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Theory Notes

FUNDAMENTALS OF PLANT PATHOLOGY

COURSE No. PATH-121

(3=2+1)

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MUKTAI XEROX 9326177334

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Text Books Recommended

Introduction to principles of Plant Pathology by R. S. Singh, Oxford and IBH Publ. Co. New Delhi (1996).

1. **Essentials of Plant Pathology by V. N. Pathak , Prakash Pbul., Jaipur (1972).**
2. **Plant Pathology by G. N. Agrios 4th edition, Academ, Press, New yourk (1997).**
3. **Introductory plant Pathology by M. N. Kamat, Prakash Publki., Jaipur (1967).**
4. **Plant diseases by R.S. Singh.**
5. **Introductory mycology by Alexopoulos, Minms and Blackwel (2004).**
6. **Introductory Plant Pathology by H.C. Dube.**

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Lecture 1

Importance of plant diseases

Plants are the only higher organisms that can convert the energy of sunlight into stored, usable chemical energy in carbohydrates, proteins and fats. All animals including humans depends on these plant substances for survival.

Plants whether cultivated or wild grow and produce well as long as the soil provides them with sufficient nutrients, moisture, sufficient lights and temperature within a normal range.

Plants however also goes sick, grow and exhibit various types of symptoms and sometimes whole plant die. It is not known whether diseased plant feel pain or discomfort. If a plant is looking different from its community then it is equal to be diseased one . Any biotic or abiotic agent which induce the disease in plant is referred as the cause of diseases.

The causative agents of disease in plants are pathogenic such as fungi, bacteria. viruses, protozoa and nematodes and environmental conditions such as lack or excess of nutrients , temperature, light etc. presence of toxic chemical in air or soil.

Economic importance of Plant Diseases:

The plant diseases are very important because they causes enormous losses to the cultivated crop. The losses due to plant diseases accounts around 26% in field storage & transportation.

1. Impact of plant diseases on population :

The **late blight of potato** is a famous example in history of plant pathology, the disease assume epidemic proportion in **Ireland in 1845** devastating the whole potato crop. The potato being the staple food of people & because of non availability of it, around 20 lakh people died due to starvation & migration of population to other lands including North American continent.

In India , ***Helminthosporium* leaf spot of rice** devaste rice crop in **west Bengal** in 1942-43 & thousands of people, died because of hunger & migrated to other part of country.

2. Change in Agricultural Pattern :

The diseases like coffee rust in Ceylon had changed the economy of country & shifting to other plantation crop like tea.

In 1885 their was epidemic of coffee rust in Ceylon which devasted the entire coffee rust went down from 228 kg/ acre to 101 kg/acre by 1878, &.because of which by 1893 the coffee export of Ceylon reduced by 93% thus making huge loss. The coffee rust became so Sevier that Ceylon has to shift itself to cultivation of tea.

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3.Food Poisoning :

The poisoning of food due to plant disease is another evil. There is death of people & animal due to consumption of contaminated rye with ergot, which produces toxin fetal to human beings & animals.

Also production of aflatoxin by *Aspergillus flavus* in foodstuff is also fetal to human beings.

4.Impact on Industry : The certain agro industries are also affected due to supply of the diseased raw material for ex. The disease red rot of sugarcane affects the sugar industries because of poor recovery of sugar form such infested material which intern increases the cost of production.

5.Impact on science : The plant disease system had provided a great scope for expanding the areas of human knowledge regarding, Micro-organism, their taxonomy, ecology, physiology & biochemistry, biophysios, genetic, molecular & cellular biology & managements practices for control of crop diseases.

6.Useful plant diseases : The man has commercially exploited the plant disease for economic gain & aesthetic value for ex. Tulip breaking the disease of flower of tulip which cause variegation in flower of tulip are much prized & covered in west.

The fungus *Cytosphaeria mangiferae* infecting the Aquilaria agallocha in Pakistan, produces a fragrant perfume known as 'uttar' in Indian subcontinent is commercially exploi

Definitions and objectives of plant Pathology

Diseases for plants have been known since ancient time.

Definitions.

Disease is defined as a disturbance in the rhythmical equilibrium in the activities of host in respect of structure or physiology or both, leading to the death of a part or entire host, or reduce the economic value of he products.

OR

Disease is a complex phenomenon, it is an interaction between the host, the pathogen and the environment.

OR

Disease is malfunctioning process caused by continuous irritation , which results in some suffering producing symptoms.

The plant disease is therefore, a structural abnormality or physiological disorder or both due to an organism or unfavorable conditions that may affect the plant or its parts or products or may reduce the economic value.

Plant Pathology : It is a science that deals with the study of diseases of plants , their development and control is called plant Pathology or phyto pathology. (Phyton = Plant, Pathos = disease, logos = Science)

Plant disease are caused by **biotic** agents like fungi, bacteria, actinomycetes, phytoplasma, viruses, nematodes, flowering parasites or by **abiotic** agents like unfavorable environmental conditions or nutritional deficiencies. Study of plant

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pathology includes the study of mycology, nematology, protozology, phycology, unfavorable environmental factors, nutritional deficiencies and flowing plant parasites.

Branches of Plant Pathology :

Microbiology : Study of Micro organisms
Bacteriology : Study of Bacteria
Virology : Study of Viruses
Mycology : Study of Fungi
Nematogy : Study of Nematodes
Protozoology : Study of Protozoa
Phycology : Study of Algae

Objectives of Plant Pathology :

Plant Pathology (or) Phytopathology is one among the branches of Agricultural sciences that deals with cause, etiology, resulting the losses and management of plant diseases with following four major adjectives.

i. Study the disease (s) / disorders caused by biotic and abiotic agents (s)
ii. Study the mechanism (s) of disease development by Plant Pathogens.
iii. Study the interaction between plant and pathogen in relation the overall environment.
iv. To develop suitable management strategies for managing the diseases and losses caused by them.

Lecture 2.

History of Plant Pathology

By studying the history of science, we get a better perspective of the subject we come to know the contributions made in that fields the problems that are encountered and the manner in which they are tacked.

The history of Plant pathology is divided into different five eras .

1. Ancient e era : Ancient to 5th Century (476 A.D.)
2. Dark era : 5th to 16th Century (476 A.D. to 1600)
3. Premodern era : 17th Century to 1853 (1600 to 1853)
4. Modern era : 1853 to 1906
5. Present era : 1906 onwards

1) Ancient era : Ancient to 5th Century (476 A.D.)

1. Diseases in plant have taken known since ancient times
2. Rust, blight, mildews, smuts were familiar to Hebrews, Greeks, Romans, Chinese and Indians, Plant diseases were recorded in Vedas (Rugveda,Atharveda) ad early as 1200 B. C.
3. Symptoms and control of disease have been mentioned in "VRIKSHAYURVED" by **Surapal** in ancient India.
4. Diseases even mention of plant diseases has been made in Buddhist literature of 500 B.C.
5. **Theophrastus** (300 B.C.) a great botanist noted occurrence of crop diseases and suggested some remedies to control them. he also wrote about plant diseases in this era.
6. **Lord pliny** 100 A.D . He described plant diseases and suggested some remedies. He believed that disease originates from the plants or from the environment.

2) Dark era (476 A.D. to 1600)

Plant pathology made very title progress during this era. Some Arbians like ibnal-awan described symptoms and control measures for some plant diseases

1440 : Printing was introduced in Europe and this reflected interest in learning Science.

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3. Premodern era 18th century to 1853 (1600 to 1853)

Robert Hooke 1665

The father of cell theory . He had developed or invented first compound microscope. He reported that plant tissues are made up of minute units called as cells.

Antony Van Leeuveen hoek1676

A Dutch worker from Holland. He invented first simple microscope with home ground lenses between two plates. He described different types of protozoa and bacteria as "Little animalcules". All unicellular microorganisms (Protozoa algae and bacteria) were firstly recorded by him.

P.A. Micheli -1729

An Italian Botanist studies several fungi and described their morphology for first time. He studies that fungi originates from spores. Father or founder of Mycology.

John Needham -1743: Reported plant parasitic nematodes in wheat galls.

Carlous Linnaeus -1753: Established Latin Binomial system of Nomenclature of plants and animals in his book "Species Plantarum".

Tillet -1755: Proved that Bunt of wheat is contagious disease and can be controlled by seed treatment.

Prevost -1807: A French Botanist suggested $CuSO_4$ seed treatment for Bunt of Wheat.

This is known as **autogenic or physiologic** period , since plant diseases were distinctly physiologic with tendency towards the mycology. At the end of the period it was clear the fungi were very closely associated with diseases.

In 1845 late blight of potato (Irish Potato Famine) was appeared in Ireland ,over one million people get died and one and half millions get migrated and the history entered the next era.

4.Modern era :1853 to 1906 .

This known as pathogenic period which was devoted the study of role of fungi causing plant diseases.

Anton de Bary 1853 :He Proved that late blight of potato was caused by *Phytophora infestans*. Founder or Father of Plant Pathology.

T.J. Burril 1873 :American Plant Pathologist. He proved bacterial nature of Fire Blight of Apple and Pear (*Envinia amylovara)*

Robert Koch 1876 : Bacterial nature of Anthrax disease in animal (1881) Gelatin is used as solidifying agent in culture media which is replaced is Agar Agar . He described the theory called "**KOCH'S POSTULATES**"

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Steps in Koch's postulate –

1) **Association** : A specific organism can always be found in association with a given disease.

2) **Isolation** :The organism can be isolated and grown in pure cultures in laboratory.

3) **Inoculation** :The pure culture will produce the same disease when inoculated into a healthy susceptible animal.

4) **Reisolation** :It is possible to recover (reisolate) the same organism in pure culture from the experimentally infected animal.

Thus, any microorganism, for being called a pathogen, should fulfill all the above four requirements called Koch's Postulates.

P.A.Millardet 1882-85 : Use of Bordeaux mixture($CuSO_4$ + Lime) for control of Downey mildew of grapes.

Adolf Mayer 1886 : Described TMV and proved that TMV should be transmitted form diseased plant to healthy plants.

Jenson 1887 : Hot water treatment for loose smut of wheat.

E.F. Smith 1890: Father of Phytobactetriology. He worked on bacterial wilt of cucurbit and crown gall diseases.

Iwanowski 1892: Demonstrated that Tobacco Mosaic Virus (TMV) can pass through bacteria proof filters and proved filterable nature of viruses.

Cragie 1827: Showed function of *Puccinia* in rust fungi.

Biffen 1905: Pioneers in Genetic of Plant diseases resistance.

Present era : 1906 onwards.

The present or current era commencing from 1906 has since remarkable discoveries.

J.C. Luthra 1931 : Solar heat treatment for loose smut of wheat.

W.M.Stanley 1935 : He proved crystalline nature of virus. He got Nobel Prize.

F.C. Bowden & Pierie 1936:Nucleoproteinous nature of virus.

G.H. Flor 1955: Gene for gene theory hypothesis.

Doi & Asuyama :Discovered mycoplasma like organisms(MLO) responsible for yellows type of disease.

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Important Contribution of Indian Phytopathologists .

E.J. Butler (1874-1943): Impcrical mycologist at IARI, New Delhi Since 1905 to 1921 and trained many workers in Mycological and plant pathological Research, he wrote a book "Fungi and Diseases in Plants" in 1918. He is called as the "Father of Modern Plant pathology in India"

K.C. Mehta (1892-1950) : Physiology & Epidemiology of cereal rusts in country. Monograph on further studies on cereal rusts in India in 1940.

B.B. Mundkar (1896-1892): Worked on cotton wilt in Bombay state, published **ustilaginales** in India. Pioneer in establishment of Indian Phytopathological society (IPS) in 1947 and Indian Phytopathology in 1918. He worked on Smut Fungi. He wrote a book "Fungi and Plant Diseases".

J.F. Dastur : He worked on "Anthracnose of cotton". Cotton wilt, pink disease of citrus, foot rot of Betelvine. He published 36 original papers of 4 books.

B.N. Uppal: He worked on Downey mildew of maize ,bajara and showed physiological specialization in *Sclerospora graminicola*. He worked on several fungal and bacterial diseases.

G.S. Kulkarni: Downey mildew of Sorghum and Pearl millet. Sorghum Smut.

V.P. Bhide: Bacterial Diseases of plant.

M.J. Thirumalachar:500 research papers, 20 genera and 300 species of fungi. He discovered antibiotic Aureofungin.

G. Rangaswami.: He worked on ,Nematode, bacterial and other diseases. Published 5 books of Micro biology and plant pathology and over 300 research papers.

P.N.Patel.: Bacterial diseases of Plants.

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Terms and concept in Plant Pathology, pathogenesis.

Old concept of Plant disease:

Plant diseases were considered to be a curse and punishment to the people by god for wrong and since they had committed religious belief superstition .

The Greek philosopher **Theophrastus** (300 B.C.)was the first to study and write about diseases of trees, cereals and legumes. He wrote a book named "Enquiry in to Plants". In this book he mentioned his experiences about plant diseases. His experience was not based on experimentation. He being unable to explain diseases. He believed that God controlled the weather that brought diseases. Plant diseases were a manifestation of the worth of God. It is due to religious belief. , superstitions or it is the effect of star, moon and bad wind.

This was continued for almost 2000 years after Theophrastus. After invention of compound microscope in the mid 1600 ,scientist enable to see many microorganisms associated with diseased plants and they come to believe that the mildews, rust and other symptoms observed on plants and microorganism found on diseased plant. Plant parts were the natural product of diseases than the cause and effect of diseases.

Louis Pasteur (1860-63) provided irrefusable evidence that microorganisms arise only from pre-existing microorganisms and fermentation is a biological phenomenon not just a chemical one.

New concept of Plant disease :I

t is accepted that a plant is healthy or normal when it can carry out its physiological functions to the best of its genetic potentials.

1. Cell division, differentiation and development.
2. Absorption of water and nutrients
3. Translocation of nutrients and water synthesis.
4. Photosynthesis.
5. Translocation and Metabolism or store the photosynthetic products.
6. Production of seed or reproductive organs or survival and multiplication.

Whenever the ability of the cells of a plant or plant part to carryout one or more of these essential functions is interfered other by a pathogenic microorganism or adverse environmental factor. The activities of the cells die or plants become diseased.

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Pathogen may cause diseases in plant by :

i) Weakening the host by continuously absorbing food from the host cells for their own use.

ii) Killing or disturbing metabolism of host cells through toxins enzymes or growth regulating substances, they secrete.

iii) Blocking the transportation of food, mineral, nutrients and water through the conductive tissues.

iv) Consuming the contents of the host cells upon contact.

Disease Triangle :

Of large number of groups of living organisms, the fungi, bacteria, mollicutes, nematodes, protozoa, viruses, viroids and parasitic higher plants invade the host plant feed and proliferate in it and induce diseases. A plant becomes diseased in most cases when it is attacked by a pathogen (biotic) or affected by an abiotic agent. Therefore in first case, for a plant disease to occur, at least two components (i.e. Plant and Pathogen) must come in contact and must interact. Even through the host and pathogen come in contact and interact, but if the environmental conditions are not congenial or within a favorable range, then disease can not develop. Therefore the third component, environmental conditions must be favourable for a disease to develop. Each of these three components (host, pathogen and environment) can display considerable variability and as one component changes it affects the degree of disease severity within an individual plant and within a plant population. Varieties/ species of plants may be more or less resistant or susceptible to the pathogen. It may be too young or to old, or plant population grown over a large area may show genetic uniformity, all of these factors can either reduce or increase the rate of disease development by a particular Pathogen. On the another hand pathogen may be more virulent or avirulent. It's density (inoculums) may be very small or extremely more. It may be in dormant stage or may require specific environmental factors. The environment may affect both the growth and resistance of host plans and also multiplication, virulence and dispersal of pathogen. The interaction of the three components of disease have been visualized as a triangle, generally referred to as the "disease triangle" (fig.)

Pathogen :Virulent , abundant and active
Host : Susceptibility, stage and density of crop
Environment : temperature, moisture and wind velocity.

Each side of the triangle represents one of the three components. The length of each side is proportional to the sum of the total characteristics of each components that favour disease i.e. if the host is resistant, matured and widely spaced; the host side and amounts of disease would be small or zero, whereas if the host/ plants are susceptible ,at susceptible stage of growth or densely planted, the host side would be long and the amount of disease could be great. Similarly, the virulent, abundant and active the pathogen, the longer the pathogen side and greater the amount of diseases. Also, more favourable the environmental conditions (e.g. temperature,

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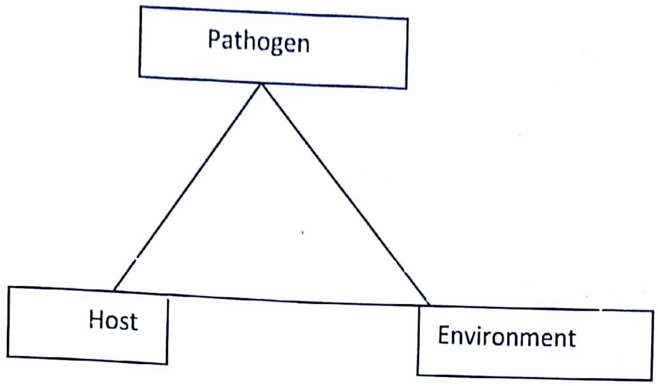
moisture and wind) helps the pathogen or that reduce the host resistance, longer will be the environmental side and greater will be the amount of disease.



