PRINCIPLES OF PLANT PATHOLOGY

Pl. Path. 111 (Cr. Hrs. 3+1)

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An introduction to Plant Pathology

- What is Plant Pathology?
- Objectives of Plant Pathology
- Disease & Disorder
- Plant Pathogens
- Classification of diseases
- Terminology

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**
- **Resulting losses and**
- **Control of plant diseases**

Objectives of Plant pathology

1. Study of origin, causes or reasons. Study of living, non-living and other causes of disease or disorder in plants- **Etiology:**
2. Study of mechanism of disease development i.e. processes of infection and colonization of the host by the pathogen. This phase involves complex host-pathogen interactions- **Pathogenesis**
3. study the interaction between the causal agent and the diseased plants in relation to environmental conditions. Generally at the population level- **Epidemiology**
4. Development of management systems of the diseases land reduction of losses caused by them- **Control/ Management.**

What is health?

The ability to carry out normal physiological functions at a acceptable level consistent to genetic potential.

- **Normal physiological functions include:**
  - **Normal call division, differentiation, and development,**
  - **Absorption of water and minerals from the soil and translocation;**
  - **Photosynthesis and translocation of photosynthates;**
  - **Utilization and storage of photosynthates;**
  - **Metabolism of metabolites and synthates;**
  - **Reproduction;**
  - **Storage of reserves for overwintering or reproduction.**

*Plant pathology is both **science** (of Learning and understanding the nature of disease)*

and

***Art** (of diagnosing and controlling the disease)*

The Concept of Disease in Plants

- plant is healthy, or normal, when it can carry out its physiological functions to the best of its genetic potential.
- **Any deviation- Disease**
- The kinds of cells and tissues that become affected determine the type of physiological function that will be
- For example, infection of roots may cause roots to rot and make them unable to absorb water and nutrients from the soil;
- infection of xylem vessels, interferes with the translocation of water and minerals to the crown of the plant;
- infection of the foliage, (leaf spots, blights, rusts, mildews, mosaics etc.), interferes with photosynthesis

