स्वाध्याय स्वमन्थन स्वावलम्बन

उत्तर प्रदेश राजर्षि टण्डन मुक्त विश्वविद्यालय, प्रयागराज

उत्तर प्रदेश सरकार का एकमात्र मुक्त विश्वविद्यालय

।। सरस्वती नः सुभगा मयस्करत् ।।

Master of Science

PGBY-102 (N)

Mycology and Plant Pathology

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संदेश

प्रयागराज की पवित्र भूमि पर भारत रत्न राजर्षि पुरुषोत्तम दास टण्डन के नाम पर वर्ष 1999 में स्थापित उत्तर प्रदेश राजर्षि टण्डन मुक्त विश्वविद्यालय, प्रयागराज उ0प्र0 का एकमात्र मुक्त विश्वविद्यालय है। यह विश्वविद्यालय उ0प्र0 जैसे विशाल जनसंख्या वाले राज्य में उच्च शिक्षा के प्रत्येक आकांक्षी तक गुणात्मक तथा रोजगारपरक उच्च शिक्षा के अवसर उपलब्ध कराने में निरन्तर अग्रसर एवं प्रयत्नशील है। तत्कालीन देश की सामाजिक एवं आर्थिक परिस्थितियों में एक वैकल्पिक व नवाचारी शिक्षा व्यवस्था के रूप में भारत में मुक्त एवं दूरस्थ शिक्षा प्रणाली का पदार्पण हुआ था, परन्तु वर्तमान परिस्थितियों तथा तकनीकी का सार्थक प्रयोग करते हुये मुक्त एवं दूरस्थ शिक्षा आज की सर्वोत्तम पूरक शिक्षा व्यवस्था के रूप में स्थापित हो चुकी है।

वर्तमान शिक्षा प्रणाली के सामने व्याप्त पाँच मुख्य चुनौतियों - (i) पहुँच (Access), (ii) समानता (Equity), (iii) गुणवत्ता (Quality), (iv) वहनीयता (Affordability) तथा (v) जवाबदेही (Accountability) को केन्द्र में रखकर घोषित देश की राष्ट्रीय शिक्षा नीति (NEP-2020) के प्रस्तावों को क्रियान्वित करने में उत्तर प्रदेश राजर्षि टण्डन मुक्त विश्वविद्यालय कृत संकल्पित है। उ0प्र0 की माननीय राज्यपाल एवं कुलाधिपति की सद्इच्छाओं के अनुरूप उत्तर प्रदेश राजर्षि टण्डन मुक्त विश्वविद्यालय, शैक्षिक दायित्वों के साथ-साथ सामाजिक दायित्वों के निर्वहन में भी लगातार नवप्रयास कर रहा है। चाहे वह गाँवों को गोद लेकर उनके समग्र विकास का प्रयास हो या ग्रामीण महिलाओं, ट्रान्सजेन्डर व सजायाफ्ता कैदियों को शुल्क में छूट प्रदान कर उनमें आत्मविश्वास जागृति व उच्च शिक्षा के प्रति अलख जगाने का प्रयास हो।

राष्ट्रीय विकास को बढ़ावा देने के लिए शिक्षा एक मूलभूत जरूरत है। ज्ञान-विज्ञान एवं तकनीकी के क्षेत्रों में हो रहे तीव्र परिवर्तनों व वैश्विक स्तर पर रोजगार की परिस्थितियों में आ रहे परिवर्तनों के कारण भारतीय युवाओं को विभिन्न क्षेत्रों में गुणवत्तापूर्ण शैक्षिक अवसर उपलब्ध कराने पर ही भारत का भविष्य निर्भर करेगा। इसीलिए विभिन्न क्षेत्रों में सफलता हेतु शिक्षा को सर्वसुलभ, समावेशी तथा गुणवत्तापरक बनाना समसामयिक अपरिहार्य आवश्यकता है। वर्तमान परिस्थितियों ने परम्परागत शिक्षा को और भी सीमित कर दिया है जिसके कारण मुक्त एवं दूरस्थ शिक्षा व्यवस्था ही एकमात्र पूरक एवं प्रभावी शिक्षा व्यवस्था के रूप में सार्थक सिद्ध हो चुकी है। ऐसी स्थिति में विश्वविद्यालय का दायित्व और भी बढ़ जाता है। इस दायित्व को एक चुनौती स्वीकार करते हुए विश्वविद्यालय ने प्राचीन तथा सनातन भारतीय ज्ञान, परम्परा तथा सांस्कृतिक दर्शन व मूल्यों की समृद्ध विरासत के आलोक में सभी के लिए समावेशी व समान गुणवत्तायुक्त शिक्षा सुनिश्चित करने तथा जीवन पर्यन्त शिक्षा के अवसरों को बढ़ावा देने के लिए अपने शैक्षिक कार्यक्रमों में जागरूकता में प्रमाणपत्र, डिप्लोमा, परास्नातक डिप्लोमा, स्नातक, परास्नातक तथा शोध उपाधि के समसामयिक शैक्षिक कार्यक्रमों की संख्या तथा गुणात्मकता में वृद्धि की है।

शैक्षिक कार्यक्रमों में संख्यात्मक वृद्धि, गुणात्मक वृद्धि तथा रोजगारपरक बनाने के साथ-साथ प्रत्येक उच्च शिक्षा आकांक्षी तक पहुँच सुनिश्चित करने के लिए अध्ययन केन्द्रों व क्षेत्रीय केन्द्रों के विस्तार के साथ-साथ प्रवेश परीक्षा, प्रशासन तथा परामर्श (शिक्षण) में आनलाइन व्यवस्थाओं को सुनिश्चित किया गया है। विश्वविद्यालय कार्यप्रणाली में पारदर्शिता तथा जवाबदेही सुनिश्चियन की दृष्टि से तकनीकी के प्रयोग को बढ़ाया गया है। 'चुनौती मूल्यांकन' की व्यवस्था सुनिश्चित करने का कार्य किया गया है, तो शिक्षार्थी सहायता सेवाओं में भी वृद्धि की जा रही है। शिक्षार्थियों की समस्याओं के त्वरित निस्तारण हेतु शिकायत निवारण प्रकोष्ठ को सुदृढ़ करने के साथ-साथ पुरातन छात्र परिषद को गतिशील किया गया है।

"गुरुकुल से छात्रकुल" के सूक्त वाक्य को आत्मसात करते हुए विश्वविद्यालय ने शिक्षार्थियों को विश्वविद्यालय द्वारा तैयार किये गये गुणवत्तापूर्ण स्वअध्ययन सामग्री उपलब्ध कराने के साथ-साथ विश्वविद्यालय की वेबसाइट पर भी उपलब्ध कराया गया है। छात्रहित को ध्यान में रखते हुए शिक्षकों द्वारा तैयार व्याख्यान को भी ऑनलाईन उपलब्ध कराया गया है।

शोध और नवाचार के क्षेत्र में अग्रसर होते हुए विश्वविद्यालय अनुदान आयोग (UGC) नई दिल्ली तथा माननीय राज्यपाल एवं कुलाधिपति, उ0प्र0 की अनुमति से विश्वविद्यालय में शोध कार्यक्रम पुनः प्रारम्भ किया गया है तथा वर्ष पर्यन्त समसामयिक विषयों पर व्याख्यान, सेमिनार, वेबिनार तथा आनलाइन संगोष्ठियों आदि की श्रृंखला भी प्रारम्भ की गयी है। विभिन्न क्षेत्रों में रिसर्च प्रोजेक्ट सम्पादन पर भी ध्यान केन्द्रित किया गया है। पुस्तकालय को अत्याधुनिक तथा सुदृढ़ बनाने हेतु कदम उठाये गये हैं। शिक्षकों व कर्मचारियों के स्वास्थ्य तथा कल्याण की योजनायें क्रियान्वित की गयी हैं।

प्रो0 सत्यकाम
कुलपति

Uttar Pradesh Rajarshi Tandon

Open University

Master of Science

PGBY-102 (N)

Mycology and Plant Pathology

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Block 2 : Plant Pathology

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Course Introduction

This course covers the Mycology and Plant Pathology in two blocks. Block I deals with mycology and Block II with plant pathology

Mycology is the study of fungi. The fungi are eukaryotic, sporebearing, an achlorophyllous and unicellular or multicellular organism that digests food externally and absorbs nutrients directly through its cell wall. They reproduce both by asexual and sexual means.

The plant pathology is the study of plants and their pathogens, the process of disease, influenced by factors such as weather, nonpathogenic microorganisms and plant nutrition.

Block-I

This block deals with mycology in five units viz. Unit 1,2,3,4 and 5. The five units are as follows.

Unit-1 Introduction of fungi which has general characteristic of fungi and classification.

Unit-2 is phycomycotina I. It deals with life cycle of *Plasmodiophora* and general information of division myxomycota.

Unit-3 is phycomycotina II. It deals with classification general characteristics and economic importance of mastigomycotina, zygomycotina and life cycle of *Synchytrium endobioticum.*

Unit-4 is Ascomycotina which has general characteristics, classification and economic importance of Ascomycotina.

Unit 5 is basidiomyotina and deuteromycotina. It deals with general characters, classification and economic importance of basidiomycotina and deuteromycotina.

Unit 1

Introduction to Fungi

Structure

1.1 Introduction

Fungi are eukaryotic microorganisms. Fungi can occur as yeasts, moulds, or as a combination of both forms. Some fungi are capable of causing superficial, cutaneous, subcutaneous, systemic or allergic diseases. Yeasts are microscopic fungi consisting of solitary cells that reproduce by budding. Moulds, in contrast, occur in long filaments known as hyphae, which grow by apical extension. Hyphae can be sparsely septate to regularly septate and possess a variable number of nuclei. Regardless of their shape or size, fungi are all heterotrophic and digest their food externally by releasing hydrolytic enzymes into their immediate surroundings (absorptive nutrition). Other characteristics of fungi are the ability to synthesize lysine by the L-α-adipic acid biosynthetic pathway and possession of a chitinous cell wall, plasma membranes containing the sterol ergosterol, 80S rRNA, and microtubules composed of tubulin.

