Acharya N. G. Ranga Agricultural University

Diploma in Agriculture

ANGRAU

Course Title: Principles of Plant Pathology

Course No.: DA 171

Credit hours: 2 (1+1)

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DA 171 - Principles of Plant Pathology 2 (1+1)

Theory – Lecture Outlines

1. Plant Pathology – Introduction, Definition and Objectives
2. Terms and concepts used in Plant Pathology
3. Plant Pathogens – Fungi, Bacteria and Phytoplasma
4. Plant Pathogens – Viruses, Nematodes and Phanerogamic parasites
5. Classification of plant diseases
6. Symptoms of fungal diseases
7. Symptoms of bacterial diseases
8. Symptoms of viral and phytoplasmal diseases
9. Survival of Plant Pathogens
10. Dispersal of Plant Pathogens
11. Process of Infection
12. Principles of plant disease management – Avoidance and Exclusion
13. Principles of plant disease management – Eradication and Protective measures
14. Principles of plant disease management – Host Plant Resistance
15. Study of symptomatology
16. Fungicides and their classification

LECTURE - 1

PLANT PATHOLOGY - INTRODUCTION, DEFINITION AND OBJECTIVES

Plant Pathology/Phytopathology (Phyton= plant, Pathos=suffering, ailment, Logos=study / discourse/knowledge) *ie*., the study of nature, development and management of plant diseases.

Definition: A branch of agricultural science which deals with cause, etiology, resulting losses and management of plant diseases.

Objectives of Plant Pathology:

1. To study the living, non-living and environmental causes of plant diseases.
2. To study the mechanisms of disease development by pathogens.
3. To study the interactions between the plants and the pathogens.
4. To develop the methods of controlling the diseases and reducing the losses caused by them.

Important phytopathogenic organisms:

In plants generally diseases are caused by fungi, bacteria, viruses and phytoplasmas.

Fungi:

Fungi are eukaryotic, spore bearing, achlorophyllous, heterotrophic organisms that generally reproduce sexually and asexually and whose filamentous, branched somatic structures are typically surrounded by cell walls containing chitin or cellulose or both with many organic molecules and exhibiting absorptive nutrition. Fungi are heterotrophic with holophytic nutrition (absorptive type). The essential elements for fungi are C, H, O, N, P, K, S, Zn, Fe, Mg, Mn, Mo, Cu and Ca. Reserve food material in the cell may be either fat or glycogen. Fats may be present in the form of oil drops and carbohydrates in the form of glycogen or sugars. Starch is never present in the fungal cell. They are present in all over the world and may be harmful or helpful to the plants and human beings. In Agriculture they are helpful in many ways, helpful in improving soil fertility, Phosphate solubilisation, antibiotics development etc.

Groups of fungi based on mode of nutrition:

1. *Saprophytes*: (sapros = rotten, phytos = plant) Organisms which obtain nutrition from dead organic matter either completely or for a part of their life. A large number of fungi fall under this category. Eg. *Rhizopus, Mucor, Alternaria.*

a. Obligate saprophytes: (obligate = to bind itself) Organisms which can never grow on living organisms or can never obtain their food from living source. They get their food only from dead organic matter. Eg. *Mucor, Agaricus*.

b. Facultative parasite: (facultas = ability) Organisms which are usually saprophytic but have ability to become as parasites.

Eg. *Pythium aphanidermatum, Fusarium solani, Rhizoctonia solani.*

2. *Parasites:* Organisms which live within or outside another organisms for their nutrition either completely or for a part of their life.
Pathogen: If a parasite damages the host then they are called as pathogens.
All pathogens are not parasites and all parasites need not be pathogens.
a. Obligate parasites: Organisms which obtain food only from living organisms (living protoplasm) and can never derive their food from dead organic matter or artificial medium. Eg. *Puccinia graminis, Plasmopara viticola*.
b. Facultative saprophytes: Organisms which are usually parasites but have ability to become saprophytes. Eg. *Ustilago maydis*

3. *Symbiosis:* Some fungi coexist with some algae or other plants.
Eg: - Algae (Lichens) Fungal Roots (Mycorrhiza).

LECTURE – 2
TERMS AND CONCEPTS USED IN PLANT PATHOLOGY

Disease: Any malfunctioning of host cells and tissues that result from continuous irritation by a pathogenic agent or environmental factor and leads to development of symptoms.

Disorder: Non-infectious plant diseases due to abiotic causes such as adverse soil and environmental conditions are termed disorders. The common characteristic of non-infectious diseases of plants is that they are caused by the lack or excess of something (temperature, soil moisture, soil nutrients, light, air and soil pollutants, air humidity, soil structure and pH) that supports life. Non-infectious plant diseases occur in the absence of pathogens, and cannot, therefore, be transmitted from diseased to healthy plants.

Pathogen: An entity, usually a micro-organism that can incite disease. In a literal sense a pathogen is any agent that causes *pathos* (ailment, suffering) or damage. However, the term is generally used to denote living organisms (fungi, bacteria, MLO's, nematodes etc.,) and viruses but not nutritional disorders.

Parasite: Organisms which derive the materials they need for growth from living plants (*host or suspect*) are called parasites.

Pathogenicity is the ability of the pathogen to cause disease.

Pathogenesis is the chain of events that lead to development of disease in the host (or) sequence of progress in disease development from the initial contact between the pathogen and its host to the completion of the syndrome.

Sign: The pathogen or its parts or products seen on a host plant.

Symptom: The external or internal reactions or alterations of a plant as a result of a disease.

Syndrome: The set of varying symptoms characterizing a disease are collectively called a syndrome.

Biotroph: An organism that can live and multiply only on another living organism. They always obtain their food from living tissues on which they complete their life cycle.
Ex: Rust, smut and powdery mildew fungi.

Hemibiotroph (Facultative Saprophyte): The parasites which attack living tissues in the same way as biotrophs but will continue to grow and reproduce after the tissue is dead called as *facultative saprophytes*.

Perthotrophs or perthophytes (**Necrotroph)**: A parasite is a *necrotroph* when it kills the host tissues in advance of penetration and then lives saprophytically.
Ex: *Sclerotium rolfsii.*

Collateral hosts: Collateral host are the wild host of crop plants having same family which are susceptible to disease during off-season of main crop.

Eg. Disease- Rice Blast- *Pyricularia oryzae*

Crop host: Paddy

Collateral host: *Brachiaria mutica, Dinebra retroflexa, Leersia hexandra, Panicum repens* etc.

Alternate host: Alternate host are the wild host plants having different family which are susceptible to disease.

