Botany

UG, Semester-II

Course-BOTHC-3

(Mycology And Phytopathology)

Unit:8-10

Dr. Parimal Mandal
Associate Professor
Department of Botany,
RAIGANJ UNIVERSITY

Unit 8: Symbiotic associations

- Lichen – Occurrence; General characteristics; Growth forms and range of thallus organization; Nature of associations of algal and fungal partners; Reproduction;
- Mycorrhiza-Ectomycorrhiza,
- Endomycorrhiza and their significance

LICHENS: GENERAL CHARACTERS

What are lichens?

- **Lichen:** structurally organized permanent symbiotic association of fungi & algae
- **Lichenology**: Branch of biology deals with study of lichen
- **Mycobiont**: fungal component of lichen
- **Phycobiont**: algal component of lichen

- **Symbiosis**: association/interaction organisms where both partners are mutually benefitted (De-Bary)
- Fungus protect algae from unfavorable conditions (drought)
- Algae in turn supplies organic food to fungus
- This type of symbiosis is called as **heliotism** (master and slave relationship)

LICHENS: GENERAL CHARACTERS

What are lichens?

- Fungal component is prominent in lichen than algal component (~90%)
- Plant body of lichen neither resembles algal or fungal morphology
- **Theophrastus** (371-284 BC) first time used them lichen to denote the superficial growth on tree barks
- Lichen are included in cryptogams
- **Acharius**: father of lichenology
- Growth of lichen is very slow

- Lichen produce a specific acid known as **lichen acid**

LICHENS: GENERAL CHARACTERS

- Distribution: World wide distribution, 500 genera and 13500 species
- Lichens do not grow near smoky polluted industrial areas
- Thus Lichens are **indicators of pollution** (*Lobaria*)
- They can tolerate extreme heat and can bury in snow for long years
- **Habitat**: Most usually on tree barks, decaying wood and rocks
  - **Saxicolous**: lichen growing on stones
  - **Corticolous**: lichen growing on tree barks
  - **Follicolous** : lichens growing on leaves
  - **Terricolous**: lichens growing on soil surface

- Few species of lichen are aquatic (*Peltigera*- marine)

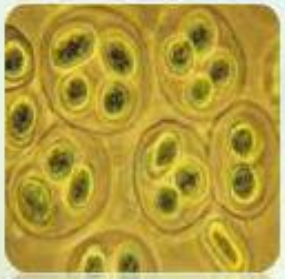
LICHENS: GENERAL CHARACTERS

- *Cladonia rangiferina* (reindeer moss) grows luxuriously in Tundra
- In India lichen found in Himalayas and higher hills of South India
- Lichen are highly pigmented and have various colors, (green, bluish, yellow, orange, reddish etc., some are white)
- Coloration is due to the pigmentation of algal component

LICHENS: GENERAL CHARACTERS

Composition of plant body of lichens

- Composition of plant body:
- **Mycobiont**: belong to either Ascomycotina or Basidiomycotina o Deuteromycotina
- **Phycobiont**: may belong to:



- Cyanophyceae : 8 genera (*Gloeocapsa, Nostoc, Rivularia*)
- Chlorophyceae: 18 genera (*Trebouxia, Trentipohlia, Cladophora*)
- Xanthophyceae: 1 genera
- Phaeophyceae: 1 genera

LICHENS: GENERAL CHARACTERS

Classification of lichens

- According to International Code of Botanical Nomenclature (ICBN) name of lichen should be on the basis of fungal component
- Lichens are divided lichens to 3 classes

1. ***Asco-lichen***
2. ***Basidio-lichen***
3. ***Lichen-inperfectii***

LICHENS: GENERAL CHARACTERS

Lichen classification:

(1). Ascolichen: Mycobiont belongs to Ascomycotina, Reproduction similar to Ascomycotina, produce Ascus and Ascospores

- Majority of lichens are Ascolichens

(2). Basidiolichens: Mycobionts belong to the Basidiomycotina

- They produce basidia and basidiospores during reproduction
- Only few lichen belongs to Basidioliche

(3). Lichen Imperfecti: fungal partners belongs to Deuteromycotina, lack sexual reproduction

LICHENS: GENERAL CHARACTERS

Diversity in thallus morphology:

- Based on thallus morphology, lichens are divided into three major groups

1. ***Crustose (Crustaceous) lichen***
2. ***Foliose lichen***
3. ***Fruticose lichen***

LICHENS: GENERAL CHARACTERS

(1): Crustose (Crustaceous) lichen:

- They have flattened thallus
- Closely attached to substratum as crusts (rocks, soil or barks)
- Thallus may be partially or completely embedded in the substratum
- Thallus is very closely attached to the substratum
- Example: *Graphis, Lecanora, Lecidia*



LICHENS: GENERAL CHARACTERS

(2).Foliose Lichen:

- They are flat dorsi-ventral, leaf like lobed thallus
- They look like the thallus of liverworts (bryophytes)
- Attached to substratum by rhizoid like structures called Rhizines
- Example: *Parmelia, Peltigera, Collema*



LICHENS: GENERAL CHARACTERS

(3). Fruticose lichen:

- Well developed shrub-like, cylindrical and branched thallus
- They grow or hang from the substratum
- Plant attached to the substratum with the help of mucilaginous disc
- Example: *Cladonia, Usnea*

LICHENS: GENERAL CHARACTERS

Lichen Reproduction:

- Reproduction by asexual and sexual methods
- **Asexual reproduction:** by various types of spores (Oidia, Picnidia)
- **Sexual reproduction:** Only fungal component reproduce sexually
- Female sex organ is called carpogonium
- Carpogonium is differentiated into basal ascogonium and an elongated trichogyne
- Male reproductive organ is spermagonia which produce spermatia

LICHENS: GENERAL CHARACTERS

Lichen Reproduction:

- Fruiting bodies of lichen are:
- Disc shaped **appothecium** (appothecia)
- Flask shaped **perithecium** (perithecia)

LICHENS: GENERAL CHARACTERS

Economic importance of lichen:

- Lichens are the pioneers of rock vegetation
- Lichens initiates xerarch type of plant succession on rock
- Lichen acid cause weathering of rock into soil particles
- Some lichens are ecological indicators, they acts as indicators of pollution
- Cladonia rangiferina, which is luxuriously grows in polar region act as the food source for some animals such as reindeers
- Lecanora is consumed as food by human
- Peltigera canina and Lobaria pulmonaria are medicinal

LICHENS: GENERAL CHARACTERS

Economic importance of lichen:

- *Prmelia* is used as a spice or condiment in some parts of India
- *Rocella* and *Lecanora* yield dye called orchil or orecin or Cudbear which are used for colouring woolen and silk fabrics
- Orecin is an excessively used chromosomal stain, it is used for the 'O' banding of chromosomes
- *Lobaria pulmonaria* is used in tanning, perfumery industry. It is also used as 'hope' in brewing industry.

What are Mycorrhizae

What are Mycorrhizae

- The word Mycorrhizae was first used by german researcher A.B Frank in 1885 and originates from the Greek mycos, meaning “fungus” and “rhiza” meaning “root”.
- Mycorrhizae is a symbiotic mutualistic relationship between special soil fungi and fine plant roots: it is neither the fungus nor the root but rather the structures from these two partners.
- Since the association is mutualistic, both organisms benefit from the associations.
- The fungus receives carbohydrates (sugars) and growth factors from the plant, which in turn receives many benefits, including increased nutrient absorption.
- In this association, the fungus takes over the role of the plant’s root hairs and Acts as an extension of the root systems.

Mycorrhizae

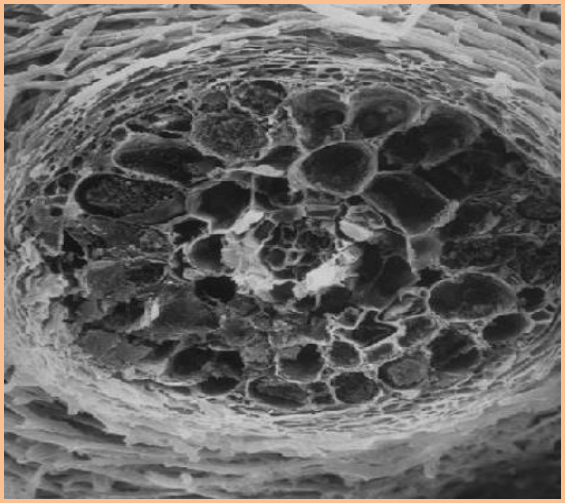
- In nature approximately 90% of plants are infected with mycorrhizae. 83% Dicots,79% Monocots and 100% Gymnosperms. Convert insoluble form of phosphorous in soil into soluble form.
- Mycorrhizae are highly evolved, mutualistic associations between soil fungi and plant roots. It is commonly known as root fungi.
- This asoociation are members of the fungus kingdom (Basidomycetes, Ascomycetes and Zygomycetes) and most vascular plants.
- Host plant receives mineral nutrients while the fungus photosynthetically derived carbon compounds from the plants.
- Mycorrhizal associations involve 3-way interactions between host plants, mutualistic fungi and soil factors.

Types of Associations

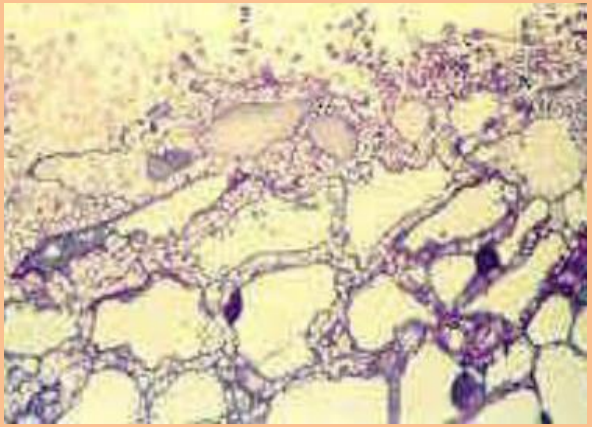
- Mycorrhizas are commonly divided into
  - Ectomycorrhizas (extracellular)and
  - Endomycorrhizas (Intracellular).
- The two types are differentiated by the fact that the hyphae of
  - Ectomycorrhizal fungi do not penetrate individual cells within the root
  - Endomycorrhizal fungi penetrate the cell wall and invaginate the cell membrane.

Ectomycorrhizas

- Ectomycorrhizas, or EcM, are typically formed between the roots of around 10% of plant families, mostly woody plants including the eucalyptus, oak, pine, and rose families, orchids, and fungi belonging to the Basidiomycota, Ascomycota, and Zygomycota.
- Plant roots are enclosed by a sheath of fungal hyphae – **Mantle**.
- Fungal mycelium penetrates between cells in cortex of the root – **Hartig's net.**



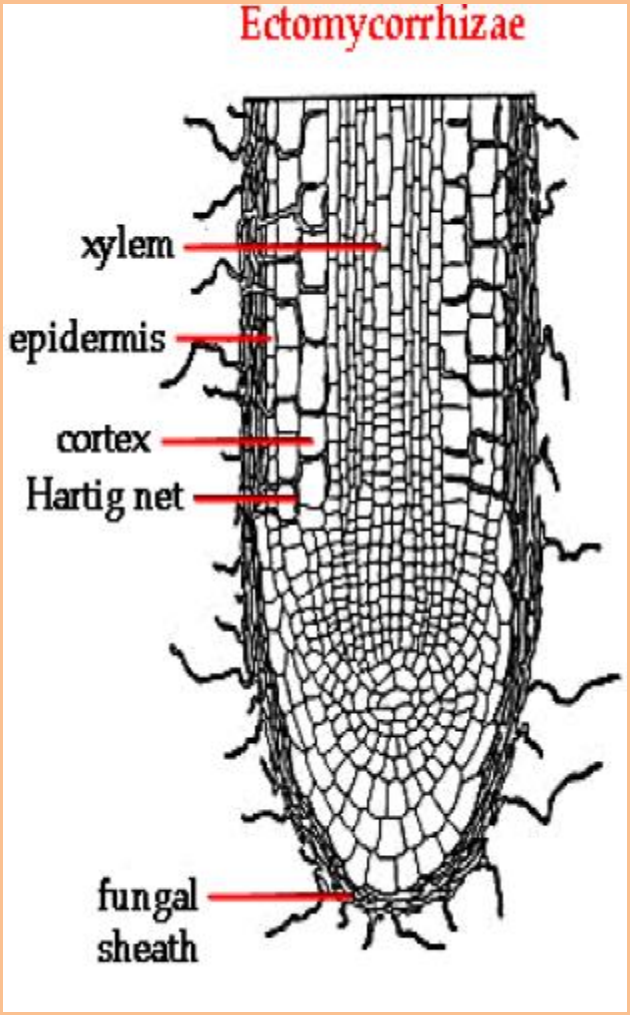
Mantle



Hartig's net

Ectomycorrhizae

Ectomycorrhizae (ECM) are association, where fungi form a mantle around roots. There is no hyphal penetration of cells. Fungal hypha is generally separate. A distinct Hartig's net is present between the cells..