Objectives

After studying this unit, you will be able:

- To identify what fungi are.
- To describe habitats of fungi
- To outline the structure of fungi
- To describe fungi reproduction
- To give an overview of fungi classification
- To know about heterothallism
- To describe parasexuality

- To explain sex hormones in fungi

1.2 Physiology

Fungi can use a number of different carbon sources to meet their carbon needs for the synthesis of carbohydrates, lipids, nucleic acids, and proteins. Oxidation of sugars, alcohols, proteins, lipids, and polysaccharides provides them with a source of energy. Differences in their ability to utilize different carbon sources, such as simple sugars, sugar acids, and sugar alcohols, are used, along with morphology, to differentiate the various yeasts. Fungi require a source of nitrogen for synthesis of amino acids for proteins, purines and pyrimidines for nucleic acids, glucosamine for chitin, and various vitamins. Depending on the fungus, nitrogen may be obtained in the form of nitrate, nitrite, ammonium, or organic nitrogen; no fungus can fix nitrogen. Most fungi use nitrate, which is reduced first to nitrite (with the aid of nitrate reductase) and then to ammonia.

Non-fungal organisms, including bacteria use to synthesize the amino acid lysine by the *meso*-α,ε-diaminopimelic acid pathway (DAP pathway), whereas fungi synthesize lysine by only the L-α-adipic acid pathway (AAA pathway). Use of the DAP pathway is one of the reasons due to which the microorganisms previously considered to be fungi. The myxomycetes, oomycetes, and hyphochytrids, are no longer classified as fungi. The DAP and AAA biosynthetic pathways for lysine synthesis represent dichotomous evolution.

SAQ.1

a. Fungi havethe ability to synthesize amino acid____________by L-α-adipic acid pathway.
b. The cell wall of fungi is made up of______________.
c. The sterol ergosterol is present in_______________of fungi.

1.3 General Characteristics of Fungi

Some of the most important characters of fungi are as follows:

1.3.1. Occurrence

- Fungi are cosmopolitan and occur in air, water, soil and on plants and animals.
- They prefer to grow in warm and humid places. Hence, we keep food in the refrigerator to prevent bacterial and fungal infestation.

1.3.2. Thallus organization

- Except some unicellular forms (e.g. yeasts, *Synchytrium*), the fungal body is a thallus called mycelium.
- The mycelium is an interwoven mass of thread-like hyphae (Sing, hypha). Hyphae may be septate (with cross wall) and aseptate (without cross wall). Some fungi are dimorphic that found as both unicellular and mycelial forms e.g. *Candida albicans*.
- The thallus may be two types: Unicellular and filamentous.

i. **Unicellular thallus:** In some of the lower fungi, thallus is more or less a spherical, single celled structure. At the time of reproduction, it becomes a reproductive unit. Such fungi are called holocarpic. In the unicellular holocarpic forms, the mycelium is absent e.g. *Synchytrium*. Some holocarpic fungi (e.g., *yeast*) producing bud cells in succession and these remain attached to one another in a chain. Such a chain of bud cells is referred to as pseudomycelium.

ii. **Filamentous thallus:** In most true fungi, the thallus is filamentous composed of Hyphae. Loosely aggregated hyphae are collectively forms a network known as mycelium. Each hypha may vary in shapes and sizes. Branching of hyphae is dichotomous. On the basis of presence or absence of septa the hyphae of mycelical fungi are of two types:

- ✓ **Nonseptate or aseptate hyphae:** Mycelium contains numerous nuclei, lying in a common mass of cytoplasm, without cross wall in the hyphae, e.g., oomycetes and zygomycetes. Such a condition is known as coenocytic. However, septa may be laid down at the time of formation of reproductive organs to delimit them from the rest of the vegetative hyphae, therefore called Pseudosepta. e.g., *Allomyces*.
- ✓ **Septate Hyphae:** Hyphae are septate and hyphal segments may contain one, two or more nuclei. E.g., Ascomycotina, Basidiomycotina, and Deuteromycotina. There are two types of septa:
  - **Primary septa:** Primary septa are formed in association with mitotic or meiotic nuclear division, and they separate the daughter nuclei. These types of septa are found in Ascomycotina, Basidiomycotina and their asexual states.
  - **Adventitious septa:** Adventitious septa are formed in the absence of mitosis or meiosis and occur especially in association with change in the local concentration of cytoplasm. These are found in lower groups of fungi as mastigomycotina and zygomycotina.

SAQ.2

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a. ____________producing bud cells in succession.

b. Loosely aggregated hyphae collectively forms a network known as___________.

c. Pseudoseptate condition is found in________________fungi.

d. Adventitious septa are found in lower group of fungi as__________and___________.

1.3.3. Different forms of mycelium

Different forms of mycelium refer to as the various shapes and the functions of mycelium which modified according to the circumstances. These includes the following forms:

i. **Plectenchyma (fungal tissue):** In a fungal mycelium, hyphae organized loosely or compactly woven to form a tissue called plectenchyma. It is two types:

- ✓ **Prosenchyma or Prosoplectenchyma:** In these fungal tissue hyphae are loosely interwoven lying more or less parallel to each other.
- ✓ **Pseudoparenchyma or paraplectenchyma:** In these, fungal tissue hyphae are compactly interwoven looking like a parenchyma in cross-section.

ii. **Sclerotia (Gr. Skleros=haid):** These are hard dormant bodies consist of compact hyphae protected by external thickened hyphae. Each Sclerotium germinates into a mycelium, on return of favourable condition, e.g., *Penicillium*.

iii. **Rhizomorphs:** They are root-like compactly interwoven hyphae with distinct growing tip. They help in absorption and perennation (to tide over the unfavourable periods), e.g., *Armillaria mellea*. It is commonly known as honey fungus, is a basiomce fungus. It casuses Armilloria root rot in many plant species and produces mushrooms around the base of trees it has infected.

iv. **Rhizoids:** A rhizoid is a short, root like filamentous branch of the thallus, generally formed in tufts at the base of the thallus. These also function as anchoring and absorbing, e.g., *Rhizophydium, Rhizopus*. *Rhizophydium graminis* is a parasite of wheat roots but causes no extensive damage to plant.

v. **Appressoria (Sing. appressorium):** It is a terminal simple or lobed swollen mucilaginous structure of infecting hyphae which adheres to the surface of the host or other substratum and helps in the penetration of the infection hyphae. These are formed by some parasitic fungi such as powdery mildews and rust. Powdery mildew diseases casused by many different species of ascomycete fungi in the order Erysiphales.

vi. **Haustoria (Sing. Haustorium):** A haustorium is an organ that is developed from a hypha usually performing the function of absorption. They are characteristic of obligate parasites. They vary in shape and may be knob like or button shaped, elongated, finger-like or branched. They secrete some specific enzymes which hydrolyse the protein and carbohydrates of the host plant. A haustorium is formed when a specilized fungul hypha penartes a plant cell wall and expands inside that cell. Haustorium is the extended structures originating from parasitic plants or hypha of fungi. e.g. include Mycoparasites among zygomycota and the Tremellales, *Sporidesmium Sclerotivorum parasitizing Sclerotinia sclerotiorum.*

vii. **Hyphal traps (Snares):** The predacious fungi develop sticky hyphae or network of hyphal loops known as hyphal traps or Snares. They help in capturing nematodes. The oyester mushroom (Pleuretus ostreatus) which is in the Basidiomycota, is a nematode - trapping fungus that usesadhesive hyphal braches. They play an important ecological role in regulating nematode dynamics in soil.

viii. **Stromata:** These are compact somatic structures much like mattresses. Fructifications are generally formed on or in them. The stromata of Epichole fungi are stucturees covering part oof the stem of grasses. Under the fungual layer, still green tissues of the plant survive, although the development of the new leaves is inhibited.

1.3.4. Cell structure

- Fungi are the eukaryotic organisms.
- The cell wall determines the characteristic shape of a cell. It protects the cell from osmotic lysis and also acts as a binding site for some enzymes.
- The chemical composition of the cell wall is not the same in all fungi. Chitin is characteristically present in the cell walls of most fungi. The chitin in fungal cell wall is not strictly identical with animal chitin, and the formula $(C_{22}H_{54}N_4O_{21})^n$ has been suggested for the fungal chitin: It is a polymer of Nacetylglucosamine.
- The cytoplasm at hyphal tip contains Golgi vesicles called chitosomes which filled with cell wall materials.
- Nucleus and mitochondria are found to connect with ER. Nucleus divides by intracellular mitosis called karyochorisis where nuclear envelop remain intact during nuclear division and internal spindle develop. Reserve food is glycogen and oil.

SAQ.3

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a. In fungal mycelium, hypha organized loosely or compactly woven to form a tissue called______________.

b. In_________________, rhizomorphs type of mycelium formed.

c. Hyphal types or snares are formed in the___________fungi.

d. The formula of chitin is________________.

e. Nucleus divides by intercellular mitosis called____________________.

1.3.5. Nutrition

❖ The fungi lack chlorophyll. Therefore, they cannot synthesize their own food. Depending on from where and how they get nutrition, fungi are of following types:

i. Saprotrophs: They obtain food from dead and decaying organic matter. They secrete digesting enzymes to outside which digest the substratum and then absorb nutrients, e.g., *Mucor, Agarious, Rhizopus* etc.

ii. Parasitic: They obtain food from living organisms. They may be facultative or obligate. Facultative parasites grow on a variety of tissues e.g., *Ustilago*. The obiigate- parasites grow only upon suitable host, e.g., downy mildews. The parasitic fungi that grow on surface of host cells and absorb food through haustoria are called ectoparasites or ectophytic parasites (e.g., *Mucor*, *Erisphae*). When parasitic fungi grow inside the host tissue are called endoparasites or endophytic parasites (e.g., *Pythium*, *Puccinia*).

iii. Predacious: Some soil fungi develop ring-like noses to trap annelids, nematodes etc. e.g., *Arthrobotrys, Zoophagus, Dactylella* etc.

iv. Symbiotic: They live in mutualistic relationship with another organism by which both are benefited. The two common examples are lichens and mycorrhiza.

❖ Lichens are symbiotic associations between fungi and algae. The fungal partner is a member of ascomycetes or basidiomycetes that provides water and nutrients, while the algal partner is a green alga or cyanobacteria that prepares food by photosynthesis.

v. Mycorrhizas: or mycorrhizae are the mutualistic symbiotic associations between soil fungi and the roots of most plant species. According to the carbohydrate theory (Bjorkman, 1949), the plants that grow in soils deficient in P (Phosphoreus) and N (Nitorogen), and high intensity light develop mycorrhizas.

❖ The two most common types of mycorrhizas are the ectomycorrhizas (ECM) and the endomycorrhizas (also known as arbuscular mycorrhiza). The two groups are differentiated by the fact that the hyphae of ectomycorrhizal fungi do not penetrate the cell wall of the plant's root cells, while the hyphae of arbuscular mycorrhizal fungi penetrate the cell wall.