When these three components of the disease triangle are quantified, the area of the triangle represents amount of disease in a plant or in a plant population. If any of the three components is zero, there can be no disease.

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Lecture 5.

Classification of plant diseases on the basis of causes :

A. Non infectious diseases :Abiotic causes / factors :
These includes mainly the deficiencies or excesses of nutrients, light, moisture, aeration , abnormalities in soil conditions, atmospheric impurities, etc. e.g. Mango tiprot or fruit necrosis, kaira disease of rice, Hollow and black heart of potato, Nutrient deficiency symptoms in various crops.

Infectious diseases :
1. Mesobiotic causes/factors :
These are disease incitants which are neither living or non living. They are considered to be threshold of life.

1. Viruses –These are infectious agents made up of one type of nucleic acid (RNA or DNA)enclosed in protein coat e. g. Potato leaf roll, leaf curl of tomato and Chilli mosaic .
2. Viroids – Naked infectious strands of nucleic acid e.g. spindle tuber of potato, citrus exocortis , tomato bunchy top.
3. Virusoids, Prions and others.

2. **Biotic causes** : This category includes diseases caused by living or animate or cellular organisms .

1. Prokaryotes –

A microorganism whose genetic material is not organized in to membrane bound nucleus .

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a. **Mollicutes** –These are wall less prokaryotes that includes Mycoplasma Like Organisms (MLO) and Spiroplasma and Spiroplasma , e. g. Grassy shoot of sugarcane , little leaf of brinjal , Sandal spike and Papaya bunchy top.

Citrus stubborn and stunt disease – caused by Spiroplasma.

b. **Rickettsia Like Bacteria (RLBs)**These are very small , sometimes submicroscopic, walled bacteria e. g. Citrus greening and pierce`s disease.

c. **True bacteria** – e. g. Brown rot or wilt of potato, soft rot of potato, and vegetables. Leaf blight of rice , citrus canker, sugarcane ratoon stunting disease, Angular leaf spot of cotton .

2.Eukaryotes –

a. **Fungi-** Nearly 70% of disease (major and minor) in any plant species of economic are caused by fungi e. g. Wart of potato Cabbage club root , Potato late blight, Downy mildew, powdery mildew, rust and smut , red rot of sugarcane .

b. **Protozoa** – Heart rot of coconut palm, phloem necrosis of coffee.

c. **Algae** – Red rust of mango, papaya etc.

d. **Metazoon animals (Nematodes)-** Root knot of vegetables molya disease of wheat and barley, ear cockle of wheat, citrus decline .

e **Flowering plant parasites** – Cuscuta , Dodder, Striga, Loranthus .

Classification of Plant diseases on the basis of occurrence & severity :

1.Endemic disease : The word endemic means "prevalent in' and confined to a particular country or district" and applied to disease. A disease is classified as endemic when it is **constantly present in moderate to severe form and is confined to a particular country or district**. e.g . Club root disease of cabbage is endemic in Nilgiri district. Alternaria leaf spot of Onion in Nasik district .

2.Epidemic or epiphytotic disease : A disease usually **occurs widely but periodically in a destructive form** is referred as epidemic or Epiphytotic disease. e.g. Powdery mildew disease in grapevine.

3.Sporadic disease : Sporadic disease is one which **occur at irregular interval and locations and relatively fewer instances**. In reality, sporadic diseases belongings to the epidemic group. e.g. Udubatta disease in rice , Angular leaf spot of cotton .

4.Pandemic diseases : These **occurs all over the word and result in mass mortality**. e.g. Damping of disease of Tomato ,Late blight of potato.

Classification of Plant diseases on the basis of symptoms produced:

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1. **Hypoplasia :** In these diseases there is under development of host tissue due to infection of the pathogen e. g. Bunchy top of Banana , Yellow vein mosaic of Bhendi or Okra.
2. **Hyperplasia :** In these diseases there is over development of host tissue due to production of toxins or growth regulating substances e. g. Root gall, Leaf curl etc.
3. **Terotological phenomenon :** In these case where the plant parts looses their original appetence & takes up different forms. This may be due to genetical or pathological factors e.g. Smut of Jowar, Rust of Wheat.
4. **Necrotic :** Under such symptoms the host tissue is destroyed and killed e.g. Blight, Wilt etc.

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Lecture 6,7,8.

Causes of plant diseases:

Groups of Microorganisms :

1) Bacteria : These are the unicellular, prokaryotic organisms or simple associations of similar cells. Cell multiplication is usually by binary fission.

2) Fungi: These are microbes devoid of chlorophyll, usually multicellular, but are not differentiated into roots, stems and leaves. They range in size from single celled microscopic yeasts to multicellular mushrooms and puff balls. The fungi reproduce by fission, budding or by means of spores borne on fruiting bodies.

3) Algae : These are relatively simple organisms; most primitive types are unicellular. All algal cells are capable of photosynthesis and are found most commonly in aquatic environments or in damp soils.

4) Protozoa : These are single celled, eukaryotic protists differentiated on the basis of morphological, nutritional and physiological characteristics. Some cause diseases in human beings and animals.

5) Viruses : They are very small parasites or pathogens of plants, animals and bacteria as well as some other protists. They can be seen only under electron microscope and can be cultivated only on living cells (obligate parasites).

Fastidious vesicular bacteria :

These are previously called as rickettsia like organisms (RLO)that cause plant diseases and can not be grown on artificial media in the absence of host cell. almost all of them are limited only to xylem/phloem.

A. Phloem inhabiting fastidious bacteria

i Phloem limited bacteria was first observed in 1970 in the phloem of clover and perewinkle affected with clover club disease, later citrus plants were affected with greening disease.

ii. They are mostly rigid rods, non motile, gram negative, 0.2- 0.5 x 1.2 μm in size, bounded by double membrane or a cell wall and cytoplasmic membrane or plasma membrane.

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iii. Both membranes are triple layered and are separated by an electron lucent zone Peptidoglycan is absent.

iv. They are transmitted by leaf hoppers, dodder and by grafting.

Diseases caused : Clover club leaf (Gram negative). Rugose leaf curl of clovers, citrus greening (vector: *Diaphorina citri).*

B) Xylem inhabiting fastidious bacteria

i. In 1973, fastidious xylem inhabiting bacteria was observed in the xylem vessels of grape plant affected with Pierces diseases and alfalfa affected with alfalfa dwarf.

ii. All the xylem inhabiting fastidious bacteria known so far are gram negative, generally rod shaped, non spore forming and non motile, 0.2 – 0.5 x 1 µm in size.

iii. The cells usually have a well defined cell wall and plasma membrane both triple layered in structure. The cell wall consist of an outer membrane, an intermediate lucent zone and an inner dense peptidoglycan layer which separate from the plasma membrane by a electron lucent zone.

iv. These fastidious bacterial cell multiply by fission. They are transmitted by xylem feeding insects like leaf hoppers and spittle bugs.

Diseases caused

a. Gram Positive

Sugar cane Ratoon stunting (*Clavibacter xyli subsp xyli)*

b. Gram negative

Pierces disease of grapes ,Peach phone disease, Plum leaf scald ,Almond leaf scorch, Citrus variegation (*CVC Chlorosis*)

Casual organism : Xylla fastidiosa

Mycoplasmas or Phytoplasma

MLOS'S : Mycoplasmas like organisms

PPLO : Plenuropneumonia like organisms

1. They belongs to class "Mollicutes".

2.Mycoplasma are unicellular ultramicroscopic, prokaryotic, self-replicating, highly Pleuomorphic, filterable organisms / entities.

3. The lack rigid cell wall (hence Pleuomorphic in nature)
But the outer boundary of the cells is the cytolasmic membrane (thus, stain gram negativ also known as triple layered unit membrane."

4.Due to lack cell wall, the cells of mycoplasma Pleuomorphic assuring various shapes v spherical, ovoid and filamentous.

5.The can pass through bacteria proof filters and can be grown in-vitro in living media facultative or obligate anaerobes, hence, they are considered as the microorganis intermediate between bacteria and viruses.

6.They contain both RNA and DNA.

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7.They are non motile, Gram-negative, require sterol or cholesterol for their growth.

8.They multiply by budding and binary fission.

9.They are resistant to antibiotics like Penicillin, Cephalosporin and Vancomycin and susceptible to tetracycline or Chloramphenicol.

Diseases caused by mycoplasma :

They are known to cause "Yellows" diseases in plant.

Economically important plant diseases caused by mycoplasma are sandal spike ,Aster yellows, Mulberry dwarf, grassy shoot of sugarcane, citrus greening, sesamum phyllody, little leaf of Brinjal etc.

They causes diseases in human and animals e.g. pneumonia (*M. pneumoniae*)

Spiroplasma :

Spiroplasma are helical prokaryotes lacking a rigid cell wall, but bounded by unit membrane 8-10 µm in thickness, with RNA (ribosomes) and DNA strand in the nuclear region.

They vary in shape form spherical to slightly ovoid to helical and branched non helical structure. Unlike phytoplasma, they can be cultured on artificial media, colonies on agar have 0-2 to 2.00 mm diameter and appears as granules but some have fried egg appearance. They do not have any flagella and reproduce by fission. They transmitted mostly by leaf hoppers. They are resistant to penicillin but inhibited by tetracycline.

Diseases Caused : Citrus stubborn (*Spiroplasma citri*), Leaf roll, Yellow dwarf of rice, Pear decline, Corn stunt, etc.

Virus

i. Virus are ultra microscopic, nucleoproteinous, self replicating, filterable, noncellular organisms, smaller than bacteria.

ii. Their size ranges from 20 to 300 nm (1 nm = 1/ 1000 µm).

iii. They can be seen under electron microscope, scanning microscope or transmission microscope.

iv. Shape varies from rod shaped (helical) spherical, polyhedral bacilliform or plemorphic.

v. The single virus particle is called as 'viron' Each viron or virus particles is chemical composed of nucleic acid and protein (nucleoproteinous).

vi. Nucleic acid in virus particle is either RNA or DNA but never both. The percentage of nucleic acid is 5-10 % and that of protein is 60-95 %.

vii. RNA may be single or double stranded and DNA is Mostly double stranded.

viii. The protecting protein coat of viron. or virus particles is known as capsid. Smaller sub unit of proteins called as capsomers and nucleic acid protected or enveloped with the capsid is called nucleocapsid.

Viii .They are obligate, intra-cellular parasites, requires living hosts to complete their life cycle therefore can not be grown on artificial media in laboratory.

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ix. They can multiply or reproduce within living hosts or cells by the process of replication of genome (RNA or DNA).

x. They do not have any cytoplasm, cytoplasmic organells and plasma `membrane.

Diseases caused by Viruses

Viruses causes diseases in human, animals and plant, Diseases, in human: small pox, AIDS(HIV), hepatitis, poliomyelitis (polio virus);
Diseases in animals foot and mouth diseases (FMD);
Diseases in Plants : Yellowing, Mosaic, Yellow mosaic, Yellow vein mosaic. Mottling chlorosis, bunchy top, sterility mosaic etc.

Viroid

1. T.O. Diener (1971} coined the term viroid.
2. Viroid are sub-microscope noncellular, infectious, self replication low molecular weight, naked ribonucleic acid (RNA)
3. Size 1/20 of smallest virus.
4. Viroids are naked nucleic acid without cote protein. It is a smallest known agents of infectious diseases (mini virus) with low molecular weight ribonucleic acid (RNA) that can infect plant cells, replicate themselves and cause disease.
5. Genome of the viroid naked (without protein coat). Single stranded (RNA) with 250-400 nucleotide, either linear or mostly circular. Viroids are smaller in size than viruses i.e. 50 nm or 1.3 to 1.3 x 10 molecular wt.
6. Viroids are notable to synthesize protein and replicase enzyme required for replication.
7. Viroids replicate by direct RNA copying in which all components required for viroid multiplication including RNA polymerase (replicase) are provided by the host.
8. Viroids are transmitted by vegetative propagation. Through pollen and seeds.

Diseases caused for Viroids. :

Potato spindle tuber, citrus exocortis, Coconut cadang cadang , tomato bunchy top.

Algae

1 .Algae are eukaryotic (except BGA). Simple plant like microorganisms with rigid cell wall containing chlorophyll they are ubiquitous organisms abundantly present in aquatic environment.
2. They have wide range of shapes and size and the common shapes are rhizoidal, filamentous and mucilaginous.
3. They are aerobic, Photosynthetic organisms, contain three types of pigments chlorophyll, carotenoids and phycocyanin.
4.Most of the algae are photoautotrophic, may reproduce either sexually or asexually.
5.Algae reproduce asexually by binary fission, fragmentation and formation of spores and sexually by formation of zygotes.

Diseases caused by Algae :

Some algae are harmful as they are pathogenic to humans. Parasitic on higher plants. They also cause problem by clogging water pipes, producing algae booms in water reservoirs growing in swimming pools and releasing toxic chemicals into bodies of water.

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Protozoa :

Protous – Primitive Zoon – animal

- Protozoa are single celled (unicellular), non photothetic, eukaryotic animal like organisms.
- Their size ranges form 2-3 micron. They lack rigid cell wall and do not contain chlorophyll.
- They make their movements with the help of cilia, flagella or pseudopodia.
- They are widely distributed in nature particularly in aquatic environment or moist habitats.
- Most of the protozoa are free living but some are symbiotic or parasitic causing diseases in plants animals and humans.
- Free living protozoa are commonly found in salt water fresh water, sand, soil and decaying organic matter.
- Protozoa reproduce sexually or asexually.
- Asexually either by binary fission / by budding or by both means.
- Sexually by fusion of two gametes.
- They have characteristic ability to regenerate the lost parts of the body. e.g. Genera : Amoeba, Paramecium. Verticilia etc.
- The free living protozoa plays an important role in maintaining the ecological balance in nature.
- It helps in purification of water as they utilize the inorganic water and phosphates for their own metabolism.
- It plays an important role in aerobic and anaerobic digestion of sewage by biological sewage treatment, e.g. Aerobic paramecium,

Disease Caused by Protozoa :

- Protozoa found in the stomach of cattle, sheep and termites helps in digestion of food (cellulose).
- It causes diseases in animals and humans e.g. Malaria caused by plasmodium malariae and sleeping sickness in human beings.

Lecture 9

FLOWERING PLANT PARASITES (PHANEROGAMS)

Most of the diseases are caused by fungi bacteria and viruses. There are few seeds plants called flowering parasites (Phanerogams) which are parasitic on living plants. Some of these attack roots of the host, while some parasites on stem. Some are devoid of chlorophyll and entirely dependent on their host for food supply, while other have chlorophyll and obtain only mineral constituents of food from host by drawing nutrition and water they are called as Holoparasites or complete or total parasite. They have haustoria as absorbing organs, which are sent deep into the vascular bundle of the host to draw nutrients, water and minerals.

Flowering Plant Parasites: There are two types of parasites.

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1) **Root Parasites:**
   i) Striga (Partial root parasite)
   ii) Orobanche (Complete root parasite)

2) **Stem Parasites:**
   i) Dodder (Cuscuta) (Complete stem parasite)
   ii) Loranthus (Partial Stem parasite)

1. Root Parasites:

1. Total or Complete or Holoparasite:

Orobanche (Broom rape or Tokra) : It is annual flashy flowering plant growing to height of about 15-50 cm long, yellow or brownish colour and covered by small thin scaly leaves. Flowers appears in the axil of leaves are white or tubular. Fruits appears in the axil of leaves are white or tubular. Fruits are capsule containing and seeds are very small, black in colour remain viable for several years. The hausteria of parasite penetrates into the roots of hosts and draw its nourishment. The growth of the plant is retarded, may die some times. It attacks tobacco, tomato, brinjal, cabbage, cauliflower.

2. Hemi Partial or Semi Root Parasite:

Striga (Witch Weed or Turfula or Talop)
Family Scrophulariaceae

It is a small plant with bright green leaves grows upto height 20-60 cm leaves beers chlorophylls and developed in clusters of 10-20 % host plant. They are obligate parasites therefore, do not obtain all their nutrient from their host root. Flowers are pink in colour, seed are very minute and produce in grate number 5000 to 100000 seeds plant per years. One flower contain 1200-1500 seeds and remains viable upto 12-40 years. Dissemination takes place with rain water, flood, wind and irrigation water. It cause yellowing and wilting of host leaves. It attacks sugarcane jowar, Maize, cereals and millets.

b. Stem Parasites:

1. Total or Complete or Holoparasite:

Cuscuta or dodder (Amarvel, Lovevine) Family: Cuscutaceae.
Genus – Cuscuta
It is non chlorophyllous, leaf less parasitic seed plant.

It is yellow pink or orange in colour and attached to the host. They do not bear leaves but bear minute function less scale leaves is produces flower and fruits. Flower are white, pink or yellowish in colour and found in clusters. Seed are form in capsules. A single plant may be produce 3000 seeds.

The first appearances of parasites is noticed as thread like leaf less stem which devoid of green pigment and twine around the stem or leaves of the host. When stem of parasitic plant comes in contact with host, the minute root like organs. i.e. hausteria penetrates into the host and absorbs. When the relation ship of the host is firmly established, the dodder plant looses the contact from soil.