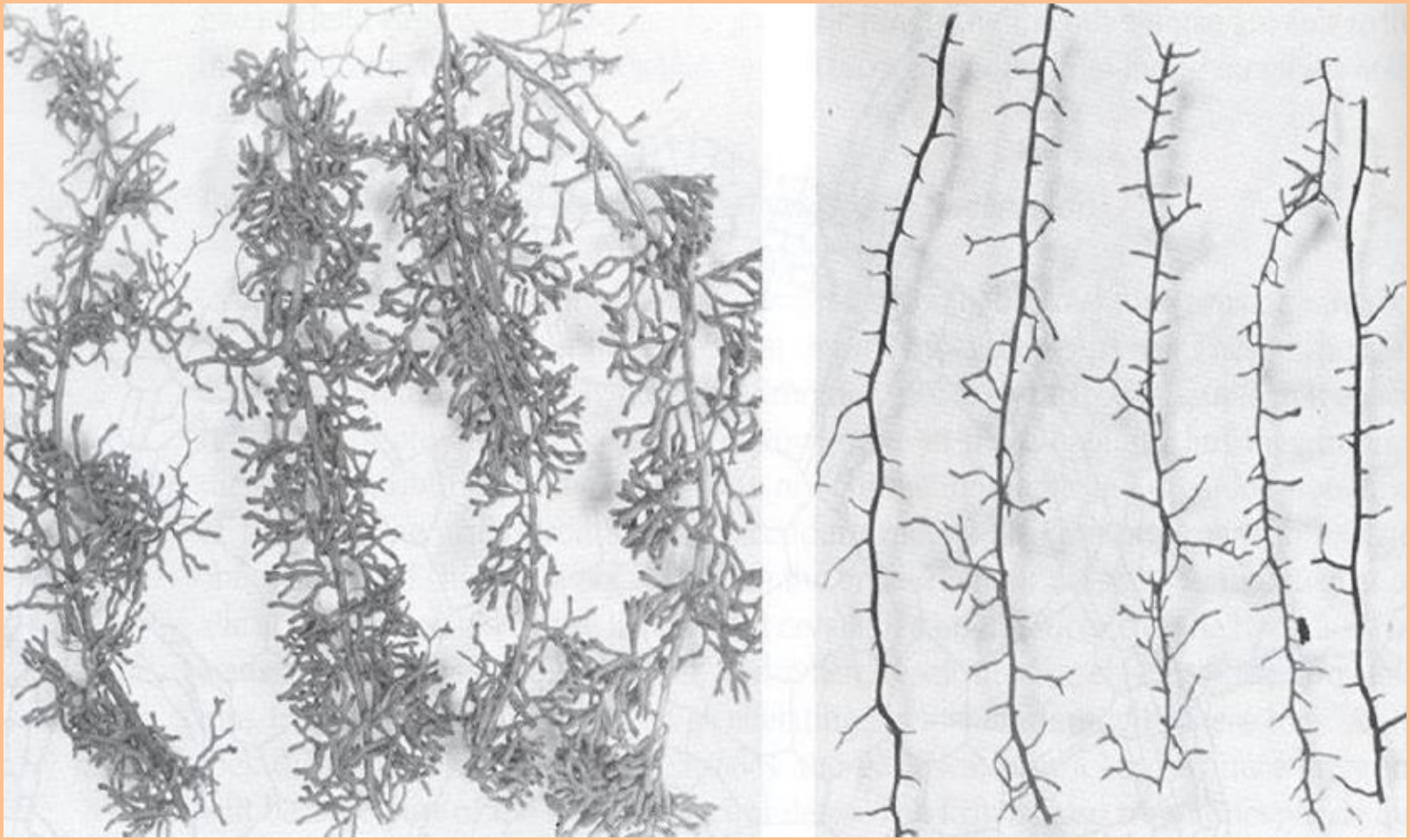
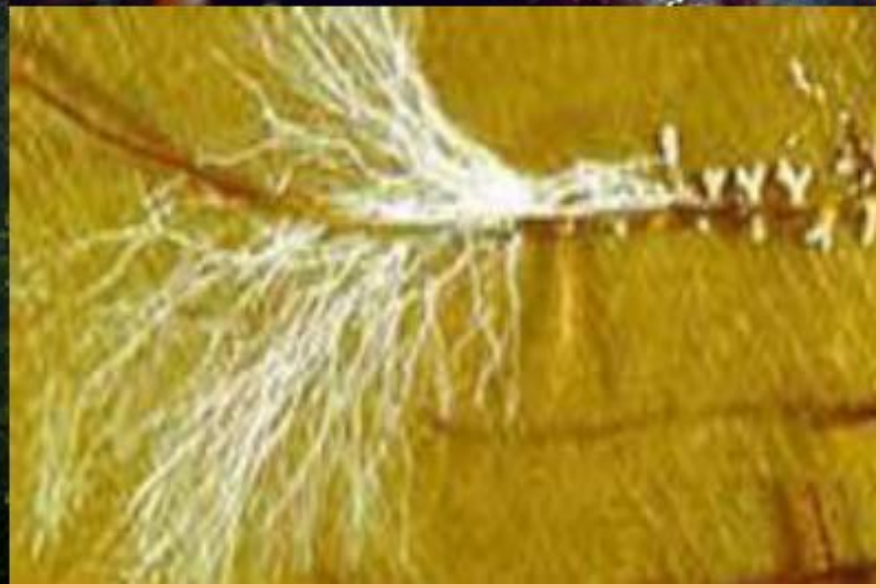


Figure 16-7 Roots of pine seedlings with (left) and without (right) the ectomycorrhizal fungus *Pisolithus tinctorius*. These are roots from the seedlings shown in Fig. 16-8. [Courtesy D. H. Marx, U.S. Department of Agriculture, Forest Service.]

Ectomycorrhizae



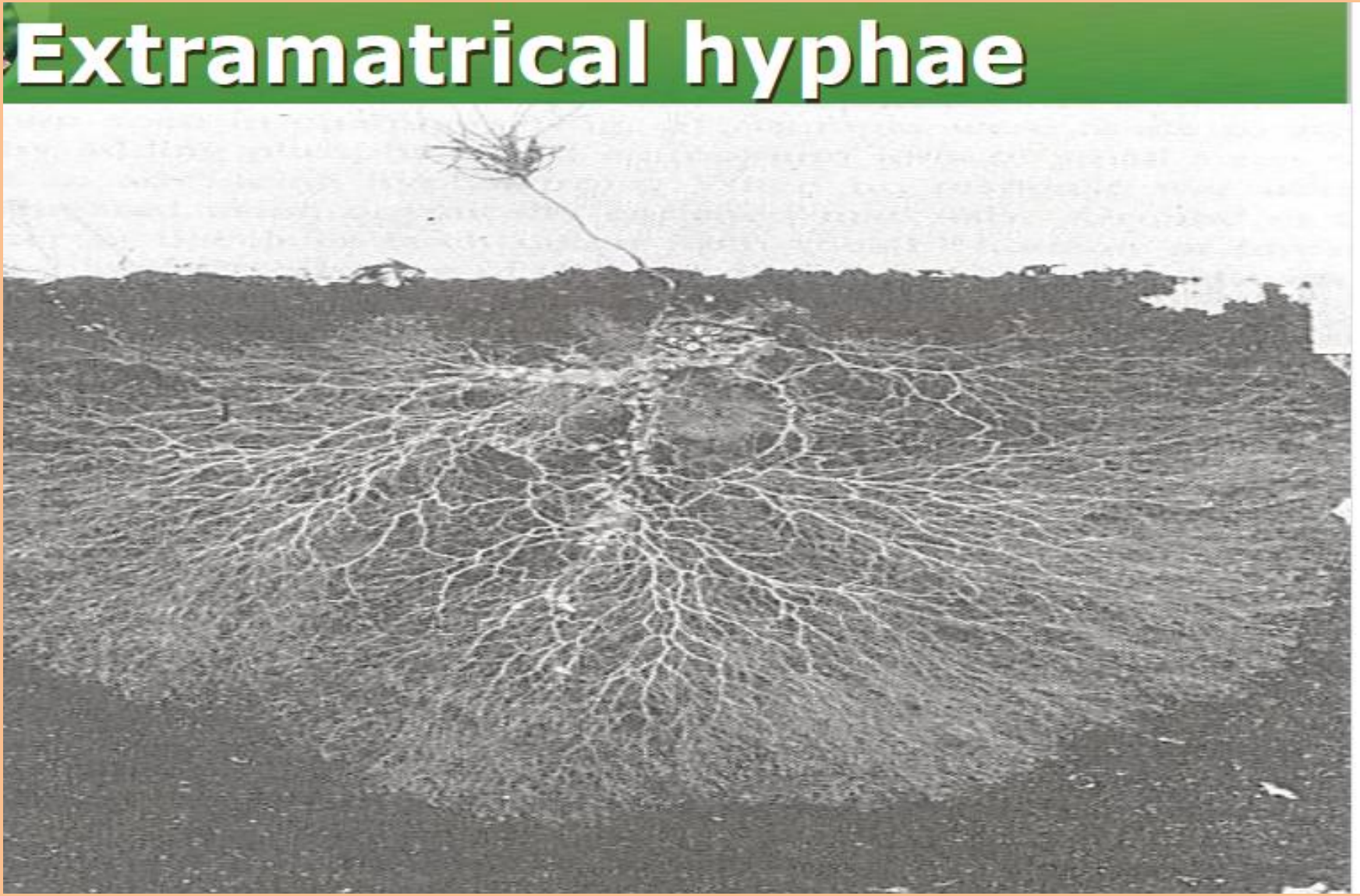
Ectomycorrhizae Symbionts

Basidiomycetes – Agaricales (many mushroom species), Lycoperdales, Sclerodermatales, few Aphyllophorales.

Pisolithus tinctorus – used to form commercial inoculum for nursery trees, common in southern pine .

Ascomycota – Pezizales – cup fungi and truffles.

Over 5000 species of fungi have been shown to form ectomycorrhizae.



Mycorrhiza increase supply of inorganic nutrients to tree. P is insoluble in most soils. Extramatrical hyphae extend over a larger volume of soil than roots can – increase ability to absorb insoluble nutrients such as P

Vesicular Arbuscular Mycorrhiza (VAM)

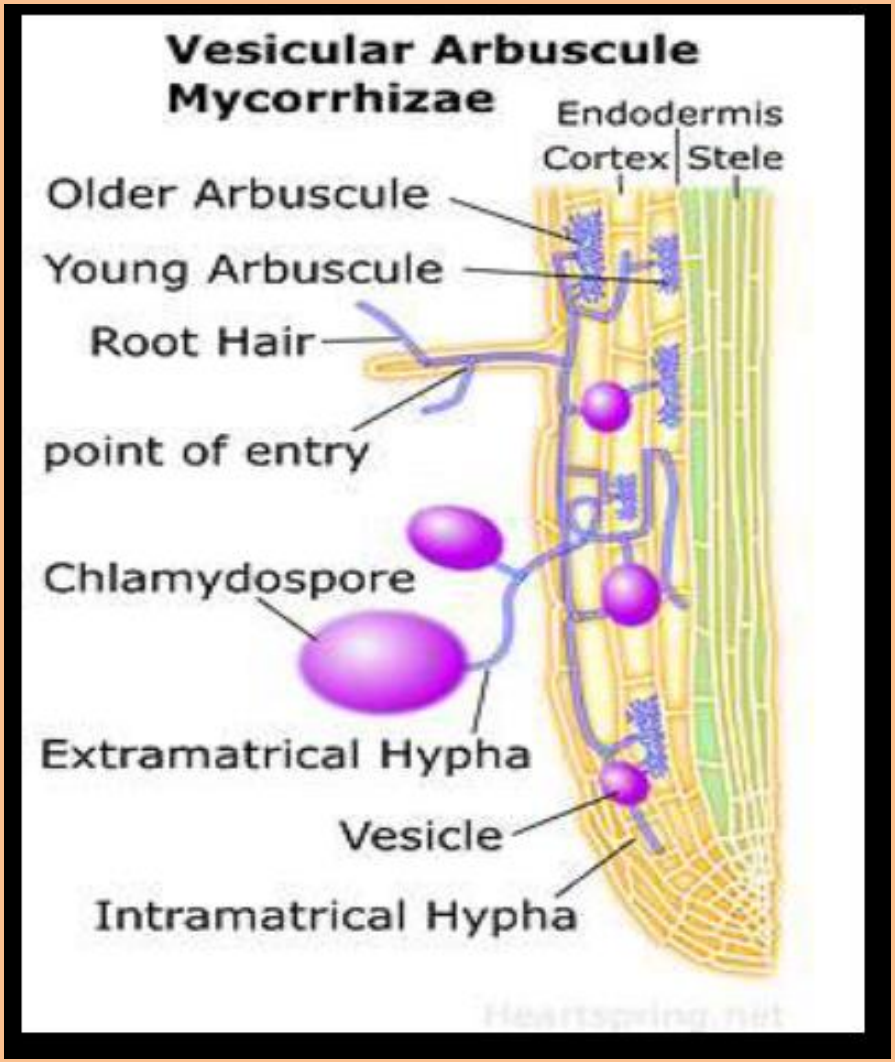
- The term mycorrhiza was taken from Greek language meaning 'fungus root'. This term was coined by Frank in 1885
- As indicated above, the mycorrhiza is a mutualistic association between fungal mycelia and plant roots.
- VAM is an endotrophic (live inside) mycorrhiza formed by aseptated phycomycetous fungi.
- VAM help in *nutrient transfer* mainly of phosphorus, zinc and sulfur.
- They also *mobilize different nutrients* like Cu(copper), K(potassium), Al(aluminum), Mn(manganese), Fe (iron)and Mg (magnesium) from the soil to the plant roots.
- They posses vesicles (sac like structure) for storage of nutrients and arbuscules for exchange them into root system.

Endomycorrhizas

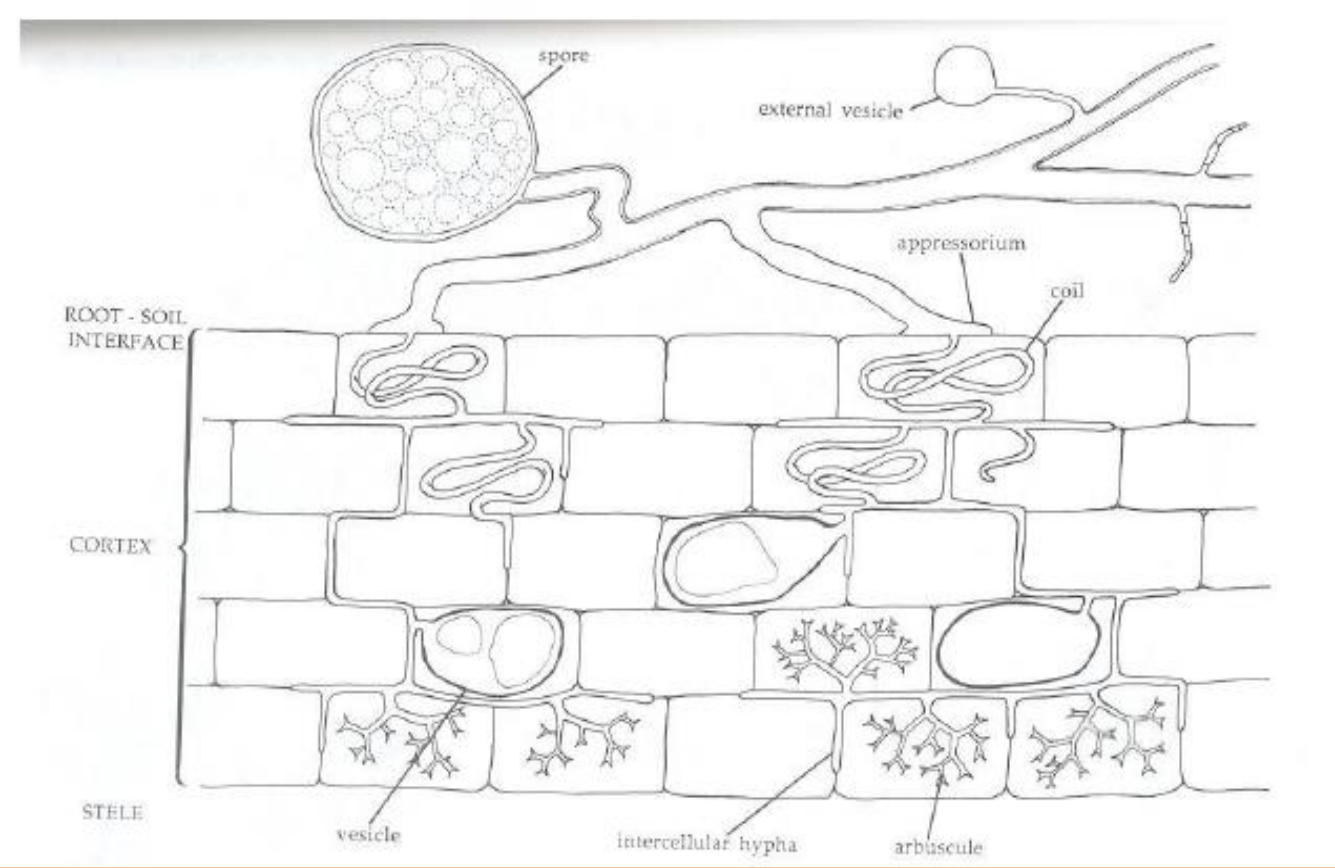
- Endomycorrhizas are variable and have been further classified as
  - Arbuscular,
  - Ericoid,
  - Arbutoid,
  - Monotropoid, and
  - Orchid mycorrhizas.
- Arbuscular mycorrhizas, or AM (formerly known as vesicular-arbuscular mycorrhizas, or VAM), are mycorrhizas whose hyphae enter into the plant cells, producing both extracellular and intracellular hyphal structures that are either balloon-like-**vesicles** (rich in lipids & thought to be involved in storage) or dichotomously branching invaginations -**arbuscules** (thought to be site of nutrient exchange between fungus and plant)

VAM fungi (Vesicular Arbuscule mycorrhizae)

- Fungi formed VAM association with plants may belongs to ascomycetes, basidiomycetes and zygomycetes.
- All VAM fungi are obligate biotrophic, as they are completely dependent on plants for their survival.