SAQ.4

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a. The example of endophytic parasites are____________and_____________.

b. Lichens are_____________association between fungi and algae.

c. The alternative names of ectomycorrhizas and endomycorrhizas are____________ mycorrhiza.

d. The fungi cannot synthesize their own food due to lack of_______________.

1.3.6. Heterothallism and Homothallism

❖ F. Blakeslee (1904) discovered mating types or genetically distinct strains in *Mucor*.

❖ He called fungi with different mating types that are called heterothallic and fungi without mating types are called homothallic.

- Nowadays we call some fungi and algae homothallic if both male and female gametes produce in the same individual can fertilize each other and heterothallic if the gametes can only be fertilized by gametes from another individual of the same species. Heterothallism introduces variations in the species.

1.3.7. Reproduction

- In fungi, reproduction may take place by three methods; vegetative, asexual and sexual.
- During asexual and sexual reproduction processes spores are the essential structures. The spores formed after meiosis are called meiospores (e.g., ascospores, basidiospores and sporangiospores) and those resulting from mitosis, called mitospores (e.g., mitospores, zoospores, aplanospores, conidia, uredospores).
- The diploid body produced as a result of sexual fusion is known as zygote which in lower fungi is termed as resting spore, oospore or zygospore.
- In higher fungi, the zygote is represented by a diploid nucleus produced in a cell (ascus or basidium). This diploid nucleus after undergoing meiosis results in the formation of haploid nuclei serving as centres for haploid sexual spores called ascospores and basidiospores.

1.3.7.1. Vegetative reproduction: In this type of reproduction, a part of mycelium separate and forms a new individual bya fragment of the parent plant or a specialized reproductive structure. Fission, budding and fragmentation are the most common methods of vegetative reproduction in a number of fungi. In addition to above-mentioned common methods they also reproduced vegetatively by other means, such as sclerotia, rhizomorphs, etc. The various methods of vegetative reproduction are:

a. **Fragmentation:** The hyphae break into small fragments. Each piece upon getting suitable conditions, germinates to form a new mycelium.

b. **Fission:** This method involves the splitting of cells into two daughter cells by the formation of a constriction followed by a cell wall formation.

Process of Fission:

- In binary fission a mature cell elongates and its nucleus divides into two nuclei.
- The daughter nuclei separate, cleaves cytoplasm centripetally in the middle till it divides parent protoplasm into two daughter protoplasm.
- A double cross wall is deposited in the middle to form two daughter cell.
- Ultimately the middle layer of double cross wall degenerates and daughter cells are separated.
- Examples: Saccharomyces, Psygosaccharomyces

c. **Budding:** A small bud formed from the parent cell which gradually increases in size and receives a part of nucleus. A cell wall is formed which separates the daughter cell from the parent cell.

Process of Budding:

- The cell wall bulges out and softens in the area probably by certain enzymes brought by vesicles.

- The protoplasm also bulges out in this region as small protuberance.
- The parent nucleus also divides into two, one of the daughter nucleus migrates into bud, the cytoplasm of bud and mother remain continuous for some time
- As the bud enlarges, a septum is laid down at the joining of bud with mother cell. Then bud separates and leads independent life.
- Some time, bud starts reproducing while still attached with mother cell. This gives branching appearance.
- Budding is the typical reproductive characteristics of Ascomycetes.
- Examples: *Yeast*

d. Sclerotia: These are perennating bodies formed by the compact masses of interwoven hyphae. Sclerotia under suitable conditions germinate to form new individuals E.g., *Claviceps, Sclerotinia*.

e. Rhizomorphs: These are root-like elongated mycelial strands. They remain dormant under unfavourable conditions and under favourable conditions develop into a new mycelium.

SAQ.5

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a. If both male and female gametes produce in the same individual can fertilize each other, the called________________.

b. In *Claviceps*, vegetative reproduction occurs with the formation of______________.

c. _______________occurs in *Yeast*.

d. _______________are root like elongated mycelial strands.

1.3.7.2.Asexual reproduction:

❖ Typically, in asexual reproduction, a single individual gives rise to a genetic duplicate of the progenitor without a genetic contribution from another individual. Perhaps the simplest method of reproduction of fungi.

❖ The majority reproduce asexually by the formation of spores. Spores that are produced asexually are often termed mitospores, and such spores are produced in a variety of ways.

❖ The spores are of diverse type and borne upon special structures called the sporophores. These spores are produced asexually and called the asexual spores.

❖ Usually the spores are uninucleate and nonmotile but multinucleate and motile spores are also found.

❖ The fungus producing more than one type of spores is called the pleomorphic or polymorphic.

❖ The spores produced inside the sporangia are termed the endogenous spores and the spores developing exogenously on the terminal ends of sporophores are called the exogenous spores.

➢ **Endogenous spores:** The endogenous spores are produced within the special spore producing cell the sporangium.

- The sporangia may be terminal or intercalary in their position. The sporophores which bear the sporangia on their apices are called the sporangiophores. They may be branched or unbranched.

- The spores produced inside the sporangia are called the endospores or endogenous spores produced inside the sporangia are called the endospores or endogenous spores.
- They may be motile or non-motile. The motile spores are called the zoospores and the nonmotile aplanospores. The zoospores are produced inside the zoosporangia.
- The protoplasm of the sporangium divides into uninucleate or multinucleate protoplasmic bits and each bit metamorphoses into a spore.
- The endogenously produced zoospores are uni or biflagellate. Each spore is without any cell wall, uninucleate and vacuolate. They can move with the help of their flagella.
- They are usually kidney-shaped or reniform and the flagella are inserted posteriorly or laterally on them. Such zoospores have been recorded from *Albugo, Pythium, Phytophthora* and many other lower fungi.
- The aplanospores are non-motile, without flagella and formed inside the sporangia. They may be uni or multinucleate (E.g., *Mucor, Rhizopus*).
- These spores lack vacuoles and possess two layered cell walls.
- The outer thick layer is epispore or exospore which may be ornamented in many cases. The inner thin layer is endospore.

➢ **Exogenous spores:**

- The spores producing externally or exogenously are either called the exogenous spores or conidia. They are produced externally on the branched or unbranched conidiophores.
- The condiophores may be septate or aseptate. The conidia borne upon the terminal apices of the conidiophores or the ends of the branches of the condiophores.
- The conidia may be produced singly on each sterigma or in chains.
- The conidial chains may be basipetal to acropetal in succession. The conidia are diverse in their shape and size.
- They may be unicellular or multicellular, uninucleate or multinucleate.
- Different genera may be recognized only by the presence of various shaped and various coloured conidia.
- The conidia of Fungi Imperfecti are multicellular and variously shaped, whereas the conidia of *Aspergillus* and *Penicillium* are smoky green coloured and the fungi are called ‘the blue-green molds.
- In other type of exospores, the sporophores develop in groups and form the specialized structure called the pustules, pycnia, aecidia, acervuli, and sporodochia.

- The pycnia are flask-shaped producing pycniospores in them.
- The acervuli are saucer- shaped widely open bodies having developed conidia in them on small conidiophores.
- In mushrooms the sporophores are compactly arranged and form an umbrella-like fructification.
- The terminal expanded portion bears gills.
- In each gill there are hundreds of sporophores called the basidia bearing basidiospores.
- The sporophores (basidia) are arranged in hymenia.

The various types of asexual spores are:

a. **Zoospores:** These are commonly found in lower fungi e.g., *Saprolegnia, Pythium* etc. They are naked spores, which after swarming, encyst, secrete a cell wall and germinate by germ tube into a thallus. They are equipped with one or two flagella

b. **Sporangiospore:** The sporangiospores or aplanospores are nonmotile and lack flagella and are formed inside the sporangium e.g. *Mucor, Rhizopus*. These spores may by uninucleate or multinucleate and possess two-layered cell wall.

c. **Conidia or conidiospores:** They are produced externally on branched or unbranched hyphal tips termed as conidiophores. The conidia may be formed singly or in chains. The conidial chains may be basipetal or acropetal in succession. Conidia may be uninucleate or multinucleate. The latter type is more common in the members of class Deuteromycetes.

d. **Arthrospore:** It is primitive type of spore formed by the breaking up of fungal mycelium. A spore is formed by separation followed by fragmentation of hyphae. Examples: *Trichosporium, Geotrichum, Coccididious imitis*

e. **Oidia:** They are produced by fragmentation of hyphae from apex to base. Each cell thus formed rounds off and separate, as a spore which under favourable circumstances germinates and forms the mycelium.

f. **Chlamydospores:** They are formed by rounding off and enlargement of terminal or intercalary cells of a hypha. These can be single or in chains. They do not separate from the hyphae but remain viable and germinate under favourable conditions.

g. **Blastospores:** It is a budding spores usually formed at the terminal end of hyphae. These spore may remain attached to hyphae and bud further to gibe branching chain of blastospores. Examples: ascomycetes, basidiomycetes, zygomycetes

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SAQ.6

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a. The fungus producing more than one type of spores is called________________.

b. The motile spores are called_______________and the non-motile spores are called ______________.

c. The aplanospores lacks__________and posses_________layered cell walls.

d. The conidia may be produced______________on each sterigma or in chains.

e. The conidial chains may be______________to________________successsion.

f. *Aspergillus* and *Penicillium* are smoky green coloured and are called _____________molds.

g. The pycnia are flask shaped producing_______________in them.

h. _______________formed by the breaking up of fungal mycelium.

1.3.7.3. Sexual reproduction: It involves the formation and fusion of gametes. Sexual reproduction found in all groups of fungi except deuteromycetes or fungi imperfecti. Sexual reproduction has three distinct phases i.e. plasmogamy (protoplasmic fusion), karyogamy (fusion of nuclei) and meiosis (reduction division of zygote). The various methods of sexual reproduction in fungi are as follows:

a. **Planogametic copulation:** This is simplest type of sexual reproduction. In this process fusion of two gametes of opposite sex or strains takes place where one or both of the fusing gametes are motile (flagellated). It results in the formation of a diploid zygote. This process is usually of these types:

   - ✓ **Isogamy:** In this process fusing gametes are morphologically similar and motile but physiologically dissimilar. These gametes are produced by different parents, e.g. *Synchytrium*.
   - ✓ **Heterogamy:** When the fusing gametes are morphologically as well as physiologically different, the process is known as heterogamy. Heterogamous reproduction is of two types: anisogamy and oogamy. **Anisogamy** consists of the fusion of two motile gametes where the male gamete is small and more active than the female gamete, e.g., Allomyces. In **oogamy** the motile male gamete (antherozooid) fuses with the large, non-motile female gamete (egg or ovum) e.g., *Synchytrium* etc.

b. **Gametangial contact:** In this process two gametangia of opposite sex come in contact with one another. The male gametangium (antheridium) transfer male nucleus or gamete into the female gametangium (oogonium) either through a pore at the point of contact or through a fertilization tube, e.g., *Phytophthora, Albugo, Pythium* etc.

c. **Gametangial copulation:** In involves the fusion of entire contents of two gametangia to form a common cell called zygote or zygospore, e.g., *Mucor, Rhizopus*.

d. **Spermatization:** Some fungi produce many minute, sporelike, single-celled structures called spermatia (nonmotile gametes). These structures are transferred through agencies like water, wind and insects to either special receptive hyphae or trichogyne of ascogonium. The contents migrate into receptive structure. Thus dikaryotic condition is established, e.g. *Puccinia*.

e. **Somatogamy:** This takes place in fungi where formation of gametes is absent. In such fungi, anastomoses take place between hyphae and their somatic cells fuse to produce dikaryotic cells, e.g, *Agaricus, Peniophora* etc.