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These affect plant get weakened and yield poorly the seeds spread by animals, water and implements and remain viable when condition are unfavorable.

It attacks berseem alfalfa, clover, flax, onion, potato, ornamental and hedge plants.

2. Partial, Semi or Hemi Stem Parasites:

Loranthus
Family- Loranthaceae.
It is a partial parasite of tree trunks and branches with brown stem, dark green leaves but no roots.

1. Stem is thick and flattened of the node, appear in clusters at the point of attack which can be easily spotted on the trees.

2. At the point of attachment with the tree, it shows swellings or tumourous growth where the haustoria are produced. It produces flowers which are long, tabular, greenish, white or red colour and found in clusters. It produces fleshy berries with single seed.

3. The affected host plant becomes stunted in growth and dispersal of seed is mostly through the birds and animals. It attacks mango, citrus, apple, guava.

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Lecture 10,11

STUDY OF SYMPTOMS OF VARIOUS PLANT DISEASES

Symptoms produced by fungal plant pathogens

Objectives:

To know about various signs/symptoms produced by fungal pathogens in the plants for correct diagnosis of the disease.

SYMPTOMS: Symptoms are expression of diseased condition. They are expressed internally as well as externally and help in general diagnosis. With the help of symptoms a diseased plant can be identified from a healthy one. However, symptoms alone are not helpful in ascertaining the exact nature of the disease. Similarly, symptoms may result from different causes, unrelated to each other, e.g. chlorosis may be due to downy mildew, viral infection or deficiency like the fever in human being that may be due to wound, typhoid or by maleria.

SIGNS: Signs are the experimental or scientific evidences of the diseases and generally confirmed by various diagonistic techniques. Signs help in accurate diagnosis of the diseases. Signs are the actual presence of the pathogen or its structures on the host or in the host as a result of menifestation, e.g. presence of whitish growth on the leaves in downy mildew of grape or jowar, bacterial ooze in ring disease of potato, etc.

1. **MOTTLING:** Partial destruction of chlorophyll in interveinal area.
2. **STEM GALLS:** The galls are produced due to infection of the fungal pathogens, e.g. white rust of crucifers, loranthus on mango.

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3. **CLUB ROOT:** The malformation of the roots into finger or toe like structure due to infection of the fungal pathogens, e.g. club root of cabbage.

4. **BLIGHT:** There is a general and rapid destruction of plant parts like shoots, leaves, blossoms, twigs, etc. The dead organ turns brown to black showing burnt appearance, e.g. early and late blights of potato, bacterial blight of paddys, etc.

5. **SPOT:** It is localised destruction of the tissues in a more or less circular manner. It is usually found on the leaves, and may develop on stem or fruit. The dead tissues which are in limited area give shapes as angular, round or circular surrounded by yellow, purple, red margin, e.g. eye spot of jowar, tikka of groundnut, angular leaf spot of cotton, etc.

6. **TAR SPOTS AND STREAKS OR STRIPES:** Necrotic area become typically tar stained found in forest trees, palms, grasses and jowar. Streaks are elongation of necrosis, e.g. bacteiral streak of paddy and jowar.

7. **BLAST:** Same as blight but spots are distinct and spindle shaped, e.g. blast of paddy.

8. **DIE BACK:** Dying of plant organ especially stem and branches from the tip downward, e.g. die back of citrus.

9. **EXUDATION:** Secretion of sticky gum like substance due to diseases, e.g. gummosis of citrus.

10. **ANTHRACNOSE:** Distruction of collenchyma and cambium tissue, lesions are sunken in the centre with raised and prominent margin, e.g. anthracnose of grape, chilli, bean, etc.

11. **BLACK HEART:** Blackening of central portion observed in potato due to high temperature and poor ventilation in storage, e.g. black heart of potato.

12. **SCAB :** Destruction of epidermal tissues in the form of scab. Infection is deep seated, e.g. scab of potato and apple.

13. **SHOT HOLE:** Decayed leaf tissues are blown away leaving holes or perforations, e.g. shot hole of ashok and mango.

14. **SMUTS:** The floral parts, usually the ovaries are destroyed and replaced by forming sori, e.g. smuts of jowar, loose smut of wheat, etc.

15. **RUSTS:** The pustules of spores usually breaking through the epidermis are seen on the host. Pustules may be either dusty or compact and white, yellow, brown, red or black in colour, e.g. white rust of crucifers, leaf rust and stem rust of wheat.

16. **ERGOT:** Normal grains are replaced by sclerotia, e.g. ergot of bajra, jowor, etc.

17. **GREEN EAR (Downy Mildew):** Flowers are converted into green and elongated diseased structures, e.g. green ear of bajra, jawar ,etc.

18. **POWDERY MILDEW:** Powdery growth consisting of mycelium and numberous conidia is seen on the host surface, e.g. powdery mildew of pea.

19. **MUMMIFICATION:** These are observed in fruits. The skin of fruit becomes hard and fruit gets shrivelled. Such fruits are called as mummified fruits, e.g. downy mildew of grape.

20. **WILTS:** Wilting or drying of entire plant observed in adult plants. The leaves and other succulent parts loose turgidity, become flaccid and droop. It is typical vascular

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symptom due to plugging of xylem vessels or toxic effect, e.g. wilt of tur, cotton, pea, gram, etc.

21. **DAMPING OFF:** Sudden wilting and collapse of seedlings observed commonly in seed beds. The stem near the soil is affected, becoming constricted and weak, e.g. damping off of seedlings like tobacco, tomato, cabbage, chili, etc.

22. **Pallor:** Partial destruction of chlorophyll in the form of streaks. There is un- healthy appearance of the plant due to deficiency or excess of water or lack of light or reduction in chlorophyll content due to pathogenic organisms, e.g. bajra seedlings affected with downy mildew.

23. **ROTS:** The tenn is applied in cases where affected tissues decay or rot. Infection of parenchyma, pith tissues and various parts. Rot imparts different colour reactions and are designated accordingly.

    a) **Dry rot:** Decay of tissues, even after rotting may sometimes remain firm or hard, e.g. dry rot of potato and corn.

    b) **Soft rot:** Decay of soft tissues, rotting accompanied by softening of the tissue, e.g. soft rot of lemon, mango, tomato, banana, etc.

    c) **Red rot:** Affected tissues become red in colour, e.g. red rot of sugarcane.

    d) **Wet rot:** In addition to softening, there is slimy oozing of liquid, e.g. storage rot in potato, citrus and other fruits, usually due to fungi.

    e) **Root rot:** Destruction of parenchyma of underground stems, e.g. *Rhizoctonia* root rot of cotton, hallow stem of jowar.

    Rots may be described sometimes according to plant part affected, e.g. stem rot (Papaya), collar rot (Groundnut), neck rot (Paddy), rhizome rot (ginger). They are also described after the discolouration produced on infection, e.g. brown rot (Potato) black rot (Cabbage), red rot (Sugarcane), etc.

Symptoms of plant diseases produced by bacteria.

Objectives: To know about various signs/symptoms produced by bacterial pathogens in the plants for correct diagnosis of the disease.

1. **TUMORS AND GALLS:** Tumors are knot like structures or over growth of the host tissue. It is bigger in size, e.g. tumor caused by the infestation of bacteria like *Agrobacterium radiobacter*. Galls are abnormal swelling or blisters or pimples/knot formed on plant parts. The bacteria induces formation of galls in plants by stimulating mature cells to resume meristematic growth. Galls are smaller in size than tumors.
2. **HAIRY ROOT:** Formation of numerous fine roots, e.g. infestation of *Agrobacterium radiobacter* var. *rhizogenes*.
3. **WILTS:** Wilting or drying of entire plant observed in adult plants. The leaves and other succulent parts loose turgidity, become flaccid and droop. It is typical vascular symptom due to plugging of xylem vessels or toxic effect, e.g. bacterial wilt of tomato.

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4. **BLIGHT:** There is a general and rapid destruction of plant parts like shoots, leaves, blossoms, twigs, etc. the dead organs turn as brown to black showing burnt appearance, e.g. bacterial blight of paddy.
5. **SOFT ROT:** The term is applied in cases where affected tissues decay or rot. Infection of parenchyma, pith tissues and various parts. Rot imparts different colour reactions and are designated accordingly, e.g. brown rot (Potato) /soft black rot (cabbage), etc.
6. **CANKERS :** Deep seated infection due to destruction of woody tissues and cambium tissues. Cankers are raised from epidermal surface of the tissue and are rough to touch, e.g. citrus canker, tomato fruit cancer, etc.

Symptoms of plant diseases produced by viral and phytoplasmal plant pathogens

Objectives: To know about various symptoms produced by viral and phytoplasmal pathogens in the plants for correct diagnosis of the disease.

SYMPTOMS OF VIRAL PLANT PATHOGENS

I. COLOUR CHANGE IN LEAVES

1. **Chlorosis:** It is also known as yellowing. there is complete destruction of chlorophyll. when the colour becomes white it is known as etiolation. These symptoms usually caused by viruses, e.g. yellowing of beans.
2. **Vein clearning/banding:** Clearing of veins i.e they turn yellow and leaf lamina remaining green, e.g. yellow vein mosaic of bhendi and hibiscus.
3. **Flecks:** Clearing of veins further turn into translucent appearance, e.g. tristeza virus in *kagzi* lime
4. **Mosaic:** Mosaic caused by virus infection are highly infectious. it is due to partial loss of chlorophyll or chlorosis in uneven patches, e.g. papaya mosaic, tomato mosaic, chilli mosaic, etc.
   a) **Yellow mosaic:** Light green and yellow patches are observed in the leaf lamina, e.g. yellow mosaic of beans.
   b) **Streak:** induction of the streaking on the infected portion mainly on the leaves, e.g. maize streak.
   c) **Mottling :** Partial destruction of chlorophyll in interveinal area, e.g. mottle leaf of citrus.
5. **Ring spots:** The formation of the characteristic chlorotic or necrotic rings on the leaves sometimes on fruit and stem, e.g papaya ring spot disease.
6. **Oak leaf pattern:** Yellow concentric lines extending along main veins, e.g. potato aucuba mosaic virus.
7. **Browning of leaf from tip downward:** e.g. rice tungro virus

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II) ABNORMALITIES OF LEAF SHAPE

1. **Enations and tumours:** Dark green tumor like outgrowth appears on the upper or lower surface of leaves (enation), e.g. pea enation mosaic.
2. **Leaf curl:** Leaves curl upward or downward, e.g. leaf curl of chilli, tobacco,papaya, brinjal, tomato, etc.
3. **Leaf roll:** Leaves roll upward or downward, plants remin stunted and have stiff upright growth, e.g. potato leaf roll, etc.
4. **Fern leaf and shoe string effect:** Leaf famina between veins is poorly developed or not developed at all, e.g. CMV on tomato, etc.
5. **Cupping of leaves:** e.g. papaya mosaic, cow pea mosaic, etc.
6. **Twisting and blistering of leaves:** Uneven growth of leaf lamina, e.g. TMV, CMV in tomato, etc.

III) ABNORMALITIES IN LEAF SIZE: Reduction in leaf size, e.g. CMV on tomato

IV) NECROSIS: Scattered flecks or patches of dead tissues appear on infected tisuues of leaves, stem, fruits, etc., e.g. tomato spotted wilt virus, potato virus X and Y, etc.

V) ABNORMALITIES IN STRUCTURE AND SHAPE OF PLANTS

1. **Stunting/dwarfing (Bushy appearance):** Reduction in size of leaves, flowers, fruits, shortening of internodes and height which results into stunded growth of plant, e.g. bunchy top of banana, pea stunt, etc.
2. **Hairy root and spindle tuber:** The formation of spindle tuber of potato due to infestation of potato spindle tuber virus.
3. **Swollen shoot:** Virus inducing the swollen shoot and the branches, e.g. cocco swollen shoot.

VI) SYMPTOMS ON BARK AND STEM:

1. **Bark scaling:** e.g. Citrus psorosis.
2. **Cracking of bark:** e.g. Citrus exocortis.
3. **Stem pitting:** Pitting and groving of the stem, e.g. citrus tristeza.

VII) SYMPTOMS ON FLOWERS:

Colour breaking (petal or flower break): Colour break symptoms which induces varigation in the colour of flower, e.g. tulip flower mosaic, pea mosaic.

VIII) SYMPTOMS ON FRUITS:

1. **Mottling of fruits:** e.g. CMV in cucumber,
2. **Watersoaked rings:** e.g. Papaya mosaic,
3. **Sunblotch of fruits: e.g.** citrus greening in mosambi.

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SYMPTOMS OF PHYTOPLASMAL PLANT PATHOGENS

1. **Phyllody :** The symptoms marked by vein clearing, stimulation of the axillary buds and transformation of the flower parts into leafy structures termed as phyllody, e.g. sesamum phyllody.
2. **Grassy shoot :** Execssive tillering at the base of infected plants and grassy transformation of the growth, e.g. grassy shoot in sugercane.
3. **Greening :** Marked by yellowing of the midrib and lateral veins of mature leaves, vein banding, distortation of leaves and blotching on the fruits, e.g. citurs greening.
4. **Little leaf:** Extreme reduction in the size of the leaves and leaves become sessile, thin, soft glabrous and pale green, e.g. little leaf of bringal.
5. **Sandle spike**: The symptoms are marked by severe reduction of leaf size and shorting of the internodes as a result leaves become stiff and crowded giving spiked appearance, e.g. sandle spike.
6. **Stunting and dwarfing (Bushy appearance):** Reduction in the plant size, leaf lamina, node and internodes because of the infection of the phytoplasmal plant pathogen, e.g. rice and barley yellow dwarf. In case of rice yellows disease induced by the phytoplasma show profuse tillerning and pronounced stunting occures.

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Lecture 12-14

General characters of fungi

1. Vegetative thallus :

The body of the fungus is called as thallus, which is without stem, root and leaves, some fungi may be unicellular (yeasts) while. Some fungi may be multicellular (moulds). A single thread like filament is called as hypha. A hypha is made up of a thin, transparent, tubular wall filled or lined with a layer of protoplasm.

A group of hypha / network of hyphae constituting the body of fungus is called as mycelium. Mycelium may be septate or aseptate i.e. coneocytic or nonseptate.

a) Nonseptate or aseptate or coneocytic mycelium :

When mycelium is not divided by cross walls called as non septate mycelium.

Depending upon the nature of parasitism with the host plant, mycelium is either ectophylic or endophytic.

b) **Septate mycelium :**
When mycelium is divided by cross walls or septa called as septate mycelium

i) **Ectophytic mycelium :**
The hyphae grows on external surface or epidermal cells by means of special sucking organs called as houstoria. e.g. powdery mildew fungi.

ii) **Endophytic mycelium :**
When hyphae grows inside the epidermal layer of plant or host tissues, is called as endophytic mycelium e.g .downey mildew fungi. Endophytic mycelium is of following types. Intercellular b) Intracellular c) Vascular

a] Intercellular mycelium
Mycelium growing in between the cells e.g. Rust fungi

b] Intracellular mycelium
Mycelium growing within the host cell e.g. Smut fungi

c] Vascular mycelium
Mycelium growing in vascular tissues of the plant. e.g. wilts.

2. Cell wall

Cell wall is well defined, typically chitinised which contains chitin or. Cellulose or both (cellulose in oomycetes), living structure of the cell coiled as organells (cytoplasm, nucleolus and protoplasm) .Nonliving structure of the cell called as Inorganells (chitin, cellulose).

3. Nutrition

In fungi nutrition is heterotrophic i.e. photosynthesis lacking and absorptive (They lack chlorophyll and can't manufacture their own food from CO_2 and water). Their mechanism of nourishment is absorption which takes place by osmosis through the cellwalls.

Fungi are divided into three groups according to the manner. They obtain their food as.

1.Saprobes. 2. Symbionts. 3. Parasites or hyper parasites.

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1. **Saprobes or Saprophytes:**

These organisms which requites dead organic matter to complete its life cycle is called as saprophytes. e.g. Mucor and Rhizophus.

2. **Symbionts or Symbiosis:**

When two dissimilar organisms lives together in close association for mutual benefits is called as symbiosis. When two or more organisms lives together in close association for mutual benefits is called as mutualism.

e.g. Lichen – Fungus and algae, Mycorrhiza - Fungi and roots of higher forest plants.

3. **Parasites:**

An organism which obtain its food form living tissues of the plants or animals is called as parasite. OR

An organism which completely depends on its host for food, called as parasite.

Among the parasite one can distinguish different degree of parasitism as i) Obligate parasites ii) Non obligate parasites iii) Facultative saprophytes iv) facultative parasites.

i] **Obligate parasites or biotrophs.**

ii] **Nonobligate parasites or Necrotrophs**

Those organisms when kills the tissue in advance of penetration and then lives on it as saprophyticaly. e.g. Sclerotium rolfsii, Claviceps, Ventruria.

iii] **Facultative saprophytes**

These are the organisms which are usually parasites in their mode of life but under certain conditions they become saprophytes. e.g. Smut, *Sphacelotheca* sp.

iv] **Facultative parasites**

These are the organisms which are usually saprophytic in their mode of life but under certain conditions they become parasites. e.g. Pythium, Phytopluthora.