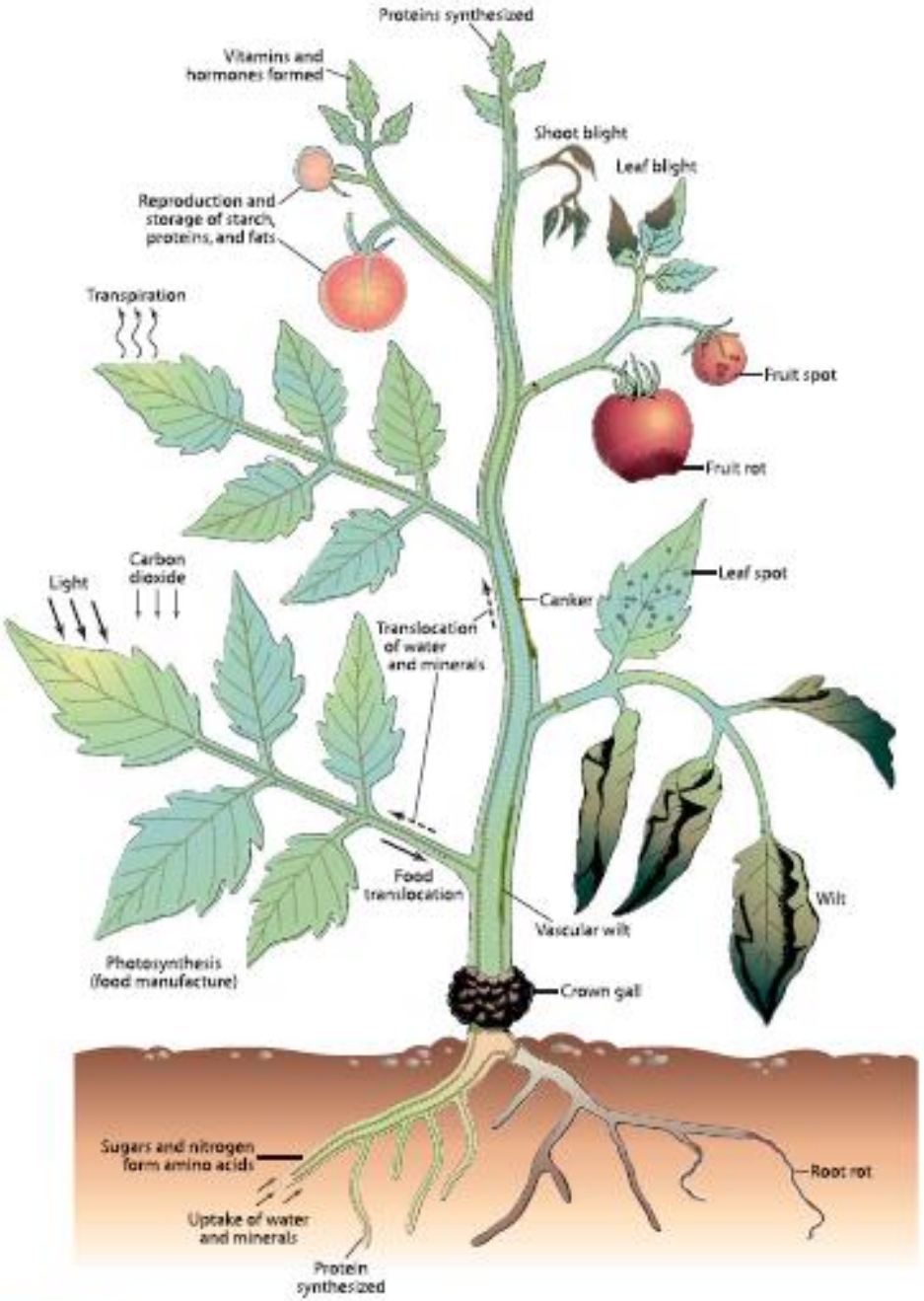


FIGURE 1-1 Schematic representation of the basic functions in a plant (left) and of the kinds of interference with these functions (right) caused by some common types of plant diseases.

What is a Disease

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

- **Disease –**

  the process in which a pathogen interferes with one or more essential plant cell functions

- **Marshall Ward (1901): disease represents a condition in which functions of the plant are not properly discharged.**

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

- **Horsfall & Diamond (1957): Disease can be defined as a physiological disorder or structural abnormality that is deleterious or harmful toe the plant or its part or product that reduces its economic value.**

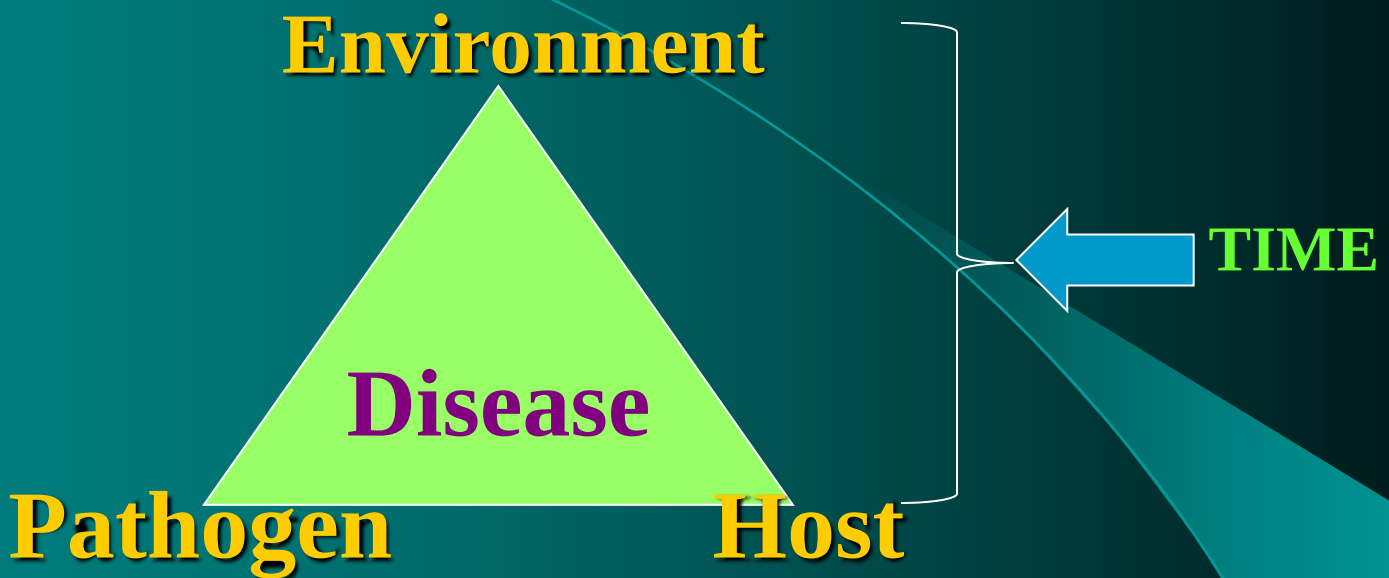
Disease can be defined as the result of interaction between host, pathogen and environment