Some sexual spores are-

a. **Ascospores:** It is usually single celled produced in a sac called ascus (plural;asci) and usually there are 4-8 ascospore in an ascus but the number may vary from species to species. The ascospore are usually arranged in a linear order. In some case ascospores are long, narrow and are arranged in parallel order.

b. **Zygospores:** Zygospores are thick walled spores formed when two sexually compatible hyphae or gametangia of certain fungi fuse together. In suitable condition, zygospore germinates to produce a single vertical hypha which forms a sporangium and releases its spores

c. **Basidiospores:** It is a reproductive spore produced by basidiomycetes. This single celled spores are born in a club shaped structure called basidium These basidiospore serves as main air dispersal unit for the fungi.

d. **Oospore:** These are formed within a special female structure called Oogonium. Fertilization of egg by male gamete in female sex organ give rise to oospoes. There are one or more oospores in each oogonium.

1.4 Fungal Cell Wall

The fungal cell wall is an essential structure with great plasticity that is vital to maintaining cellular integrity and viability. The cell wall plays an important role in different biological functions such as controlling cellular permeability and protecting the cell from osmotic and mechanical stress. In addition to these important functions, the cell wall mediates interactions with the external environment through adhesins and a large number of receptors that, after their activation, will trigger a complex cascade of signals inside the cell. The cell wall is uniquely composed of polysaccharides and proteins as well as lipids and pigments. Furthermore, some wall components are very immunogenic and stimulate cellular and humoral responses during infection. β-glucans and mannans, as well as antibodies directed against them, are very useful diagnostic tools since they can be detected in patients with invasive fungal infection. As mentioned above, the cell wall represents an indispensable structure, that its disruption can have serious effects on cell growth and morphology resulting in cell death. Hence, it is considered a good antifungal target.

The cell wall is a specific and complex cellular organelle composed of glucans, chitin, chitosan, and glycosylated proteins. Proteins are generally associated with polysaccharides resulting in glycoproteins. Together, these components contribute to the cell wall rigidity. The synthesis and maintenance of cell wall involves a large number of biosynthetic and signaling pathways.

1.4.1. Structure

The cell wall is structured in different layers where the innermost layer is a more conserved structure on which the remaining layers are deposited and can vary between different species of fungi. The composition and organization of fungal cell walls are compared and contrasted in the text below.

1.4.2. Glucans

Glucan is the most important structural polysaccharide of the fungal cell wall and represents 50–60% of the dry weight of this structure. Most polymers of glucan are composed of 1,3 linkage glucose units (65–90%), although there are also glucans with β-1,6 (in *Candida* but not in *Aspergillus*), β-1,4, α-1,3 and α-1,4 links. The β-1,3-D-glucan is the most important structural component of the wall, to which other components of this structure are covalently linked. The β-1,3-D-glucan is synthesized by a complex of enzymes located in the plasma membrane called glucan synthases. The genes encoding β-1,3-D-glucans, *FKS1* and *FKS2*, were initially identified in *Saccharomyces cerevisiae*. Analogs of these genes are currently known in several species of *Candida*, *Aspergillus*, *Cryptococcus*, and *Pneumocystis* among other fungi. Disruption of one of these genes affects cell growth but elimination of both causes cell death. The α-1,3-glucan is also a fundamental component of the fungal cell wall and is synthetized by α-glucan synthase (*AGS1*).

1.4.3. Chitin

The chitin content of the fungal wall varies according to the morphological phase of the fungus. It represents 1–2% of the dry weight of yeast cell wall while in filamentous fungi, it can reach up to 10–20%. Chitin is synthesized from n-acetylglucosamine by the enzyme chitin synthase, which deposits chitin polymers in the extracellular space next to the cytoplasmic membrane. The chitin content in the *C. albicans* hyphae wall is three times higher than that of yeasts while the chitin content of the mycelial phases of *Paracoccidioides brasiliensis* and *Blastomyces dermatitidis* is 25–30% of that yeast phase.

1.4.4. Glycoproteins

Proteins compose 30–50% of the dry weight of fungal wall in yeast and 20–30% of the dry weight of the wall of the filamentous fungi. Most proteins are associated to carbohydrates by O or N linkages resulting in glycoproteins. Cell wall proteins have different functions including participation in the maintenance of the cellular shape, adhesion processes, cellular protection against different substances, absorption of molecules, signal transmission, and synthesis and reorganization of wall components.

1.4.5. Melanin

Melanin is a pigment of high molecular weight that is negatively charged, hydrophobic and insoluble in aqueous solutions and protects fungi against stressors facilitating survival in the host. The fungi produce melanin by two routes, from 1, 8-dihydroxynaphthalene (DHN) intermediate and from L-3, 4-dihydroxyphenylalanine (L-dopa). Melanin production contributes to fungal virulence, improves resistance to environmental damage such as extreme temperature, UV light and toxins, and is important for invasion and dissemination. For example, *C. neoformans* melanin has been linked with dissemination of yeast cells from the lungs to other organs, is known to influence the immune response of the host) and inhibit phagocytosis. In *Aspergillus*, melanin inhibits macrophage apoptosis that have phagocytosed melanized conidia.

Cell wall composition and taxonomic classification of representative medically important fungi

Principal cell wall polymer	Taxonomic Group	Examples
Chitin-chitosan	Zygomycetes	*Rhizopus arrhizus*
Chitin-glucan	Ascomycetes (mycelial)	*Pseudallescheria boydii*
	Basidiomycetes (mycelial)	*Schizophyllum commune*
Glucanmannan	Ascomycetes (yeast)	*Sacchamomyces cerivisea*
Chitin-mannan	Fungi imperfecti	*Candida albicans*
	Basidiomycetes (yeast)	*Filobasidiella neoformans*

1.5 Fungal Organelles

Within the plasma membrane of fungi is the colourless cytoplasm in which sap-filled vacuoles may occur. In young hyphae and hyphal tips, the cytoplasm appears rather uniform and homogeneous. Immersed in the cytoplasm are structures known as the organelles and inclusions

(Figure1.1).

The organelles are living structures, each with a specific function. The inclusions are dead, have no specific function and thus are not essential to cell survival.

Amongst the cell organelles are included the endoplasmic reticulum, mitochondria, ribosomes, Golgi apparatus and vacuoles. Lomasomes which are membranous structures lying between the cell wall and plasma membrane are common. Examples of inclusions are the stored foods (glycogen, and oil drops) pigments and secretory granules.

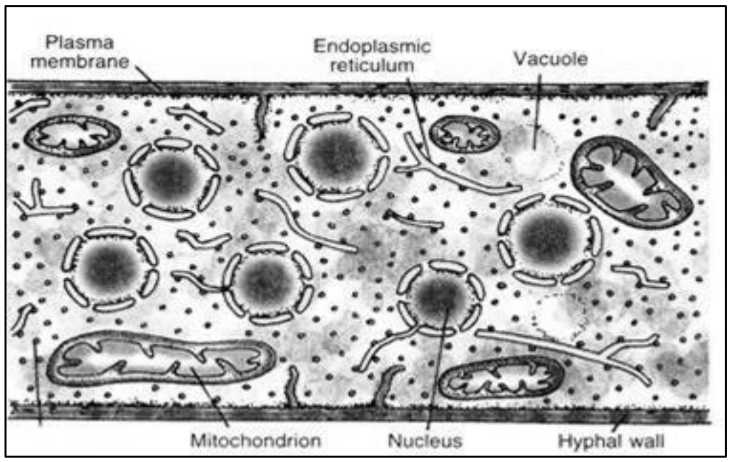

Figure1.1: Fine structure of a hypha near the growing tip of *Mucor* based on an Electron micrograph

1.5.1. Endoplasmic Reticulum:

The presence of endoplasmic reticulum in the fungal cytoplasm has been demonstrated by the use of electron micro scope. It is composed of a system of membranes or microtubular structures usually beset with small granules which by some scientists are likened to the ribosomes. In many fungi, the endoplasmic reticulum is highly vesicular. Usually it is loose and more irregular than in the cells of green plants.

1.5.2. Mitochondria:

The cytoplasm contains small, usually spherical bodies known as the mitochondria. Each mitochondrion is enveloped by a double membrane. The inner membrane is infolded to form the cristae which are in the form of parallel flat plates or irregular tubules.

The cristae contain the same fluid that fills the space between the two membranes. The mitochondria function as the power house of the cell. There is no fundamental difference between the mitochondria of fungi and those of green plants. However, Hawker (1965) holds that the cristae of fungal mitochondria are fewer, flatter and more irregular than those of the green plants.

1.5.3. Golgi Apparatus (Dictyosomes):

With the exception of Oomycetes there is less certainty of the occurrence of structures similar to those of the golgi apparatus (dictyosomes) in fungi. Moore and Muhlethaler (1963) reported a golgi apparatus consisting of three flattened sacs surrounded by many bubble-like structures in Saccharomyces cells.

1.5.4. Vacuole:

The cytoplasm of young hyphae or fungal cells and hyphal tips lacks vacuoles. They appear further back or in the old cells. With age, they enlarge and show a tendency to coalesce and ultimately reduce the cytoplasm to thin lining layer immediately within the cell wall.

1.5.5. Inclusions:

The cytoplasm contains various kinds of inclusions. Examples of stored foods are lipid globules, granules of glycogen, oils and the carbohydrate trehalose, proteinaceous material and volutin. The glycogen may occur in vacuoles.