5. **Nuclear status:** Eukaryotic multinucleate, mycelium being homocakaryotic. Heterokaryotic or haplold or diplold or dikaryotic (limited duration). Well defined structures i.e. nuclear membranes nucleolus. Chromatin material.

6. **Sexuality :** Sexual or asexual and homo or heterothallic
7. Life Cycle: Simple to complex
8. Sporocarps: Microscopic or macroscopic and showing limited differentiation
9. Distribution: Cosmopolitian of all parts of world.

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Definition of fungus, somatic structures types of fungal thalli and modifications.

Definition : **Fungi** is defined fungus as eukaryotic / nucleated, spore bearing, achlorophyllous organism generally produced by sexual / asexual method and whose filamentous branched somatic structure is typically covered by cell wall and cell wall further consist of either cellulose or chitin or glucon or some other complex organic carbohydrates.

Sucking organs :

1. **Haustoria :** They are nothing but organs for absorption. It is the lateral outgrowth of I intercellular or superficial hyphae which will help to absorb food and nutrients form the host. They are of different shapes and size ranging from knob like structures is simple, lobed, branched, coiled and they are able to penetrate only in the cell well and not in the plasma membrance
2. **Appressoria (apprimere – to press against):** These are localized swellings of the tip of germ rube or older. Hyphae that develop in response to contact with the host. In simple these are special structures for attachment in the early stage of infection. From these a minute infection peg usually grows and enters the epidermal cell of the host

Types of Fungal Thalli :

1. **Homothallic fungi:** If male and female sex organs or both the gametes are produced on the same thallus, they are self fertile / Self compatible.e.g. Powdery mildew of Mung – *Spharotheca fulginne*.

2. **Hetrothallic fungi:** If male and female sex organs or both the gametes are produced on the different thallus, they are self sterile or self incompatible. e.g. Rust fungi.

Fungus Tissues :

1. Plectenchyma (Gr. Plekein = tp weave + enchyma = infusion) During certain stages of fungal development, the mycelium become organized in to loosely or compact woven tissues as against the loose hyphae ordinarily found in the mycelium.

The plectenchyma is of two types

a. Prosenchyrna b. Pseudoparenchyma

a. Prosenchyma (Gr.Pros = towards + enchyma = infusion)

The loosely woven tissue in which the component hyphae with elongated cells lie more or less paralled to one another is called prosenchyma .Pseudonarenchyma (Gr. Pseudo – fulse + parenchyma – a type of plant tissue)

The fungal tissues which are closely packed in the form of more or less isodiametric or oval cells resembling the parenchyma cells of higher plants are called pseudoparenchyma. Both prosenchyma and pseudoparenchyma compose various types of vegetative (somatic) and reproductive structures shoma is usually made up of prosenchyma while sclerotium is made up .

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Lectuire 15

Reproduction in fungi:

Reproduction is the formation of new individuals having typical characters of the species. Fungi reproduce by spores. Spore is an unit of reproduction.

Asexual Reproduction :

It is also known as somatic or vegetative reproduction and does not involve the union of two nucleus / sex organs.

Methods of Asexual Reproduction :

1. By fragmentation of soma / cell sap / hyphae
2. Binary fission
3. Budding
4. Production of spores

1.By fragmentation of soma / cell sap / hyphae

Mycelium and each fragment grows into a new individual the hyphae break up into their component cells as oidia / arthrospores which behave like spores. If the cells become enveloped in a thick wall before they separate form other hyphal cell, adjoining them are called as chlamydospores e.g. Oidia of Powdery Mildew. Each fragment further germinate to form hyphae.

2.Binary fission

Fission of somatic cell into daughter cells. parent cell divides into two by a formation of constriction or by formation of divider e.g. . Yeast or True fungi

3. Budding

It is the production of bud / small outgrowth form a parent cell. A bud informed, the nucleus and parent cell divides and one daughter nucleus migrates into the bud. Bud increases in size and forms a new individual e.g. Rust and Smut fungi yeast fungi.

4. Production of spores

Spores produced may be conidia / sporangispores basipetal-oldest at the top and youngest at the bottom. Acropetal- oldest at the bottom and youngest at the top.

Sexual Reproduction :

Union of two nuclei or gametes of opposite sex a gamete is unisexual i.e. haploid

The process of sexual reproduction consists of three distinct phases.

1. **Plasmogamy** Union of two protoplast bringing two haploid nuclei together in the same or common cell.

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2. **Karyogamy**

Actual fusion of two haploid nuclei brought together as a result of plasmogamy. Karyogamy immediately follows plasmogamy.

3. **Meiosis**

The nuclear fusion is followed by meiosis (reducing division), meiosis reduces to number of chromosomes to haploid.

The sex organs in fungi are called gametanigia, Gametangia from differentiated sex cells called gametes or may contain one or more gamete nuclei.

Methods of sexual reproduction :

a. Planogametic copulation
b. Gametangial contact
c. Gametangial copulation
d. Spermatization
e. Somatogamy
f. Heterokaryosi
g. Dikaryotization

a. **Planogametic copulation**
Fusion of two naked gametes, one/ both of which are motile. It is completed in three manners.

1. **Isoplanogamtic copulation:** It involves tow motile identical similar gametes but
differs in their physiology e.g. *Synchytricum olpidium*

Isogamous : It male and female are of same shape and size.

2. **Anisoplanogametic copulation:** It involves union of dissimilar motile gametes of
which one is larger than other, e.g. O-Blastocladiales Genus – Aliomyces

Anisogamous : Morphologically dissimilar but distinct is size and shape.

3. **Heteroplanogametic copulation:** Fusion of non-motile female gamete and motile male gamete is known as Heteroplanogametic copulation.

b. **Gametangial contact** .

In this method two gametangia of opposite sex comes in contact and one / more nuclei migrates form male to the female.

The male nuclei enters the female gametangium through a pore developed by the dissolution of gametangial walls at the point of contact while in other species fertilization tube acts as a passage for the male nuclei.

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After the passage of nuclei has been accomplished the organisms continues its development in various ways and antheridium eventually disintegrates, e.g. Oomycetes, Ascomycetes

c. **Gametangial copulation.**

Entire protoplast is transferred into the female gametangia a involves the fusion of two protoplast in a common cell. Sex gametes are indistinguishable / morphological identical. Copulation occurs either by complete fusion of tow protoplast. It is common in class- Trichomycetes and zygomycetes.

d. **Spermatization**

It involes the formation of small spores or seed like structures/ spermatia e.g. Spematiospores

Spermatia acts as a male gamete which is uninucleate/ spore like and carried out by wind, water, insects to the receptive hypha (female gametangium). A pore developed at the plant of contact and the contents of the spermatia passes into receptive hypha which serves as a female organ, e.g.Pycniospores and Receptive hypha is rusts.

e. **Somatogamy**

No gametes are involved. Vegetative hypha itself acts as male and female gamete and bring about sexual reproduction, e.g Smut fungi

f. **Dikaryotization**

Degenerate type of sexuality. It is accomplished through migration of nuclei form one cell to another cell of vegetative hypha, often through mechanism of clamps. The two nuclei remain in pair and divide as such and only fuse prior to the formation of spores. No special sex cells are produced. Clamp connections are formed during nuclear division, e.g. Class – Basidiomycetes

g. **Heterokaryosis**

It is defined as phenomenon of coexistence of genetically different nuclei in the cell and the individual which possess this condition is called as heterokaryotic. e.g. Fusarium, Alternaria.

This process is in the nature of vegetative grafting so commonly met within higher plants and is independent sex. It is 'brought about by hyphal fusion and anastomosis or bridging / vegetative hyphal /carrying nuclei of different genetically reactions and of common occurrence in Fungi Imperfecta, giving rise to new nuclear combination and resulting in the origin of new forms.

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Lecture 16,17

NOMENCLATURE : BINOMIAL SYSTEM OF NOMENCLATURE, RULES OF NOMENCLATURE

Taxonomy

Taxonomy is the science that deals with the identification nomenclature (naming) and classification (systematic arrangement) of organisms.

Nomenclature

It is the system of assigning names to the taxonomic groups / organisms according to international rules.

Systematics

It is scientific study of organisms with the ultimate object of characterizing and arranging them in an orderly manner.

By Binomial system of nomenclature was developed by Carlous Von Linnaeus (1707-1778) which is now universally used. As per the binominal system the name of organism is composed of two words i.e. the first word.a noun indicating the name of genus in which bacterium has been grouped and the second word is and adjective indication the name of species, e.g. *Erwinia amylovora* which in which Erwinia is the genus and coli is the species

Rules of Nomenclature

Following rules should be observed while righting of binomial.
1. The name of the genus should always be capitalized.
2. Species name should not be capitalized.
3. Binomial when written should always be underlined separately; when printed italicized.
4. The name or abbreviated name of the scientist describing the species for first time should be written after binomial e.g. Pseudomonas syringae Val Hall.

If the name is revised, the name of the original describer should be written in bracket followed by the name of the revising scientist
e.g. *Xanthomonas compestriies* pv *oryzae* Ishiyaina Dye.

To avoid confusion the same binomial should not be used to name

two different species.

The year in which organism was described should be written after

the name of the author / scientist.

A sequence of taxonomic categories employed in the classification

of microorganism (**in ascending order**) is given below.

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Sr. No.	Rank	Name Ending	Description
1.	Strain (Type Strain)	--	It is population of organism that descent form of single organism / pure culture isolate
2.	Species	--	Collection of strains having similar characteristics
3.	Genus	--	A group / collection of similar / closely related species.
4.	Family	aceae	A group / collection of similar genera
5.	Order	ales	A group of similar families
6.	Class	ces	A group of similar orders
7.	Division	--	A group of similar classes
8.	Kingdom	--	A group of similar divisions

****

Lecture 18,19

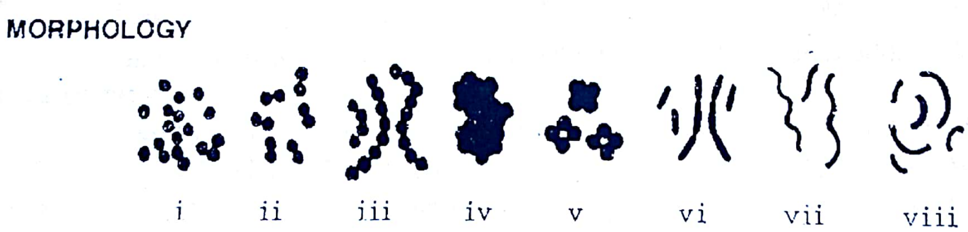
Classification of fungi: Key to division, sub-division ,order and classes..

Lecture 20,21,22

BACTERIA:

Morphology ,Cytology and other characters :

Bacteria are the microscopic, possess rigid cellwall, unicellular, prokaryotic protists lacking chlorophyll and divide chiefly by transverse binary fission. Among the major characteristics of bacterial cells are their size, shape, structure and arrangement, which



constitute the morphology of the cell.

Different morphological form of Bacteria

i Micrococci ii Diplococci iii Streptococci iv Saphylicocci v. Sarchina vi Rod-shaped bacteria vii Sprilla viii Vibrios

I) General structure of bacaterial cell: The main components of a bacteria call are (1) Capsule, (2) cell well (3) Cytoplasmic membrane (4) Cytoplams, (5) Nuclear region (6) Flagellum. (7) Pilli

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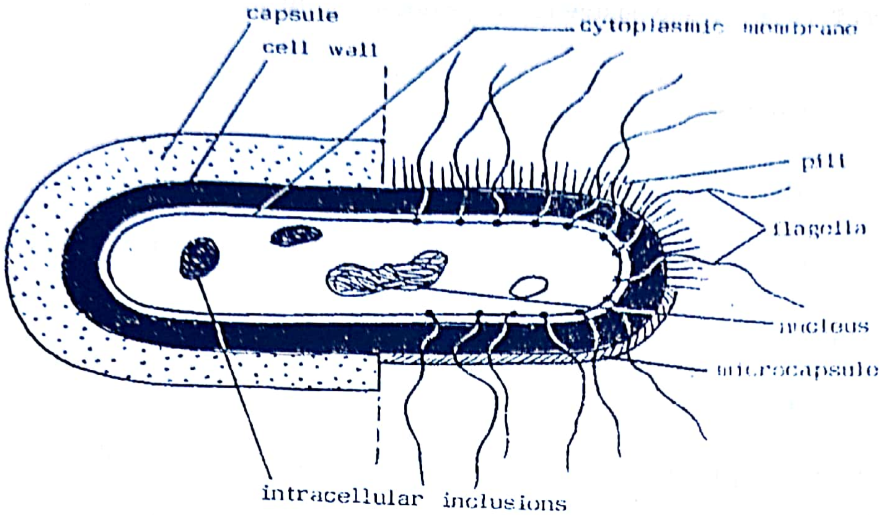

A typical bacterial cell. Right to the dotted line represents the non-capsulated, flagellate rod.

1) **Capsule :** In many bacteria cells develop an enclosing cover of gummy material forming a layer of considerable thickness. This layer is known as capsule or smile layer. Capsule serves as reservoir of food and site for disposal of waste substances. Chemically, it is polysaccharide in nature. It protects the bacterial cell during adverse condition.

2) **Cell wall:** It is a thin, sharply defined, and relatively firm structure beneath the capsule. Bacterial cell wall is rather stable and resistant to the action of most substances except strong acids and alkalis. All the food material which enters in to the cell must diffuse through the cell wall. It is composed of complex carbohydrates, cellulose, chitin, and other polysaccharides.

Bacterial cell wall is rigid and gives definite shape to bacterial cell. Peptidoglycan, a polymer present in the cell wall determine the shape and offers rigidity to cell wall. Cell wall thickness ranges from 10 to 25 nm. Cell wall Constitutes 10 to 40 % dry weight of bacterial cell . Bacterial cell wall has two functions .

1) It gives definite shape to bacterial cell.
2) It is essential for growth and division.

Peptidoglycan is rigidity giving principle of cell wall. It is polymer of a) DPA-diaminopimelic acid b) Muramic acid and c) Techoic acid .

In addition to this it is also contains amino acid, amino sugars , carbohydrates and lipids. Above chemicals join to form polymer of Peptidoglycan.Major building blocks of Peptidoglycan are as below :

1) AGA (Acetyl glucose amine)
2) AMA (Acetyl muramic acid)
3) Peptide : containing four or five types of acids.

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On the basis of structure and chemical composition of cell wall, bacteria are divided in to two groups:

1) Gram +ve bacteria
2) Gram -ve bacteria

A) Gram +ve bacteria :

Cell wall of such bacteria contains an insoluble polymer called Peptidoglycan . Peptidoglycan has major portion of techoic acid and unipartite layered cell wall e.g *Bacillus subtilis* .

B) Gram -ve bacteria :

In addition to **Peptidoglycan** such bacteria also have **lipopolysaccharide,** in their cell wall, which is endotoxin and determines antigenecity, toxigenocity and sensitivity to **bacteriophase.** Chemically gram –ve wall being complex , contain higher **lipid portion** and more **amino acids**. Under electron microscope cell wall shows tripartite structure e.g. ***Escherchia coli.***

Functions of cell wall : 1) Protection of protoplast 2) Maintenance of elongate shape of bacilli 3) helps in flagellar motion 4) Exerts selective permeability.

3) **Cytoplasmic membrane or Plasma membrane:** Extremely thin but distinct membrane surrounding the cytoplasm. It functions as selective membrane, controls passage of nutrients and waste products. Responsible for gram staining reactions.

4) **Cytoplasm :** Inside the cytoplasmic membrane there is a colloidal substance containing 70-90 percent water, known as cytoplasm. It is usually clear or watery or slightly viscous in consistency. Cytoplasmic inclusions consist of
   i) Granules of stored food particles like carbohydrates.
   ii) Droplets of fat may be found distributed into cytoplasm.
   iii) Metachromatic granules of organic metaphosphate may also be present.
   iv) Elementary sulphur is also present in the cells of certain sulphur bacteria in the form of drop lets. Cytoplasmic area – RNA and Nuclear area – DNA.

5) **Nucleus:** Presence of nucleus has been established with certainly only a few years back. It has been shown that all bacteria contain intracellular bodies with the chemical properties expected of DNA which divide in co – ordination with the division of the cell. By following special staining methods with the help of electron microscope, it has been possible to demonstrate the bacterial nucleus. Although composition is still unsettled one. It is however shown that the nucleus consists of tiny granules of chromatin scattered through out the cytoplasm.

6) **Flagella :** They are the organs of locomotion. Most commonly bacterial motility is due to the presence of hair like appendages known as flagella. The flagella vibrate actively and thus propel the organism forward.

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7) **Pilli (Fimbriae):** These are smaller, shorter, numerous, hairlike structures as compared to flagella. They can not produce regular waves. They are visible only with electron microscope and are present in motile bacteria. Pilli have following three functions:

1.They are helpful in adherence to host.