Eg. Disease: Black stem rust of wheat – *Puccinia graminis tritici*

Crop host: Wheat

Alternate host: Barberry (*Berberis vulgaris*)

Inoculum: It is the part of the pathogen which on contact with susceptible host plant causes infection (or) the infective propagule which on coming in contact with the host plant causes an infection is known as inoculum.

Primary inoculum: The propagules that cause primary infections are called as primary inoculum.

Secondary inoculum: The spores or other structures of the pathogen can cause secondary infection are called secondary inoculum.

Inoculum potential: The energy of growth of a parasite available for infection of a host at the surface of the host organ to be infected (or) The resultant of the action of environment, the vigour of the pathogen to establish an infection, the susceptibility of the host and the amount of inoculum present.

Incubation period: The period of time (or time lapse) between penetration of a host by a pathogen and the first appearance of symptoms on the host. It varies with pathogens, hosts and environmental conditions.

Predisposition: It is the action of set of environments, prior to penetration and infection, which makes the plant vulnerable to attack by the pathogen. It is related to the effect of environments on the host, not on the pathogen, just before actual penetration occurs.

Hypersensitivity: Excessive sensitivity of plant tissues to certain pathogens. Affected cells are killed quickly, blocking the advance of obligate parasites.

Infection is the establishment of parasitic relationship between two organisms, following entry or penetration (or) the establishment of a parasite within a host plant.

Systemic infection: The growth of pathogen from the point of entry to varying extents without showing adverse effect on tissues through which it passes.

Epidemic or Epiphytotic disease: A disease usually occurs widely but periodically in a destructive form is referred as epidemic or epiphytotic disease.
Ex: Late blight of potato – Irish famine (1845).

Endemic: A disease constantly present in a moderate to severe form and is confined to a particular country or district.
Ex: Club root of cabbage in Nilgiris
Black wart of potato – *Synchytrium endobioticum* – Darjeeling district

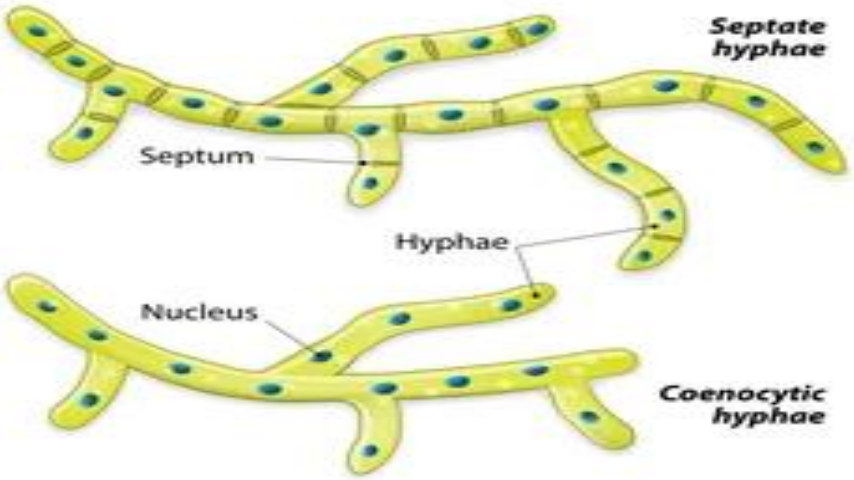
Sporadic disease: Occur at very irregular intervals and locations and in relatively fewer instances.
Ex: Udbatta disease of rice, Angular leaf spot of cucumber –*Pseudomonas lachrymans*

LECTURE - 3

PLANT PATHOGENS – FUNGI, BACTERIA AND PHYTOPLASMA

Fungi:

Many damages are caused by fungal activity. The most important of these are infections of crop plants and other plants, infections of humans and animals, contamination of food items by fungal growth, and damage to many species by their actions. Hypha is a thin, transparent, tubular filament filled with protoplasm. Network of hyphae is called mycelium. Based on the presence absence of septation fungi can be classified into two types



1. Coenocytic fungi 2. Multicellular fungi

Coenocytic hypha/ Aseptate hypha: A hypha without septa is called aseptate /non-septate/ coenocytic hypha wherein the nuclei are embedded in cytoplasm. Coenocytic hyphae develop sepatation upon injury or at the time of vegetative reproduction.

Eg. Oomycota members like *Phytophthora, Albugo* and Zygomycota members like *Rhizopus* and *Mucor.*

Multicellular fungi: Highly developed fungi belonging to Ascomycota, Basidiomycota and other mitotic fungi have well developed filamentous branched **multicellular mycelium**. Mycelium may be uninuleate or multinucleate. Under multinucleate condition mycelium may contain genetically identical nuclei known as homokaryotic while the mycelium which contains nuclei of different genetic constituents it is referred as heterokaryotic. Some fungal hyphae are provided with partitions or cross walls which divide the fungus into a number of compartments /cells. These cross walls are called septa. The septa may be complete septa or incomplete septa. A septum is a solid without any pore or perforations or with a central pore or more than a one pore. Perforated septa provide the movement of cellular material from cell to another.

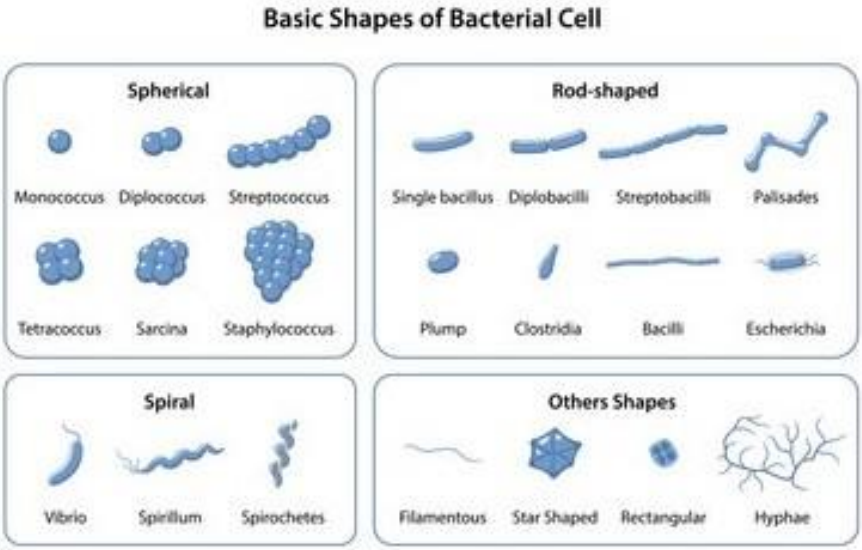
Bacteria:

Bacteria are microscopic organisms that can only be seen under a microscope. These do not have chlorophyll. Reproduced by binary fission. These are prevalent in all types of habitats. These are spread over the bodies of soil, water, air, and organisms. Grow on a variety of foods. Some bacteria live as parasites in plants, animals, and humans. Some other bacteria coexist with plants.