There are no starch grains. Of the pigments, the fungi lack chlorophyll. Carotenoids are often conspicuous by their presence and may occur throughout the cytoplasm or concentrated in the lipid granules or distributed in the cell wall. The cytoplasm, in addition, secretes several kinds of ferments, enzymes and organic acids.

SAQ.7

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a. The β-1,3-D-glucan is synthesized by a complex of enzymes located in the plasma membrane called_______________.

b. The chitin content in the_______________hyphae wall is three times higher than that of yeasts.

c. The fungi produce melanin by two routes, from_______________intermediate and from_____________________.

d. ________________which are membranous structures lying between the cell wall and plasma membrane are common.

1.6 Classification of Fungi

- ❖ The classification of fungi is designed mainly for practical application but it also bears some relation to phylogenetic considerations.
- ❖ The division of mycota, or fungi and moulds, includes the true slime moulds (Myxomycetes), the lower fungi (Phycomycetes), and the higher fungi (Eumycetes).
- ❖ The fungi can be classified according to the various parameters including;
    - Classification based on taxonomy hierarchy
    - Classification based on spore Production
    - Classification of medically important fungi
    - Classification based on route of acquisition
    - Classification based on virulence

1.6.1. Classification based on taxonomy hierarchy:

- ❖ Alexopolous and Mims proposed fungal classification in 1979. They place the fungi including the slime molds in the kingdom mycetae of the super kingdom Eukaryota which, in addition, includes four other kingdoms. They divide the kingdom mycetae into three divisions namely:
    - ✓ Gymnomycota
    - ✓ Mastigomycota
    - ✓ Amastigomycota
- ❖ The division is subdivided into subdivision, classes, sub-classes, and orders.

- **Division I: Gymnomycota:** It includes phagotrophic organism devoid of cell walls. This division comprises two subdivisions; Acrasiogymnomycotina and Plasmodiogynomycotina.

1. **Subdivision: Acrasiogymnomycotina:** It includes a single class Acrasiomycetes.

   Class 1. Acrasiomycetes : Lacks flagellated cells except for one species. The class comprises:

   Sub class 1. Acrasiomycetidae

   Sub class 2. Dictyosteliomycetidae

2. **Subdivision: Plasmodiogymnomycotina:** It is divided into two classes:

   Class 1. Protosteliomycetes

   Class 2. Mycomycetes: It includes the true slime mold and comprises three sub class namely:

   Sub class 1. Ceratiomyxomycomycetidae,

   1 Order: Ceratiomyxales

   Sub class 2. Mycogasteomycetidae,

   4 Orders: Liceales, Echinosteleales, Trichlales, Physarales

   Sub class 3. Stemonitomycetidae,

   1 Order: Stemonitales

- **Division II: Mastigomycota:** Includes fungi with absorptive nutrition, unicellular or filamentous, mycelium coenocytic. It comprises two sub divisions:

1. **Sub division: Haplomastigomycotina:** Includes fungi with uni-or, bi-flagellate zoospores.

   Class 1. Chytridiomycetes– Fungi producing zoospores furnished with a single whiplash flagellum inserted at the posterior end.

   Class 2. Hyphochytridiomycetes- Motile cells with a single tinsel flagellum inserted at the anterior end.

   Class 3. Plasmodiophoromycetes- Parasitic fungi producing biflagellate motile cells with both the flagella of whiplash type inserted at the anterior end.

2. **Sub division: Diplomastigomycotima:** Sexual reproduction ooagamous, zoospores biflagellate.

   Class 1. Oomycetes,

   4 Orders: Lagenidiales, Saprolegnailes, Leptomitales, Peronosporales

- **Division III: Amastigomycota:** Fungi with absorptive nutrition, motile cells lacking, mycelium aseptate or septate. This includes four sub divisions:

1. **Sub division: Zygomycotina**

   Class 1. Zygomycetes – it includes six orders.,

   Class 2. Trichomycetes – it comprises five orders.

2. Sub division: Ascomycotina: Fungi usually with a septate mycelium producing haploid ascospores in sac like cells called asci.

Class 1. Ascomycetes: Divided into five sub classes:

Sub class 1. Hemiascomycetidae- comprising three orders.

Sub class 2. Plectomycetidae- Five orders

Sub class 3. Hymenoascomycetidae – Ten orders

Sub class 4. Laboulbeniomycetidae – Two orders

Sub class 5. Lowloascomycetidae – five orders

3. Sub division: Basidiomycotina: Septate mycelium, produces basidiospores, exogenously on various types of basidia.

Class 1. Basidiomycetes: it is split into 3 sub clases:

Sub class 1. Holobasidiomycetidae

Sub class 2. Phragmobasidiomycetidae

Sub class 3. Teliomycetidae

4. Sub division: Deuteromycotina: It includes imperfect fungi in which sexual stage is unknown. It comprises a single class.

Class 1. Deuteromycetes

Sub class 1. Blastomycetidae

Sub class 2. Coelomycetidae

Sub class 3. Hyphomycetidae

❖ Martin (1965) proposed a classification according to the spore formation in fungi. The outline of classification is given;

Division Mycota: These include non-green, nucleated thallophytes which are saprophytes or parasite in nutrition.

Subdivision Myxomycotine: Thallus is achlorophyllus, multinucleated mass of protoplasm called plasmodium, e.g., slime molds.

Subdivision Eumycotina: All the fungi except the slime molds are included in this subdivision.

Lower fungi: They have simple thallus which are unicellular and others filamentous (mycelium), usually septa is not present.

Class Chytridiomycetes: Motile cells have a single flagellum of whiplash type inserted at the posterior end.

Class Hyphochytridiomycetes: Motile cells possesses a single flagellum of tinsel type inserted at the anterior end.

Class Plasmodiophoromycetes: Motile cells are biflagellated (whiplash type), but one is longer than the other one.

Class Oomyceters: Motile cells are biflagellated, nearly equal length, one of these points forwards and the other trails behind.

Class Zygomycetes: Motile cells are absent. Asexual reproduction take place by sporangiospores.

Class Trichomycetes: Motile cells are lacking. Asexual reproduction take place by conidia. Higher fungi: The somatic phase consists mostly of a mycelium which is usually septate.

Class Ascomycetes: The characteristic spores called ascospores are produced endogenous within sac like structure called asci.

Class Basidiomycetes: Characteristic spores called basidospores are produced exogenous on club shaped structure called basidia.

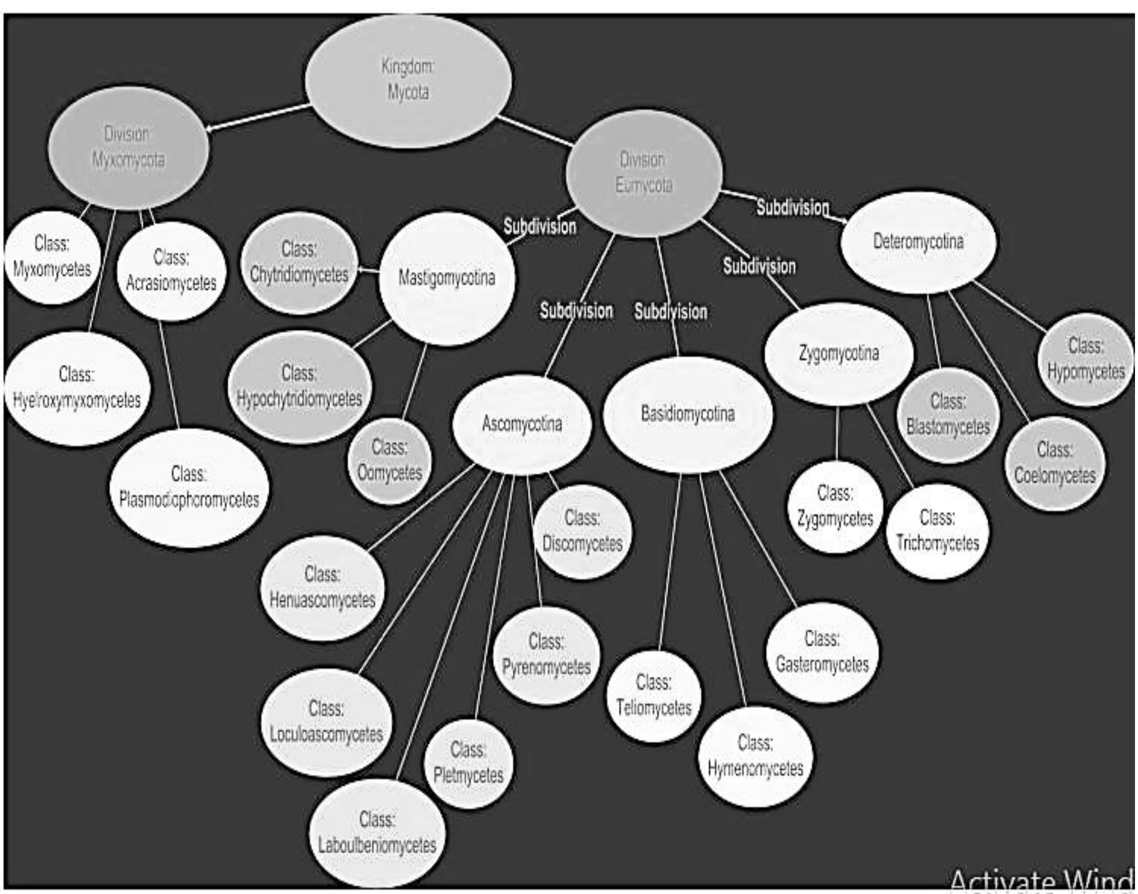
Class Deuteromycetes: Sexual stage is unknown. The somatic phase consists a septate mycelium which multiply by conidia.

- A more natural system of classification of fungi was proposed by Ainsworth (1973) which has been accepted by many mycologists today like Webster (1980), Bilgrami (1985 and Dube (1987) **(Figure 1.2)**.

Figure 1.2 Ainsworth Classification

1.6.2. Classification based on spore production:

- On the basis of the organisation of the vegetative thallus, the morphology of reproductive structures, the way of spores production and particular life cycle involved the kingdom mycota is classified into following divisions.



- **Phycomycetes**

- ✓ It includes the simplest type of fungi. It is also called as Algae-Fungi because most of the characteristics of them are similar to algae like *Vaucheria*.
- ✓ They have simple thallus which is unicellular or coenocytic or aseptate filaments.
- ✓ They reproduce asexually by the formation of zoospores or non-motile spores.
- ✓ Sexual reproduction is isogamous or heterogamous which takes place by gametangial contact.
- ✓ The diploid phase is represented by zygote.
- ✓ Phycomycetes has been classified into subclasses: oomycetes and zygomycetes.