How Pathogens affect Plants

There are many ways in which plant disease pathogens can affect plants

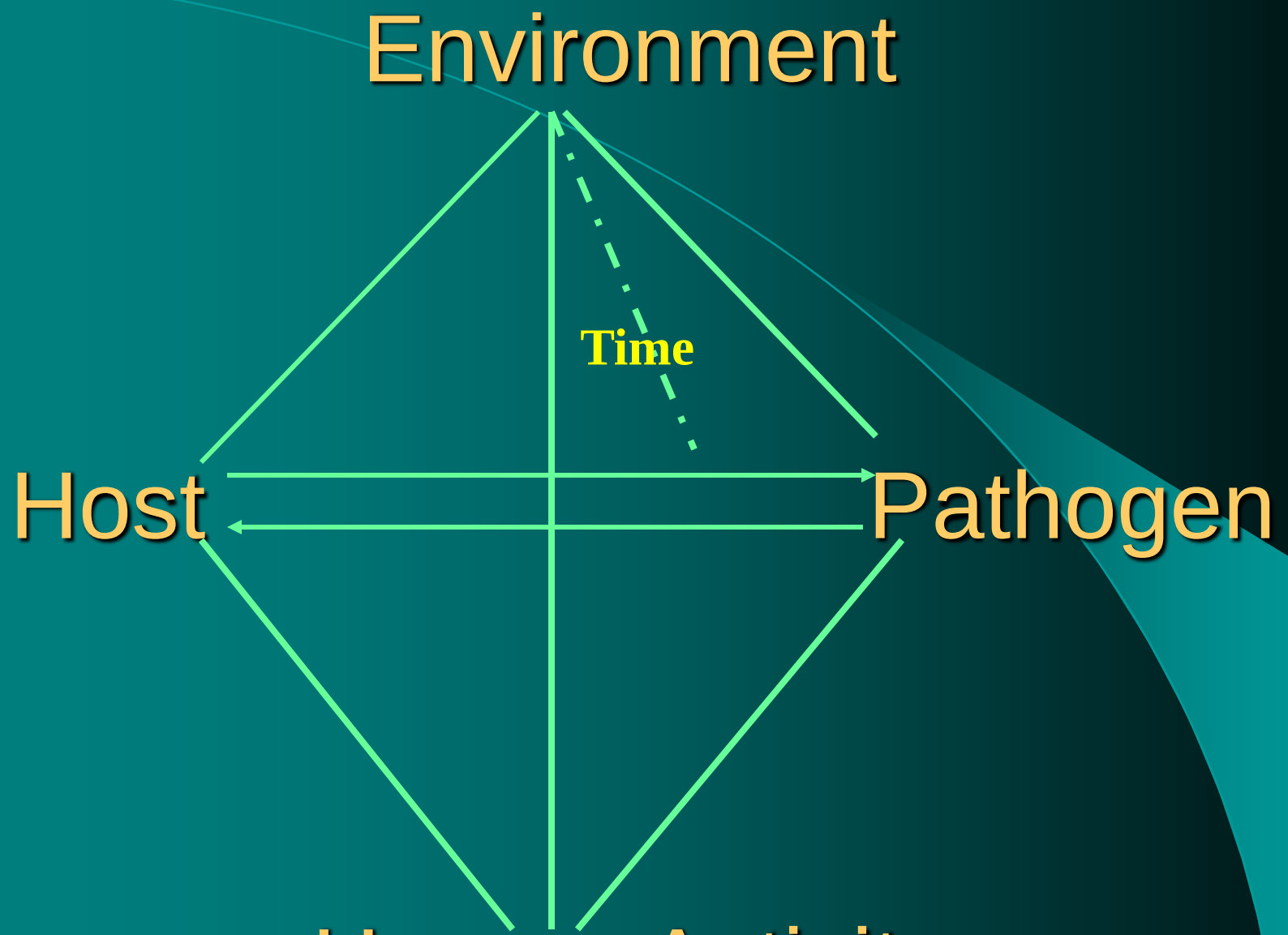
- **By utilizing host cell contents**
- **By killing host or by interfering with its metabolic processes through their enzymes, toxins etc.**
- **By weakening the host due t continuous loss of the nutrients.**
- **By interfering with the translocation of the food, minerals land water.**
  - **They can suppress the chlorophyll content.**
  - **They can reduce the leaf area.**
  - **They can curb the movement of solutes and water through the stems.**
  - **They sometimes reduce the water-absorbing capacity of the roots.**
  - **They suppress the translocation of photosynthates away from the leaves.**
  - **They sometimes promote wasteful use of the products of photosynthesis as in the formation of galls.**