Bacteria are morphologically identified into four shapes.

1. Cocci (round) 2. Bacillus (rod) 3. Comma-like curved back (Vibrio) 4, Spiral (Spirillum).

According to food /nutrition, bacteria are classified into two main types as Heterotrophs and Autotrophs. Besides causing some harmful damage to the plants, there are many uses in agriculture. The role of various bacteria is highly crucial in the industrial sector. Bacteria are used in the manufacture of many organic acids, enzymes, amino acids, and antibiotics.



Phytoplasma

Nocard and Roux (1898) discovered Mycoplasma which causes pneumonia in animals and they couldn't be filtered through bacteriological filters. Certain of the plant diseases were found associated with organisms that resembled Mycoplasmas hence are referred to as Mycoplasmas Like organisms(MLO's) or Phytoplasmas given by Doi *et al*. (1967)

Important characteristics of Phytoplasmas:

- Size vary from 100 nanometers to 1 micrometer diameter
- Wall less, covered by trilamellar unit membrane with lipoproteins
- Cells pleomorphic
- Aerobic to facultative anaerobes
- Found intracellularly in phloem vessels of plants
- Ribosomes are of bacterial type
- Genome is made up of double stranded circular DNA
- Self-replicable by transverse binary fission
- Obligate parasites
- Non-flagellate, non-spore former and Gram negative.
- Resistant to **penicillin** but sensitive to **tetracycline** and chloramphenicol
- No Reversion to bacteria in penicillin free media unlike L- forms which revert back to bacteria eg., *Agrobacterium tumefaciens*
- Transmission is by leaf hoppers and grafting
- They require **sterols** for growth
- Can be controlled by thermotherapy by growing plants at 37- 40 ^{0}C.
- Nearly 70 different types of diseases occur in about 250-300 plant species.

Diseases caused by Phytoplasma

1. Aster yellows 2. Sesamum phyllody 3. Sandal spike 4. Little leaf brinjal 5. Grassy shoot of sugarcane 6. Potato witches broom

LECTURE – 4
PLANT PATHOGENS – VIRUSES, NEMATODES AND PHANEROGAMIC PARASITES

Viruses:

Viruses are high-molecular-weight nucleoproteins that can survive in a living host. They can pass through filters. Viruses contain only one type of nucleic acid. It could be either DNA or RNA while other organisms have two types of nucleic acids. The basic properties of living organisms such as nutrition, respiration, reproduction, etc. are not found in viruses. Viruses do not have any of the structures found in cellular organisms, such as cell membrane, biomass, nucleus and cells. Viruses show inanimate properties. Replication of virus occurs by using the host's protein synthesising machinery while still in the host cell. Viruses can mutate. In this way viruses have inanimate and animate properties. Plant viruses do not enter the host cell on their own. They enter the cell through wounds in the cell membrane or by insects. Viruses have no cell structure. Once removed from living cells, the viruses become completely inactivated. Symptoms produced by the virus in plants may appear externally or internally.

Nematodes

Nematodes are ubiquitous, present in all moist to watery ecological niches in diverse situations like cold oceans, hot springs, mountain peaks, soil ecosystem, plants as well as animals. Typical symptoms indicating nematode attack are root knots or galls, root lesions, excessive root branching, injured root tips and stunted root systems, loss of chlorophyll, yellowing, hypertrophy and hyperplasia etc. The symptoms of nematode infestation in plants are similar to those symptoms produced by fungi and bacterial infection. Nematode life cycle starts with egg and second instar juveniles attacks the plants and cause diseases. Males and females exists in different shapes. They possess well developed mouth parts with stylet that suck out the plant cell cytoplasm, killing the plant cell and moves ahead of the lesion.

Phanerogamic plant parasites:

Phanerogamic plant parasites body is divided into distinct roots, shoots, and leaves. They are commonly called flowering plants. They produce special reproductive structures and generate seeds and are categorized as Tracheophytes. Many types of flowering plant parasites can cause significant damage to horticultural crops and field crops. These parasites belong to the families Loranthaceae, Orobanchaceae, Convolvulaceae, Lauraceae, Santalaceae and Belanophoraceae. They absorb and deplete nutrients from the plant, inhibit plant growth, releasing toxins in the plants causing damage to the plants. These parasites produce seeds and spread to other areas through the air, birds and animals, as well as through soil. The cut stem plants in *Cuscuta* can also grow into new parasites and cause damage to crops. The seeds of *Orobanche* and *Striga* survive for many days in soil. These mostly hang on stems and roots and cause damage to crops. Parasites make contact with tissues and absorb nutrients from plants.

There are two types of these parasites:

Stem parasites: *Cuscuta, Loranthus.*

Root parasites: *Orobanche*, *Striga.*

For management of phanerogamic parasites, the seeds and propagative materials with phytosanitary certificate should only be used for cultivation.

Cuscuta and *Loranthus* should be pruned and destroyed. When crop rotation is adopted, the seeds of flowering plant parasites should be grown in a crop rotation system that can inhibit or inhibit the growth of other parts. Trap crop should be planted wherever possible to reduce inoculum potential. They can also be prevented by using herbicides specifically designed for phanerogamic plant parasites.

Cuscuta

Striga

Loranthus

LECTURE - 5
CLASSIFICATION OF PLANT DISEASES

There are different methods of classifying diseases.

1. **Based on the disease infected crops** *eg.* Field crop diseases, horticultural crop diseases, forest tree diseases etc.

2. **Disease based on plant parts:** Disease can be classified as leaf and fruit disease based on plant part infected

3. **Classification according to pathogens**: Fungal diseases, bacterial diseases, virus diseases etc

4. **Based on source of inoculum:** Based on the means of survival of inoculum that helps in establishment of disease. *eg.*, Through soil (Soil borne), through air (air borne),seeds and insects.

5. **The nature of the host's response**: eg., Necrosis, nodules *etc.*

6**. Depending on the nature of the disease:**

1. Epidemic
2. Endemic.
3. Sporadic

7. **Classification of diseases on the basis of symptoms**: This type of classification contributes to the proper study of diseased plants. Crop plants infected with pathogen exhibit varied symptoms. Diseases are classified as follows according to the functional changes in the host with these symptoms. *eg.*, damping off, root rot, wilt, powdery mildew, smut, leaf spots etc.