- **Oomycetes**

- ✓ It ranges from a primitive unicellular thallus to a profusely branched filamentous mycelium.
- ✓ Many members of them are terrestrial and obligate parasites.
- ✓ Asexually they reproduce by biflagellate zoospores.
- ✓ Oogamous reproduction that involves the fusion of male and female gametes to form oospore.
- ✓ Oospore undergoes meioses to produce haploid biflagellate zoospores.
- ✓ Example; *Phytophthora infestans* (causes potato blight).

- **Zygomycetes**

- ✓ The group is named zygomycetes because a diploid resting spore called the zygospore is formed during the life cycle.
- ✓ They are mostly saprophytic, some others are parasites on plants and animals.
- ✓ The vegetative body is mycelium which is well developed, profusely branched and coenocytic.
- ✓ The absence of motile sexual or asexual cells.
- ✓ The asexual reproduction takes place by sporangiospores, aplanospores or by conidia.
- ✓ Sexual reproduction occurs by conjugation of gametangia resulting in the formation of zygospore.
- ✓ Examples; *Rhizopus, Mucor* etc.

- **Ascomycetes**

- ✓ The species of ascomycetes are called the sac fungi because they produce sexual pores within the sac-like ascus.
- ✓ Ascomycetes are mostly terrestrial occurring as saprophytes or parasites.
- ✓ They have well-developed, branched, septate mycelium except *Yeast*. *Yeast* is a unicellular fungus.
- ✓ Asexually they reproduce by non-motile spores, conidia, oidia or chlamydospores.
- ✓ Sexual reproduction takes place by the fusion of gametangia of opposite mating types.
- ✓ There is absence of motile cells.
- ✓ Examples, *Saccharomyces cerevisiae*, *Penicillium*, *Aspergillus* etc

- **Basidiomycetes**

- ✓ The members of basidiomycetes are saprophytic or parasitic. The group is named basidiomycetes as they produce the basidiospores at the club-shaped basidium during sexual reproduction.
- ✓ Mycelium is highly developed, profusely branched and septate.
- ✓ The mycelia are differentiated into two mating types; (+ve) and (-ve).
- ✓ There are two kinds of mycelium; primary mycelium and secondary mycelium.
- ✓ Asexual reproduction takes place by fragmentation, budding, oidia, conidia or chlamydospore.
- ✓ The dikaryotic cell is formed during sexual reproduction.
- ✓ The absence of motile cell throughout the life cycle.
- ✓ These are the most advanced fungi as their fructifications are often large and prominent.
- ✓ Examples; Mushrooms, Puccinia, Ustilago etc.

- **Deuteromycetes (The Imperfect Fungi)**

- ✓ Deuteromycetes compromises more than 17000 species of the diverse habits and habitats. It is considered as an artificial class of fungi.
- ✓ The fungi are saprophytes as well as parasites. Parasitic fungi cause serious diseases to plants, animals including human beings.
- ✓ Some of them are unicellular while others are multicellular.
- ✓ They reproduce asexually by conidia along with some other types of spores.
- ✓ The sexual reproduction is entirely absent.
- ✓ The asexual stage or imperfect stage in Deuteromycetes is well defined. But the sexual or perfect stage is absent in life cycle, therefore, they are called 'Fungi Imperfecti'.
- ✓ Example; *Alternaria, Fusarium, Helminthosporium* etc.

1.6.3. Classification based on medically important fungi

- ❖ Mycoses are classified as superficial, cutaneous, subcutaneous, or systemic (deep) infections depending on the type and degree of tissue involvement and the host response to the pathogen.

a. Superficial mycoses (or tineas): Occur in the tropics and are restricted to the outer surface of the hair and skin, e.g., *Piedraia hortae*.

b. Cutaneous mycoses: There are three genera of fungi (*Microsporum, Trichophyton and Epidermophyton*) that commonly cause disease in the non-living tissues of skin, hair, or nails/claws of people and animals, by growing in a zone just above where the protein keratin is deposited.

c. Subcutaneous mycoses: They are normally saprotrophic inhabitants of soil, particularly in tropical and subtropical areas of Africa, India and South America.

d. Systemic mycoses: They are infections that affect the whole body. We divide these into mycoses due to primary (usually dimorphic) virulent pathogens, and those due to opportunistic pathogens.

1.6.4. Classification based on route of acquisition

a. Infecting fungi may be either exogenous or endogenous.

b. When classified according to the route of acquisition, a fungal infection may be designated as exogenous or endogenous in origin.

c. If classified as exogenous, an infecting organism may be transmitted by airborne, cutaneous, or percutaneous routes.

d. An endogenously-acquired fungal infection may be acquired from colonization or reactivation of a fungus from latent infection.

1.6.5. Classification based on virulence

❖ Primary pathogens can establish infections in normal hosts.

❖ Opportunistic pathogens cause disease in individuals with compromised host defense mechanisms.

- Deep mycoses are caused by primary pathogenic and opportunistic fungal pathogens.
- The primary pathogenic fungi are able to establish infection in a normal host; whereas, opportunistic pathogens require a compromised host in order to establish infection (e.g., cancer, organ transplantation, surgery, and AIDS).
- The primary deep pathogens usually gain access to the host via the respiratory tract. Opportunistic fungi causing deep mycosis invade via the respiratory tract, alimentary tract, or intravascular devices.
- The primary systemic fungal pathogens include *Coccidioides immitis, Histoplasma capsulatum, Blastomyces dermatitidis*, and *Paracoccidioides brasiliensis*.
- The opportunistic fungal pathogens include *Cryptococcus neoformans, Candida, Aspergillus spp., Penicillium marneffei*, the Zygomycetes, *Trichosporon beigelii*, and *Fusarium spp*.

SAQ.8

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a. The fungi of Haplomastigomycotina bears________________zoospores.

b. ______________producing biflagellate motile cells with both the flagella of whiplash type inserted at the anterior end.

c. ______________proposed a classification according to the spore formation in fungi.

d. Oogamous reproduction that involves the fusion of male and female gametes to form _____________.

e. The dikaryotic cell is formed during_______________reproduction.

1.7 Heterothallism

The term Heterothallism was first used by an American geneticist A.F. Blakeslee in 1904 when he observed that zygospores could develop in some spp. only when two mycelia of different strains were allowed to come in contact with each other **(Figure 1.3)**.

Blakeslee made these observations as a result of his studies on zygospore formation in Mucorales. He found that in some species of Rhizopus, zygospores were formed freely while in others like R. nigricans zygospores were formed rarely.

In Mucor hiemalis too, zygospores were formed rarely. On the basis of his studies, he divided the various species of Mucorales into two groups: Heterothallic and Homothallic.

Thus heterothallic species are those which require mycelia of two different strains to interact to enable the zygospores to be formed while the homothallic species are those which require mycelia of only one strain to interact for the formation of Zygospores.

According to Blakeslee (1904) Heterothallic condition is **"essentially similar to that in dioecious plants and animals and although in this case the two complimentary individuals which are needed for sexual reproduction are in general not so conspicuously differentiated morphologically as in higher forms, such a morphological difference is often distinctly visible."**

He concluded that the Zygospore formation is a sexual process. In homothallic species, the mycelium is bisexual while the mycelium in heterothallic species is unisexual, (+) and (-) strains represent the two different sexes.

Heterothallism may therefore be defined as the condition in which Zygospore formation takes place only when mycelia arising from asexual spores of two genetically different mating types (+) and (-), are allowed to interact.

On **the** other hand, the condition, in which one individual originating from a single asexual spore is capable of forming zygospores independently, is known as Homothallism.

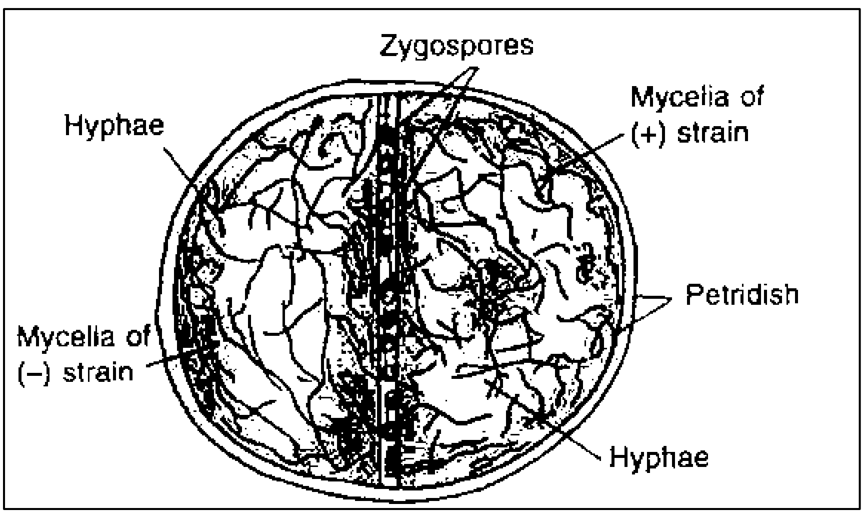

Figure 1.3: *Mucor hiemalis*. Zygospore formation indicating Heterothallism

Blakeslee proved the phenomenon of heterothallism on the basis of the experiments he conducted using several species of Mucorales. He inoculated spores of two different strains of Mucor hiemalis on a petridish containing synthetic agar medium.

After a few days it was observed that the zygospores were formed along the zone of contact of two mycelia. In another experiment he inoculated spores of only one strain on a petridish containing synthetic agar medium and after some time it was observed that absolutely no zygospores were produced in this experiment.

From these experiments, he concluded that zygospores could be formed only when mycelia of two different strains were allowed to come in contact.

Blakeslee and his coworkers (1928) examined different genera of Mucorales to test whether these were homothallic or heterothallic. Most of the genera tested were homothallic while only a few genera were found to be heterothallic.

In heterothallic species of Mucor mucedo, the zygospores upon germination produced germsporangia which contain spores of only one strain (either + or -).

In this case, zygospores could be formed only when mycelia formed from spores of (-) strain formed in germ sporangia produced on germination of zygospores are allowed to come in contact with the mycelia produced from the spores of (+) strain.

But in the heterothallic species of Phycomyces nitens, Spores of (+) and (-) strains are produced in the same germ sporangium. Blakeslee thus regarded the (+) and (-) strains of heterothallic species as differing in sex and the term heterothallism may therefore be treated as equivalent to dioecism in haploid organisms.

Since the discovery of heterothallism in Mucorales by Blakeslee, the phenomenon has been reported in several groups of fungi. Though variations may occur, but all heterothallic species share one common feature of inter-mycelial contact.