Disease Triangle



Conditions for disease

- Host should be susceptible
- Pathogen should be virulent
- Environment should be favourable for the disease



Disease Tetra-hedron

Classification of plant diseases

- **Based on type of symptoms**
  - Blights
  - Rusts
  - Smuts
  - Rots
  - wilts

- **Based on type of crop**
  - Cereal diseases
  - Vegetable diseases
  - Fruit
- **Based on type of organ affected**
  - Fruit diseases
  - Root diseases
- Based on cause:
  - **Infectious diseases**
  - **Non-infectious diseases**

Plant Disease Agents

- Living organisms - including fungi, bacteria, viruses and nematodes
- Nonliving agents - including unbalanced soil fertility, toxic chemicals, air pollution, frost, drought, sunburn, wind and hail

Infectious Plant Disease Causes

- **Fungi**
- **Bacteria**
- **Viruses**
- **Viroids**
- **Virusoids**
- **Protozoa**
- **Nematodes**
- **Algae**
- **Parasitic Plants**

Non-infectious diseases (due to abiotic factors

- Environmental stress/ excess
  - Temperature e.g. high or low
  - Moisture e.g. excess- rotting or Stress-wilt/drying
  - Air
  - Light e.g. etiolation
- Nutritional imbalance
  - Excess
  - Deficiency e.g. N deficiency, Zn deficiency

Disorder

- Disorder: **Iron Deficiency**

  Abnormal physiological change due to non-parasitic agent or is a non-parasitic physiological malfunctioning due to either excess or deficiency in environmental factors or nutrients.

e.g. Physiological wilt, sun scald, Nutrient deficiency)

Scope & Importance of plant diseases

Scopes & Importance of Plant Diseases

- Plant pathology deals with different aspects of plant diseases and has wide scope than human pathology which only deal with only one aspect
- In recent years plant pathologists have begun to specialize in particular aspect. The field in which notable advances have been made are:
  - Interaction between host and pathogen at chemical, molecular and genetic level
  - Plant virology, chemistry of fungitoxicity
  - Disease forecasting

- On practical aspects much advances have been made in plant protection chemicals; breeding for disease resistance
- Increased population emphasizes the application of all possible means to meet the food requirements
  - Expansion of crop area
  - Improved methods of cultivation
  - Increased use of fertilizers
  - Improved varieties
  - Increased irrigation
  - Crop protection

Importance of Plant Diseases

- Late blight of potato-1841-51 (Irish famine)
- Coffee rust 1867-1870 (Srilanka)
- Downy mildew of grapes (1880s) (France)
- Bengal Famine 1942 (India)
- Bacterial Blight of Rice 1963 (Bihar)
- Southern corn leaf blight -1970 (USA)