Endomycorrhizas



- VAM is a type of mycorrhiza in which the fungus penetrates the cortical cells of the roots of a vascular plant.
- Characterized by the formation of unique structures, arbuscules and vesicles by fungi of the phylum Glomeromycota (VAM fungi).
- VAM fungi help plants to capture nutrients such as phosphorus, sulfur, nitrogen and micronutrients from the soil.
- It is believed that the development of the arbuscular mycorrhizal symbiosis played a crucial role in the initial colonisation of land by plants and in the evolution of the vascular plants.

Actions of Mycorrhiza

- Increase nutrient uptake of plant from soil such as P nutrition and other elements: N, K, Ca, Mg, Zn, Cu, S, B, Mo, Fe, Mn, Cl
- Increase diversity of plant.
- Significant role in nutrient recycling.
- More tolerant to adverse soil chemical constraints which limit crop production.
- Increase plant resistance to diseases and drought.
- Stimulate the growth of beneficial microorganisms.
- Improve soil structure.
- Stable soil aggregate – hyphal polysaccharides bind and aggregate soil particles.

Importance of Mycorrhiza

- Enhances the feeding areas of the plant root is as the hyphae spreads around the roots.
- Mobilizes the nutrients from distantance to root.
- Removes the toxic chemicals (example : phenolics) which otherwise hinder nutrient availability.
- Increases absorption of phosphate by crops.
- Uptake of zinc also increases.
- Increases uptake of water from soil.
- Increases uptake of sulphur from the soil
- Increases the concentration of cytokinins and chloroplast in plants.
- They protect plants during stress condition.

Unit 8: Applied Mycology

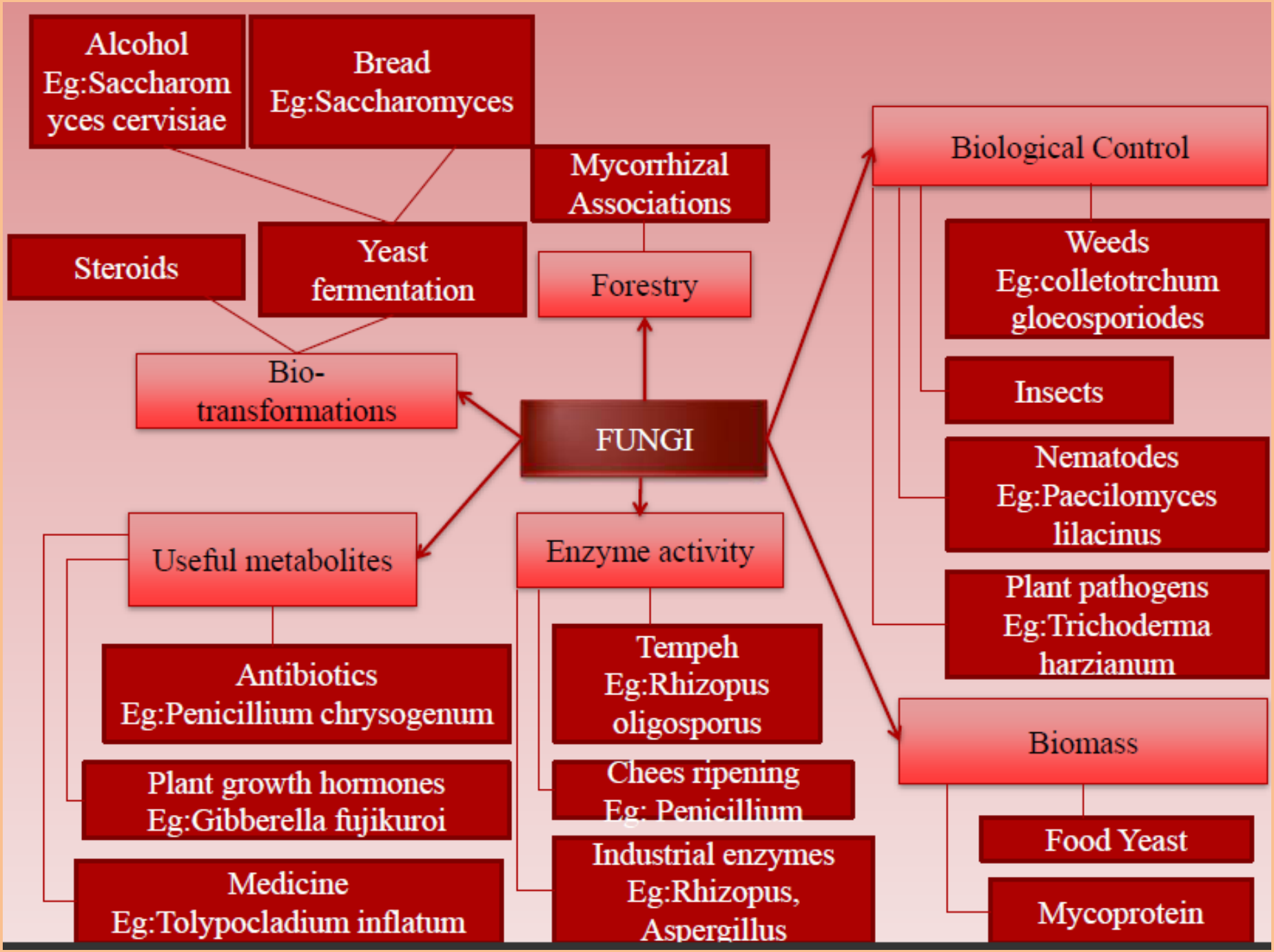
Role of fungi in biotechnology; Application of fungi in food industry (Flavour & texture, Fermentation, Baking, Organic acids, Enzymes, Mycoproteins); Secondary metabolites (Pharmaceutical preparations); Agriculture (Biofertilizers); Mycotoxins; Biological control (Mycofungicides, Mycoherbicides, Mycoinsecticides, Myconematicides); Medical mycology.

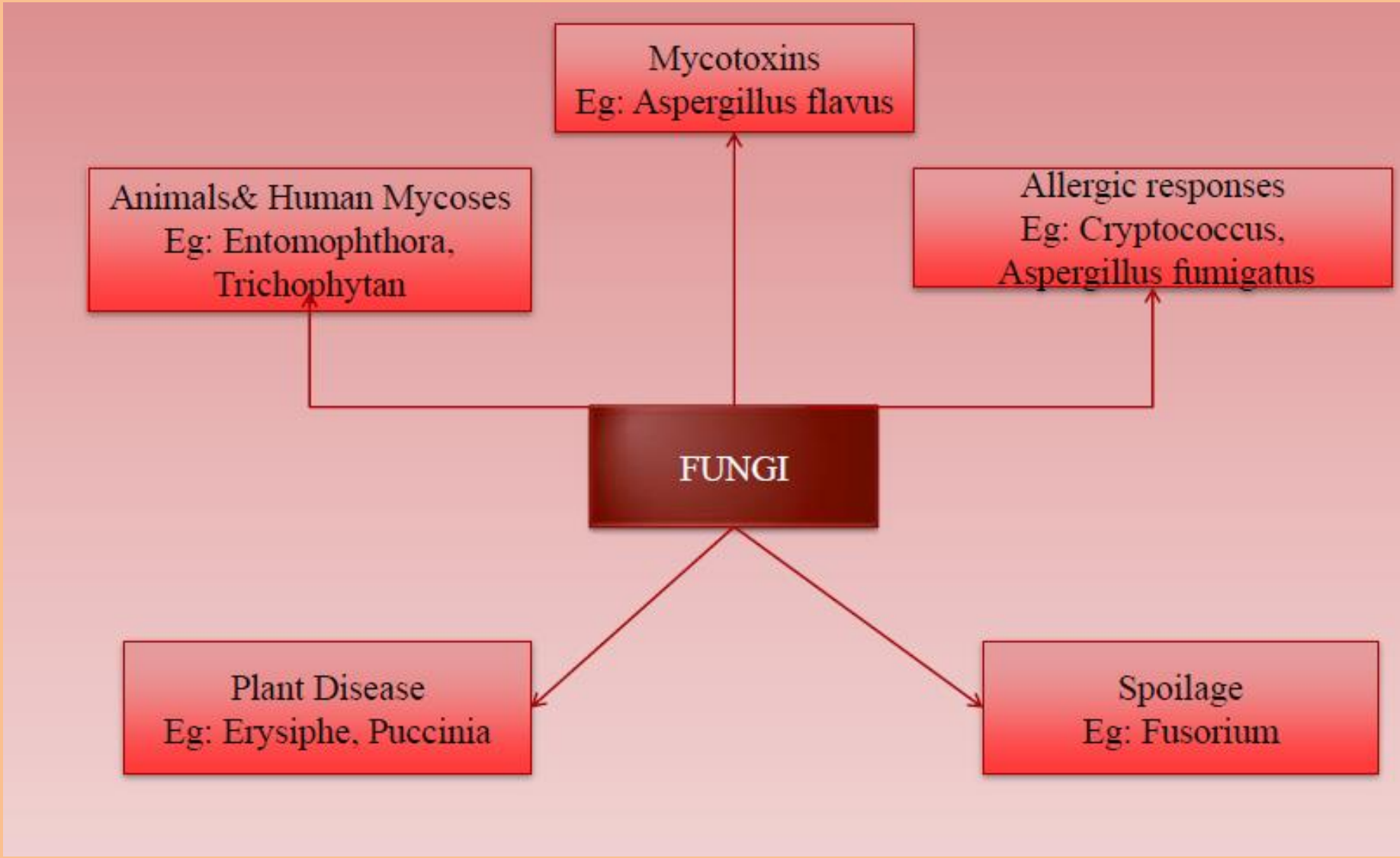
Potential Application Of Fungi In Industry

- Fungi are prominent sources of pharmaceuticals and are used in many industrial fermentative processes, such as the production of enzymes, vitamins, pigments, lipids, glycolipids, polysaccharides and polyhydric alcohols.
- Fungi are extremely useful in making high value products like myco-proteins and acts as plant growth promoters and disease suppressor.
- Fungal secondary metabolites are important to our health and nutrition and have tremendous economic impact. In addition to this, fungi are extremely useful in carrying out biotransformation processes.
- Recombinant DNA technology, which includes yeasts and other fungi as hosts, has markedly increased market for microbial enzymes.

Fungi in Industry

A. Fungi in enzyme production
B. Major Vitamins from fungi
C. Organic acids from fungi
D. Fungi in medicine
E. Fungal metabolites of pharmaceutical importance
F. Fungi in beverage industry
G. Designing of vectors


Alcohol
Eg:Saccharomyces cervisiae
Bread
Eg:Saccharomyces
Mycorrhizal Associations
Steroids
Yeast fermentation
Forestry
Bio-transformations
FUNGI
Biological Control
Weeds
Eg:colletotrchum gloeosporiodes
Insects
Nematodes
Eg:Paecilomyces lilacinus
Plant pathogens
Eg:Trichoderma harzianum
Useful metabolites
Enzyme activity
Biomass
Antibiotics
Eg:Penicillium chrysogenum
Tempeh
Eg:Rhizopus oligosporus
Plant growth hormones
Eg:Gibberella fujikuroi
Chees ripening
Eg: Penicillium
Food Yeast
Medicine
Eg:Tolypocladium inflatum
Industrial enzymes
Eg:Rhizopus, Aspergillus
Mycoprotein


Mycotoxins
Eg: Aspergillus flavus
Animals& Human Mycoses
Eg: Entomophthora,
Trichophytan
Allergic responses
Eg: Cryptococcus,
Aspergillus fumigatus
FUNGI
Plant Disease
Eg: Erysiphe, Puccinia
Spoilage
Eg: Fusorium

Major Vitamins from Fungi

Vitamin	Fungus producing	Uses
Riboflavin (Vitamin B2)	*Ashbya gossypii* *Candida famata*	Increasing energy levels; boosting immune system function; maintaining healthy hair, skin, mucous membranes, and nails; slowing aging
Panthothenic acid (Vitamin B5)	*Fusarium oxysporum*	Used orally for osteoarthritis, rheumatoid arthritis, Parkinson's disease, nerve pain, premenstrual syndrome (PMS), enlarged prostate,
NADH	*Candida boidinii*	Treating high blood pressure, high cholesterol, depression, and Parkinson's diseasereducing signs of aging; and protecting against the side effects of an AIDS drug called zidovudine (AZT)
S-adenosylmethionine(SAMe)	*Sachharomyces saké*	used for depression, osteoarthritis, chronic lower back pain, Alzheimer's disease, slowing the aging process, attention deficit-hyperactivity disorder (ADHD),migraine, headache, and lead poisoning.

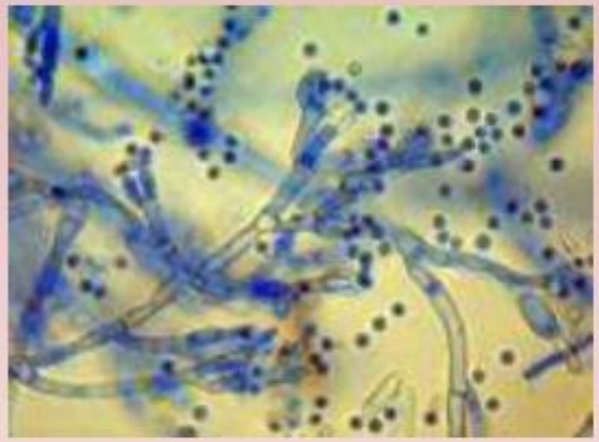
Fungi for industrial use

- Fungi are used in Industries for manufacturing large varieties of useful materials for mankind such as Metabolites, enzymes and food.
- The Filamentous fungi are used in many different process in food Industry for manufacture of different metabolites and variety of other processes.