While in *Dictyuchus monosporous* it is dioecism, in *Ascobolus magnificus*, it is expressed as self- sterility or self-incompatibility. Both the fungi resemble the heterothallic Mucorales in that sex-organs or gametangia are formed only when opposite strains come in contact.

In Dictyuchus monosporous the two sex-organs are formed by different strains but in Ascobolus magnificus, each strain produces sex organs but these are self-sterile **(Figure 1.4).**

On the basis of these observations, the heterothallism may be of two types: Morphological heterothallism and Physiological heterothallism.

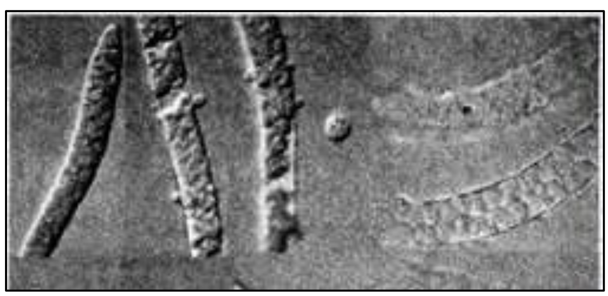

Figure 1.4: ***Dictyuchus monosporus***

1.7.1. Morphological heterothallism:

Morphological heterothallism may be defined as the condition when morphologically different male and female sex organs are produced in two closely associated mycelia.

The two sex organs or gametes are so morphologically different that it is easier to term one of them as male and the other as female-examples of such type of morphological heterothallic fungi are: Achlya ambisexualis, A. bisexualis, Blastocladiella variabilis, Dictyuchus monosporus, Phytophthora palmivora and Peronospora parasitica (photographs given below).

However, in Blastocladiella variabilis the male and female gametangia are morphologically distinct, the male being smaller than the female **(Figure 1.5)**.

Whitehouse (1949) also used the term haplo-dioecious for morphologically heterothallic species of fungi.

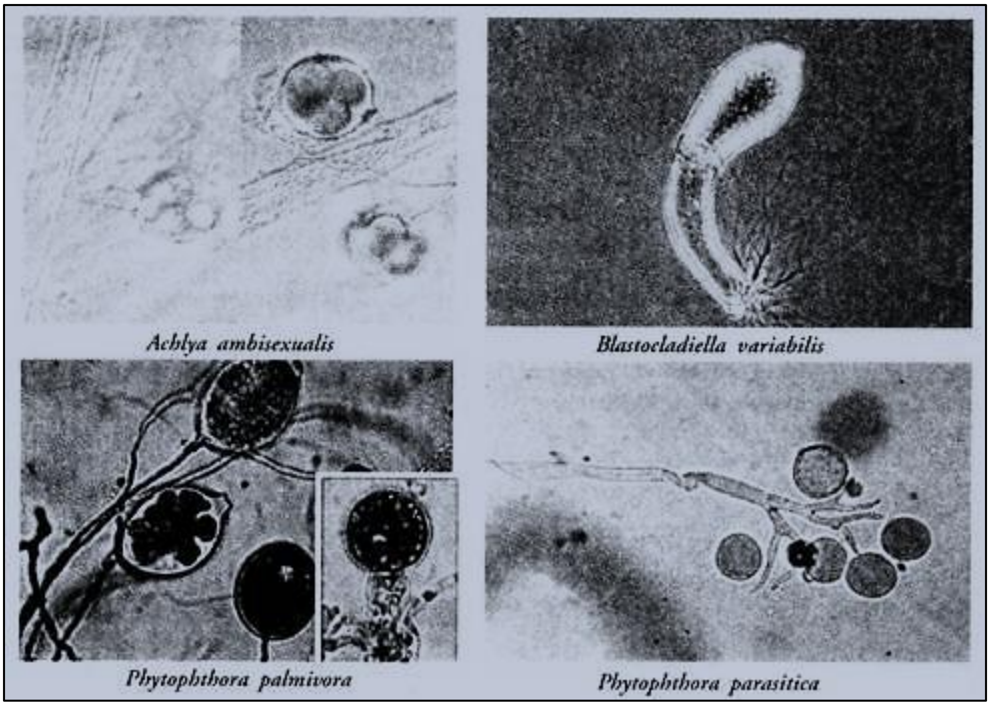

Figure 1.5

1.7.2. Physiological Heterothallism:

In physiological heterothallism, the interacting thalli differ in mating type or incompatibility, irrespective of the presence or absence of the sex organs or gametes. This means that sexual reproduction takes place by two morphologically similar but physiologically different hyphae in physiological heterothallism.

The gametangia as well as gametes do not show morphological differentiation but physiologically they behave differently.

Physiological heterothallism may be of two types:

(i) Two Allelomorphs or Two-Allele Heterothallism:

When nuclei of both the mating types are different in genetic characters, this type of Heterothallism is known as Two-Allele heterothallism. In these types compatibility is governed by a pair of Alleles represented by A and a located at single same locus of the chromosome.

Due to the dominance of A over a, A is represented by (+) and a by (-). At the time of meiosis, separation of the chromatids take place. Half of the haploid spores thus have (+) and the other half (-) allele.

The spores bearing (+) allele will produce (+) mycelia and the spores with (-) allele will give rise to (-) mycelia. The mycelia of (+) and (+) and (-) and (-) are self-sterile or self-incompatible. Thus, two complimentary mating types (+) and (-) are essential for sexual reproduction.

Two-Allele heterothallism has been reported in several fungi of like *Ascobolus magnificus, Puccinia graminis, Neurospora sitophila Mucor mucedo, Ustilago kolleri* etc. (photographs given below) **(Figure 1.6).**

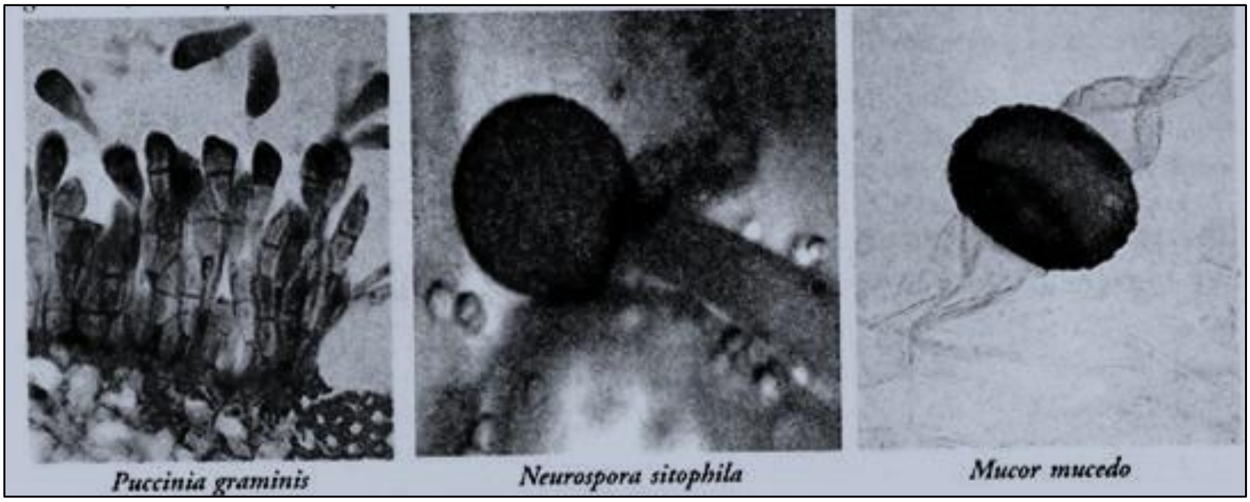

Figure 1.6

(ii) Multiple Allelomorph or Multiple Allele Heterothallism:

In this type of heterothallism, more than two (multiple) alleles determine the sexual compatibility. These may be located at one (bipolar) or two (tetrapolar) loci.

Because of the larger number of alleles involved in this type of heterothallism, chances of mating of compatible strains increase.

As stated above, the multiple allele heterothallism may be of two types:

(a) Bipolar Multiple-allele heterothallism

(b) Tetrapolar multiple-allele heterothallism.

(a) Bipolar Multiple-Allele Heterothallism:

This type of heterothallism is controlled by multiple alleles at a single locus, instead of a pair of Alleles. For example, if the locus is named as L, the multiples alleles will be designated as L_1, L_2, L_3, L_4—Ln and these are present on the single locus L.

The meiotic division will give rise .to thalli which may be of several mating types, generally equal to the number of alleles. The thallus containing the allele L_1 can mate with a thallus of any mating type except L_1**(Figure 1.7)**.

Similarly, L_2 can mate with any thallus except that containing L_2 allele and so on. In this type of heterothallism, incompatibility factors are more commonly involved. Bipolar multiple allele heterothallism is characteristic of Basidiomycetes except rusts and smuts.

	L_1	L_2	L_3	L_4
L_1	N	C	C	C
L_2	C	N	C	C
L_3	C	C	N	C
L_4	C	C	C	N

Figure 1.7: Bipolar multiple allele heterothallism. C-compatible, N-non compatibble

(b) Tetrapolar Multiple Allele heterothallism:

This type of heterothallism is characteristic of Basidiomycetes except rusts. In this type of heterothallism, which is very similar to bipolar multiple allele heterothallism, compatibility is determined by two loci.

Multiple allele—the compatible factor is present on two loci L_1 and L_2 of two Chromatids of a chromosome. At the time of meiotic division, both the loci are separated with chromatids.

It is estimated that at least 100 alleles are present on each locus. In *Schizophyllum commune*, 122, alleles of factor A and 61 of B have been identified in the laboratory.

According to rough estimates, the number of alleles may be even more, about 350-450 of L_1, and 65 of L_2. Any two mating types, which differ in allele present on L_1 and L_2 are compatible.

If the allele composition of mating type is A_1 B_1, it would be compatible with any other type of allele composition except A_1 B_1. But the mating type with allele composition is not fully compatible with allele composition A_2 B_2 or A_2 B_2.

Figure 1.8 fully explains type of heterothallism which has been reported in *Ustilago maydis* and *Comprinus firmaterius*.

A_1B_1	A_1B_2	A_2B_1	A_2B_2	
A_1B_1	N	NFC	NFC	C
A_1B_2	NFC	N	C	NFC
A_2B_2	NFC	C	N	NFC
A_2B_2	C	NFC	NFC	N

Figure 1.8: Tetrapolar multiple allele heterothallism. N-non-compatible, NFC- not fully compatible, C- compatible

This type of heterothallism encourages out-breeding. Whereas in bipolar multiple Allele heterothallism, the out-breeding is 25%, in tetrapolar, it is 100%. This may be due to enormous increase in the number of possible mating types of thalli.