Estimated annual losses worldwide

Losses are more in developing world
and
less in develop world

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

Losses caused by Plant Diseases

Examples of Severe Losses Caused by Plant Diseases

Disease	Location	Comments
Fungal		
1. Cereal rusts	Worldwide	Frequent severe epidemics; huge annual losses
2. Cereal smuts	Worldwide	Continuous, although lesser, losses on all grains
3. Ergot of rye and wheat	Worldwide	Infrequent, poisonous to humans and animals
4. Late blight of potato	Cool, humid climates	Annual epidemics, e.g., Irish famine (1845–1846)
5. Brown spot of rice	Asia	Epidemics, e.g., the great Bengal famine (1943)
6. Southern corn leaf blight	U.S.	Historical interest, epidemic 1970, $1 billion lost
7. Powdery mildew of grapes	Worldwide	European epidemics (1840s–1850s)
8. Downy mildew of grapes	U.S., Europe	European epidemic (1870s–1880s)
9. Downy mildew of tobacco	U.S., Europe	European epidemic (1950s–1960s); epidemic in North America (1979)
10. Chestnut blight	U.S.	Destroyed almost all American chestnut trees (1904–1940)
11. Dutch elm disease	U.S., Europe	Destroying American elm trees (1918 to present)
12. Pine stem rusts	Worldwide	Causing severe losses in many areas
13. Dwarf mistletoes	Worldwide	Serious losses in many areas
14. Coffee rust	Asia, South America	Destroyed all coffee in southeast Asia (1870s–1880s) since 1970 present in South and Central America
15. Banana leaf spot or Sigatoka disease	Worldwide	Great annual losses
16. Rubber leaf blight	South America	Destroys rubber tree plantations
17. Fusarium scab of wheat	North America	Severe losses in wet years
Viral		
18. Sugar cane mosaic	Worldwide	Great losses on sugar cane and corn
19. Sugar beet yellows	Worldwide	Great losses every year
20. Citrus tristeza (quick decline)	Africa, Americas	Millions of trees being killed
21. Swollen shoot of cacao	Africa	Continuous heavy losses
22. Plum pox or sharka	Europe, North America	Spreading severe epidemic on plums, peaches, apricots
23. Barley yellow dwarf	Worldwide	Important on small grains worldwide
24. Tomato yellow leaf curl	Mediterranean countries, Caribbean Basin, U.S.	Severe losses of tomatoes, beans, etc.
25. Tomato spotted wilt virus	Worldwide	On tomato, tobacco, peanuts, ornamentals, etc.
Bacterial		
26. Citrus canker	Asia, Africa, Brazil, U.S.	Caused eradication of millions of trees in Florida in 1910s and again in the 1980s and 1990s
27. Fire blight of pome fruits	North America, Europe	Kills numerous trees annually
28. Soft rot of vegetables	Worldwide	Huge losses of fleshy vegetables
Phytoplasmal		
29. Peach yellows	Eastern U.S., Russia	Historical, 10 million peach trees killed
30. Pear decline	Pacific coast states and Canada (1960s), Europe	Millions of pear trees killed
Nematode diseases		
31. Root knot	Worldwide	Continuous losses on vegetables and most other plants
32. Sugar beet cyst nematode	Northern Europe, Western U.S.	Continuous severe annual losses on sugar beets
33. Soybean cyst nematode	Asia, North and South America	Continuous serious losses on soybean