2 They make possible attachment of bacteriophage on bacterial surface.

3 Sex pilli serve as conjugation tube in sexual reproduction of bacteria

e.g. special 'F' pilus in *E. coli.*

8) Plasmid : In addition to chromosomal DNA many bacteria contain exrachromosomal DNA in closed circular double strands form. This unit of genetic material capable of independent replications called plasmid. Plasmids are found in almost every known type of bacterial cell. Most of the plasmids are dispensable i.e. they are not required for survival of cell in which they reside . In many cases, however, they are essential under certain environmental condition such as in the presence of an antibiotic, these helps to tide over the unfavourable environmental condition. There role in modern biotechnology have opened a new era of genetic engineering. Plasmids are autonomous genetic element.

II) Size of Bacteria and its measurements:

Dimensions of micro organisms are expressed in terms of micro – millimeter, abbreviated to micron. One micron is equal to one millionth of a meter. It is 0.001 mm or 0.0001 cm.

Although different species of bacteria vary in size and shape, of each species is constant. Bacteria commonly studied, have size ranging between 0.2 to 0.5 in diameter and 1 to 5μ in length. One trillion bacteria can be arranged in one cubic centimeter. (one trillion = one million million).

III) Shape of Bacterial cells :

Four types of cells are found amongst the bacteria

1) Spherical 2) Rod shaped 3) Spiral 4) Filamentous.

1) Spherical organism is designated as Bacillus.

2) A rod shaped organism is designated as Bacillus.

3) A spiral organism is designated as Spirillum.

4) The term tricho bacteria includes those forms which develop as long filamentous or branched bacteria.

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Arrangement and Grouping of bacterial cells: The bacterial cells are surrounded by a thin (rarely thick) layer of gelatinous material which tends to keep the cells together.

The grouping of cells largely depends upon the manner of multiplication and the direction of the planes of division. It is a general rule that the wall that divides bacterial cell into two daughter cells is formed at right angles to the longer axis. Since Cocci have no longest axis, cell division may occur in any direction.

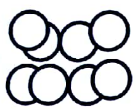
A) Grouping in Cocci. :

1) **Micrococcus** : When daughter cells separate out soon after their formation.

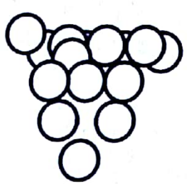
2) **Diplococcus :** When the cells remain attached in pairs.

3) **Streptococcus :** Here successive planes of division are constantly parallel and thus results in a chain of cells.

4) **tetrads** : four cells, cling together forming a square.



5)Sarcina: cells clinging together in cubes made up of eight or its multiple (Cell division in three)



6) **Staphyllococcus** : When the cells remain attached in irregular masses resembling a bunch of grapes.

B) **Grouping in Bacillus**: The rod shaped bacteria may be long or short, usually straight, it may also be some what curved. It may have rounded ends or may be even concave.

Grouping is possible in bacillus because of the division is only in one plane.

1) **Microbacillus** : Separate rods.
2) **Pallisade:** The cells form group in pallisade, like the matchsticks filled in matchbox e.g *Corynebacterium diptheriae*
3) **Streptotacillus** : Rods in chain.

C) Grouping in spirillum.

No grouping in spirillum. They may be thin, broad, short or long.

D) **Tricho bacterium**: Consists of long threads which may be branched or unbranched Branching may be true or false.

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Involution forms: Consistency of form is usually a marked feature of bacteria during its early stages of growth, but in old cultures and under certain conditions which are not favorable for the growth, bacteria may attain abnormal or unusual shapes such as thread like filaments, or club shape etc. these are termed as involution forms . Certain species of bacteria show this character much more readily than others e.g. Root nodule bacteria.

IV) Motility:

Several methods of movement are to be found among the bacteria. Mostly all cocci are nonmotile. Many of the bacilli and spirila are motile. The bacterial movement may be

i) Flagellar movement ii) Flexuous movement iii) Gliding movement.

i)Flagellar movement : Most commonly, bacterial motility is due to the presence of one or more slender, thread like appendages known as flagella.

Different terms are in use to describe the bacteria possessing one or more flagella at various places and they are :-

1) **Atrichous:** Organisms without flagella.
2) **Monotrichous**: Organisms having a single flagellum at one end.
3) **Amphitrichous :** Bacteria with a single flagellum at each end.
4) **Lophotrichous**: Organisms with a cluster or tuft of flagella at one or both ends.
5) **Peritrichous**: Flagella on all over the body.

ii) **Flexuous Movement**: Organisms belonging to groups of Spirochaetes, the cells of which are slender and relatively long, they move about in the same fashion as snakes by bending of the cell body. This type of movement is known as flexuous movement.

iii) **Gliding Movement**: This type of movement is common in the bacteria produces slime. (Myxobacteria, Cyanobacteria etc.) The movement involves progress through secreted slime sheath. When the sheath is attached to the substance, the sheath does not move, but the bacterial filaments does, elongating the tube. If the filament is unattached by its slime sheath, the sheath moves among the filament but does not progress.

V) **Endospore Formation in Bacteria :**

Certain bacteria produce spores inside (within) the cell called endospores. The spore is a metabolically dormant form which, under appropriate conditions, can undergo germination and outgrowth to form a vegetative cell. These structures are unique to bacteria. These are thick-walled, highly refractile bodies that are produced (only one per cell) by *Bacillus, Sporosarcina, Thermoactinomyces* (all aerobic), *Clostridium, Desulfotomaculum* (anaerobic) and a few other genera.

The shapes of endospores and also their location within the cell vary depending on the species. Ex.

Bacillus cereus : Spores are elliptical and centrally located.

Clostridium tetani : Spores are spherical and terminall located.

Clostridium subterminale : Spores are ovoid and sub-terminally located.

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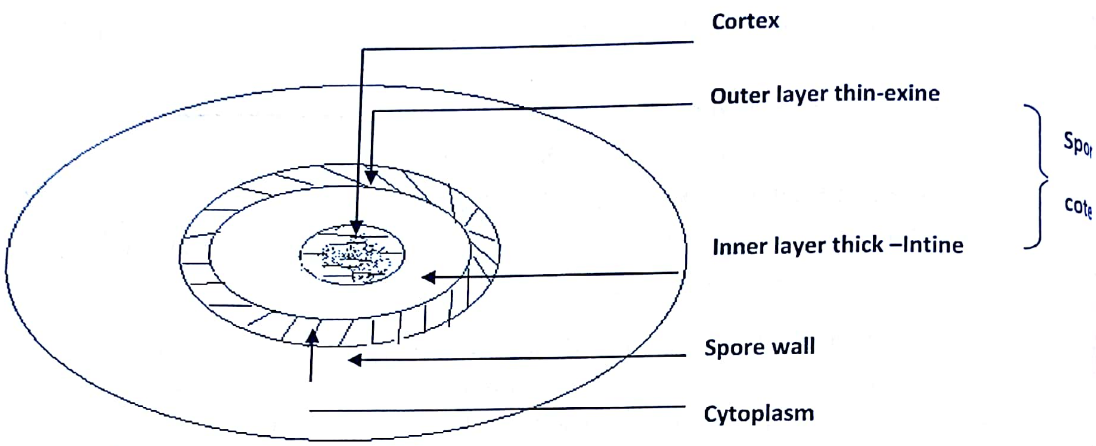
Cells growing in rich media but which are approaching the end of active growth produce endospores. Ageing or heat treatment is needed to activate the dormant spores in a suitable medium. The endospores are extremely resistant to desiccation, staining, disinfectants, radiations and heat. Ex. *Clostridium botulinum* spores resist boiling for several hours. Most can resist treatment at 80°C for at least 10 minutes. During sporulation, dehydration of developing spores occurs. The dehydrated state may be an important factor for heat resistance. All endospores contain dipicolinic acid (DPA) which accounts for 10-15 % of spores' dry weight. It occurs in combination with large amounts of Calcium and is probably located in the core (central part). The Ca-DPA complex formed at advanced stage may possibly play a role in the heat resistance of endospores.



Endospore

♦♦♦♦

Prokaryotes, Classification of Prokaryotes (bacteria) According to Bergey's manual of Systematic Bacteriology

Defn

Prokaryotes : Prokaryotic organisms are those in which nucleus is primitive type and nuclear material is not enclosed within the nuclear membrane.

Bacteria are placed in the Kingdom "Prokaryotae", because of the prokaryotic cellular organization of the members. However, extremely diverse groups of microorganisms (prokaryotic) differing in morphological physiological and ecological properties are found within this kingdom. In the beginning, descriptions and information of bacterial systematics / classification was being published in the comprehensive volumes of " Bergey's Manual of Determinative Bacteriology" (1923 first edition). The 8th edition of Bergey's manual, published in 1974 was the last of such comprehensive manuals and from 1984 onwards it was renamed as "Bergey's Manual of Systematic Bacteriology" it is the most widely accepted and

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used reference document / book for classification and identification of bacteria. Bergey's manual consist of four separate volumes and each volume is further divided into different sections (I[st] volume : 1-11 sections, II volume : 12-17 sections, III volume : 18-25 sections and IV volume : 26-33 sections.).

The classification of bacteria / prokaryotes (of significance in agriculture and allied fields) given in "Bergey's Manual of Systematic Bacteriology" is listed as follows.

VOLUME :1

Section – 1

The spirochetes (order – Spirochaetals), the two important families are i. Leptospiracea, important genus : leptospira and ii. Spirochactacea, important genus is Spirochaels.

Section – 2

Acrooic / microaccrophillic, motile, helical / viborid Gram –negative bacteria, the important genera (o academic interest) in this section are : Azopirillam, Cmmpylobacler and Bdellovibrio. Azospirillam cells are vibrioid with single polar flagellum, present / found within the roots of grasses, wheat, corn and other plants or as. Tree living soil organisms they are either aerobic / microorophilic and fiz N2 within plant roots. Important species are A. lipajernom and A. brasilense.

Section - 3

Non-Motile (or racly motile), Gram-negative curved bacteria : Family-Spirosmacease, Genera : Spirosoma, Runellas and Flectobactillus.

Section – 4

Garm-negative, aerobic rods and cocci : it is one the largest. Section containing inst diverse group of bacteria important in agriculture such as :

i) Family : Pseudomonadaceae, Three important genera are.......

a. Pseudomonas – Several species are pathogenic to humans, animals and plants; cause spoilage of maeat and other foods, specis like P.Syringasc, casue diseases like leaf sport, leaf stripe, wilt and necrosis; P. fluorescens, is a common soil saprophyte that produce a fluorescent pigment.

b. Xanthomonas – produce characteristic yellow pigment Xanthomonadins; all species are pathogenic to plants causing cliseases such as sport, streaks, cankers, wilts and rots. Xanthomonads, produce exoçellular polysaccharides i.e. xanthan gums useful industrial application.

c. slimy masses with fingerlike morphology. Species are saprophytic, commonly found on tricking filter beds, in sewage treatment plants, where they oxidize the organic matter of the sewage.

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2. Family :Azotobacteriaceae.

Two important genera are Azolobacler and dAzomonas. The species are saprophytes, found in soil;wter and plant rhizosphere, ix N2 undr aerobic conditions and forms dessication resistant spores called "cysts"

3. Family : Rhizobiaceae

Three important genera are Rhizobium, Bradyrluzobium and Agroibacterium. Bacteria of the genus Rhizobhom and Bradyrixobium fix atmospheric, N2 sysmbiotically in legumes by inducing root nodules, whereas, species o the gnus agrobacterium, do not fix N2 but they are plant pathogenic inducing zumors in crown, roots and stems of dicoty ledons.

4. Family : Methylococcaceae

Two important genera are Methyoloccus and Methylomonos. Bacteria are obligate methane – oxiders, use methane gas as sole carbon and energy source undr acrobic and microacerophilic conditions.

5. Family : Acetobacteriaceae

Two important genera are Acetobacter and Guucanobacter Member of these two genera are saprophytes, found is sugar / alcohol, enriched acidic environments such as flowers, fruits, bear, wine, vinegar, honey etc. They are industrially important: Acetobacters (peritrichous) are used to make vinegar and Glucanobacters (polar flagella0 are involved in the manufacture of chemicals like dihydroxyacetone, sorbose etc.

Section : 5

Facultative anaerobic Gram – negative rods

Two important families and important genera in respective families are.

1. Family : enterobacteriaceas, important genera are…..

a. Escherichia – e.g. E. coli, inhabitant of lower portion of the intestine of human and warm-blooded animals, causes gastroenteritis and urinary tract infections.

b. Shigella – species are pathogenic, causing bacillary dysentery in humans called shigellosis.

c. Salmonella – All species are pathogenic in humans causing enteric fevers typhoid and paratyphoid fevers, gastroenteritis and septicemia.

d. Enterobacter – Species occur in water, sewage, soil, meat, plants and vegetables. Some species are opportunistic human pathogens.

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e. Erwinia – Species mainly associated with plants causing diseases such as blights, cankers, die-back, leaf spot, wilts, discoloration of plant issues and soil rots.

f. Yersinia – These are parasites of animals but can also cause infections in humans such as plague (*Y.pestis*)

2. Family : Vibrionaceae : Important genera are……

Vibrio, Aeromonas

Most Vibrio are harmless saprophytes, but some species are pathogenic in human,

e.g.*V. cholerae*, causing cholera in humans.

Section – 7 : Dissimilatory sulfate or sulfur reducing Bacteria.

®®The bacteria / organisma belonging to this section are obligate anaerobes using sulfate, sulfur or other oxidized sulfur compounds as election acceptors and reducing them to H2S. These are gram-negative found in mud, and marine environments and in intestinal tract of humans and animals, The important genera are Desulfovibrio (Vibrioid and helieal cells), Desulfococcus (Spherical cells) and desulfosarcina.

Section – 8 : The rickettsias and Chlamydias

These are any, non-motile, Gram-negative bacteria. They an obijgate parasites, able to grow only within host cells, the two important genera are Rickcitisia and Coxiella (Family – Rickettsias). The species of Rickettsias caused diseases like ocky mountain spotted. Fever, classical typhus fever, sarub syphus and the single species of genus Coxiella causes Q fever a type of pneumaonia (Coxiella burnelil).

Section – 10 : The Mycoplasraa

These are very small organisms devoid of cell wall. Because of lack of cell wall, mycoplasmas are not inhibited by penicillin antibiotic; howver, they can be inhibited by antibiotics that affect protein synthesis (e.g. tetracycline or chloramphenicol). They can be cultivated invitro (in laboratory) on synthetic media as facultative anaerobes / obligate anaerobes. Mycoplasmas are placed in the Division – Tenericutes, class – Mollicutes and Order – Mycoplasmatales, containing three families viz.

i. Mycoplasmataceae, genera Mycoplasma and Ureplasma,

ii. Acholeplasmatoceae, genus Acholeplasma.

iii. Spiroplasmataceae, genera, Spiroplasma. Anaoroplasma and Thermoplasma.

Species of the genus, Mycoplasma are pathogenic to human and animals, e.g. M. pneumoniae, causing primary atypical pneumonia inhumans, members of the genus Ureplasma cause urethrities inhumans, pneumonia and urogenital disease in cattle. Citrus stubborn is one of the important disease caused by Spiroplasma (S. citri) in Citrus.

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Section 12 : Gram Positive Cocci

In this section, 15 diverse genera of bacteria are placed together only because they are non-spore forming, chemo-organotrophic, Gram-positive cocci. The two important families are i. Deinococcacceae, (genus Deinococcus) ii. Micrococcaceae,(Genera : Micrococcus, Planococcus and Staphyloccoccus).

Micrococci are non-motile, aerobic, oxidative harrnless saprophyies occurring in seit and (reshwaer. Planococi are also haraless saprophytes that occur in maring evironments. Stophylococcia are non-motile, facultively anaerobic parasites. Major. Pathogenic species is S. Causing wound infections, postoperative infections, food poisoning (Stapholococcai) in humansand mastitis in cattle.

Other genera are streptococcus, aerotolarant, homofermentative (end product of sugar fermentation is lactic and only), most are pathogenic to humans and animals, e.g. s. pyogenes, causes sore throat,scarlet fever and other human infections;inhabit in the intestinal tracts of humans and animals (hence called enterococcus) causing urinary tract infections; S. lacds and S/ cremories, are harmless contaminants of milk and dairy products and therefore, widely used as "Starter cultures" in the manufacture of buttermilk and cheeses; S.pneumoniae, also called Pneumococcus, causing lobar pneumonia in humans.

Leuconoslocs, are harmless saprophytes. Occurring in grass, silage, grape leaves and spoiled food. They are heterofermentative, producing, Co2 and ethanoi or acetic acid in addition to lactic acid and are often used as starter cultures for manufacture of butter, buttennilk and cheese.

SECTION – 13

The important genera under this section are

Bavillus : Species such as , B. sublillis and B. cereus are nesophilic sprophytes producing exoenzymes that hydrolyze sarch and casein later species can cause a type of food poisoning;B. stenothermophilus, is thermophitic species sociated with spoilage of canned foods,; B.Polymyza, has abilicy of N2 fixation undr anaerobic conditions, B. furingiensis and B.Popililae ar pathogenic to insects (lepdoptera), e.g. B. papililae cause milky disease of Japanese back grub; B anthracis, is the onbly species of Bacillus that is bighly pathogenic to humans and animals causing anthrax disease.

Sporosarcina : This gerus contain cooci that are arranged I accads or cubical packets of eight cells. They are widely distributed in fertile soil where they decompose urea.