8. **Based on the causative agent of the disease :**

Infectious Diseases - Infectious diseases are caused by a biological pathogen or pathogen and spread from one area to another. eg. Fungal, bacterial diseases etc.

Non-Infectious Diseases - Diseases infect plants due to non-infectious agents. These diseases do not spread from one plant to another or to another area. *eg*. Low and high temperatures such as unfavorable weather conditions, soil nature (loamy soils), nutrient deficiencies can cause certain symptoms in plants.

LECTURE – 6
SYMPTOMS OF FUNGAL DISEASES

Symptoms of Fungal diseases:

1. **Damping off** - This rot is caused by a variety of fungi. Even well-germinated seeds will not grow into seedlings if the disease infects. In the first stage, the seedlings can be observed in the germinated premises in the planted soil. In the second stage, the germinated plant tissues develop water-soaked spots on the stem that touches the ground and turn pale brown. This disease causes the plants to wither and die. The two stages described above are called the pre-emergence damping off stage and the post-emergence damping off stage. The rot is caused by fungal species such as *Pythium*, *Phytophthora* and *Fusarium*. Disease infestation can be caused by pathogens that can dormant in the soil and seed.
2. **Root Rot:** This rotting occurs at root zone region. As a result, the water supply to the plant is affected. Plants become susceptible and exhibit stunted growth. The leaves turn yellow and fall off. Eventually plants die. Fungi that cause root rot can also live in the soil as facultative parasites and saprophytes.
3. **Wilt**: The root system and vascular tissues are completely affected and the plants wither due to inability to supply enough water required for evaporation. The petioles in the lower part of the plant bend downwards as an early sign. This symptom is called as epinasty. The lower leaves turn yellow and gradually dry out. When the sun is high, some of the leaves wilt during the day and become turgid again at night. Discoloration of vascular bundles is observed due to formation of tyloses and gum when split open.
4. **Downy Mildew:** These are primarily foliage blights. They attack and spread rapidly in young, tender green leaf, twig, and fruit tissues in which the sporangiophores and spores of a fungus appear as a downy growth on the lower surface of leaves and stems, fruit, etc., caused by fungi in the family Peronosporaceae. They develop and are severe when a film of water is present on the plant tissues and the relative humidity in the air is high during cool or warm, but not hot, periods. plant disease Ex: *Peronospora, Plasmopara* and *Sclerospora*,
5. **Powdery mildew**: Small yellowish green spots appear on the leaves and appear on all parts of the plant as ash scattered due to the growth of white fungus in those areas. The symptoms are caused by some fungi belonging to the *Erysiphe* family.
6. **Rust disease:** Appears as red, brown or sometimes orange coloured spots or blisters on host plants. This rust is expected to be caused by certain fungi belonging to the order *Uredinales*.
7. **Smut Disease:** Infected plants do not show any symptoms till the time of normal flowering. During flowering, the flowers of infected plants form black charcoal-like fungal spores instead of seeds. These spore clusters are formed when the fungal network enters the host tissue intracellularly and expels innumerable teliospores from the filament cells. Smuts are caused by fungi belonging to the genus *Ustilaginales*.

8. **Blight and Anthracnose**: Brown spots are formed on the leaves and cause complete drying of leaves. Anthracnose rot is a black bird eyed shaped spot on plants caused by certain fungi of the genus *Melanconiale*s.
9. **Leaf spots**: Blight causes sudden and abrupt exposure of leaves. But in leaf spot diseases, depending on the causative agent, small spots appear, which are important in shape, size and color.

LECTURE – 7
SYMPTOMS OF BACTERIAL DISEASES

Symptoms of bacterial diseases:

Similar to pathogenic fungi, bacteria also causes various symptoms on different parts of the plant.

1. **Leaf spots and blights**: On the leaves, due to death or necrosis of the cells lead to development of brown to black coloured spots, restricted by veins and veinlets giving angular appearance. They are often but not always surrounded by yellow halo. Ex: Angular leaf spot of Cotton caused by *Xanthomonas*

   Some of the leaf spots enlarge in size and coalesce with each other leading to complete yellowing and browning which results in death of the plant. These symptoms are termed as blights. In blights, the necrosis of the tissues is rapid. Blights are exhibited by *Pseudomonas* and *Xanthomonas* genera. Ex: Bacterial blight of Paddy caused by *Xanthomonas*

2. **Cankers:** A necrotic, often sunken, lesion on a stem, branch, or twig of a plant. The lesions appear as minute water soaked round, yellow spots which enlarge slightly and turn brown, eruptive and corky These pustules are surrounded by a characteristic yellow halo. The crater-like appearance is more marked on infected fruits than on leave
   Bacterial cankers exhibit girdling. Ex: Citrus canker caused by *Xanthomonas*

3. **Soft rots**: Some bacteria releases enzymes which rotten the host tissue. Very often ooze exudation can be observed from the rotten tissues. Ex: Soft rot of carrot caused by *Erwinia*.

4. **Tumors and Galls:** Tumor is the malignant overgrowth of the tissue. Galls are the abnormal, localized swellings. In some bacterial infections, abnormal increase in cell number (hyperplasia) and cell size (hypertrophy) leads to conversion of infected parts into tumors and galls. Ex: Crown gall of apple caused by *Agrobacterium*.

5. **Wilt:** Some of the bacteria enters the plant system and accumulates in the phloem of the plant. This leads to blockage in the translocation of water and minerals to the crown of the plant. As a result drooping of plant parts occurs. Bacterial ooze is characteristically observed when cut through the infected portion Ex: Bacterial wilt of tomato caused by *Ralstonia.*

LECTURE – 8
SYMPTOMS OF VIRAL AND PHYTOPLASMAL DISEASES

Disease Symptoms caused by viruses in plants may appear externally or internally. External features can be identified due to stunted growth, mosaic and deformities and colour changes.

