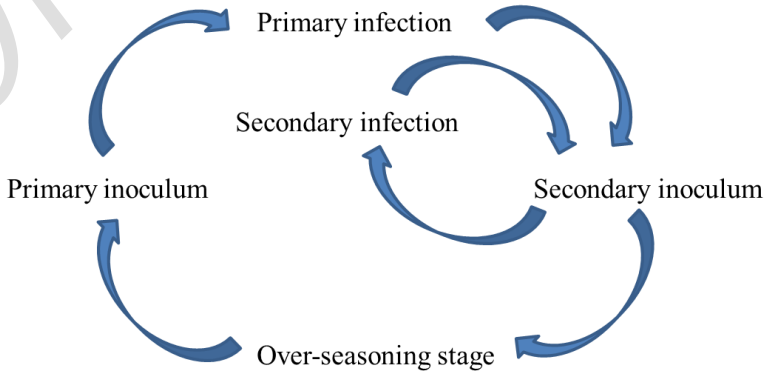
- **Monocyclic:**

- Some pathogens complete only one or even part of one disease cycle in one year and are called mono-cyclic or single cycle pathogens.
- In mono-cycle pathogens, the primary inoculum is the only inoculum available in a growing season, since there is no secondary infection.
- The amount of inoculum produced at the end of the season, however, is greater than that at the start of the season. So in monocycle disease the amount of inoculum may increase steadily from year to year.
- Ex: Smuts, vascular wilts



- **Polycyclic:**

- Some pathogens complete more than one generation per growth season and so are called polycyclic or multi-cycle pathogens.
- In polycyclic fungal pathogens, the primary inoculum generally consists of sexual spores or sclerotia or pseudosclerotia or infected mycelium.
- Once primary infection takes place, large number of asexual spores (secondary inoculum) is produced in each infection sites and these spores causes secondary infection that produces more asexual spores for more infection.



- Polycyclic pathogens can complete many disease cycles per year and with each cycle the amount of inoculum is multiplied manyfold.
- Ex: Downy mildews, late blight of potato

- **Polyetic:**

- Some pathogens may not complete one disease cycle in one year, but instead may take several years before the inoculum it produces in the host can be disseminated and initiate new infection. They are called polyetic or multi-year pathogens.

- Although polyetic pathogens do not cause many new infections over a given area in a single year, and their amount of inoculum does not increase greatly within a year (as they survive in perennial host) at the end of each year they have almost as much inoculum as it had at the end of previous year.

- Ex: Pear decline, Citrus tristeza

- **Koch's postulates:**

Robert Koch enunciated certain rules or criteria that should be satisfied before the identity of the disease-producing organism in a particular disease could be established. These rules are known as Koch's postulates.

Koch's postulates

- A specific organism must always be associated with a disease.

- The causal organism must be isolated from the diseased plant (first isolate) and grown in pure culture and accurately described.

- The organism must be identified.

- The inoculations with inocula from pure culture of the causal organism must reproduce the disease in the same species or variety of plant from which the causal organism was isolated.

- The causal organism must be re-isolated (second isolate) from the plant in which disease has been produced by inoculating with inocula from pure culture. The physiological and morphological characters of the first and second isolates should be compared.

Drawbacks

- In case of some pathogens like some phytoplasmas, fastidious vascular bacteria, protozoa, fungi and viruses, culture or purification of the pathogen is not yet possible. The pathogen often cannot be re-introduced in the host to reproduce the disease (Ex-powdery mildew). Thus with these pathogens, Koch's postulates cannot be followed.
- In case of root diseases, inoculation and isolation of the pathogen are both difficult.
- It do not include the following concepts:
    - Asymptomatic carrier state.
    - Many viruses do not cause illness in all infected individuals (Ex-Polio virus cause paralysis in 1% of those infected.
    - Infection with the same virus may lead to markedly different diseases.
    - Multiple causation

- One syndrome may have different caused under different settings.
- Diseases may be caused due to nutrient deficiencies without involvement of pathogens.

Modifications

Here are Koch's postulates for the 21st century as suggested by Fredricks and Relman:

- A nucleic acid sequence belonging to a pathogen should be present preferentially in the diseased organs or gross anatomic sites and not in those organs that lack pathology.
- Fewer, or no, copy numbers of pathogen-associated nucleic acid sequences should occur in hosts or tissues without disease.
- With resolution of disease, the copy number of pathogen-associated nucleic acid sequences should decrease or become undetectable. With clinical relapse, the opposite should occur.
- The nature of the microorganism inferred from the available sequence should be consistent with the known biological characteristics of that group of organisms.
- Tissue-sequence correlates should be sought at the cellular level: efforts should be made to demonstrate specific *in situ* hybridization of microbial sequence to areas of tissue pathology and to visible microorganisms or to areas where microorganisms are presumed to be located.
- These sequence-based forms of evidence for microbial causation should be reproducible.