Clostridium : Members of the genus are fermentative and some species are important in agriculture i.e. C. batulimn., coses food poisoning known as botulism; C letani, casue tehu

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inhumans; C.perfringes, cause wound infection (gas grene) and food poisoning; C.Pasteurianum, mesophile labiting in soil and having ability to fix N2.

Desalfatomaculum : Sulfate reducing bacteria.

15: Non spore forming Gram – Positive, irregular shaped rods.

This section includes heterogenous and variety of bacteria bic or facultative anaerobic nature and, filamentous or non and rods. Some of the important genera are.

Synebacteriom : These are saprophytes occurring in soil & water, animal and human parasites and pathogens, e.g. sliphtheriac casue diphtheria inhumans, also causes diseases in plants.

Cycle i.e. cells in log phase are rregular rods and cells stationary phase are coccoid.

iv. Microbaclerium : These are saprophyies accruing in milk, dairy products and diary equirpments.

v. Cellulomonas : The species are important cellulose deccmposer / degrading bacteria.

Section 16 : Mycobacteria.

Contain a single Genus Mycobacterium, these are aerobic, slightly curved or straight rods, cell wall contains 90% mycolic acid and are acid fast in staining reaction. Many species are pathogenic to humans. e.g. M. tuberculosis. Cause fuberculosis and M. leprae, casue leprosy discase in human.

VOLUME : II

Section 18 : Anoxygenic photorophic bacteria.

These bacteria are Gram _ negative, photolithotrophic / photoautotrephic containing bactericchlorphyll and various water soluble carotenoid pigments. These bacteria grow phototrophically only under anaeronic conditions and are incapable of forming O2 (hence called anoxygenic). Anoxygenic phototrophic bacteria are divided in to two major groups. On the basis of their pignentaiton i.e. a) Purple bacteria and b) Green bacteria

a) Purple bacteria : Have two important families are i)Chromatiaceae (purple sulfar bacteria) and ii) rhodospirillaceae (purople non-sulfur bacteria)

i) Family, Chromatiacear, (Purple sulfur bacteria) have four important genera viz. Chromatium (cells avoid to rod shaped), Thicystis (coccoid), Thiosorillum (hehcal), Thiosarcina. All genera are photolithotrophic H2S or elemental sulfur as the

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electrondonor for CO_2 fixation, Most specter are anaerobic and cannot grow in the dark even under microaerophilic conditions.

ii) Family Rhodospirillacene, contain purple, non-sulfur bacteria with variable shapes : helical (Rhodospirilium), ovord or spherical (Rhodopseudomonas) or avoid (Rhodomicrobium). They ar pholoorganotrophs for which organic substances serve both as sources of carbn and electrons for the reduction of CO_2 Photosynthesis occurs only under anaerobic conditions in the presence of light.

b) Green bacteria : Two families and important genera

are.

i) Family : Chlorobiaceae, genera : Chlorobiom (Green Sulfur bacteria) Prosthecochloris

ii) Family : Chloroflexacene, genus : Chloroflexus (Green non-sulfur bacteria)

Section 19 : Oxygenic Phototrophic Bacteria

The typical bacteria cluded in this section are Cyanobacteria Blue green algae). These are widespread in soil, freshwater, and marine habitats Cyanobacteria are useful in N_2 fixation. Adding organic matter in sold and preventing incipient crosion. Some Cyanobacteria grow in symbiosis with other organisma. E.g. lichen (synbiosis of algne with fungi). They are also associated with certain protozoa, called as "Cyanellae". Cyanobacteria contain chlorophyll 'a' rather than bactriochlorophyl and othe pigments such as water soluble carotenods and phycobillins (phycocyanin and allophycocyanin). BGA plays important role in N_2 fixation in paddy crop e.g. Anabaena,Nostoc, chlorela etc

Section 20 : Aerobic chemolithotrophic bacteria and asscciated organisms

This section includes chemolithotrops. (e.g. nitrifying bacteria) colourless sulfur bacteria (Thiebacillus, tmospira), cbligately chemolihotrophic hydrogen bactera (Hyderogenobacter), iron and manganes oxidizing and / or depositing bacteria (Siderocapsa) and magnetotatic bacteria (Aquaspirilham). The families and important genera under this section are as follows.

Family : Nitrobacleriacene (Nitrifiving bactera). Nitrifying bacteria are morphologically either rods, cocci or helical. They are aerobic autotrops, incapable incapable of chemolithotrophic growth with the exception of one species, nlrooacler wingoradskyi. They nitrifying bacteria comprise two distinct metabolic groups viz. i) ammonia oxidixer (oxidize ammonia to nitrite) e.g. nilrosonionas, Nilrcsolobus, Nitrospina, Nitrifying bacteria are commonly preset in soil, where they play in important role in the nitrogen cycle, N_2 fixation and in maintaining the fertility of soil.

Sulfur Bacteria : The cultrvable genera of sulfur metabolizing bacteria are Thobacillus (Gram-negative, short rods) and thiomicrospira (helea) Both genera are videly distributed in soil, fresh wate cool-miner are marine environments. They derive energy from oxidati

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of reduced sulfur compounds (e.g. sulfides, elemental sulfur, thiosulfate, sulfite etc.) and the final oxidation product is sullace. Some species, Thooacillus ferrooxidans, oxidize ferrous iron to ferric form. Some species, are obligate autotrophs (e.g. T.thiooxidans, T.thioparus and Thiomicrospira pelohila) and others are facultative autotropns(e.g. Thiobacillus novellas).

Section 25 : Archacobacteria / Archaebbacteria

The archaebacteria differ from eubacteria (true bacteria) in at least two bio-chemical traits. i.e. i) they lack peptidoglycan and naranic acid in thien cellwaslls and ii) membrane lipids / fatty acids are either –linked to giycerol in archaebacteria and esterlinked in eubactera at present, at least three main categories of Achaebacteria are recognized a) methane producers (Methanogenes). b) the red extrmo halophiles and c) the thernoaciciphiles.

These are stringent anaerobes that obtain energy through clation of H2 or format and reduce CO2 with the formation of gas (CH4). The important genera of methance-producing bacteria are; methanobacleriam (Gram – negative, Shortods), melhanosarcina (Gram – positive Cocci), Methanococus – positive, pleomorphic cooci), Methanomicrobium (Gram – negative, pleomorphe) methanomicrobium (Gram – negative short rods), chmospirillum (Gram- negative, curved rods or filaments).

Extreme halphiles

These are chemoorganotrophic, Gram –negative, acrobic rods (e.g. Holobacterium) or cocci (Helococcus).

Theromoacidophiles

These are aerobic, Gram –negative Archaebacteria with ability to grow under highly acidic conditions at high temperatures.

Two important genera are : Thermoplasmas and Sulfolobus.

VOLUME IV

Positive filamentous bacteria of complex morphology

These are soil organisms which are harmless and faw to humans, animals and plants. In soil, they play important role in degradation of plant and animal residues and some are best producers of anlibiotics. Bacteria included in this VOLUME IV are categorized as follows, under different sections.

Nocardiform Actinomycetes (sect. 26), the important genera are Nocardia, Rhodococcus, pseudonocardia.

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Actiomycetes with multicolour sporangia (sect. 27) imoortant genera are : Geodermatophilus, Dermatophilus and frankia, like rhizobium are highly efficient microaerophilic N2 fixers that induce stem nodules in woody plants (e.g. alders).

Actiomyceous, harmlessbacteria occurring in neutral sous as saprophytes. They degrade polymeric organic substance is soil (starch pection and chitin). Streplomyces have the ability to prodace great number of variety of antibiotics. Some of the important species of the genus Streptomyces producing antibiotics. Are listed below.

Species	Antibiotic
S. venezuelae	Cholramphenicol
S. Dureofaciens	Chlcrotetracycline (Auremycin)
S. erythraeus	Erthoromycin.
S. fradiae	Neomycin
S. noursei	Nystatiin
S. rimosus	Oxyteracycline (Terranmycin)
S. griscus	Streptomycin
S. Viriaifaciens	Tetracycline.

Reproduction of bacteria and Methods of reproduction♣

A) Asexual methods:

a) Transverse Binary Fission (TBF) : It is the most common and important mode of cel division in the usual growth cycle of bacteria. A single cell divides into two after developing transverse septum (cross wall). It is an asexual process. A bacterial cell inoculated to fres medium takes nutrients. The biochemical synthesis takes place. The nutrients are converted t cell substances like RNA, DNA, proteins, enzymes and other macromolecules. The cell mas and size increases and the new cell wall building blocks are synthesized. Subsequently, th process of TBF is initiated. In some species, a mating or conjugation of cells may preced binary fission. In TBF, septum formation does not begin until chromosome content of the cel has been doubled i.e. cell division is triggered by completion of DNA replication. The firs step is an inward growth of the cytoplasmic membrane at the middle of the cell. A mesosom is usually attached to the cytoplasmic membrane at this location, particularly in Gram +v cells, and may have a role in synthesis of new membrane material. The next step is the inwar

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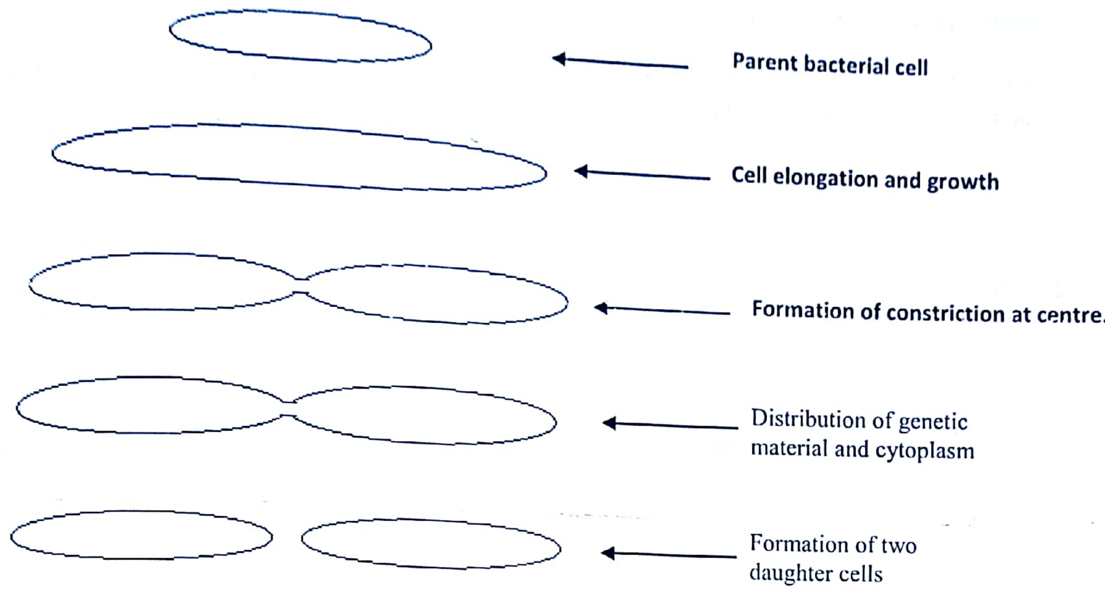
growth of the cell wall to form a septum that ultimately splits to allow separation of the two daughter cells.



b) Budding : A small protuberance (bud) develops at one end of a bacterial cell, it enlarges and eventually develops into a new cell which separates from the parent. Ex. *Rhodopseudomonas acidophila*.

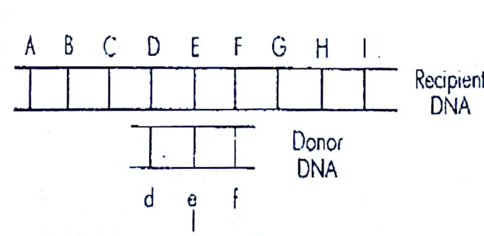
c) Fragmentation : Bacteria producing filamentous growth ex. *Nocardia* reproduce by fragmentation of the filaments into small bacillary (rod shaped) or coccoid (spherical) cells, each of which give rise to new growth.

d) Formation of conidiospores or sporangiospores : *Streptomyces* and related bacteria produce many spores per organism by developing cross-walls (septation) at the hyphal tips. Each spore gives rise to a new organism.

B) Sexuality in Bacteria (Genetic Recombination in Bacteria) :

Genetic recombination is the formation of a new genotype by reassortment of genes following an exchange of genetic material between 2 different chromosomes, which have similar genes at corresponding sites. These are called homologous chromosomes and are from different individuals. Progeny from recombination have different gene combination than that of parents. In bacterial recombination, the cells do not fuse. Only a portion of chromosome from the donor cell (male) is transferred to the recipient cell (female). The recipient cell thus becomes a merozygote (partially diploid). Recombination takes place after merozygote transformation occurs.

Mechanism of Bacterial Recombination :



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1) Inside recipient cell, the donor NA fragment is positioned alongside the recipient DNA in such a way that the homologous genes are adjacent.

2) Enzymes act on the recipient DNA, causing nicks and excision of a fragment.

3) The donor DNA is integrated into the recipient chromosome in place of the excised DNA. The recipient cell then becomes the recombinant cell because its chromosome contains DNA of both, the donor and the recipient cells.

In bacteria, the genetic recombination results from 3 types of gene transfer.

a) Conjugation : Transfer of genes between two cells that are in physical contact.

b) Transformation : Transfer of cell-free or "naked" DNA from one cell to another.

c) Transduction : Transfer of genes from one cell to another by a bacteriophage.

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Lecture 23,24,25.

PLANT VIRUSES

i. Virus are ultra microscopic, nucleoproteinous, self replicating, filterable, noncellular organisms, smaller than bacteria.

ii. Their size ranges from 20 to 300 nm (1 nm = 1/ 1000 µm).

iii. They can be seen under electron microscope, scanning microscope or transmission microscope.

iv. Shape varies from rod shaped (helical) spherical, polyhedral bacilliform or plemorphic.

v. The single virus particle is called as 'viron' Each viron or virus particles is chemical composed of nucleic acid and protein (nucleoproteinous).

vi. Nucleic acid in virus particle is either RNA or DNA but never both. The percentage of nucleic acid is 5-10 % and that of protein is 60-95 %.

vii. RNA may be single or double stranded and DNA is Mostly double stranded.

viii. The protecting protein coat of viron. or virus particles is known as capsid. Smaller sub unit of proteins called as capsomers and nucleic acid protected or enveloped with the capsid is called nucleocapsid.

Viii .They are obligate, intra-cellular parasites, requires living hosts to complete their life cycle therefore can not be grown on artificial media in laboratory.

ix. They can multiply or reproduce within living hosts or cells by the process of replication of genome (RNA or DNA).

x. They do not have any cytoplasm, cytoplasmic organells and plasma `membrane.

Diseases caused by Viruses

Viruses causes diseases in human, animals and plant, Diseases, in human: small pox, AIDS(HIV), hepatitis, poliomyelitis (polio virus);
Diseases in animals foot and mouth diseases (FMD);
Diseases in Plants : Yellowing, Mosaic, Yellow mosaic, Yellow vein mosaic. Mottling chlorosis, bunchy top, sterility mosaic etc.

Transmission of viruses

Viruses in leaves of indicated host plants Mechanical Inoculation is the application of virus bearing fluid to the surface of leaves. In such a way that virus can enter into the cell. When the plant is susceptible, local lesions may occur on inoculated leaves. Systematic symptoms may occur on other parts of the pl. or the infections is latent.

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Many viruses can be transmitted mechanically but those that persist in the vector usually can not be. In principle, each succeptiable pl can be used as a test plant. But a no of Spp and cultivars an in use internally to particular viruses and an called differential hosts / Indicator p/s.

Inoculation is carried out by dusting wet leaves with fine carborundum powder and rubbing leaves gently with inoculums carborundum greatly increases the pt. of entry of virus.

Usually the colyledons of cucumber and the primary leaves of cowpea and beans on inoculated, b'coz older pls an less succeptible. However in chenopedium amaranticolar local lesions produced best in expanded nature leaves. Well nourished, rapidly growing pls an most susceptible expecially with plotted p/s watch out with for N_2 difficiency.

The sap of some pl. spp. In toris to test pls. spp is toxic to test pl. The dilution of the sap 1: 10 with H2O or 0.01 M phosphate buffer pH 7.0 is advised other pls contain tannin with virus inhibiting properties [e.g. strawberry, Raspberry], Nicotine, pH-8 increase infectivity carnetions, cucumber, bean, capasicum, patura also contain inhibitions which frequency prevent the transmission of virus from these pls. to test pls. inhibition may be lessened by diluting the sap or sometimes by rubbing tissues of diseased pl. over the test pl.

Transmission is fundamental property of viruses plant viruses being obligate parasites must be spread from one susceptible host to another and need to be introduced in living cell for their survival and continuity.

The knowledge of virus transmission is important to:

 Recognize a virus as cause of the disease if transmitted from infected to healthy plant How virus spread in field – help in its control Establish biological relationship of interaction between virus and its vector Mechanical transmission is very important for lab. Study of viruses.