Additional Diseases Likely to Cause Severe Losses in the Future

Disease	Comments
Fungal	
1. Late blight of potato and tomato	New mating type of fungus spreading worldwide
2. Downy mildew of corn and sorghum	Just spreading beyond southeast Asia
3. Karnal bunt of wheat	Destructive in Pakistan, India, Nepal; since the 1980s introduced into Mexico and in the 1990s into U.S.
4. Soybean rust	Spreading from southeast Asia and from Russia; already in Hawaii, Puerto Rico, and South America
5. Monilia pod rot of cacao	Very destructive in South America; spreading elsewhere
6. Chrysanthemum white rust	Important in Europe, Asia, and recently in California
7. Sugar cane rust	Destructive in the Americas and elsewhere
8. Citrus black spot	Severe in Central and South America
9. Sweet orange scab	Severe in Australia
Viral	
10. African cassava mosaic	Destructive in Africa; threatening Asia and the Americas
11. Streak disease of maize (corn)	Spread throughout Africa on sugar cane, corn, wheat, etc.
12. Hoja blanca (white tip) of rice	Destructive in the Americas so far
13. Bunchy top of banana	Destructive in Asia, Australia, Egypt, Pacific islands
14. Rice tungro disease	Destructive in southeast Asia
15. Bean golden mosaic	Caribbean basin, Central America, Florida
16. Tomato yellow leaf curl.	East Mediterranean, Caribbean, the Americas
17. Plum pox	Destructive in Europe, spreading into U.S.
Bacterial	
18. Bacterial leaf blight of rice	Destructive in Japan and India; spreading
19. Bacterial wilt of banana	Destructive in the Americas; spreading elsewhere
20. Pierce's disease of grape	Deadly in southeast U.S.; spreading into California
21. Citrus variegation chlorosis	Destructive in Brazil; spreading
22. Citrus greening disease	Severe in Asia; spreading
Phytoplasmal	
23. Lethal yellowing of coconut palms	Destructive in Central America; spreading into U.S.
Viroid	
24. Cadang-cadang disease of coconut	Killed more than 15 million trees in the Philippines to date
Nematode	
25. Burrowing nematode	Severe on banana in many areas and citrus in Florida
26. Red ring of palms	Severe in Central America and the Caribbean
27. Pinewood nematode	Widespread and becoming severe in North America

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.**

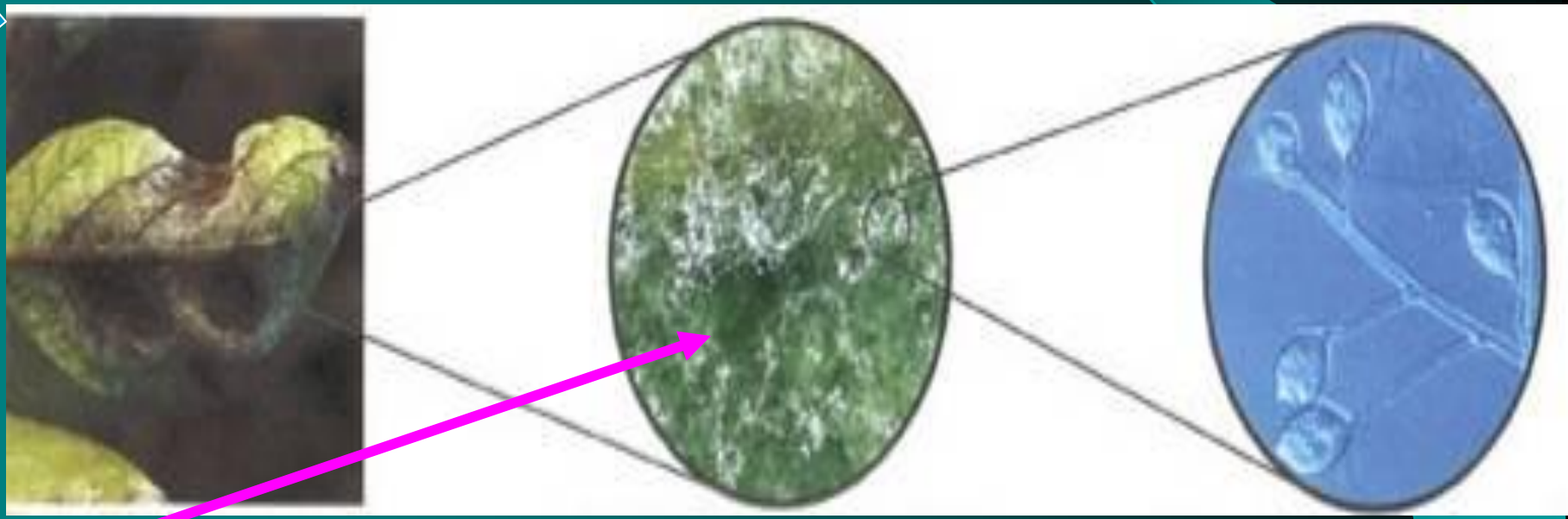
What is Pathogen?