Antibiotic from Fungi

- Role of fungi in Medicine.
  # Antibiotics
    > Penicillin – Penicillium notatum
    > Streptomycin- Streptomyces griseus

Antifungel
    > Penicillium griseofulvum



Antibiotic from Fungi

Penicillin: It is derived from ***Penicillium chrysogenum*** **was first** used successfully to treat an infection caused by a bacterium. The natural penicillin's have a number of disadvantages. They are destroyed in the acid stomach, and so cannot be used orally. It act only on gram positive bacteria.

Cephalosporin's: The original fungus found to produce the compounds was a *Cephalosporium*, hence the name.

Griseofulvin: The only broadly useful antifungal agent from fungi is **griseofulvin.** The original source was ***Penicillium griseofulvin*****.** Griseofulvin is fungi static, rather than fungicidal. It is used for the treatment of dermatophytes,

Fungi in antibiotics

Medicine	Fungus involved	Use
Penicillin	*Penicillium chrysogenum*	Anti-bacterial(gram +ve)
Cephalosporin	*Cephalosporium*	Anti-bacterial(gram +ve)
Griseofulvin	*Penicillium griseofulvum*	Fungi-static, treatment of dermatophytes
Lentinan	*Lentinus sp.*	Against *Mycobacterium tuberculosis, Listeria sp.* and *Herpes Simplex Virus-I(HSV-1)*
Schizophyllan	*Schizophyllum*	Antibacterial(against *Staphylococcus aureus*)

Immunomodulatory properties

- Mushrooms and polypores are rich source of natural antibiotics. The cell wall glucans are well known for their immunomodulatory properties, and the secondary metabolites are active against bacteria and viruses.
- Exudates from mushroom mycelia are active against protozoa such as the malarial parasite *Plasmodium falciparum.*

Non-antibiotic Therapeutics from Fungi

- There are non-antibiotic therapeutic agents obtained from fungi that have revolutionized medical practice.
- Cyclosporin is an important immunosuppressant drug that is used in organ transplantation surgery.
- Cyclosporin-A is derived from *Tolypocladium inflatum,* and *Aspergillus sp.*
- About 20% of the drugs produced by pharmaceutical industry today are derived from fungi
- Lovastatin is a cholesterol biosynthesis inhibitor derived from *Aspergillus terreus. It is one of the many* drugs used as a cholesterol reducing agent. A similar cholesterol reducing drug is produced from *Penicillium citrinum, and it is called Pravastatin.*
- Fungi are the source of vitamin B12 (*Saccharomyces cerevisiae) and other vitamins (S. cerevisiae, Ashbya* sp., *Blakeslea sp.) and hallucinogens (Psylocybe sp.)*

Fungal Drug

Penicillin

Griseofulvin

Cyclosporin

Lentinan

Pravastatin

Lovastatin

Immune Suppressants

Cyclosporin A: It is a primary metabolite of several fungi, including *Trichoderma polysporum* and *Cylindrocarpon lucidum*. Cyclosporin A is a cyclic peptide consisting of mainly hydrophobic amino acids.

Gliotoxins: Belong to a class of compounds called Epi-poly-thiodioxopiperazines. Produced by many fungi including *Aspergillus fumigatus*.

Statins

- ***Aspergillus terreus*** a soilborne fungus, produces a secondary metabolite called lovastatin and ***Aspergillus Phoma*** *produces squalestatin .*
- *Both has been* used to reduce or remove low density lipoproteins from blood vessels in humans
- Statins have been implicated in attracting stem cells to damaged tissues. The stem cells then appear to regenerate the tissue.

Brewing and baking (Ancient biotechnologies)

The fungi form the most useful basis in industries like: **baking and brewing** (*Saccharomyces cerevisiae*), preparation of cheese (*Penicillium roqueforti* and *P. camemberti*),

Bread making

- Basic ingredients are wheat, water, yeast, fat, sugar and salt.
- Dough is made by mixing ingredients together.
- Dough then ferments at 27oC in a humid atmosphere.
- The yeast, *Saccharomyces cerevisiae, feeds on* the sugar breaking it down anaerobically to ethanol and carbon dioxide.
- The bubbles of CO2 remain trapped in the sticky dough causing it to rise.
- Dough is then cut and placed in loaf tins.
- Dough then goes through a final fermentation at 45oC.
- The baking kills the yeast, evaporates off the alcohol and cooks the flour.
- A modern bakery can make 10 000 loaves of bread per hour.

Secondary metabolites (Pharmaceutical preparations)

Secondary metabolites (SM) are compounds that are not necessary for a cell (organism) to live, but play a role in the interaction of the cell (organism) with its environment. These compounds are often involved in plants protection against biotic or abiotic stresses. Secondary metabolites are from different metabolites families that can be highly inducible in response to stresses. Primary metabolites perform essential metabolic roles by participating in growth and development. It is important for mankind.

Fungal source	Active Ingredient	Medicinal properties
Ganoderma lucidum	**Ganoderic acid, Beta-glucan**	Liver protection, Antibiotic properties, Inhibits cholesterol synthesis
Lentinula edodes	**Eritadenine, Lentinan**	Lower cholesterol, Anti-cancer agent
A. bisporous	**Lectins**	Enhance insulin secretion
P. sajor-caju	**Lovastatin**	Lower cholesterol
G. frondosa	**Polysaccharide, Lectins**	Increases insulin secretion, Decrease blood glucose
Auricularia auricula	**Acidic, polysaccharides**	Decrease blood glucose
Flammulina velutipes	**Ergothioneine, Proflamin**	Antioxidant, Anti cancer activity
Trametes versicolor	**Polysaccharide-K (Kresin)**	Decrease immune system depression
Cordyceps sinensis	**Cordycepin**	Cure lung infections, Hypoglycemic activity, Cellular health properties, Anti-depressant activity

Secondary metabolites (Pharmaceutical preparations)

PHARMACODYNAMIC	COMPONENT	SPECIES
Antibiotics	Beta Methoxy Acrelate	Oudemanasilla radicata
Antiviral	Protein Polysaccharide	Lentinula edodes
Cardio tonic	Volvatoxin Flammutoxin	Polyporaceae volvariella
Decrease Cholesterol	Eritadinine	Collubia vellutipes
Reduce Blood Pressure	Triterpene	Ganoderma Lucidum
Anti Thrombus	5-GMP	Psolliata hartensis
Increase Bile secretion	Armillarisia A	Armillariella Tobescens
Analgesic/Sedative	Marasmic Acid	Maramius androsaceus

Enzymes sourced from fungi

Enzyme preparations.

Invertase- saccharomyces cerevisiae

Preparation of organic acids.

Aspergillus niger – Oxalic acid

The major enzymes sourced from fungi

Enzymes are large biomolecules that are responsible for many chemical reactions that are necessary to sustain life. Enzyme is a protein molecule and are biological catalysts. Enzymes increase the rate of the reaction. Enzymes are specific, they function with only one reactant to produce specific products. Enzymes have a three-dimensional structure and they utilize organic molecules like biotin and inorganic molecules like metal ions (magnesium ions) for assistance in catalysis.

Sr. No.	ENZYME	SOURCE
1	Acid, alkaline & neutral proteases	*Aspergillus oryzae; A. niger, A. flavus; A. sojae*
2	Cellulase	*Trichoderma koningi*
3	Diastase	*Aspergillus oryzae*
4	Glucoamylase	*Aspergillus niger; A. oryzae*
5	Invertase	*Saccharomyces cerevisiae*
6	Lactase	*S. lactis; Rhizopus oryzae*
7	Ligninase	*Phanerochaete chrysosporium*
8	Lipase	*Rhizopus spp.*
9	Pectinase	*A. niger*; *Sclerotinia libertina*

Fungi in Enzymes production

There are several multinational companies having stake in manufacturing industrial enzymes from fungi. Biocon India Ltd. is a major bulk enzyme producer in India.

Use of Enzymes for different purposes

- Food ----------45 %
- Detergent----- 34 %
- Textile ----------11 %
- Leather---------- 3 %
- Pulp/paper-------1 %
- Others ----------6 %

THE MAJOR ENZYMES SOURCED FROM FUNGI

ENZYME	SOURCE	USES
•Acid, alkaline & neutral proteases	*Aspergillus oryzae; A. niger A. flavus; A. sojae*	Meat tenderization, Bakery
•Cellulase	*Trichoderma koningi*	Paper industry, Detergent, Coffee
•Diastase	*Aspergillus oryzae*	Acid reflux, Food Supplement
•Glucoamylase	*Aspergillus niger; A. oryzae*	Sweeteners
•Invertase	*Saccharomyces cerevisiae*	Sugar Candies
•Lactase	*S. lactis; Rhizopus oryzae*	Lactose intolerant patients
•Ligninase	*Phanerochaete chrysosporium*	Pulp and Paper industry
•Lipase	*Rhizopus spp.*	Baking, Pancreatic disorders
•Pectinase	*A. niger, Sclerotinia libertina*	Fruit juices

Organic acids produced from fungi

Commercial production of organic acid—citric acid with the help of *Aspergillus niger* and of some vitamin preparations. Yeast played a very important role in the nutrition of German people during World Wars I and II. There are several organic acids produced on a commercial scale from fungi. Some examples are given here.

Organic acid	Source	Uses
Citric acid	*Aspergillus niger*	In food preservation, powerful cleaning agent and in cosmetic products
Fumaric acid	*Rhizopus nigricans*	Used in food and beverage products, as oral pharmaceutical formations
Gluconic acid	*Aspergillus niger*	Acidity regulator as food additive, cleaning products
Itaconic acid	*A. terreus*	Prepare acrylic fibres and rubbers, reinforced glass fibre, in water treatment systems, artificial diamond and lens
Kojic acid	*A. oryzae*	Used in food and cosmetics as skin

BIO FERTILIZER

'Biofertilizer' is a substance which contains living microorganism which, when applied to seed, plant surfaces, or soil, colonizes the rhizosphere or the interior of the plant and promotes growth by increasing the supply or availability of primary nutrients to the host plant. Biofertilizers are not fertilizers.

Fertilizers directly increase soil fertility by adding nutrients. Biofertilizers add nutrients through the natural processes of fixing atmospheric nitrogen, solubilizing Phosphorus, and stimulating plant growth through the synthesis of growth promoting substances.

Biofertilizers can be grouped in different ways based on their nature and function

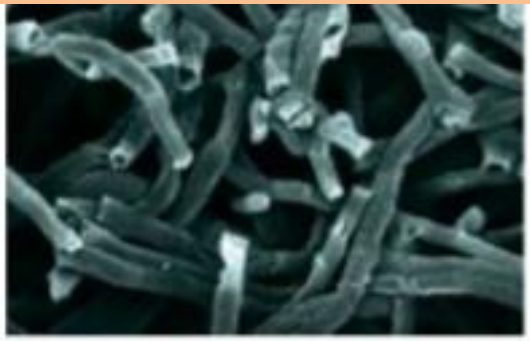
1) Mycorrhiza
2) Nitrogen (N2) fixing Biofertilizers
3) P Solubilizing Biofertilizers
4) P Mobilizing Biofertilizers
5) **Biofertilizers for Micro nutrients**
6) Plant Growth Promoting Rhizobacteria (PGPR)
7) Plant Growth Promoting Fungi (PGPF)

Mycoprotein

- Mycoprotein is the protein from fungi. The main mycoprotein on sale in Europe and North America is called Quorn. It was originally developed as a food source to combat food shortages.
- Quorn is the leading meat free brand within the UK and Ireland. All Quorn products contain mycoprotein which is derived from the fungus ***Fusarium venenatum.***

Mycoprotein

- **Mycoprotein**, also known as **fungal protein**



- Mycoprotein means protein from fungi
- The main mycoprotein on sale in Europe and North America is called **Quorn**
- All Quorn products contain mycoprotein derived from the fungus ***Fusarium venenatum***

Harmful activities

- Fungi cause diseases to human, animals and plants. They cause destruction to clothes, paper, jute, leather, rubber, Paints, petroleum products, good grains and other bakery products. Harmful effects are:

(1) Many fungi cause very much loss to our timber trees by causing wood rot. Armillaria mellea, the honey mushroom causes red rot of apple and many forest trees. Many species of Polypores attack forest trees causing wood rot.

(2) Some would fungi like Rhizopus, Mucor, Aspergillus spoil our food. Their spores are always in the air and settle down on exposed jams, pickles, jelly, bread and fruits and develop mycelia and make food articles unfit for human use.

(3) Some parasitic fungi are causative agents of diseased of our cops, fruits and other economic plants. In them fungi like Puccimia and ustilago cause rusts and smuts. They are great enemies of crops and cause loss by reducing crop yield. The rusts reproduce yellow, orange or black pustules on the stem and leaves of cereal plants while smuts attack forests and produces a black powdery mass of smut spores in the place of seed and fruits. Damage caused to cereals (wheat, maize, oat and barley) by rust and smuts amounts to several hundred millions of rupees annually. Fungi diseases in plants are:

(i) While rust of crucifers by crystopus cindidus.
(ii) Powdery mildew by Erisiphae species.
(iii) Fruit root of apple by Rhizopus arrhizus.
(iv) Late blight of Potato by Phytopora infestans.
(v) Red rot of sugar came by colletorichum falcatum.
(vi) Some parasitic fungi cause diseases to animals.

Saprolegnia which occurs as saprophyte on dead fish or flies behave as facultative parasite producing serious diseases to crops and gold fishes.

(4) Some fungi are also cause some important diseases in human beings. Asperigillus as A.miger, A.fiavus, A.fumigatus are common human pathogens. Disease caused in aspergilloses of lungs and ears. Some parasitic fungi live in mucous membrane of throad, bronchii and lungs. Few fungi cause skin discoloration. A well known skin disease rung worm or "Dead" is also a fungus disease.