1. **Mosaic:** Symptom of certain viral diseases of plants characterized by intermingled patches of normal and light green or yellowish colour on the leaves. The spots may be angular or rounded. If these mosaic spots form on veins as well, it is called Vein mosaic vein flecking.
2. **Petal break /Flower break:** Due to viral infection, the flowers in the inflorescences show colour break symptoms which take the form of streaking, flecking or sectoring of the petal tissues with a colour different from the normal thus the inflorescence look attractive as if it is split. Ex: Tulip breaking
3. **Yellowing:** Infected leaves completely lose their green colour or chlorophyll and turn yellowish green. Sometimes the whole plant turns yellow. Plant growth is greatly affected due to chlorophyll decline.
4. **Vein clearing:** Tissue close to vein turn yellow and the remaining area remains green Eg: - Bhendi yellow vein mosaic.
5. **Vein banding:** Tissue along the vein will be green, and the rest turn chlorotic. Eg: Tobacco leaf curl.
6. **Dwarfing**: Small or little leaves. The petioles are so short leaves appear to be sticking to the stem. Affected plants have narrow, soft, smooth and yellow shorter leaves. Newly formed leaves are much shorter. Internodes of the stem are also shortened. Plant give a bushy appearance. Mostly there is no flowering but if flowers are formed they remain green. Fruiting is rare, if any fruit is formed, it becomes hard, tough and fails to mature. Young fruit turns necrotic, get mummified and cling to the plant. Ex: Rice dwarf, Brinjal little leaf.
7. **Distortion:** Infected plants exhibit abnormal growth due to excessive cell growth or cell division. Leaves, veins and other plant parts exhibit galls or tumour formation.
8. **Necrosis:** Death of cells surrounding the virus infected tissues. The dead cells turn into brown colour. Ex: Tobacco necrosis

Vein banding

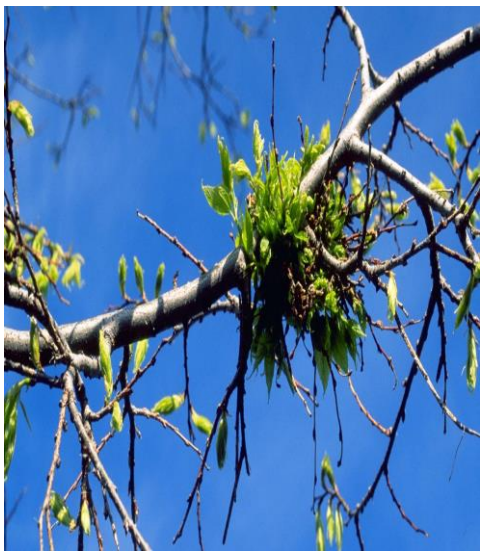
Vein clearing

Internal Symptoms: Tissues exhibit abnormal enlargement (hypertrophy) or excessive multiplication (hyperplasia) or decrease in organ development (hypoplasia) in infected plant cells, such cells are called inclusion bodies.

Symptoms of Phytoplasma infection

Yellowing of plant parts (yellowing and stunting), little leaf, virescence (greening of flowers), phyllody (flowers turn into green leafy structures), witches broom (broom like growth or massed proliferation caused by the mass clustering of branches) bronzing of leaves.

Sesamum phyllody



Witches broom

LECTURE – 9

SURVIVAL OF PLANT PATHOGENS

(Pattern of survival)

Survival is the first link in infection chain or disease cycle. The initial infection that occurs from the sources of pathogen survival (Infected host as a reservoir of inoculum, saprophytic survival outside the host or dormant spores and other structures in or on the host or outside the host) in the crop **is primary infection** and the propagules that cause this infection are called **primary inoculum**. After initiation of the disease in the crop, the spores or other structures of the pathogen are sources of **secondary inoculum** and cause **secondary infection**, thereby spreading the disease in the field.

Eg. The fungus (*Phytophthora infestans*) causing late blight of potato survives in seed tubers or in soil. Infected tubers bring the primary infection in the field while primary inoculum (PI) present in soil causes primary infection of the crop from healthy seed. The PI may also be brought by wind from neighbouring fields or long distances. Then the fungus produces spores on leaves. These spores are dispersed by wind and water and reach healthy plant surfaces to cause new infections. This is secondary infection. The primary infection initiates the disease and secondary infection spreads the disease.

SOURCES OF SURVIVAL OF PATHOGENS:

1) Infected host as reservoir of inoculum (or) survival in vital association with living plants.

2) Survival as saprophytes outside the host.

3) Survival by means of specialized resting structures in or on the host or outside the host.

4) Survival in association with insects, nematodes and fungi.

1. Infected host as reservoir of inoculum: The infected host serving as reservoir of active inoculum is grouped into following types

- **a)** Seed: Seed may be externally seed borne or internally seed borne.
  Eg. *Ustilago nuda tritici, Pseudomonas syringae* pv. *tomato*
- **b)** Collateral hosts (Wild host of same families): Collateral host are the wild host of crop plants having same family which are susceptible to disease during off-season of main crop.
  Eg. Disease- rice blast - *Pyricularia oryzae*
  Crop host: Paddy
  Collateral host: *Brachiaria mutica, Dinebra retroflexa, Leersia hexandra, Panicum repens* etc.

c) Alternate host (Wild host of other families): Alternate host are the wild host plants having different family which are susceptible to disease.
   Eg Disease-Wheat stem rust -*Puccinia graminis tritici*
      Crop host: Wheat
      Alternate host: Barberry
d) Self-sown crops: Self-sown rice plants harbour the pathogen (*Rice tungro virus*) as well as vector (*Nephottetix virescens*).
e) Ratoon crops: Eg: Sugarcane mosaic.
f) Survival by latent infection: Eg. *Xylella fastidiosa*

2. Saprophytic survival outside the host: The ability to live saprophytically enables many plant pathogens to survive in the absence of growing susceptible plants. Saprophytic survival usually occurs in or on the soil.

3. Survival as dormant spores or specialized resting structures: During unfavourable conditions plant pathogens forms dormant structures. After getting favourable conditions, they become active and affects the host. Among the different plant pathogens, fungi mostly produces dormant structures.

Eg. Dormant spores {Conidia (Peach leaf curl pathogen, *Taphrina deformans*), Chlamydospores (Wilt pathogen, *Fusarium* sp.), oospores (Downy mildew fungi), perithecia (Apple scab pathogen, *Venturia inaequalis*) etc.}.

Other dormant structures such as thickened hypha, sclerotia (Cottony rot fungus, *Sclerotinia sclerotiorum*), microsclerotia (*Verticillium*), Rhizomorphs (*Armillaria mellea*).

4. Survival in association with insects, nematodes and fungi: Several important plant pathogens may survive within the insect body and over winter therein. The corn flea beetle, *Cheatocnema pulicaria* carries inside its body, the corn wilt pathogen, *Xanthomonas stewartii* and thus helps in over wintering.

LECTURE – 10

DISPERSAL OF PLANT PATHOGENS

The second link in infection chain is the dissemination of plant pathogens. Plant pathogens complete their life cycle by transport of spores or infectious bodies acting as inoculum from the infected host to healthy plant at various distances resulting in the spread of the disease. The dispersal of plant pathogens from infected plant parts to healthier ones occurs through two different ways:

1. Direct or Active or Autonomous dispersal

2. Indirect or passive dispersal.

I) Active or Direct or Autonomous dispersal: In this method the dispersal of plant pathogens from one to other areas takes place through soil, seed and planting material during normal agronomic operations. There is no major role of external agencies like insects, wind, water, etc. in this type of dispersal.