- Any entity that can cause disease in a host

  eg. Fungus, Bacteria, virus, Phytoplasma, Viroids, RLO's, Parasitic Plants, Nematodes

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

Biotrophs – do not kill plant cells. They penetrate the cell wall and establish a continuous relationship or move from cell to cell. e.g. Rusts, powdery mildew,

Facultative Parasite:

usually grows and completes life cycle on dead material, but can do so on living tissue. Sclerotinia

Facultative Saprophyte:

usually grows and completes life cycle on living tissue, but can do so on dead material. *Phytophthora infestans*

Necrotrophs — kill their host before feeding on the cells or the 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
- 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 defence that minimises crop losses with out restricting the disease development.
- Resistance: Ability of the host to resist the attack of the pathogen
  - Horizontal resistance
  - Vertical resistance
- Hypersensitivity: is the quick death of the host tissue in the vicinity of the pathogen
- Disease escape: it is ability of the susceptible host to avoid the damaging disease stress e.g. unfavorable environment/ growth habit

- 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

Terms describing microbial habitats related to plants:

- Epiphytic = organisms growing on the surface of photosynthetic organisms
- Endophyitc= organisms growing inside the host

- Phylloplane = leaf surface

- Phyllosphere = area surrounding the leaf and impacted by it
-
- Rhizoplane = root surface

- Rhizosphere = area surrounding the root and impacted by it

Plant Pathology- Today & Future

- **Molecular Plant Pathology**
  - **Discovery of WM Stanley in 1935 about proteinaceous nature of the TMV can be considered as beginning of the molecular Plant \Pathology, though two years later, Bawden and Pierie showed the presence of small amount of RNA with it.**
  - **Gierrer & Schramm in 1956 – RNA as infectious not protein and also replicate.**
  - **1941, Beadle & Tatum showed that one gene code for one enzyme**
  - **1942, HH Flor- Gene for Gene hypothesis**
  - **1953, Watson & Crick- DNA in a double helix form – a major discovery**
  - **In mid 1960s , TMV studies helped in elucidation of the gentic code showing that specific base triplet of DNA (and RNA) code for a certain amino acid.**

Plant Pathology- Today & Future

- **In 1970s, study on *Agrobacterium tumefaciens* *T-DNA* contain Ti-Plasmid having many genes, of which two code for growth hormones leading to tumour formation. Later these plasmids were used as vector to transfer genes to other organisms including plants.**
- **Later viruses were also used as vectors in genetic engineering.**
- **In 1984, Albersheim et al., identified a molecule later called elicitor, in the cell wall of the *Phytophthora megasperma* that act as elicitor of the defence response in its soybean host.**
- **In 1984, Staskawicz *et al.*, isolated first avirulence gene from bacterium *Pseudomonas syringae* pv. *glycines***
- **These studies help in understanding of the host pathogen interaction and resistance phenomenon.**
- **In 1986, hrp initially called bacterial hypersensitive response protein , and thought to have role in hypersensitive reaction of bacterial infection but later found to have role in transport of protein in pathogenic bacteria and also the transport of bacteria into plant cells.**

Plant Pathology- Today & Future

- **In 1986, Beachy et al., transformed the tobacco plants (Transgenic) by transferring the cp gene of TMV and impart resistance to TMV infection- such resistance called as pathogen derived resistance.**
- **In 1989, Dickman and Kolattukudi, transformed a fungus by inserting cutinase enzyme coding gene, facilitating direct penetration of its host thus proving the role of cutinase enzyme in direct penetration.**
- **In 1991, Broglie et al., showed that plants transformed with cutinase gene exhibit enhanced resistance to fungi having chitin in their cell wall.**
- **In 1990, Cheim et al., produced a resistant transgenic tobacco with gene coding for stilbene synthetase, a enzyme that synthesise phytoalexin.**
- **In 1992, Johal and Briggs, isolated the first resistance gene (HM-1)from corn against *Cochliobolus carbonum***
- **De Wit isolated the first avirulence gene *(avr9)* in *Cladosporium fulvum* infecting tomato.**

Plant Pathology- Today & Future

- **Similarly, advances were also made in the diagnostic and detection techniques helping in accurate and quick detection and identification of the pathogens.**
  - **ELISA**
  - **Monoclonal antibodies,**
  - **DNA probes**
  - **PCR based methods**
  - **RFLP**
  - **RT-PCR**
  - **IC/RT-PCR**
- **In management of diseases**
  - **Cp mediated resistance**
  - **SAR**
  - **Gene silencing**

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