Methods of transmission

 Non-Insect transmission: Sap inoculation/ Mechanical: TMV, PVY Seed: BCMV, Fungi: Olpidium brassicae- TNV Vegetative & graft transmission: PVY, PLRV,

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Fruit viruses □ Nematodes: Xiphinema index: Grapevine fan leaf virus □ Dodder: CMV, TRV □ Insect Transmission: PVY, CMV, BGMV

Mechanical Transmission

□ Occurs when plant come in contact with other plant and leaves rub together □ By the action of humans □ Mechanical transmission involves the introduction of infective virus or biologically active virus into a suitable site in the living cells through wounds or abrasions in the plant surface □ This method is generally used for experimental purposes under laboratory conditions- also known as Sap inoculation

Methods

□ Leaf rub □ Cotton swab □ Pinprick □ Microinjection □ Steps: □ Sap extraction □ Extraction medium □ Use of additives □ Choice of suitable host: most common are Nicotiana spp., Chenopodium spp., Cucumis sativus, Gomphrena, Datura spp, Phaseolus vulgaris

Insect transmission

□ Vector: various biological agents which introduce the virus into plant tissue are called vectors. □ Insects –most important group □ > 400 spp. have been reported to transmit plant viruses. □ 94% of these belong to Phylum Arthropod in this 90 % are insects □ 70% of insects belong to Homoptera in which Aphididae are the most important group. □ Others: leafoppers,plant hoppers, whiteflies, beetles, mealy bugs thrips, mites □ Others: fungi, nematodes □ In general plant viruses transmitted by one group of vectors are not transmitted by other group except: TRSV which can be transmitted nematodes and by thrips & spider mites.

Transmission by fungi:

□ Teakle 1960: TNV transmitted by fungus Olpidium brassicae □ Barley yellow mosaic virus: Transmitted by the plasmodiophorid fungus Polymyxa graminis (Kusaba et al., 1971; Adams, 1990a), which is an obligate root parasite.

Polymyxa graminis: the vector of several cereal viruses including e.g. Bymovirus Benyvirus,, Furovirus, Pecluvirus and Pomovirus

Light micrograph of barley root stained with methylene blue, showing plasmodium of Polymyxa graminis.

• The virus is acquired when the plasmodia of the fungus are growing inside the barley root cells and it is transmitted within the zoospores or resting spores that it produces.

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Nematode transmission

 Two single-stranded RNA virus genera, Nepovirus (NEPO) and Tobravirus (TOBRA), have nematode vectors Nepoviruses: Comoviridae family Tobraviruses: family not yet assigned

Seed Transmission:

 About 1/7th of the viruses transmitted through seed Effective mean of introducing virus into crop at early stages with number of infection loci. Help in dispersal across area Economically important Help in virus survival

Seed transmission occurs in two ways Externally seed borne due to external contamination of the seed with virus particles (TMV, PVX) Internally seed borne (BCMV, CMV, BYMV, ULCV) due to infection of the living tissues of the embryo. Virus may be found in different parts of the seed but generally in embryonic tissues The embryo become infected by two routes Directly from mother plant By pollens Developing embryo can be infected before fertilization by the infection of the gametes or by direct invasion of the embryo after fertilization Virus moves through the testa of immature seed after fertilization and reach micropylar region for embryo infection to occur. Micropyle is in close contact with the base of embryonic suspensor that help in nutrient flow to embryo.

Virus Host Plants	Observation	Host Plants
Bean common mosaic	BCMV	Phaseolus vulgaris
Cucumber mosaic virus	CMV	Nicotiana tabaccum
Potato Virus – X	PV – X	Nicotiana tabaccum
Potato Virus – Y tobaccum	PV – V	Nicotiana tabaccum
Tobacco mosaic virus	TMV	Nicotiana tabaccum
Tobacco necrosis virus	TNN	Nicotiana tabaccum
Tobacco rattle virus	TRN	Nicotiana tabaccum
Tobacco spotted wilt virus	Town	Nicotiana tabaccum

Lecture 28,29,30

PLANT DISEASE MANAGEMENT : Principles

1. Introduction :

Measures taken to prevent incidence of a disease, reduce the amount of inoculum that initiates and spread the disease in the crop and , finally, minimize the loss caused by the disease have been traditionally called control measures.

Since the 1970s there has been a general tendency to consider these measures as management strategies rather than control because the control measures generally manage the

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population of the pathogens at an innocuous level, not necessarily eliminating them from he ecosystem.

The principles of plant disease management can have two approaches, viz,

1. **management of a single disease of the crop and**
2. **planning for overall health of the crop.**

1. management of a single disease of the crop : Management planning for a disease is directed against a specific disease which is causing heavy losses, such as late blight of potato, without taking into consideration other fungal, bacterial or virus diseases of the same crop.

Management of crop health involves an integrated plan in which all diseases of any significant nature for the crop are taken into consideration, although major stress may be against the most common and severe disease.

Obviously, the second approach, though difficult, is of more practical value for the farmer because he is interested in increasing the productivity of the crop and therefore, prefers a plant that can provide safeguard against all possible diseases occurring in the area.

In planning for health of the crop, the procedures for management are arranged in such a manner that maximum number of disease of the crop are partly or wholly managed by minimum number of operations and repetition of operations for each separate disease is avoided.

2. Some Considerations in plant disease management :

The aim of disease management is to check the reduction in economic gain from a crop. If the control measures fail to increase economic gain, even if disease incidence is reduced. No farmer is likely to accept the recommendations for plant disease management.

Therefore the cost benefit-ratio is very important consideration in the application of control measures.

Relationship between disease control and disease cycle: Knowledge of following aspects of disease development is essential for effective and economic disease control.

1. Identification of the cause of the disease.
2. Mode of perpetuation and dissemination of the infections agent of the disease.
3. Host-parasite relationship and means of secondary spread.
4. Effect of environment on pathogenesis in the plant and spread of the disease in the plant population.

The knowledge of these stages of the disease cycle helps in selecting control measures, which directly or indirectly destroy the pathogen or suppress its growth.

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Lecture 31,32,33.

INTRODUCTION AND CLASSIFICATION OF FUNGICIDES

What is fungicide?

The word 'fungicide' originated from two Latin words, *viz.*, 'fungus' and 'caedo'. The word 'caedo' means 'to kill.' Thus, the fungicide is any agency/chemical, which has the ability to kill the fungus. According to this meaning, physical agents like ultra violet light and heat should also be considered as fungicide. However, in common usage, the meaning is restricted to chemicals only. Hence, fungicide is a chemical that is capable of killing fungi.

Fungistat

Some chemicals do not kill the fungal pathogens. However, they simply arrest the growth of the fungus temporarily. These chemicals are called fungistat and the phenomenon of temporarily inhibiting the fungal growth is termed as fungistasis.

Antisporulant

Some other chemicals may inhibit the spore production without affecting the growth of vegetative hyphae and are called as 'Antisporulant' The antisporulant and fungistatic compounds do not kill the fungi

Though, the fugistats and antisporulants do not kill fungi, they are included under the broad term fungicide. Hence, in broad sense, the fungicide is defined as "A chemical substance which has the ability to prevent damage caused by fungi to growing crops and their products".

Fungicides can be broadly grouped based on their

(i) mode of action (ii) general use and (iii) chemical composition.

I. Mode of action

Protectant: As the name suggests, protectant fungicides are prophylactic in their behaviour. Fungicide, which is effective only if applied prior to fungal infection, is called a protectant, e.g., zineb, sulphur.

Therapeutant: Fungicide that is capable of eradicating a fungus after it has caused infection and thereby curing the plant is called 'chemotherapeutant', e.g., carboxin, oxycarboxin antibiotics like Aureofungin. Usually chemotherapeutants are systemic in their action and affect the deep-seated infection.

Eradicants: Eradicants are those which remove pathogenic fungi from an infection court (area of the host around a propagating unit of a fungus in which infection could possibly

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occur), e.g., organic mercurials, lime sulphur, dodine, etc. These chemicals eradicate the dormant or active pathogen from the host. They can remain effective on or in the host for some time.

II. Based on general uses

The fungicides can also be classified based on their use in managing the diseases.

1. Seed protectants: E.g., captan, thiram, organomercuries, carbendazim, carboxin, etc.
2. Soil fungicides (preplant): E.g., chloropicrin, formaldehyde, vapam, dazomet, etc.
3. Soil fungicides (for growing plants): E.g., Bordeaux mixture, copper oxychloride, captan, PCNB, thiram, etc.
4. Foliage and blossom protectants: E.g., capton, ferbam, zineb, mancozeb, chlorothalonil, etc.
5. Fruit protectants : E.g., captan, maneb, carbendazim, mancozeb, etc.
6. Eradicants: E.g., organomercurials, lime sulphur, etc.
7. Tree wound dressers : Eg. Bordeaux paste, Chaubattia paste, etc.
8. Antibiotics: E.g., Actidione, Griseofulvin, Streptomycin, Streptocycline, etc.,
9. General purpose sprays and dust formulations.

III. Based on chemical composition

Non-systemic fungicides

i. Sulphur fungicides

Use of sulphur in plant disease control is probably the oldest one and can be classified as inorganic sulphur and organic sulphur. Inorganic sulphur is used in the form of elemental sulphur or as lime sulphur. Elemental sulphur can be either used as dust or Wettable sulphur, later being more widely used in plant disease control. Sulphur fungicides emit sufficient vapor to prevent the growth of the fungal spores at a distance from the area of deposition. This is an added advantage in sulphur fungicides as compared to other fungi toxicants.

Sulphur is a contact and protective fungicide, normally applied as sprays or as dust. It is generally used to control powdery mildews of fruits, vegetables, flowers and tobacco. This is also effective against apple scab (*Venturia inaequallis*) and certain rusts, leaf blights of field crops and fruit diseases.

Dust formulations	: Sulphur dust (300 mesh)
Lime Sulphur	: It can be prepared by boiling 9 kg or rock lime and 6.75 kg of sulphur in 225 litres of water.
Wttable sulphur formulations	: Wetasul, Microsul, Thiovit, Sultaf, Cosan, Wetsulf, Sulfex, Cosavet, etc.

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ii. Dithiocarbamates

Organic compounds of sulphur are now widely used in these days. All these compounds, called as 'carbamate fungicides', which are derivatives of dithiocarbamic acid. Dithiocarbamates are broadly grouped into two, based on the mechanism of action.

Monoalkyl Dithiocarbamates: E.g., zineb (Hexathane 75% WP, Dithane Z-78, Funjeb, Lonocol, Parzate C), maneb (Dithane M22, Manzate WP, MEB), mancozeb (Dithane M - 45, Indofil M - 45, Manzeb), nabam (Chembam, Dithane A-40, Dithane D-14, Parzate Liquid), and vapam (Vapam, VPM, Chemvape, 4-S Karbation, Vita Fume).

Dialkyl Dithiocarbamates: E.g., thiram (Thiride 75 WDP, Thiride 750, Thiram 75% WDP, Hexathir, Normerson, Panoram 75, Thiram, TMTD, Arasan, Tersan 75, Thylate, Pomarsol, Thiuram), ziram (Cuman L. Ziram, Ziride 80 WDP, Hexaazir 80% WP, Corozate, Fukiazsin, Karbam white, Milbam, Vancide 51Z, Zerlate, Ziram, Ziberk, Zitox 80% WDP), ferbam (Coromat, Febam, Ferberk, Femate, Fermate D, Fermicide, Hexaferb 75% WP, Karbam Black, Ferradow).

Diseases controlled: These fungicides are used for control of a wide range of diseases like leaf spots, blights, anthracnose, rusts, downy mildews, etc. of many crops plants.

iii. Copper fungicides

The fungicidal action of copper was mentioned as early as 1807 by Prevost against wheat bunt disease (*Tilletia caries*), but its large-scale use as a fungicide started in 1885 after the discovery of Bordeaux mixture by Millardet in France. The mixture of copper sulphate and lime was effective in controlling downy mildew of grapevine caused by *Plasmopara viticola* and later, late blight of potato (*Phytophthora infestans*).

Some other copper sulphate preparations later developed were Bordeaux paste, Chaubattia paste, Burgandy mixture and Cheshunt compound, which are all very effectively used in the control of several plant diseases. In addition, some preparations of copper like copper oxychloride (Blitox 50, Cupramar 50 WP, Fytolan, Micop D-06, Micop W -50, Blue copper 50, Cupravit, Cobox, Copper bond, Copter, Cuprasol, Canopy, Cuprax, Bilmix 4% dust, Mycop, Topgun 50 WG), cuprous oxide (Fungimar, Perenox, Copper Sandoz, Copper 4% dust, Perecot, Cuproxid, Kirti copper) and copper hydroxide (Coside 101 – 77 WP) are also used.

Some of the important diseases controlled by copper fungicides:

Copper fungicides are used as protective fungicides for foliage applications and as a soil drench. The freshly prepared BM has high tenacity. Diseases like late blight (*Phytophthora infestans*) of potato, apples scab (*Venturia inaequalis*), downy mildew of grapes, damping off of seedlings, pink diseases, stem canker, leaf diseases and rusts

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of several crops, soil borne diseases *viz.*, wilt, collar rot, root rots, etc. are effectively managed by these fungicides. They are also used as wound dressers.

iv. Mercury fungicides

Mercury fungicides can be grouped as inorganic and organic mercury compounds. Both the groups are highly fungitoxic and were extensively used as seed treatment chemicals against seed borne diseases. These compounds show bactericidal property also. However, due to their residual toxicity in soil and plants and their extreme toxic nature to animal and human beings, the use of mercury fungicides is beings discouraged. In most of the countries, the use of mercury fungicides is banned and in countries like India, the use of mercury fungicides is restricted only in seed treatment for certain crops.

Inorganic mercury compounds: These are mercuric chloride (Merfusan, Mersil), and mercurous chloride (Cyclosan, M-C Turf fungicide).

Organomercurials: Methoxy ethyl mercury chloride [Agallol, Aretan, Emisan, Ceresan wet (India)], phenyl mercury chloride [Ceresan dry (India), Ceresol, Leytosan], ethyl mercury chloride [Ceresan (USA)].

Diseases controlled: The mercury fungicides are used mainly for treatment of seeds and planting materials, either by dry, wet or slurry method. For seed treatment, 1 per cent metallic mercury is applied at 0.25 per cent concentration. Mercurous chloride is limited to soil application in crop protection because of its phytotoxicity.

v. Heterocyclic nitrogen compounds

Heterocyclic nitrogen compounds are mostly used as foliage and fruit protectants. Some compounds are very effectively used as seed dressers. Some of the commonly used fungicides are captan (Captaf 50 WP, Cohocap 50WP, Captan 75 WP, Esso Fungicide 406, Orthocide 406, Vancide 89, Deltan, Metpan, Hexacap), captafol (Foltaf, Difolaton, Difosan, Captaspor, Foleid, Sanspor), glyodin (Glyoxaliadine, Glyoxide, Glyodin, Glyoxide dry, Glyodex 30% liquid and 70% WP) and folpet (Phartan, Acryptan, Phaltan, Folpan, Orthophaltan).

Diseases controlled: Captan and captafol are mainly seed dressing fungicides used to control diseases of many seed and soil borne diseases of fruits, ornamental and vegetables. In addition, captan, glyodin and folpet are used as foliar sprays for management of diseases like leaf spots, blights, anthracnose, rusts, downy mildews, etc. of many crops plants.

vi. Dicarboximide compounds

Iprodione (Rovral) and vinclozolin (Ronilan, Ornalin) are two important fungicides in this group. They are broad spectrum, contact fungicides and control the

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diseases caused by species of *Botrytis, Sclerotinia, Monilinia, Alternaria, Helminthosporium, Fusarium, Penicillium, Rhizoctonia*, etc.

vii. Organo – Phosphorous fungicides

Ediphenphos is available as Hinosan 50% EC and 2% D. It has a specific action against *Pyricularia oryzae* (blast), *Corticium sesakii* and *Cochliobolus miyabeanus* in rice.

Systemic fungicides

Since the late 1960s, there has been substantial development in systemic fungicides. Any compound capable of being freely translocated after penetrating the plant is called systemic. A systemic fungicide is defined as fungitoxic compound that controls a fungal pathogen remote from the point of application, and that can be detected and identified. Thus, a systemic fungicide could eradicate established infection and protect the new parts of the plant. Based on chemical structure, systemic fungicides can be classified as Benzimidazoles, Thiophanates, Oxathilins and related compounds, pyrimidines, morpholines, organo-phosphorus compounds and miscellaneous group.

i. Oxathilin and related compounds

This group of systemic fungicide is also called as carboxamides, carboxylic acid anillides, carboxa anillides or simply as anillides which are effective only against the fungi belong to *Basidiomycota* and *Rhizoctonia solani.* Some of the chemicals developed are Carboxin (Vitavax 10% D, Vitavax 75% WP, Vitavax 34% liq. Vitaflow), and oxycarboxin (Plantvax 5G, Plantvax 5% liq. Plantvax 1.5 EC, 10% dust, 75 WP).

Diseases controlled: These fungicides are used for the management of seed borne diseases in cereals, pulses, ornamentals, vegetables, etc.

ii. Benzimidazoles

The chemicals of this group show a very broad-spectrum activity against a variety of fungi. However, they are not effective against bacteria as well as fungi belonging to phylum *Oomycota*. Two types of fungicidal derivates of benzimidazoles are thiabendazole and fuberidazole. The fungicides in this group are carbendazim (Bavistin 50 WP, MBC, Dersol, Sten 50, Zoom, Tagstin, Agrozim, Jkenstin), and benomyl (Benlate 50 WP, Benomyl).