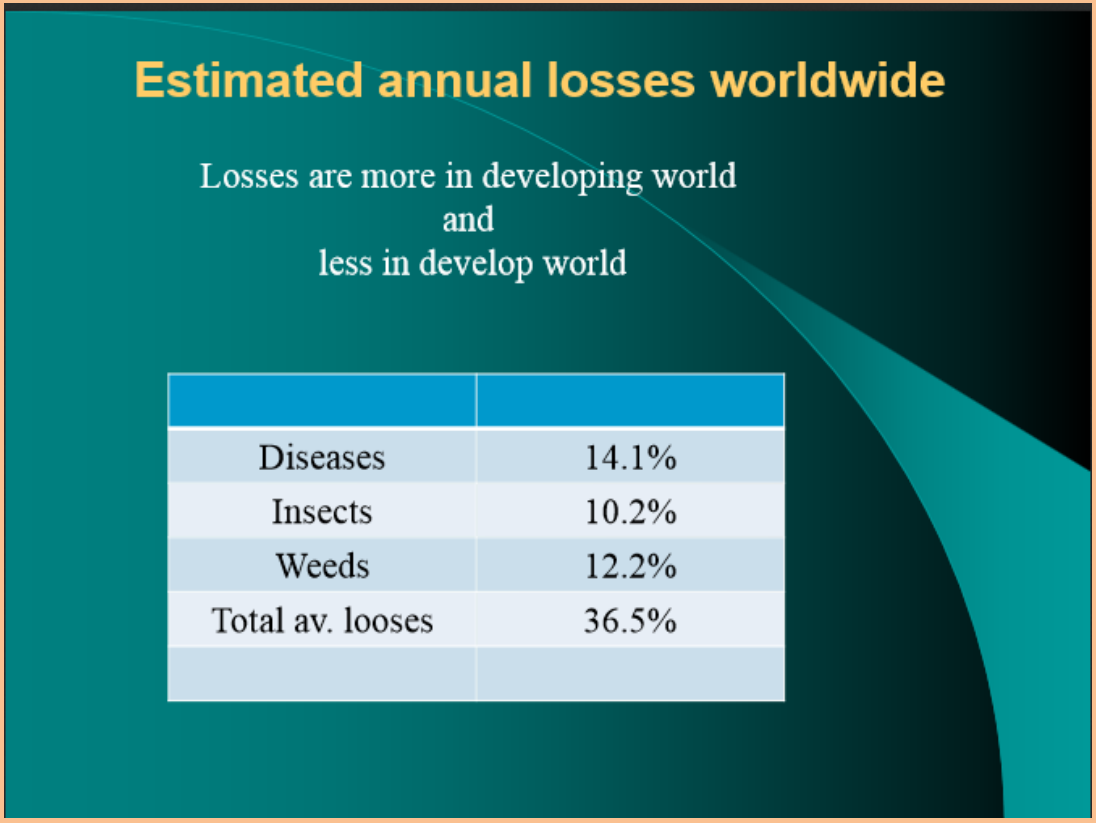
Unit 10: Phytopathology

Terms and concepts; General symptoms; Geographical distribution of diseases; Etiology; Symptomology; Host-Pathogen relationships; Disease cycle and environmental relation; prevention and control of plant diseases, and role of quarantine.

Bacterial diseases – Citrus canker and angular leaf spot of cotton. Viral diseases – Tobacco Mosaic viruses, vein clearing. Fungal diseases – Early blight of potato, Black stem rust of wheat, White rust of crucifers.

Importance of the Plant Diseases

- Globally, enormous losses of the crops are caused by the plant diseases. The loss can occur from the time of seed sowing in the field to harvesting and storage.



Diseases	14.1%
Insects	10.2%
Weeds	12.2%
Total av. looses	36.5%

Plant Diseases and famine

Important historical evidences of plant disease epidemics are

- Late blight of potato-1841-51 (Irish famine) by *Phytophthora infestans, Class- Oomycota*
- Coffee rust 1867-1870 (Srilanka) by *Hemileia vastatrix , Class- Basidiomycota*
- Brown spot of rice Bengal famine 1942 (India) by *Helminthosporium oryzae , Class Deuteromycotina*

synonyms:

Asexual stage (Anamorph)-*Drechslera oryzae, Bipolaris oryzae),*

Sexual stage (Teleomorph)- *Cochliobolus miyabeanus*

What is Plant Pathology?

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

- Plant pathology is that branch of agricultural, botanical or biological sciences which deals with the study of:
  - Cause of the disease
  - Result- losses and
  - Control of plant diseases

Plant Disease Definition

Stakman & Harrar (1957) defined disease as physiological disorder or structural abnormality that is deleterious to the plant or its part or product, that reduces the economic value of the plant. e.g., wilt, potato blight, Loose smut of wheat, karnal bunt of wheat

Disease is a harmful deviation from normal functioning of physiological processes. (British Mycological Society, 1950)

Disease is a process or a change that occurs over time. It does not occur instantly like injury.

History of Plant Pathology

- Historical perspectives show that the attention of man to plant diseases and the science of plant pathology were drawn first only in the European countries. Greek philosopher Theophrastus, Father of Botany (about 286 BC) recorded some plant diseases about 2400 years ago.

- Historically, plant pathology of India is quite ancient as the Indian agriculture, which is nearly 4000 years old, much before the time of Theophrastus.

- Plant diseases, other enemies of plants and methods of their control had been recorded in the ancient books viz., *Rigveda, Atharva Veda (1500-500 BC), Artha Shastra of Kautilya (321-186 BC), Sushruta Samhita (200-500AD), Vishnu Purana (500 AD), Agnipurana (500-700 AD), Vishnudharmottara (500-700 AD) etc.*

History of Plant Pathology

- W. M. Stanley (1935) – "Isolation of crystalline protein possessing the properties of TMV" Shared Nobel prize 1946
- Millardet (1885) – Bordeaux mixture

Downy Mildew – A (little) History

P.M.A. Millardet (a French botanist) first used **Bordeaux mixture** (copper sulfate and lime) to control downy mildew in the vineyards of France

- He noticed that a copper sulphate-lime powder mixture that was sprinkled on grapevines along highways to prevent stealing of the grapes *also* controlled downy mildew
- This observation led to the discovery and development of **Bordeaux mixture**

- The **Indian Agricultural Research Institute (IARI)** commonly known as **Pusa Institute** is India's premier national Institute for agricultural research, education and extension, situated in Delhi, it is financed and administered by the Indian Council of Agricultural Research (ICAR). The IARI was responsible for the research leading to the "**Green Revolution in India**" of the 1970s.

- The institute was originally established in 1905 at Pusa, Bihar, as Agricultural Research Institute (ARI),

- E. J. Butler- is the First Mycologist at the Imperial Agricultural Research Institute at Pusa, He is also called as Father of Indian Plant Pathology.

- In 1918 he produced Book- "Fungi and Diseases in Plants"

- He published a Monograph on potato disease, wilt of cotton, rice, sugarcane diseases & cereal rusts

Rachel Carson – Silent Spring

Silent Spring is an environmental science book by Rachel Carson. The book was published on 27 September 1962 and it documented the detrimental effects on the environment—particularly on birds—of the indiscriminate use of pesticides.

That led to a nationwide ban on DDT for agricultural uses, and creation of the U.S. Environmental Protection Agency

Terminology

Terminology

- Parasite
- Pathogenicity
- Symptom
- Syndrome
- Host
- Collateral host
- Susceptibility
- Pathogen
- Pathogenesis
- Sign
- Hypersensitivity
- Alternate host
- Resistance
- Tolerance

- **Parasite**

  An organism that lives on or in another organism and obtains food from the second organism

- **Pathogenicity-** is the ability of a pathogen to cause the disease by interfering with one or more of the essential plant cell functions.

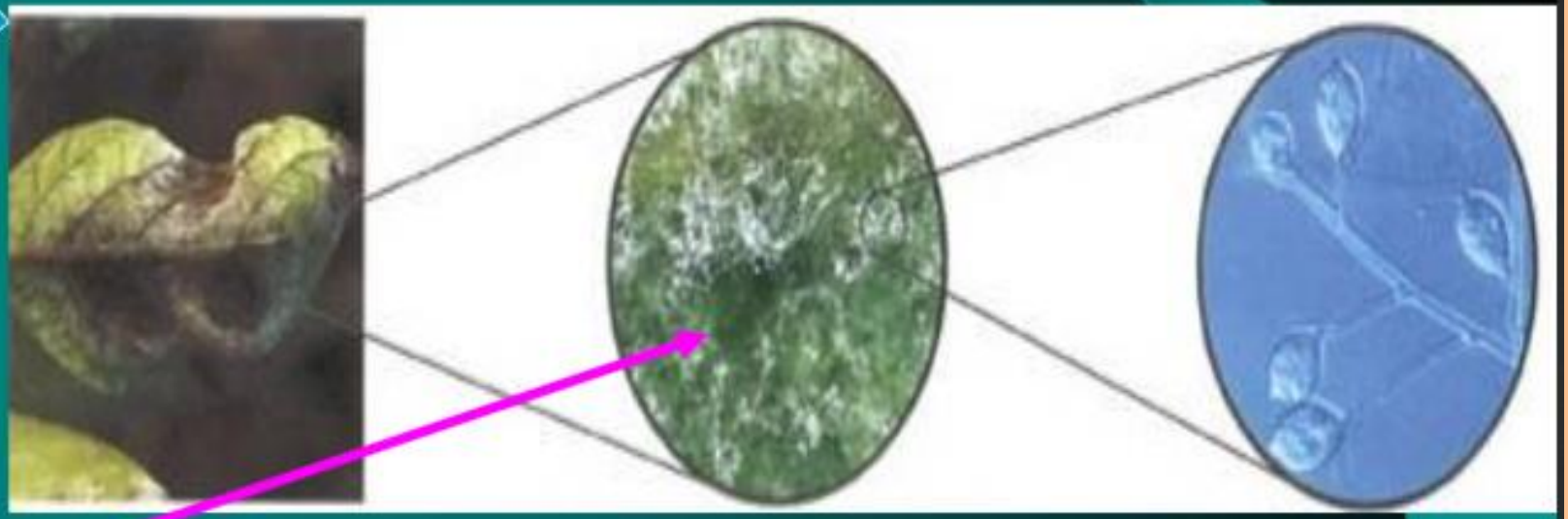
Symptom and Signs

Visible effects of disease on plants that is any detectable changes in color, shape or functions of the plant in response to a pathogen or disease-causing agent is a symptom.

Signs of plant disease are physical evidence of the pathogen, for example, fungal fruiting bodies, bacterial ooze, or nematode cysts.

symptom and Sign

- **Symptom** – are the expression of the disease caused by the manifestation of the physiological reaction of the plant due to harmful activity of the pathogen



Sign - physical evidence of the presence of disease agent (*e.g.*, mold or fungal spores, bacterial ooze)

Syndrome

Defined as sequential appearance of disease symptoms on a plant during the development of the disease

or sum total of symptoms exhibited by a disease

Fleck or necrotic spot

↓

Blight

↓

Fungal growth

↓

Death of of organ or plant

Symptoms

A.Necrotic: Decay of plant parts, ring spot, mildew, as well as root and crown rots flourish in cool weather on saturated soils.

B.Hypoplastic : Failure of a tissue or organ to achieve complete development. Hypoplasia or hypogenesis, underdevelopment of a tissue, organ, part of the body, or entire organism

C.Hyperplastic: Overgrowth of tissue by increase number of cell division. Hyperplasia an increase in the number of structural elements of tissues or organs

Biotrophs and Necrotrophs

- Some fungi obtain their nutrients from a living host (plant or animal) and are called **biotrophs**;
- Others obtain their nutrients from dead plants or animals and are called **saprotrophs** (saprophytes, saprobes).
- Some fungi infect a living host, but kill host cells in order to obtain their nutrients; these are called **necrotrophs**.

Biotrophs/obligate parasite – do not kill host plant. They penetrate the cell wall and establish a continuous relationship, take nourishment and complete life cycle on living host . e.g. *Exobasidium vexans*

Necrotrophs – kill their host before feeding on the cells or cell's contents and live on dead tissue. *Rhizoctonia* .

Host: any organism that harbour another organism is called host

Alternate host: is the host that help in the completion of the life cycle of the pathogen and its survival, belong to diff. family

Collateral host: host of the same family and help in the survival of the pathogen

Infection: Establishment of organic relationship between host and pathogen . It may be primary and secondary.

Pathogenesis: Chain of events that takes place during the development of disease (inoculation to survival of the pathogen)

Susceptibility: Inability of the host to resist the attack of the pathogen

Tolerance: is a type of defense that minimises crop losses with out restricting the disease development.

Resistance: Ability of the host to resist the attack of the pathogen

- –**Horizontal resistance** – non-specific or polygenic or multigenic resistance, Many genes collectively control.
- –**Vertical resistance** – Specific, monogenic/oligogenic, single gene or few genes control.

Hypersensitivity: is the quick death of the host tissue in the vicinity of the pathogen

Virulence: It is defined as the degree of pathogenecity of a particular isolate or race of the pathogen .

Aggressiveness: it is the capacity of the pathogen to invade and colonize the host and to reproduce on or in it.

Predisposition: it is the set of conditions that makes the plant vulnerable to the attack of the pathogen.

Parasite: An organism living upon or in another living organism (the host) and obtaining the food from the invading host.

Pathogen: An entity, usually a micro-organism that can cause the disease.

Pathogenicity: The relative capability of a pathogen to cause disease.

Pathogenesis: It is a process caused by an infectious agent (pathogen) when it comes in contact with a susceptible host.

Symptoms: The external and internal reaction or alterations of a plant as a result of disease.

Primary infection: The first infection of a plant by the over wintering stage or over summering stage of the pathogen.

Inoculum: That portion of pathogen which is transferred to plant and cause disease.

-Primary inoculum

-Secondary inoculum

Symptoms: The external and internal reaction or alterations of a plant as a result of disease.

Incubation period: The period of time between penetration of a pathogen to the host and the first appearance of symptoms on the plant.

Disease cycle: The chain of events involved in disease development.

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

Invasion: The penetration and spread of a pathogen in the host.

Single cycle disease (Monocyclic): This type of disease is referred to those caused by the pathogen (fungi) that can complete only one life cycle in one crop season of the host plant. e.g. club root of crucifers, sclerotinia blight of brinjal etc.

Multiple cycle disease (Polycyclic): Some pathogens specially a fungus, can complete a number of life cycles within one crop season of the host plant and the disease caused by such pathogens is called multiple cycle disease e.g. wheat rust, rice blast, late blight of potato etc.

Mutualism: Symbiosis of two organisms that are mutually helpful or that mutually support one another.

Antagonism: The counteraction between organisms or groups of organisms.

Mutation: An abrupt appearance of a new characteristic in an individual as a result of an accidental change in genes present in chromosomes.

Cop Damage: It is defined as any reduction in the quality or quantity of yield or loss of revenue resulting from crop injury.

Deficiency: Abnormality or disease caused by the lack or subnormal level of availability of one or more essential nutrient elements.