1. Transport of the dormant structures of the pathogen along with **pure seeds**: Pathogen inoculums may survive inside the seed or outside or associated with seed. i.e.,

a) Contamination of seed with the propagules of pathogens.

b) Seed infestation.

c) Seed infection.

(e.g., seeds of *Cuscuta*, sclerotia of ergot fungus, smut sori, etc.).

2a. **Dispersal through soil:**

Cysts of nematodes and dormant fungal structures (sclerotia) move from one to other place through soil particles

2b.Dispersal by the soil: - Dispersal by the soil involves movement/transport of soil containing plant pathogens from one place to another. It takes place by

- Farm workers

-Agricultural implements

- Farm animals

- Movement of grafts/seedlings from one nursery to another.

3. **Dispersal by plant parts or other propagative material**: Plants/plant parts other than the seed are useful in the long distance dispersal.

Example:- Citrus canker-citrus fruits/seedlings.

- Panama disease of Banana- suckers

- Bunchy top of Banana- suckers
- Red rot of sugarcane- Setts.
- *Tristeza* virus disease- Grafts/root stocks

II. Passive Dispersal (Indirect): The dispersal of plant pathogens is dependent on external agents like wind, water/other agents.

1. Wind/Air.
2. Water
3. Dispersal through the members of the animal kingdom.
   a) Man
   b) Farm animals
   c) Insects
   d) Nematodes
4. Phanerogamic parasites.
5. Fungi.

Passive dispersal includes the transport of infected seed material of vegetatively propagated fruit crops, banana suckers and sugarcane setts. Organisms that help in dispersal of plant pathogens are known as vectors. Viral diseases are usually tramsmitted by insects

S. No.	**Vector**	**Disease**
1	Insects	*Rice tungro virus*, Yellow mosaic in pulses, Bhendi *Yellow vein mosaic virus*, Little leaf of brinjal
2	Man	*Tobacco mosaic virus*
3	Birds and Animals	Phanerogamic parasites
4	Nematodes	Tobacco necrosis
5	Water	Downy mildew, Sugarcane red rot
6	Air	Wheat rust, powdery mildew

LECTURE -11

PROCESS OF INFECTION

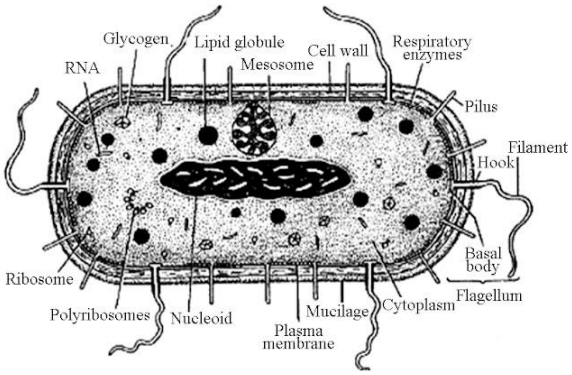
Plant pathogens move from one place to another or from diseased to healthy plant and establishes the pathogenic relationship to cause infection (disease).

The success of process of infection depends on the following factors:

a. Host plant should be susceptible
b. Pathogen should possess virulence or aggressiveness
c. Multiplication rate of the pathogen should be fast
d. Pathogen population should be more enough to cause the disease (Inoculum potential)
e. Environmental factors should be favourable for entry of pathogen and establishment of infection in host plants.

The process of infection completely takes place only when all the above factors are favourable for the pathogen. Process of infection occurs in three stages, *i.e.*, pre-penetration, penetration and post-penetration.

1. **Pre-penetration stage:** As soon as the pathogen comes in contact with the susceptible host, especially in case of fungal pathogens, some series of events takes place. The fungal spores germinate and produce hypha in order to penetrate the host leaf surface. Due to some bio chemical reactions the developing hypha dissolves the cuticle and invades into the leaf, absorbs the nutrients, perpetuate (continuous increase of pathogen population) and cause the disease. While the bacterial cells attaches to the leaf surface with specialised hair like structures (appendages) *i.e.*, fimbriae or pili. Most of the bacteria and fungi invade the host plants through the stomata.



As, nematodes cannot perpetuate outside the host, they get attracted to the root exudates produced by the host plant and penetrates into the plant through the weak points on the roots.

2. **Penetration stage:** After the pathogen enters the susceptible host the infection process completes. At this stage the pathogen penetrates the plant surfaces by direct penetration or indirectly through wounds or natural openings (stomata). Majority of the bacteria and fungi invades the host plant through the wounds caused by cultural

practices or field implements and cause the disease. Due to some bio-chemical activities the pathogens weakens the plant surface and penetrates.

3. **Post-penetration stage:** In this stage pathogens enter into the host plant, establishes pathogenic relationship and exhibits the disease symptoms by destroying the host cells. Bacteria and fungi produces enzymes and toxins which dissolves the cell wall of host tissue. Thereby, the pathogens absorb the nutrients, weakens the plant and disturb the normal functioning of the plant.

LECTURE – 12

PRINCIPLES OF PLANT DISEASE MANAGEMENT – AVOIDANCE AND EXCLUSION

Complete prevention or eradication of plant diseases is not possible. For complete eradication of the disease preventive measures should be adopted, which is a continuous process and requires high investment. In the present scenario, instead of complete disease eradication, adopting disease management practices provide good results by reducing the disease severity and finally minimizing the yield losses.

In plant disease management five principles plays an important role

General principles of plant disease management

1. **Avoidance**: Avoiding disease by planting at times when, or in areas where, inoculum is ineffective due to environmental conditions, or is rare or absent
2. **Exclusion of inoculum**: Preventing the inoculum from entering or establishing in the field or area where it does not exist
3. **Eradication**: Reducing, inactivating, eliminating or destroying inoculum at the source, either from a region or from an individual plant in which it is already established
4. **Protection**: Preventing infection by creating a chemical toxic barrier between the plant surface and the pathogen
5. **Disease resistance (Immunization)**: Preventing infection or reducing effect of infection by managing the host through improvement of resistance in it by genetic manipulation or by chemical therapy.

I. Avoidance of the pathogen: Avoiding disease by planting at times when, or in areas where, inoculum is ineffective due to environmental conditions, or is rare or absent.

The following methods aim at avoiding the contact between the pathogen and susceptible stage of the crop.

a. Proper selection of geographical area: Many fungal and bacterial diseases are more severe in wet areas than dry areas.