Diseases controlled: Effective against a wide range of fungi affecting field crops, fruits and ornamentals. These fungicides are very effective against rice blast, apple scab, powdery mildew of cereals, rose, curcurbits and apple, sigatoka leaf spot of banana, turmeric leaf spot, rust diseases in many crops and diseases caused by *Verticillium and Rhizoctonia*. They are also used for seedling dip, seed treatment and soil drench and as

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pre-and post-harvest sprays or dips for the control of storage rots of fruits and vegetables.

iii. Thiophanates

These compounds represent a new group of systemic fungicides based on thiourea. They are the derivatives of thioallophanic acid. These fungicides contain aromatic nucleus, which is converted into benzimidazole ring for their activity. Hence, thiophanates are often classified under benzimidazole group and the biological activity of thiophanates resembles of benomyl. The important compound developed under this group is thiophanate methyl (Topsin M 70 WP, Cercobin-M 70 WP, Envovit-methyl, Mildothane).

Diseases controlled: Same as that of benzimidazoles.

iv. Morpholines

This group includes tridemorph (Calixin 75 EC, Bardew, Beacon). It controls powdery mildew diseases of cereals, vegetables and ornamentals. In addition, it is highly effective against *Mycosphaerala musicola, Exobasidium vexans* and rust diseases or cereals, pulses and coffee.

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v. **Pyrimidines**

Pyrimidins include fenarimol (Rubigan), etc. It is very effective against powdery mildews and rusts of several crops, *Venturia* and *Monilinia* in fruits (pome fruits).

vi. **Triazole compounds**

This group includes fungicides *viz.*, triadimefon (Bayleton), bitertanal (Baycor), bitertanol (Baycor), tricyclazole (Beam, Bim), hexaconazole (Contaf 5 EC, ANVIL 5 EC), myclobutanil (Systhane), propiconazole (Tilt 25 EC), penconazole (Topas 10 EC), difenoconazole (Score 25% EC), etc.

Diseases controlled: They are having broad-spectrum activity against diseases like rust, powdery mildews, leaf spots, anthracnoses, etc. of several crops.

vii. **Organo phosphorous compounds**

It includes kitazin / iprobenphos (Kitazin 48% EC, Blataf). It is used to control blast (*Pyricularia oryzae*) and sheath blight of rice.

viii. **Piperazine -** Triforine (Saprol-EG, Fungitex). Effective against powdery mildew, scab, and rust on ornamentals and cereals and active against storage diseases of fruits.

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ix. Other systemic fungicides

Other systemic fungicides are metalaxyl (Apron 35 SD, Ridomil, Ridomil MZ 72 WP, Ridomil Gold), fosetyl Al (Alliette 80 WP), and cymoxanil (Curzate). They are having very effective systemic selective action against diseases caused by *Oomycetes*, e.g., damping-off, root rots, stem rots (*Pythium, Phytopthora* spp.), and downy mildew of several crops.

Other important fungicides

The important fungicide, which is not included in any of the group described earlier, is chlorothalonil (Kavach 25% WP, Bravo, Daconil, Termil, Chlorothalonil 40 SC, Safegaurd, Spektrum). It is broad spectrum, contact fungicide effective against many fungal diseases of field, orchard, ornamental and plantation crops.

Miscellaneous fungicides

Many aromatic compounds have important anti-microbial properties and have been developed as fungicides. Some important benzene compounds commonly used in plant disease control are Quintozene, i.e., PCNB (Brassicol, Terraclor, Tritisan 10%, 20%, 40% D and 75% WP, PCNB 75% WP), and Dinocap (Karathane, Arathane, Mildex, Crotothane).

Diseases controlled: PCNB is used for seed and soil treatment against *Botrytis, Sclerotium, Rhizoctonia* and *Sclerotinia* spp. Dichloran is a protective fungicide and very effective against *Botrytis, Rhizopus and Sclerotinia* spp. Dinocap is a non-systemic acaricide and recommended to control powdery mildews on various crops.

ANTIBIOTICS

Antibiotic is defined as a chemical substance produced by one microorganism, which in low concentration can inhibit or even kill other microorganism. Because of their specificity of action against plant pathogens, relatively low phytotoxicity, absorption through foliage and systemic translocation and activity at low concentration, the use of antibiotic is becoming very popular and very effectively used in managing several plant diseases. They can be grouped as antibacterial antibiotics and antifungal antibiotics. Most antibiotics are products by several actinomycetes and a few are from fungi and bacteria.

I. Antibacterial antibiotics

1. Streptomycin sulphate

Streptomycin is an antibacterial antibiotic produced by *Streptomyces griseus*. It is streptomycin sulphate and sold as Agrimycin-100, Streptomycin sulphate, Plantomycin, Streptocycline, Paushamycin, Phytostrip, Agristrep and Embamycin. Agrimycin -100

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contains 15 per cent streptomycin sulphate + 1.5 per cent tetramycin (Oxy tetracycline). Streptocycline and paushamycin contains nine parts of streptomycin and 1 part of tetracycline hydrochloride.

This group of antibiotics act against a broad range of bacterial pathogens causing blights, wilt, rots etc. This antibiotic is used at concentrations of 100-500 ppm. Some important diseases controlled are blight of apple and pear *(Erwinia amylovora)*, Citrus canker *(Xanthomonas campestris p.v. citri)*, Cotton black arm *(X.c.* p.v. *malvacearum)*, bacterial leaf spot of tomato *(Pseudomonas solanacearum)*, wild fire of tobacco *(Pseudomonas tabaci)* and soft rot of vegetables *(Erwinia carotovora)*.

2. Tetracyclines

Antibiotics belonging to this group are produced by many species of *Streptomyces*. This group includes Terramycin or Oxymicin (Oxytetracycline). All these antibiotics are bacteriostatic, bactericidal and phytoplasmastatic. These are very effective against seed-borne bacteria. This group of antibiotic is very effective in managing phytoplasma diseases of a wide range of crops. These are mostly used as combination products with Streptomycin sulphate in controlling a wide range of bacterial diseases. Oxytetracyclines are effectively used as soil drench or as root dip controlling crown gall diseases in rosaceous plants caused by *Agrobacterium tumefaciens*.

II. Antifungal antibiotics

1. **Aureofungin:** It is a hepataene antibiotic produced in sub-merged culture of *Streptoverticillium cinnamomeum* var. *terricola*. It is absorbed and translocated to other parts of the plants when applied as spray or given to roots as drench. It is sold as Aureofungin -Sol. containing 33.3% Aureofungin and normally sprayed at 50-100 ppm concentration. The diseases controlled are citrus gummosis (*Phytophthora* sp.), powdery mildew (*Podosphaera leucotricha*), and scab (*Venturia inaequalis*) of apple, groundnut Tikka, downy mildew, powdery mildew and anthracnose of grapes, potato early and late blight. As seed treatment it effectively checks several diseases. As a trunk application/root feeding @ 2 g of aureofungin – sol + 1g of copper sulphate in 100 ml of water effectively reduce Tunjavar wilt of coconut.
2. **Griseofulvin:** This antifungal antibiotic was first discovered to be produced by *Penicillium griseofulvum* and now by several species of *Penicillium, viz., P. patulum, P. nigricans, P. urticae, and P. raciborskii*. It is commercially available as Griseofulvin, Fulvicin and Grisovin. It is highly toxic to powdery mildew of beans and roses, downy mildew of cucumber. It is also used to control *Alternaria solani* in tomato *Sclerotinia fructigena* in apple and *Botrytis cinerea* in lettuce.
3. **Cycloheximide:** It is obtained as a by-product in streptomycin manufacture. It is produced by different species of *Streptomyces*, including *S. griseus* and S. *nouresi*. It is commercially available as Actidione, Actidione PM, Actidione RZ and Actispray. Cycloheximide is active against a wide range of fungi and yeast. Its use is limited

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because it is extremely phytotoxic. It is effective against powdery mildew of beans *(Erysiphe polygoni)*, bunt of wheat *(Tilletia* spp.*)* brown rot of peach *(Sclerotinia fructicola*) and post harvest rots of fruits caused by *Rhizopus* and *Botrytis* spp.

4. **Blasticidin:** It is a product of *Streptomyces griseochromogenes* and specifically used against blast disease of rice caused by *Pyricularia oryzae.* It is commercially sold as Bla-s.

5. **Antimycin:** It is produced by several species of *Streptomyces,* especially *S. griseus* and *S. kitasawensis.* It is effectively used against early blight of tomato, rice blast and seeding blight of oats. It is commercially sold as Antimycin.

6. **Kasugamycin:** It is obtained from *Streptomyces kasugaensis.* It is also very specific antibiotic against rice blast disease. It is commercially available as Kasumin.

7. **Thiolution:** It is produced by *Streptomyces albus* and effectively used to control late blight of potato and downy mildew of cruciferous vegetables.

8. **Endomycin:** It is a product of *Streptomyces endus* and effectively used against leaf rust of wheat and fruit rot of strawberry *(Botrytis cinerea).*

9. **Bulbiformin:** It is produced by a bacterium, *Bacillus subtills* and is very effectively used against wilt diseases, particularly Red gram wilt.

10. **Nystatin:** It is also produced by *Streptomyces noursei* and successfully used against anthracnose disease of banana and beans. It also checks downy mildew of cucurbits. As a post harvest dip, it effectively reduces brown rot of peach and anthracnose of banana in storage rooms. It is commercially marketed as Mycostain and Fungicidin.

11. **Eurocidin:** It is a pentaene antibiotic produced by *Streptomyces anandii* and called as pentaene G-8. It is effectively used against diseases caused by several species of *Colletotrichum* and *Helminthosporium.*

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FUNGICIDE FORMULATIONS

The trade names under which different companies market various formulations of the same compound vary widely. However, all marketed fungicides should state clearly the common name of the fungicide and the amount of active ingredient of it contained in the formulated product. Commercial fungicides are formulated in various ways and most commonly available formulations are Emulsifiable Concentrates (EC) Wettable Powders (WP), Dusts (D), etc.

Commercially available fungicides usually consist of a mixture of active ingredient (a.i.) and other substances including diluents, wetting agents, stickers, emulsifiers, etc. Formulations containing mixtures of different active ingredients (especially mixtures of protectant and systemic fungicides) are also widely used now a day. Different formulations incorporating the same active ingredient may be used for distinct purposes like seed treatment, foliar application, etc.

1.Emulsifiable concentrates (EC)

These are liquid formulations which can be diluted with water before application. The active ingredient is dissolved in a solvent. The fungicides and solvents will often not mix with water, so an emulsifying agent or water dispersible oil is mixed. When these emulsifiable concentrate is added to water, a milky mixture is formed, which is a suspension of active ingredient and emulsified solvent in the water. e.g, propiconazole, difenoconazole, etc.

2.Wettable powder (WP)

Wettable powder is a very common formulation for most of the fungicides, which is used for spray mixtures. The modern wettable powders are water-dispersible which have the quality to wet easily and disperse well in water. They are also called as Water-Dispersible Powders (WDP). The active ingredient is incorporated, usually at the rate of 30-80% with a finely ground inert dust (filler) such as kaolin, a wetting agent and a suspending emulsifying agent. E.g., Indofil M – 45, Blitox 50 WP, etc.

A highly developed type of water-dispersible powder is called as colloidal powder, which is so finely divided that the individual particles will never sediment out. A typical colloidal powder contains 5-50% active ingredient with non-ionic wetting agents, thickening agents and a hydrophilic diluents (carrier).

3.Dusts (D)

Dust formulations usually contain 1-10% active ingredient for direct application in dry forms. They are manufactured in such a way that they are light enough to be carried by a slight breeze for a considerable distance. The finely divided particles of active ingredient are carried on a carrier particle. The commonly used carriers (diluents) are attapulgite, kaolin, talc, pyrophylite, diatomaceous earth, bentonite, calcium silicate, hydrated silica, calcium carbonate, magnesium carbonate, gypsum, lime, etc. E.g., Blimix 4 % dust, Micop D 06, etc.

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Granules (Pellets)

Pellets are the formulations of the fungicide with inert material formed into particles about the size of coarse sugar. The granules normally contain 3-10% of the active ingredient. Due to their size, the granules do not drift but have limited application being confined to soil and seed treatments. Granules have the advantage they can be measured in dry form more easily and accurately than dusts or wettable powders. E.g., Topgun 50WG, Cosavit, Wokovit, Cumulas 80 WG, etc.

5.Suspension or slurries

A dry form of the active ingredient is mixed with a liquid in these formulations. Such formulations usually contain a high percentage of active ingredients similar to Wettable powders. They are mixed with water for final use and require agitation. These are mostly used as seed dressers in seed processing companies. E.g., Flovin 35 SC, Cumal L 27 SL, Share 40 SC.

6.Solutions

True solutions are formulations in which active ingredient or a combination of active ingredients and a solvent is dissolved in water. Solutions have the advantage of requiring no agitation after formulation is added in water. Now a day, the manufacturers are concentrating to develop new formulations to increase the efficacy of the chemicals. Some new formulations developed are soluble liquid (SL), e.g., Cuman L 27 SL and Casu – B 3 , Soluble powder (SP), Water-soluble concentrate (WSC), Suspension Concentrate (SC), e.g., Share 40 SC and Contaf plus 5 SC and Aqua Flow (AF).

Adjuvants

The fungicides can be commonly applied as either spraying or dusting. In spraying method, the toxicant is made into a suspension in water. In order to increase the efficacy of the water mixed sprays, certain substances like wetting agents, dispersing agents, spreaders, stickers, etc. are added during the formulation of fungicides. These auxiliary spray material are also called as **adjuvants**, which are usually inert materials added to improve the physical characteristics of the toxicant and its carrier. Most of the material used are surface-active agents and therefore induce variation in either surface tension or interfacial tension. The various adjuvants are grouped as follows.

1.Dispersing agents (Deflocculating agents)

These are the substances, which keep fine particles away from each other to prevent deflocculation. These materials, when added to formulations, ensure uniform suspension and retard sedimentation of particles in the spray suspension. These are also called as deflocculating agents. E.g., Gelatin, plant gums and milk products.

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2.Emulsifying agents

In powders (WDP), the active ingredient is incorporated, usually at the rate of 30-80%, with a finely ground inert dust (filler) such as kaolin, a wetting agent and a suspending agent. The commonly used suspending agents are sodium lignin sulphonate (Sulphite dye), methylcelluloses, polyvinyl acetate and aluminum silicate. In addition, spreader-sticker is sometimes desirable, especially on plants with glossy or waxy leaves. Agitation is generally necessary to keep uniform suspension.

A typical colloida! powder contains 5-50% active ingredient with non-ionic wetting agents (1-10% polyethylene oxide condensate), thickening agents like carboxy methylcellulose and a hydrophilic diluents (carrier) such as bentonite.

Many surface-active substances like soap function as emulsifying agent, which retard the settling out of droplets of water immiscible liquids like oils. This helps in uniform mixing of substances in water suspensions.

3.Wetting agents (Wetters)

These are the material, which are added to ensure that there will be no layer of air between a solid and a liquid as they reduce the surface tension of the particles. Wetting agents, when added to aqueous fungicidal preparation, help in easy deposition on leaves. E.g., Polyethylene oxide condensate, esters of fatty acids and flour.

4.Spreading agents (Spreaders)

Spreaders are the materials added to establish improved contact between the spray materials and plant surface and thus ensuring a good coverage of fungicide. Wetting must precede spreading and this is the only distinction between wetting and spreading. Spreaders also reduce the surface tension and thus improve contact. E.g., soap, flour, sulphate amines, soap amines, mineral oils, glyceride oil, terpene oil, resonates and petroleum sulphonic acids.

5.Stickers (Adhesives)

The material, which are added to spray or dust to improve the adherence to plant surfaces are called as stickers. They increase the tenacity of the fungicidal preparations, thus increasing the residual action. E.g., Polyvinyl acetate, polybutanes, fish oil, linseed oil, milk casein, gelatin, dextrines, polyethylene polysulphide, starch, gum arabic, hydrocarbon oils and bentonite clays. Milk casein and gelatin also act as good spreading and wetting agents besides acting as stickers.

6.Safeners: A Chemical, which reduces the phytotoxicity of another chemical, is called safener. E.g., copper sulphate is phytotoxic to plants, but with addition of lime its toxicity is reduced. Lime is, therefore, a safener. Lime is used universally with chemicals to prevent the formation of, or to neutralise arsenic, which is phytotoxic to plants. Glycerin oils are also used as safeners.

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Toxicity levels of chemicals

The toxicity levels of the fungicidal formulations are based on the IC_{50} values. IC_{50} means the concentration of the chemical at which 50 per cent growth of the test organisms is inhibited. The toxicity levels of the chemicals in all formulations as coloured triangle.

Triangle Colour	Toxicity Level	IC_{50} Value (mg/kg body weight)	
		Oral	Dermal
Red	Extremely toxic	1-50	1-200
Yellow	Highly toxic	51-500	201-2000
Blue	Moderately toxic	501-5000	2001-20000
Green	Slightly toxic (Least toxic)	> 5000	> 20000

IC = Inhibitory concentration

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