Disease Cycle

- **Pathogenesis/ Disease Cycle** – a series of events that occur in succession during a pathogenic relationship of a pathogen and host that leads to disease

  The study of disease cycle generate information about

  -Source of perpetuation of pathogen

  -Mode of spread

  -Help in formulation of control measures

  Disease Cycle may be

  ----------monocyclic or

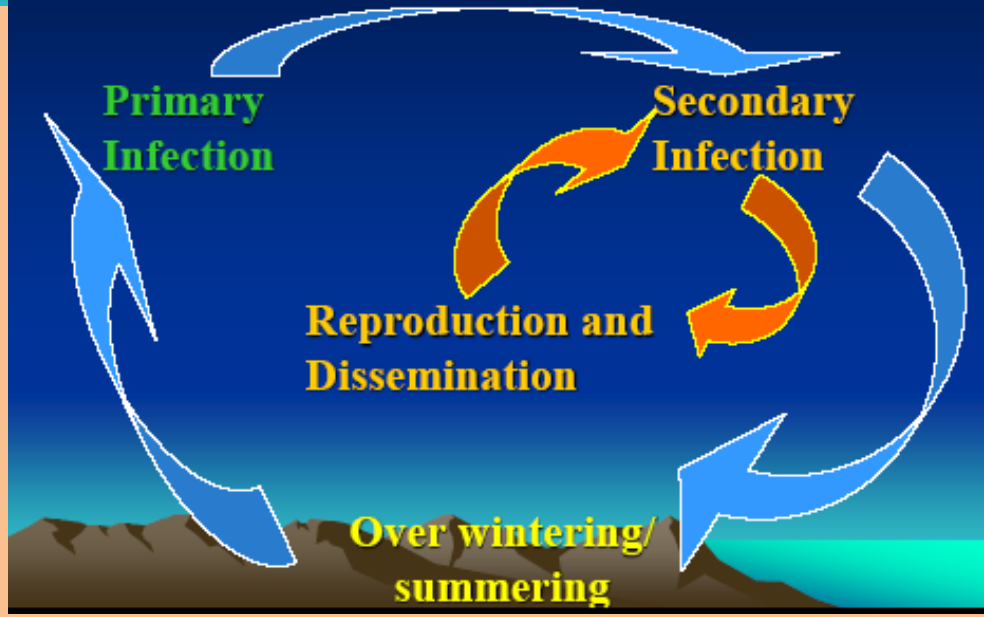
  ----------polycyclic

Primary Disease Cycle

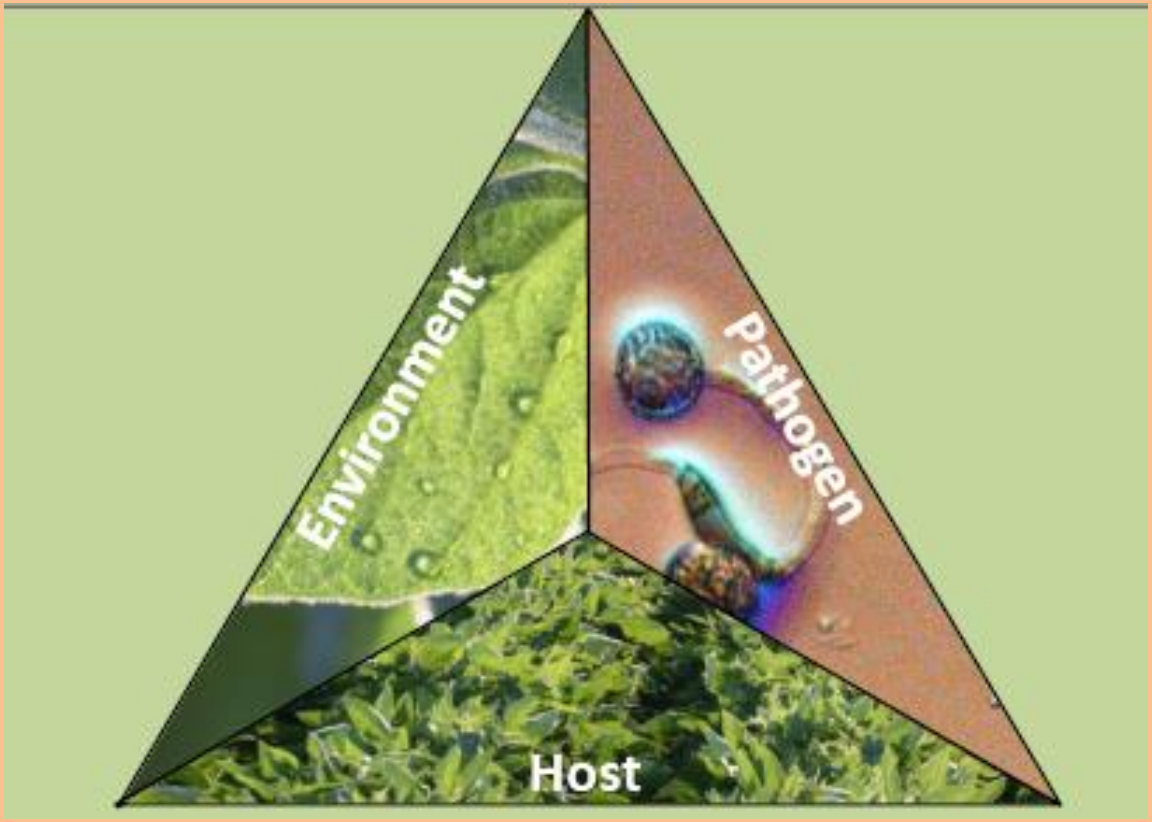
Monocyclic Disease

Secondary Disease Cycle

Polycyclic Disease



The Disease Triangle



Conditions for disease

----Host should be susceptible

----Pathogen should be virulent

----Environment should be favourable for the disease

Disease triangle

The disease triangle or plant disease triangle is a visual diagram used to explain the development of plant disease.

In order for disease to occur a pathogen must interact with a host plant. If these two components do not come into contact, disease cannot develop. However, the development of plant disease is further regulated by environmental conditions, with ideal conditions favoring the development of disease and unfavorable conditions deterring disease. These three components make up the plant disease triangle:.

Inoculation

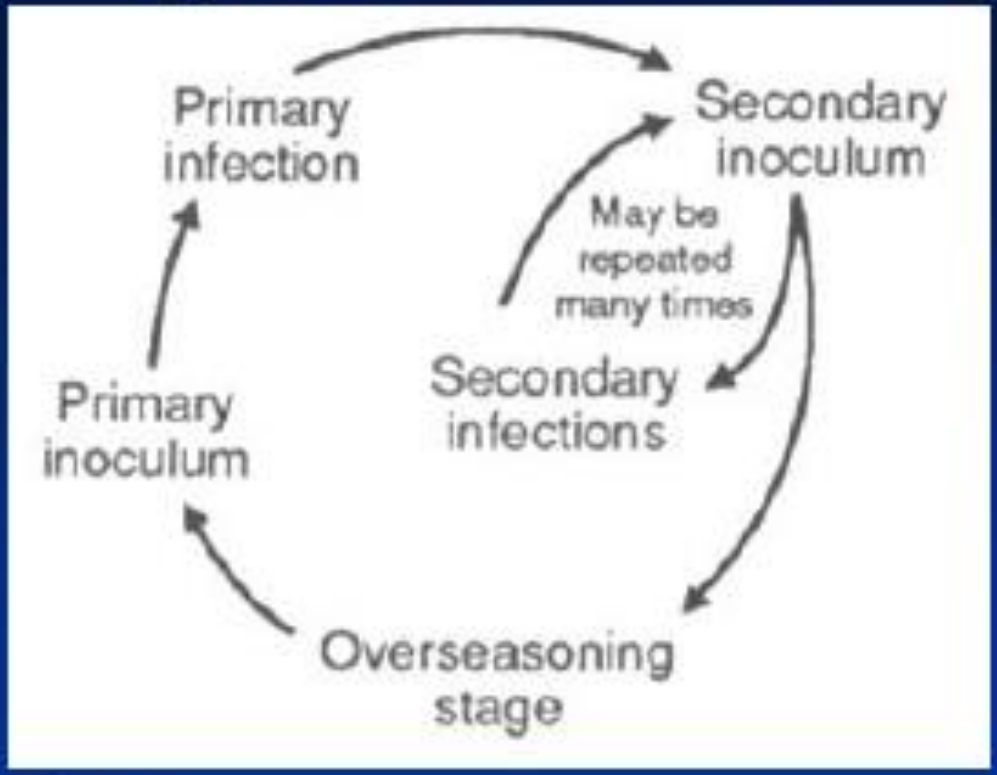
It is the process by which the pathogen come in contact with its host

Inoculum: any part or propagule of pathogen that can cause disease (may consist of single unit of the pathogen or whole of the pathogen)

Types of Inoculum

1. Primary inoculum (Sclerotia, mycelium, oospore)
2. Secondary inoculum (conidia, urdospores, zoospores)

Types of inoculum



Types of Inoculum

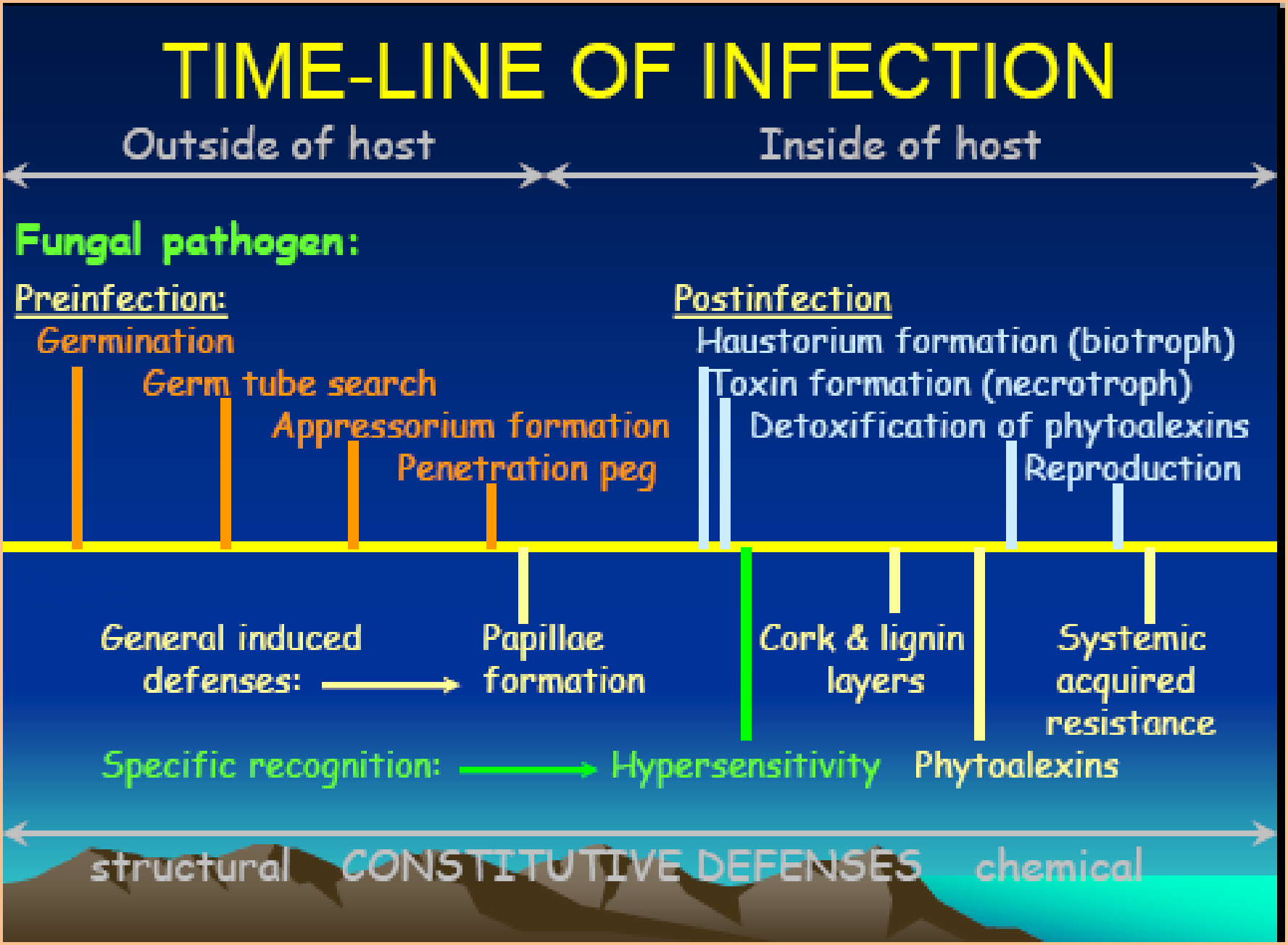
1. Primary inoculum (Sclerotia, mycelium, oospore)

2. Secondary inoculum (conidia, urdospores, zoospores)

Infection

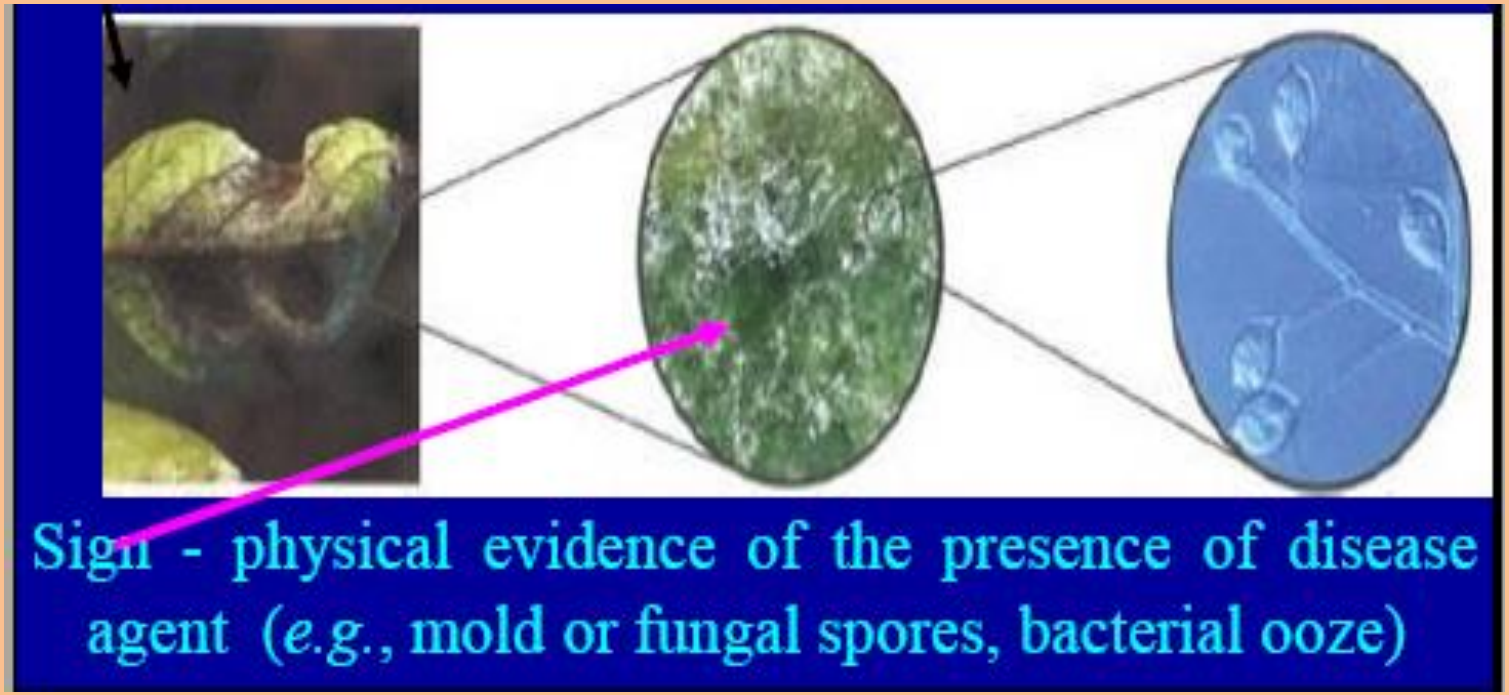
Local infection: An infection affecting a limited part of a plant e.g. leaf spot.

Systemic infection: infection that spread point of infection to different parts of the plants e.g. wilts, virus infection, loose smut .