Ex. In case of broad beans anthracnose disease incidence is more in wet areas. Disease can be avoided by cultivating these plants in dry areas for seed production. In bajra, coincidence of rainy days with flowering results in smut and ergot disease which causes severe yield losses. Hence, sowing of bajra should be avoided when flowering time coincides with rainy days.

b. Proper selection of the field: Proper selection of field will help in the management of many diseases, especially the soil borne diseases. Raising of a particular crop year after year in the same field makes the soil sick, where disease incidence and severity may be more.

Ex. Wilt of redgram, green ear, smut and ergot of bajra, root knot forming nematodes etc. Adopting crop rotation method in diseased fields by avoiding cultivation of these crops for some years is advisable.

c. **Time of sowing:** Generally pathogens are able to infect the susceptible plants under certain environmental conditions. Alteration of date of sowing can help in avoidance of favourable conditions for pathogen.

   Eg. *Rhizoctonia* root rot of redgram is more severe in the crop sown immediately after rains. Delayed sowing will help in reducing the incidence of the disease.

   Eg. Infection of black stem rust of wheat is more in late sowing, hence, early sowing helps in reduction of stem rust incidence.

d. **Disease escaping varieties:** Certain varieties of crops escape the disease damage because of their growth characteristics.

   Eg. Short duration varieties of pea escapes the powdery mildew disease. While the varieties of groundnut having erected leaves have lesser incidence of leafspot diseases.

e. **Selection of seed and planting material:** Through seed and propagating material many plant diseases spreads in the field by infecting healthy plants. Hence, selection of seed and seedling material from certified (healthy) sources will effectively manage the spread of loose smut of wheat, bunchy top of banana and whip smut of sugarcane.

II. **Exclusion of the pathogen:** These measures aims at preventing he inoculum from entering or establishing in the field or area where it does not exist. It includes the following methods

a. **Quarantine:** Restricting the entry or movement of diseased plants from infected areas to uninfected areas is called as quarantine. If in a region the disease incidence is more and there is a chance of spread of the disease through seed or propagating material the government will enforce some control measures to prevent the entry of diseased material to disease free regions. These control measures are called as ‘quarantine regulations’. The planting materials like seeds and propagating materials are allowed only after thorough checking at national, international airports and seaport.

b. **Inspection and Certification:** Crops grown for seed purpose are inspected periodically for the presence of seed borne diseases. The seeds will be permitted to use only after confirmation of the absence of seed borne diseases. As soon as the diseased plant were observed during crop growth, they were removed and destroyed.

c. **Seed treatment:** The seeds or the propagating materials will be treated with hot air or hot water or chemicals so that the pathogen propagules get killed and the seeds/ planting material will be free from the disease.

LECTURE - 13

PRINCIPLES OF PLANT DISEASE MANAGEMENT – ERADICATION AND PROTECTIVE MEASURES

Eradication: Elimination of the pathogen from the infected plants or from the infection sites is not possible. Instead, the crop can be protected by reducing the inoculum density of the pathogen without notable yield loss. Inoculum density of the pathogen can be reduced by following methods.

a. **Bio control agents:** The main aim of biocontrol is to reduce the population of plant pathogens or eliminate the pathogens from the infection site or slowing down the infection process. By using bio control agents there will be reduction in inoculum density or disease producing activity of a pathogen. Many fungi and bacteria are used as biocontrol agents in controlling or eradicating the plant diseases.
   Ex. *Trichoderma asperellum* (Fungi) and *Pseudomonas fluorescens* (Bacteria)
b. **Crop rotation:** Continuous cultivation of the same crop in the same field helps in the perpetuation of the pathogen in the soil. Soils which are saturated by the pathogen are often referred as sick soils. Due to continuous mono-cropping and increased sickness the soils will not be suitable for growing that particular host crop. In these soils cultivation of resistant varieties or tolerant varieties or using non host crops is recommended. By using these methods the pathogen or pathogen propagules will survive for few days and die due to lack of host plants. For pathogens with less host range by using crop rotation the diseases can be completely eradicated.
c. **Collection and destruction of plant debris**: Presence of single infected plant in the field acts as the source for production of spores, which infects the healthy plants and cause disease. The disease infected plants should be collected and destroyed at the initial stages of infection so as to reduce the primary inoculum in the field. Complete destruction of alternate or collateral hosts will eradicate the pathogen as, under unfavourable conditions or in absence of susceptible hosts the pathogen survives on them.

Protective measures: Sometimes it is difficult to completely control or manage the disease with the methods discussed above like avoidance, exclusion and eradication. In such cases chemicals were used to protect the host plant or to eradicate an existing infection. These chemicals are either applied on the leaf surface on which they form a layer and kill the pathogen or inhibit the growth of the pathogen. These chemicals are referred to as protective chemicals. Many of the viruses are transmitted through the insects. Hence, application of insecticides reduces the insects so there will be reduction in spread of the viral diseases.

Hot water treatment of certain seeds, bulbs and nursery stock is done to kill many pathogens present in or on the seed and other propagating material. Dipping the roots in chemical solution for some time helps in destruction of many nematodes and fungi which spread from nursery to main filed while transplanting.

LECTURE 14

PRINCIPLES OF DISEASE MANAGEMENT – HOST PLANT RESISTANCE

Resistant varieties are most simple, practical, effective and economical method of plant disease management. In plants disease resistance is of two types:

1. Genetical disease resistance
2. Biochemical disease resistance

In plants disease resistance can be developed through three methods:

1. **Selection and Hybridization:** The plants which are resistant to the disease and gives low yields are crossed with the plants which are susceptible to disease and with high yields or with high quality results in high yielding, disease resistant and high quality crop.
2. **Creating genetic changes by using biotechnology:** Genetic engineering and tissue culture methods are used to create changes in genes in plants. These genetically modified plants are produced in large numbers which are virus tolerant, insect tolerant and herbicide tolerant. Biotechnology helps in the development of artificial seeds, disease resistant and stress tolerant plants.
   Ex. Bt cotton
3. **Induction of acquired resistance:** By stimulation of some microorganisms plants develop some kind of acquired resistance. There will be stimulation of resistance genes in plants when phosphates and carbonates are sprayed on the leaf surface.
4. **Resistance development using chemicals:** When systemic fungicides and antibiotics are applied on the plants they release some chemicals inside the plant so that they develop resistance against the diseases.

LECTURE – 15

STUDY OF SYMPTOMOLOGY

Any malfunctioning or abnormalities of host cells / tissues that result from continuous irritation by a pathogen may lead to development of symptoms.

The external or internal reactions or alterations of a plant as a result of a disease are called symptoms. The pathogen or its parts or products seen on a host plant is sign.