TIME-LINE OF INFECTION
Outside of host
Inside of host
Fungal pathogen:
Preinfection:
Germination
Germ tube search
Appressorium formation
Penetration peg
Postinfection
Haustorium formation (biotroph)
Toxin formation (necrotroph)
Detoxification of phytoalexins
Reproduction
General induced defenses:
Papillae formation
Cork & lignin layers
Systemic acquired resistance
Specific recognition:
Hypersensitivity
Phytoalexins
structural
CONSTITUTIVE DEFENSES
chemical

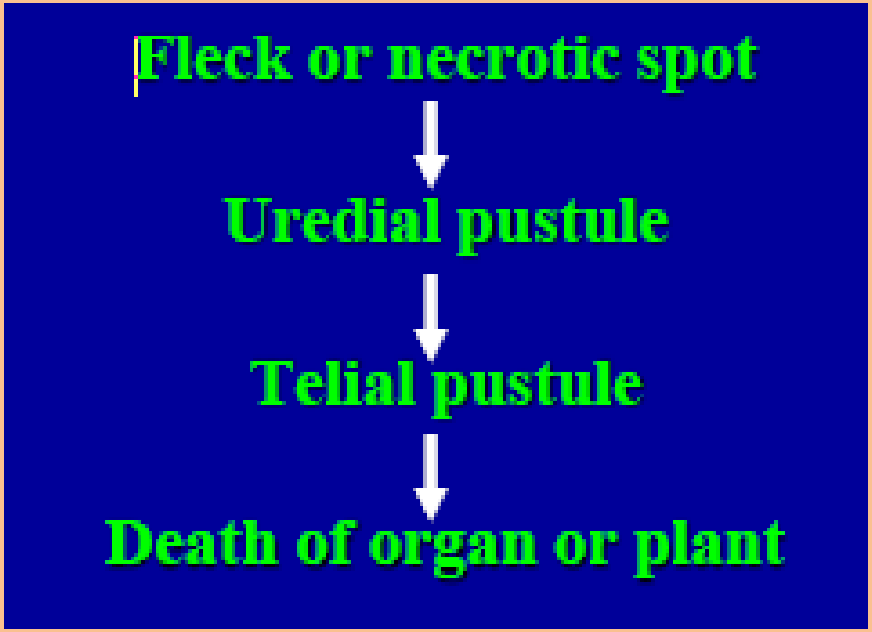
Disease symptom and Sign

Symptom – are the expression of the disease caused by the manifestation of the physiological reaction of the plant due to harmful activity of the pathogen



Disease Syndrome

Defined as sequential appearance of disease symptoms on a plant during the development of the disease or sum total of symptoms exhibited by a disease



Types of symptoms

- Morphological symptoms
- Histological symptoms

Morphological symptoms

Morphological: (Externally detectable symptoms caused by any pathogen e.g. blight, leaf spot

–Necrosis

–Hypotrophy & Hypoplasia

–Hypertrophy & Hyperplasia

Necrosis

Degeneration of protoplast followed by death of the tissue or organ or plant

- ***Plesionecrosis (Nearly dead):*** necrotic symptoms expressed before the death of the protoplast are called plesionecrosis.

E.g. yellowing, hydrosis, wilting

- ***Holonecrosis:*** necrotic symptoms expressed after the death of the protoplast are called holonecrosis. In this the affected tissue turns brown in colour

E.g. Rots, spots, blights

Hyperplastic & Hypertrophic symptoms

- **Hyperplasia:** A plant overgrowth due to increased cell division.
- **Hypertrophy:** A plant overgrowth due to abnormal cell enlargement.
  - Wound tumors-
  - **Galls** - An abnormal plant structure formed in response to parasitic attack by certain microorganisms (bacteria, fungi, viruses) or insects.
  - **Witches Broom** -An abnormal form of plant growth characterized by profuse outgrowth of lateral buds to give a broom like appearance.
  - **Enations**- A symptom caused by certain plant viruses in which there are small outgrowths on the plant

Hypoplastic symptoms

- Atrophy/ Hypoplasis/ dwarfing/ Stunting
- **Rosette:** in this the internodes do not enlarge and leaves are clustered like petals of rose e.g. Peach rosette, ground rosette
- **Albication**: Complete repression of colour caused by viruses, bacteria, fungi, and iron deficiency
- **Mosaic:** appearance of dark green and light green areas on leaves e.g. Tobacco mosaic
- **Chlorosis:** failure of chlorophyll to develop fully.

Koch's Postulates

Robert Koch (1884-1890) forwarded four essential procedural steps called postulates for correct diagnosis of a disease and its actual causal agent. The postulates are:

1. **Recognition:** The pathogens must be found associated with the disease in the diseased plant. The symptom of the disease should be recorded.
2. **Isolation**: The pathogen should be isolated, grown in pure culture in artificial media. The cultural characteristics of the pathogen should be noted.
3. **Inoculation**: The pathogen of pure culture must be inoculated on healthy plant of same species/variety. It must be able to reproduce disease symptoms on the inoculated plant identical to step 1.
4. **Re-isolation:** The pathogen must be isolated form the inoculated plant in culture media. Its cultural characteristics should be similar to those noted in step 2 (This step was added by E.F. Smith).

Koch's postulates,

If all the postulates are proved true, then the isolated pathogen is identified as the actual causal organism responsible for the disease.

Pathotoxins and phytoalexins

Pathotoxin: A chemical of biological origin, other than an enzyme, that plays an important causal role in a plant disease. Most pathotoxins are produced by plant pathogenic fungi or bacteria. Some pathotoxins are highly selective to cause severe damage and typical disease symptoms on plants susceptible to the pathogens.

Phytoalexin: Any antibiotic produced by plants in response to microorganisms. Phytoalexin accumulation is just one part of an integrated series of plant responses leading from early detection to eventual

Epidemic and Epidemiology

Epidemic

A phenomenon when a pathogen spreads to and affects many individuals within a population over a relatively large area and within a relatively short time.
(The dynamics of change in plant disease in
time and space.)

Epidemiology

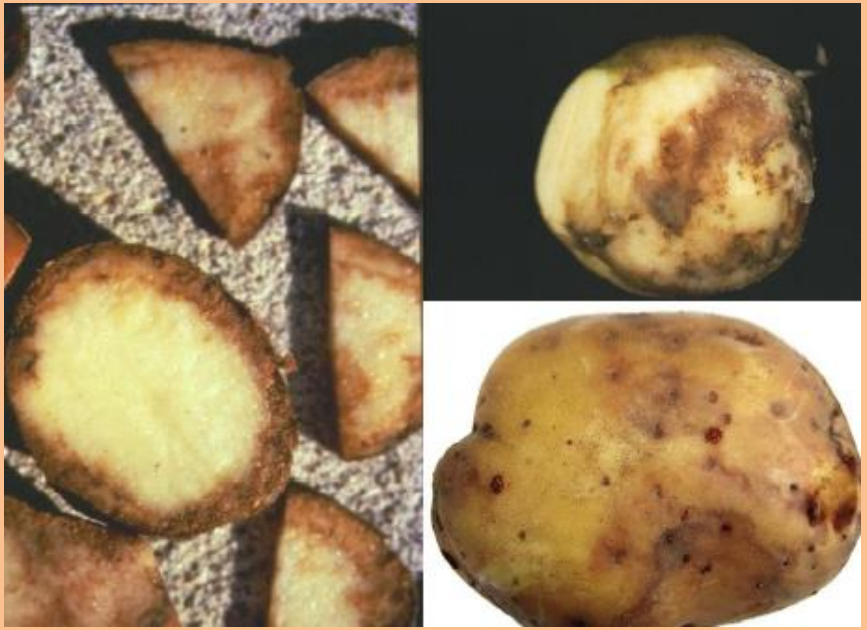
The study of epidemics and the factors that influence them.

Epidemics of past

- The Irish potato famine of 1845–1846 was caused by the Phytophthora late blight epidemic of potato,

- the Bengal famine of 1943 was caused by the *Cochliobolus (Helminthosporium) brown spot epidemic of rice.*

The Irish potato famine of 1845–1846



Elements of an Epidemic

1. Host
2. Pathogen
3. Environment

Interactions of the 3 main components are described by the disease triangle.

Elements of an Epidemic

Host factors

i. Levels of genetic resistance or susceptibility of host

ii. Degree of genetic uniformity of host in a particular field

iii. Type of crops

- Annual crops & foliar or fruit diseases develop much more rapidly (in weeks)
- Perennial woody diseases take longer time to develop (in years)

iv. Age of host plants

- Some plants are susceptible only during growth period & become resistant during mature period

Elements of an Epidemic

Pathogen factors

i. Levels of virulence

ii. Quantity of inoculum near hosts

iii. Type of reproduction of the pathogen

Polycyclic or monocyclic pathogens

iv. Ecology of the pathogen

Depends on the type of pathogen

v. Mode of spread of the pathogen

Air-borne, soil-borne, vector-borne

Elements of an Epidemic

Environmental factors

i. Moisture

- Rain, dew, high humidity
- Dominant factor in diseases caused by oomycetes, fungi, bacteria & nematodes

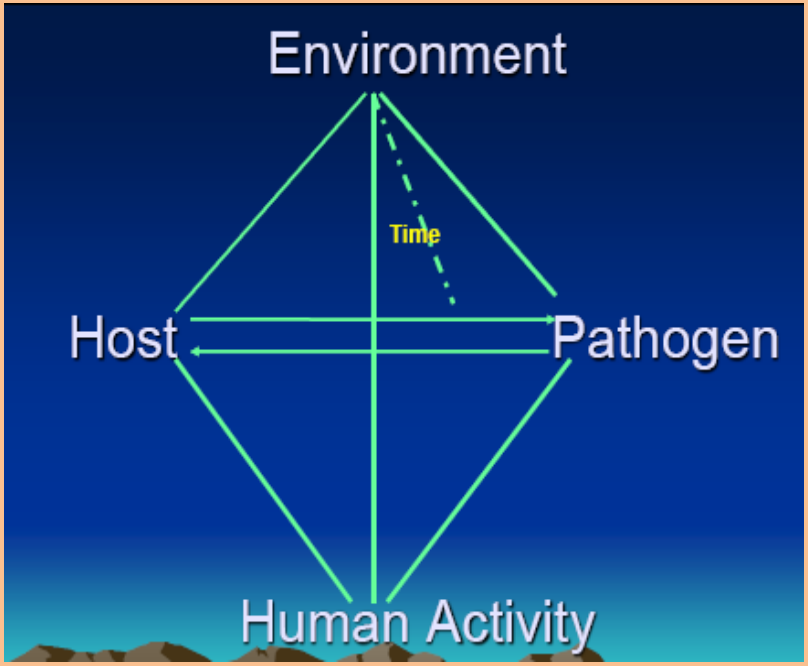
ii. Temperature

- Affects disease cycles of pathogens

Disease development is also affected by

4. Time
5. Humans
   - –Interactions of the 5 components are described by the disease pyramid.

Disease Tetra-hedron/Disease pyramid



- Susceptible host
- Virulent pathogen
- Favourable environment
- Development of disease is affected by
  - ✓Duration & frequency of each element of over time,
  - ✓Duration & frequency of favourable environment

Interrelationships of the factors involved in plant disease epidemics.

Elements of an Epidemic

Time factors

- Season of the year
- Duration & frequency of favorable temp. & Rains
- Appearance of vectors, etc.

Human factors

- Site selection & preparation
- Selection of propagative materials
- Cultural practices
- Disease control measures

Patterns of Epidemics

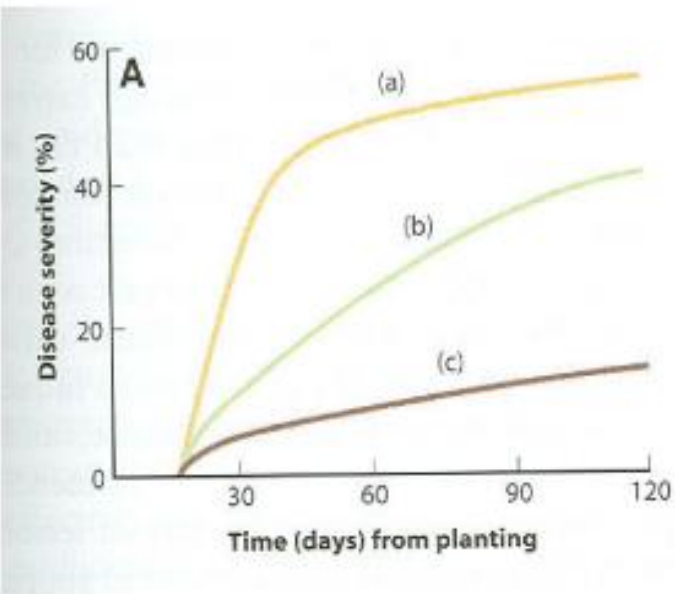
1. Monocyclic diseases

- Examples: root diseases, wilt diseases
- Long disease cycle (complete 1 cycle/year)

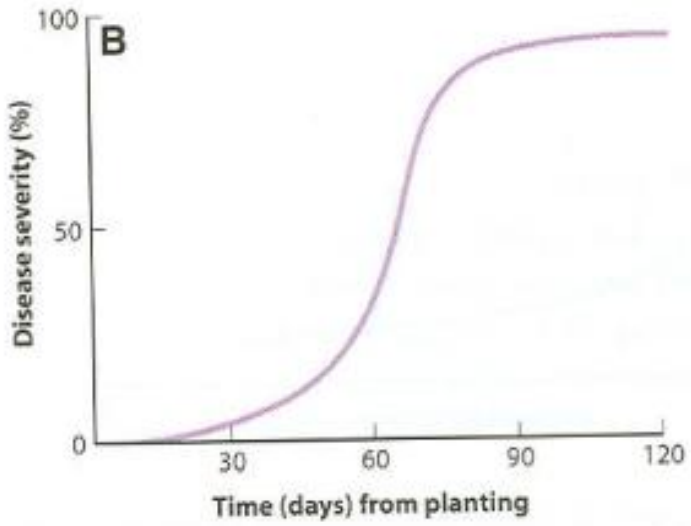
2. Polycyclic diseases

- Examples: leaf rust, leaf blight, leaf spot, mosaic
- Short disease cycle (produce many generations in 1 growing season, 2-30 cycles/year)

Disease-progress curve



Three monocyclic diseases of different epidemic rates.



Polycyclic disease, such as late blight of potato.

Source: Agrios (2005)

Basic epidemic patterns

Saturation-type curve: monocyclic diseases

Sigmoid curve: polycyclic diseases

New Tools in Epidemiology

1. Molecular tools

- Polymerase Chain Reaction (PCR), Enzyme Linked Immunosorbant Assay (ELISA), DNA Fingerprinting, etc.
- For rapid & accurate detection & identification of pathogens

2. Data management

- Geographic Information System (GIS), Global Positioning System (GPS), Remote Sensing, etc.
- To assist in disease control strategies

3. Disease modeling & forecasting

- To predict the probability of outbreaks

Late blight of potato

Symptoms (On Potato)

•Symptoms of late blight of Potato are **small, light to dark green, circular to irregular-shaped water-soaked spots**. These lesions usually appear first on the lower leaves. Lesions often begin to develop near the leaf tips or edges. The pathogen on the lower surfaces of the leaves was **seen as a white downy mass**. The disease is at most aggressive under damp conditions and will **rapidly kill all the aerial parts of a plant**. A cycle of infection to sporulation can take as little as four days. **If there is a dry period, the disease pauses but will resume when the weather turns damp again.**

• Infected potato tubers show surface damage only, but the damage may **allow other microorganisms to enter the tuber and destroy it**. The rot can be so severe that entire fields may smell of rotting vegetation.

Late blight of potato

- **Causal Organism: The pathogen that causes late blight of Potato (*Solanum tuberosum*) is *Phytophthora infestans***

Control measure:

1. **Cultural practices: certified seed of potatoes should be used for planting,**
2. **Potato waste should be burned or treated with herbicides as should volunteer plants.**
3. **Disease-resistant varieties**
4. **Avoid frequent or night-time overhead irrigation of potatoes.**
5. **The infection can be treated by repeated spraying with fungicides including: Chlorothalonil, Copper preparations such as Bordeaux mixture;, Mancozeb; Maneb; Metalaxyl; Ridomyl/ Bravo, TPTH.**
6. **Harvest should not be started until plant are completely dead**
7. **Remove infected tubers before storage**
8. **BIOLOGICAL CONTROL**

With antagonistic fungi and bacteria, mycorrhizae, antibiotics

I. **Fungi: *Trichoderma harzianum, Verticillium dahliae***
II. **Bacteria: *Pseudomonas syringae, Bacillus subtilis***

Bordeaux mixture

Bordeaux mixture consists of cupric sulfate or copper sulfate ($CuSO_4$), Lime and Water. Bordeaux mixture is used most frequently to prevent grapevine mildew, apple scab, pear scab, and spots on stone fruits. Its fungicidal activity is associated with the slow formation of copper compounds, the ultimate toxicant being the cupric ion.

Bordeaux mixture (Composition)

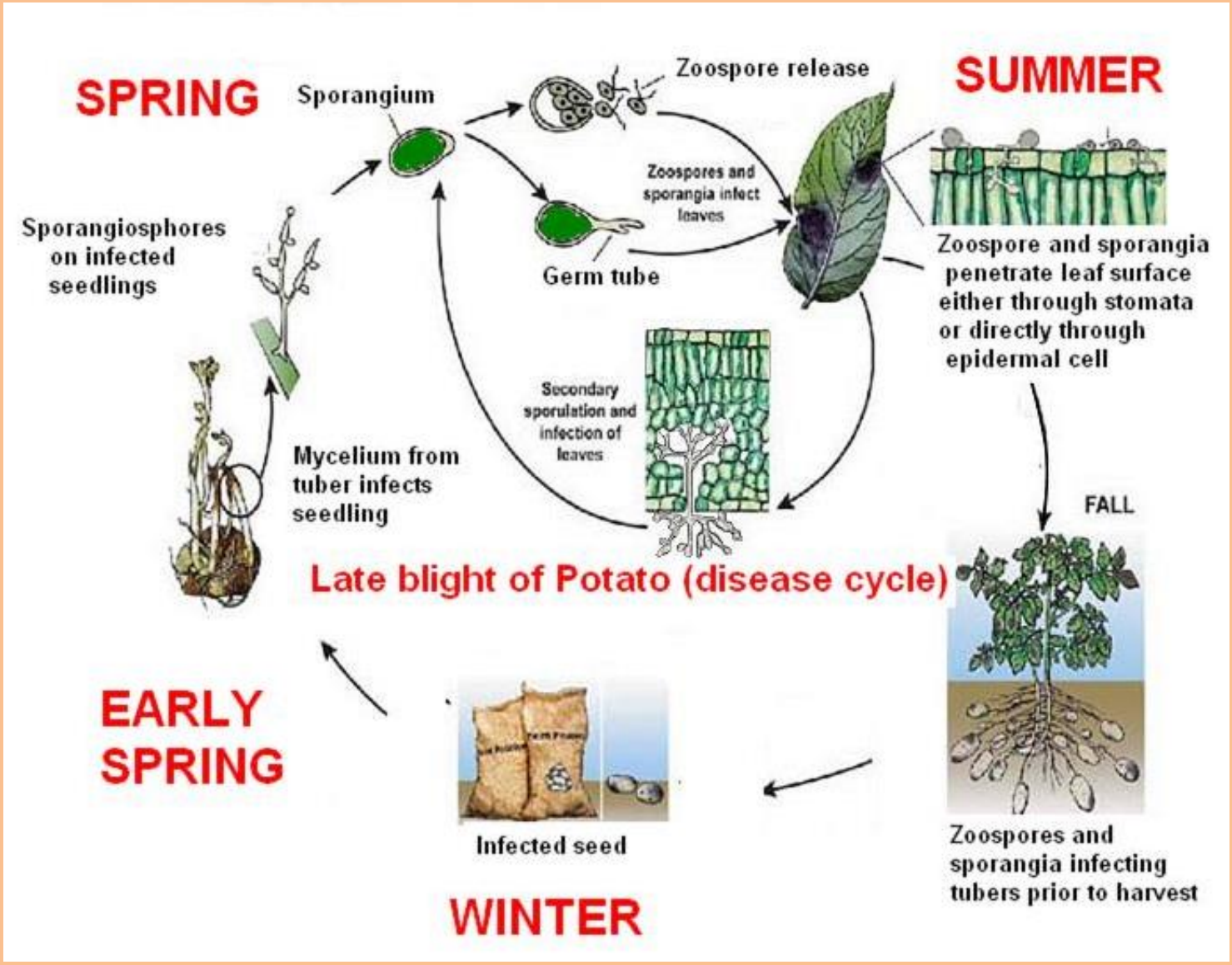
I.	Copper sulfate ($CuSO_4$)	1 Kg
II.	Calcium hydroxide $Ca(OH)_2$	1Kg
III.	Water	100 Litres

Fungicide

Any toxin used to kill or inhibit growth of fungi (*see* fungus) that cause economic damage to crop or ornamental plants (including rusts in cereals, blight in potatoes, mildew in fruits) or endanger the health of domestic animals or humans.

A. Vitavax .....(5,6-dihidro-2-methyl-1,4-oxathiin-3-carboxanilide)
B. Granozan .....(.Ethylmercuric chloride)
C. Captan .....(*N*-trichlorome-thylthio-3a,4,7,7a-tetrahydrophthalimide)
D. Karathane ....(2,4-dinitro-6-(2-octyl)-phenyl crotonate)
E. Zineb .....(Zinc ethylenebis (dithiocarbamate)

Disease Cycle: Late blight of potato



Black steam rust of wheat

Symptoms (On wheat)

- Plants do not usually show obvious disease symptoms **until 7 to 15 days after infection** when the **oval pustules** (**uredinia**) of powdery, **brick-red urediniospores** break through the epidermis. Microscopically, these red spores are **covered with fine spines**. The pustules may be abundant and produced **on both leaf surfaces and stems of wheat**. Later in the season, pustules (**telia**) of black **teliospores** begin to appear in infected grass species Microscopically, **teliospores are two celled and thick walled**.

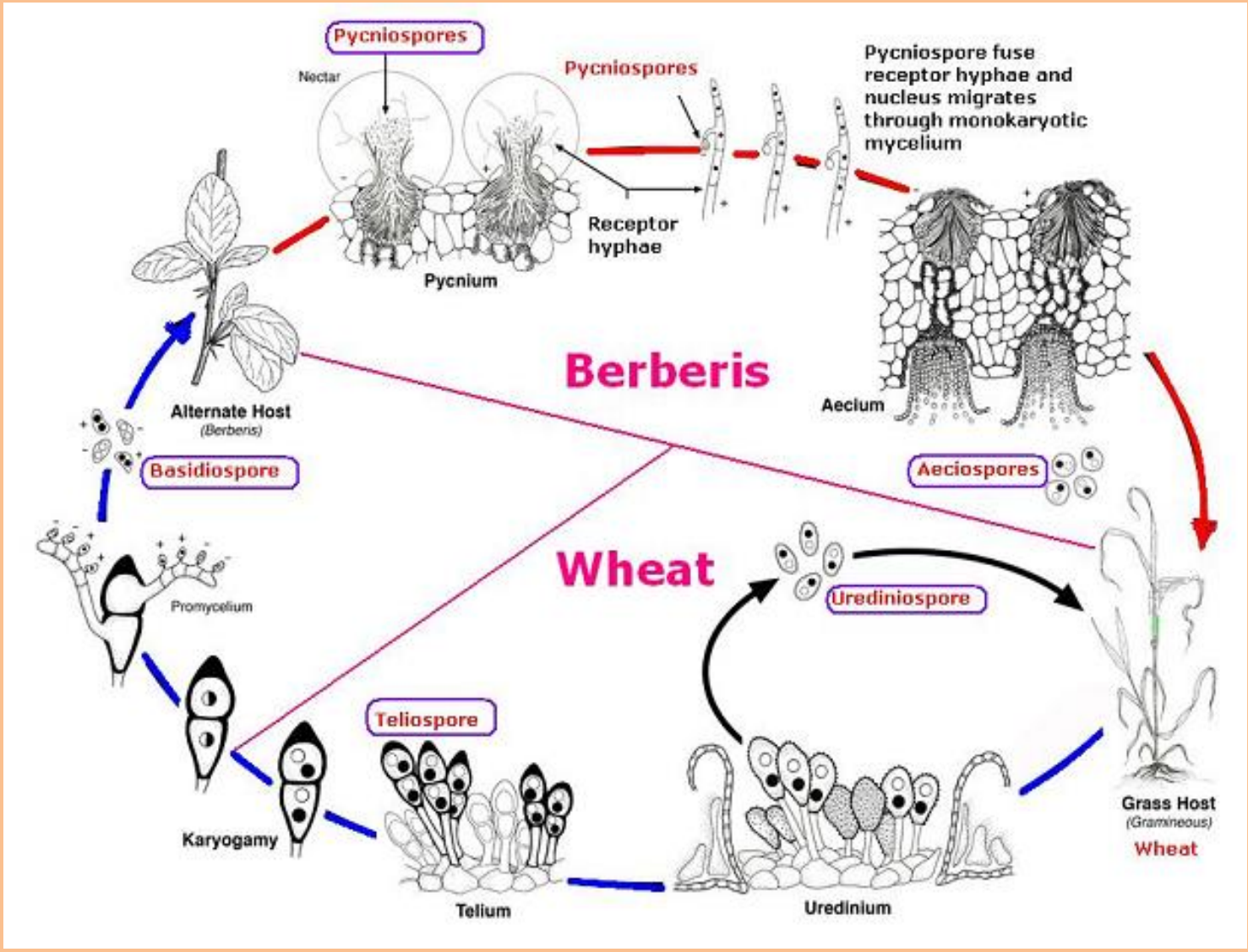
Black steam rust of wheat

Causal Organism: The pathogen that causes stem rust of wheat (*Triticum aestivum*) is *Puccinia graminis* f. sp. *tritici*.

Control Measure

a. Cultivation of resistant varieties
b. Cultivation of early sowing and early maturing varieties
c. Avoiding thick sowing and heavy irrigation
d. Destroying the weed plants and diseased tillers
e. Avoiding heavy doses of nitrogenous fertilizers
f. Judicious use of potassic fertilizer helps in minimizing the susceptibility of plants

Disease cycle: Stem rust of wheat



Plant Disease Control

Principles of Plant Disease Management

- Pathogen Exclusion
- Pathogen eradication and
- Reduction of inoculum
- Plant protection
- Resistant Varieties
- Integrated Management

Plant Disease Management

- The word '**control'** is a complete term where permanent 'control' of a disease is rarely achieved whereas, 'management' of a disease is a continuous process and is more practical in influencing adverse affect caused by a disease. Disease management requires a detail understanding of all aspects of crop production, economics, environmental, cultural, genetics and epidemiological information upon which the management decisions are made.
  - **But Prevention is better then cure**

Principles of plant disease management:

There is six basic concept or principles or objectives lying under plant disease management

1. Avoidance of the pathogen
2. Exclusion of the pathogen
3. Eradication of the pathogen
4. Protection of the host
5. Disease resistance
6. Therapy

1. Avoidance of the pathogen: Occurrence of a disease can be avoided by planting/sowing a crop at times when, or in areas where, inoculum remain ineffective/inactive due to environmental conditions, or is rare or absent.

2. Exclusion of the pathogen: This can be achieved by preventing the inoculum from entering or establishing in a field or area when it does not exist. Legislative measures like quarantine regulations are needed to be strictly applied to prevent spread of a disease.

3. **Eradication of the pathogen:** It includes reducing, inactivating, eliminating or destroying inoculum at the source, either from a region or from an individual plant (rouging) in which it is already established.

4. **Protection of the host:** Host plants can be protected by creating a toxin barrier on the host surface by the application of chemicals.

5. Disease resistance: Preventing infection or reducing the effect of infection of the pathogen through the use of resistance host which is developed by genetic manipulation or by chemotherapy.

6. Therapy: Reducing severity of a disease in an infected individual.

The first five principles are prophylactic (preventive) procedure and the last one is curative

1. Avoidance of the pathogen: Occurrence of a disease can be avoided by planting/sowing a crop at times when, or in areas where, inoculum remain ineffective/inactive due to environmental conditions, or is rare or absent.

i. Choice of geographical area

ii. Selection of a field

iii. Adjustment of time of sowing

iv. Use of disease escaping varieties

v. Use of pathogen-free seed and planting material

vi. Modification of cultural practices

2. **Exclusion of the pathogen:** This can be achieved by preventing the inoculum from entering or establishing in a field or area when it does not exist. Legislative measures like quarantine regulations are needed to be strictly applied to prevent spread of a disease.

   i. Treatment of seed and plating materials
   ii. Inspection and certification
   iii. Quarantine regulations
   iv. Eradication of insect vector

3. Eradication of the pathogen: It includes reducing, inactivating, eliminating or destroying inoculum at the source, either from a region or from an individual plant (rouging) in which it is already established.

i. Biological control of plant pathogens

ii. Eradication of alternate and collateral hosts

iii. Cultural methods: a. Crop rotation b. Sanitation of field by destroying/burning crop debris c. Removal and destruction of diseased plants or plant parts d. Rouging iv. Heat and chemical treatment of diseased plants

v. Soil treatment: by use of chemicals, heat energy, flooding and fallowing

4. **Protection of the host:** Host plants can be protected by creating a toxin barrier on the host surface by the application of chemicals.

i. Chemical control: application of chemicals (fungicides, antibiotics) by seed treatment, dusting and spraying

ii. Chemical control of insect vectors

iii. Modifications of environment

iv. Modification of host nutrition

5. Disease resistance: Preventing infection or reducing the effect of infection of the pathogen through the use of resistance host which is developed by genetic manipulation or by chemotherapy.

Use of resistant varieties: Development of resistance in host is done by

i. Selection and hybridization for disease resistance

ii. Chemotherapy

iii. Host nutrition

iv. Genetic engineering, tissue culture

6. Therapy: Reducing severity of a disease in an infected individual

Therapy of diseased plants can be done by

i. Chemotherapy
ii. ii. Heat therapy
iii. iii. Tree-surgery