Disease symptoms:

a. **Necrotic symptoms:** When susceptible plants are attacked by the pathogens, renders the normal physiological process and results in the death of the cells in the diseased areas and develop necrotic lesions. The following disease symptoms come under necrosis.
   Ex: Blight, Blotch, Decay, Scab, Shot hole, spot, Wilt, Yellowing.
b. **Hypertrophy/ Hyperplasia**
   Hyperplasia: Hyperplasia is the enlargement of a plant tissue due to excessive increase in the number of plant cells produced. Hyperplasia results in the overdevelopment in size of plants or plant organs in the diseased areas.

   Hypertrophy: Hypertrophy is excessive growth due to the enlargement of individual cells. This condition also results in the overdevelopment in the size of plants or plant organs in the diseased areas. Ex. Callus, Witches broom, Scab, Tumefication, etc.

   Hypoplasia: When the pathogen attacks it results in the failure of plants or plant organs to develop fully due to decreased production of the number of cells. The following disease symptoms come under hypoplasia.
   Ex. Chlorosis, Dwarfing, Etiolation, Russetting, etc.

Signs are the visible physical presence of either the pathogen itself or the structures formed by the pathogen. Common examples of easily detected signs are those such as

i Vegetative structures - Fungal mycelia, Felt, Haustorium, Rhizomorph, Sclerotia, etc.

ii Reproductive products- Acervuli, Apothecia, Asci, Basidium, Cleistothecia, Conidiophores, Mildews, Mold, Mushroom, Pycnia, Sporodochium, Stroma, etc. By the above reproductive products the following disease symptoms are noticed. Ex. Bunt, Downy mildew, Powdery mildew, Rust, Smut, Sooty mold, etc.

iii Disease products: Many bacterial diseases especially bacterial leaf blight in rice shows bacterial ooze on the upper leaf surface. Likewise, in sorghum the appearance of sticky substance helps in the identification of sugary disease.

LECTURE – 16

FUNGICIDES AND THEIR CLASSIFICATION

The chemicals that kill fungi are known as fungicides. Some of the fungicides do not kill the fungi, but inhibits the growth of the fungi. Such fungicides are called as 'fungistats'. Whereas, some of the fungicides neither kill the fungus nor inhibit the growth of the fungi but they inhibits the sporulation in fungi. These are called 'antisporulants'.

Classification:

The classification of fungicides is done based on the following characteristic features:

A. Chemical nature

B. Mode of action against fungi

C. Process of general uses

A. Chemical nature:

1. Sulphur

    Inorganic Sulphur: Sulphur dust, lime Sulphur, Wettable Sulphur

    Organic Sulphur: Thiram, Mancozeb, Zineb, Maneb, Metiram, Propineb

2. Copper

    Copper Sulphate: Bordeaux mixture, Bordeaux paste, Burgundy mixture, Cheshunt compound

    Copper carbonate: Chaubattia paste

    Copper Oxychloride: Fytolan, Blitox, Blue copper

    Copper hydroxide: Kocide

    Cuprous Oxide: Perenox

3. Mercurials

    Organic: Ethyl mercury chloride, Phenyl mercury acetate

    In organic: Mercuric chloride, mercurous chloride

4. Quinones

    Dichlone, Chloranil

5. Heterocyclic Nitrogen compounds

    Captan, Folpet, Difolatan

6. Benzenes

    Dexon, Dicloran, Dinocap

7. Oxathins

Carboxin: Vitavax

Oxycarboxin: Plantvax

8. Benzimidazoles

Thiabendazole, Benomyl, Carbendazim, Thiophanate methyl

9. Pyramidines

Dimethirimol, Ethirimol

10. Morpholines

Tridemorph, Dodemorph

11. Trizoles

Propiconazole, Tebuconazole, Difenoconazole, Myclobutanil, Triadimefon

12. Strobilurins

Azoxystrobin, Trifloxystrobin, Pyraclostrobin

13. Acylalanine

Metalaxyl

14. Organophosphorous

Edifenphos, Iprobenphos

15. Organo tin compounds

Fentin acetate, Fentin chloride

16. Carboxylic acid amides

Dimethomorph

17. Melanin biosynthesis inhibitors

Tricyclazole, Carpropamid

18. Dithiolanes

Isoprothiolane

19. Antibiotics

Aureofungin, Cycloheximide, Validamycin, Kasugamycin

20. Miscellaneous

Fosetyl Aluminium, Triforine, Cymoxanil, Phenyl derivatives

B. Based on mode of action:

1. Protectants
2. Eradicants
3. Therapeutants (systemics)

1. *Protectants*

Fungicide which is effective only if applied prior to fungal infection is called a protectant. (Ex: Sulphur, Zineb).

For example: For management of leaf spots fungicides are applied prior to start of infection by pathogen.

These fungicides inhibits the vegetative growth as well as sporulation of fungi present on the plant surface.

2. *Eradicants*

The fungicides kill the dormant or actively growing pathogenic fungi. These fungicides kill the fungi present on the high moisture plant surfaces as well as fungi present within the plant (Ex: Lime Sulphur, dodine). These fungicides also work as protectants.

3. *Therapeutants (systemics)*

Fungicide which is capable of eradicating a fungus after it has caused infection is called therapeutant (Ex: Vitavax, Aureofungin). These fungicides are capable of killing the fungi present within the plant.

C. Process of general uses

On the basis of general uses, fungicides are classified as follows:

1. Seed protectants
2. Foliage, blossom and fruit protectants
3. Fungicides that protect the plants from injury
4. Soil fungicides

The fungicides can be applied by any of these following ways:

1. Soil drenching
2. Broadcasting
3. Furrow application
4. Fumigation.

DA-171- Principles of Plant Pathology 2 (1+1)

Practical Class Outlines

1. Introduction to Plant Pathogens- observation of disease symptoms- preservation of disease specimens

2. Study of plant disease symptomatology

3. Identification of diseases in paddy, sugarcane

4. Identification of diseases in maize, jowar, bajra, ragi, kora

5. Identification of diseases in redgram, blackgram, greengram, chick pea

6. Identification of diseases in groundnut, sunflower, castor, sesamum

7. Identification of diseases in cotton, tobacco, chilly

8. Identification of diseases in bhendi, brinjal, tomato, cucurbits

9. Identification of diseases in coconut, banana, guava, mango, sapota

10. Identification of diseases in papaya, pomegranate, citrus, rose, turmeric, ginger

11. Observation of disease infection through microscope and identification of fungal propagules

12. Identification of dormant stages of plant pathogenic fungi and identification of plant pathogens on weeds.