According to Garrett (1963), **"heterothallism promotes the out-breeding and therefore subserves the same end as the sexual process, which it renders most efficient. Hetrothallism is not the same as sex, it is refinement super imposed upon it."**

SAQ.9

a. The term______________was first used by an American geneticist A.F. Blakeslee in 1904.
b. In Blastocladiella variabilis the male and female______________are morphologically distinct, the male being smaller than the female.
c. Heterothallism is known as______________heterothallism.
d. Heterothallism promotes the____________.

1.8 Parasexual Cycle

In some fungi, true sexual cycle comprising of nuclear fusion and meiosis is absent. These fungi derive the benefits of sexuality through a cycle known as Parasexual Cycle.

The Parasexual Cycle is defined as a cycle in which plasmogamy, karyogamy and meiosis (haploidisation) take place but not at a specified time or at specified points in the life-cycle of an organism. Generally, parasexual cycle occurs in those fungi in which true sexual cycle does not take place. The members of class Deuteromycetes (Deuteromycotina) in which sexual cycle does not occur, exhibit parasexual cycle generally.

Parasexual cycle was first discovered by Pontecarvo and Roper of University of Glasgow in 1952 in Aspergillus nidulans, the imperfect stage of Emericella nidulans. Since then parasexual cycle has been discovered not only in several members of Deuteromycetes but also in fungi belonging to Ascomycetes and Basidiomycetes.

1.8.1. ***Steps Involved in Parasexual Cycle:***

According to Pontecarvo (1958), parasexual cycle in A. nidulans involves the following steps (Figure 1.9):

- (i) Formation of heterokaryotic mycelium
- (ii) Fusion between two nuclei (Karyogamy)
  - (a) Fusion between like nuclei
  - (b) Fusion between unlike nuclei
- (iii) Multiplication of diploid nuclei
- (iv) Occasional Mitotic crossing over.
- (v) Sorting out of diploid nuclei
- (v) Occasional haploidisation of diploid nuclei, and
- (vii) Sorting of new haploid strains.

A brief account of these steps are being presented below:

(i) Formation of heterokaryotic mycelium:

Heterokaryotic mycelium is formed in several ways. The most common is by the anastomosis of somatic hyphae of different genetic combinations.

The foreign nucleus or nuclei introduced into a mycelium multiplies and its progeny spreads through the mycelium rendering it heterokaryotic. Mutation in one or more nuclei of a homokaryotic mycelium also makes it heterokaryotic.

It happens in some of the fungi belonging to Ascomycetes. Still a third way is by the fusion of some of the nuclei and their subsequent multiplication and spread among the haploid nuclei. In this type of heterokaryotic mycelium a fixture of haploid and diploid nuclei occur.

(ii) Fusion between two nuclei (Karyogamy):

The fusion of nuclei in the mycelium has been demonstrated. The nuclear fusion may be of two types: (a) fusion between like nuclei and (b) fusion between unlike nuclei. The nuclear fusion results in the formation of homozygous or heterozygous diploid nucleus respectively.

If the genotype of unlike nuclei present in the heterokaryotic mycelium is A and B, then five types of nuclei can be formed by their fusion: two types of haploid nuclei (A and B), two types of homozygous diploid nuclei (AA and BB) and one type of heterozygous diploid nucleus (AB).

(iii) Multiplication of diploid nuclei:

The above mentioned five types of nuclei multiply at about the same rate but the diploid nuclei are present in much smaller number than the haploid nuclei. Pontecarvo's (1958) estimates a proportion of one diploid heterozygous nucleus to 1000 haploid nuclei.

(iv) Occasional mitotic crossing over:

During multiplication of diploid nuclei, mitotic crossing over may take place. This results in the formation of new gene combinations. These recombinations, which are dependent on the existence of heterokaryosis, give the fungus some of the advantages of sexuality within the parasexual cycle.

According to Pontecarvo's (1958) estimates, the amount of recombinations which may be expected to occur in an ascomycete through its parasexual cycle is 500 times smaller than through its sexual cycle.

However, in Peni*cillium chrysogenum* and *Aspergillus niger*, diploidisation and mitotic crossing over occur more frequently indicating the importance of parasexual cycle in evolution of new strains.

(v) Sorting out of Diploid nuclei:

In those fungi which produce uninucleate conidia, sorting out of the diploid nucleus occurs by their incorporation into conidia which germinate to produce diploid mycelia. Diploid strains of several important imperfect fungi have been isolated.

Roper (1952) first synthesized and isolated diploid strains of *Aspergillus nidulans*. The conidia of diploid strains are somewhat larger than those of haploid strains.

(vi) Occasional haploidisation of the diploid nuclei:

Occasionally, some hyphae of diploid mycelium form haploid conidia which form haploid mycelia on germination. The formation of haploid conidia by diploid mycelium indicates that haploidisation occurs in some diploid nuclei.

(vii) Sorting of new haploid strains:

Some diploid nuclei undergo haploidisation in the mycelium and are sorted out by incorporation of haploid nuclei in the uninucleate conidia. Some of these haploid strains are genotypically different from their parents because of their mitotic recombinations.

Thus, after the parasexual cycle has operated for some time, the mycelium may contain the following types of nuclei:

(a) Haploid nuclei like those of both the parents,

(b) Haploid nuclei with various new genetic recombinations,

(c) Several types of diploid homozygous nuclei, and

(d) Several types of diploid heterozygous nuclei.

1.8.2. Significance of Parasexual Cycle*:*

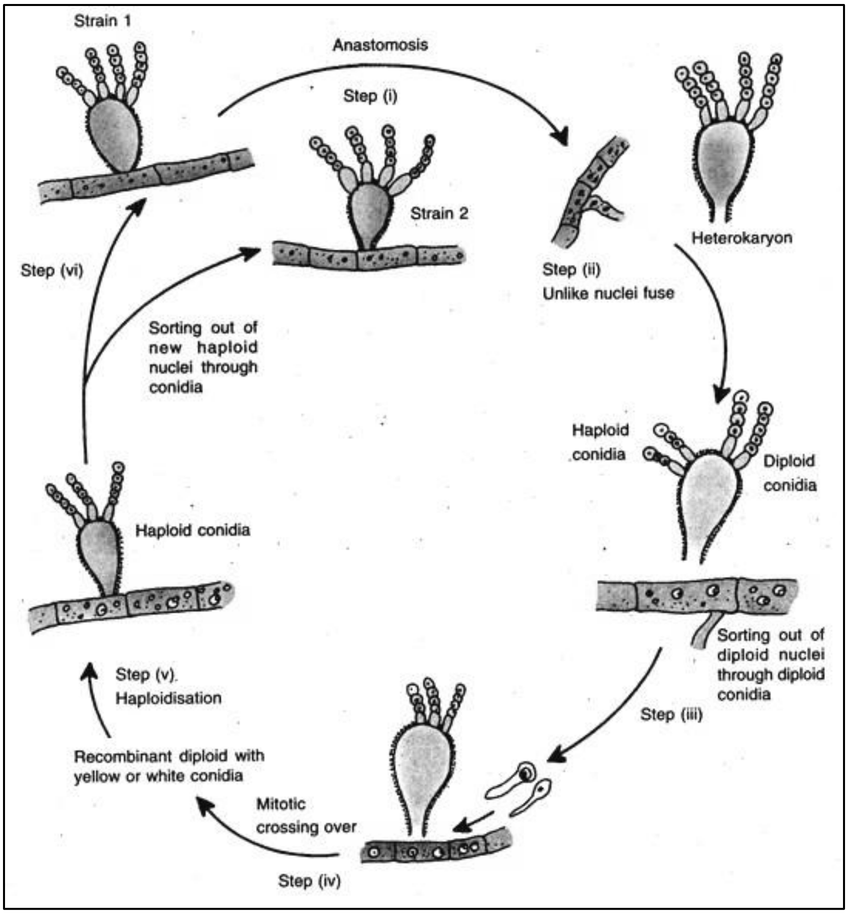

Figure 1.9: Pontecarvo's (1958) idea of parasexual cycle

Parasexual cycle is of importance in industrial processes. Several fungi which are used in various industrial processes belong to fungi imperfecti or Deuteromycetes and in these fungi only parasexual cycle operates.

New and better strains of these fungi are obtained by mutation through parasexual cycle. The strains of desirable characters can be developed through mitotic recombinations.

Parasexuality can also be applied in the analysis of genetic and physiological processes of perfect and imperfect fungi. Parasexual cycle has also been successfully employed in genetic control of pathogenicity and host-range in several species of Fusarium.

1.9 Sex hormones in Fungi

It was de Bary (1881) who first reported the presence of sex hormones in dioecious species of *Achlya*. In 1908, Kaufmann supported the contention of de Bary on the basis of his observations on Saprolegnia hypogyna.

According to Kaufmann, the development of antheridial hyphae is stimulated by certain hormones. Studies conducted by Couch (1924) and Bishop (1957) on Dictyuchus and Sapromyces reinschii and Raper (1954) on Achlya have substantially confirmed the role of hormones in sexual reproduction in fungi.

Therefore, the sex hormones may be defined as a diffusible substance playing a specific role in the sexual reproduction that produces it.

Machlis (1972) has classified the sex hormones into the following three types:

(1) Erotactins

(2) Erotropins, and

(3) Erogens.

Erotactin is a sexual hormone which attracts motile gametes, erotropin is the sex hormone that induces chemotropic growth of sexual structures and erogen is the sex hormone that controls the induction and differentiation of sexual structures.

However, the sex hormone may perform more than one functions, as in Achlya, the hormone that controls development of sexual structures also determines the direction of the sex organs.

1.9.1. Description of some important Sex-Hormones:

Although a large number of sex hormones have been reported, only a few have been chemically characterised and extensively studied. These are – Sirenin, Antheridiol and Oogoniol, Trisporic acid and Yeast D factor.

These are briefly described here:

1. Sirenin:

It is a sperm attracting hormone produced by water mould *Allomyces*, *A. macrogynous* and *A. arbuscula*. It is the female gametes which release sirenin to attract the male gametes.

The synthesis of sirenin by female gametes and their function to attract male gametes was demonstrated by Machlis (1958). The empirical formula of sirenin is C15 H 24O2 and the molecular weight is 236.

It is an oxygenated sesquiterpene and is species specific. Although both D- and L- forms have been isolated, L- form is biologically effective **(Figure 1.10)**.

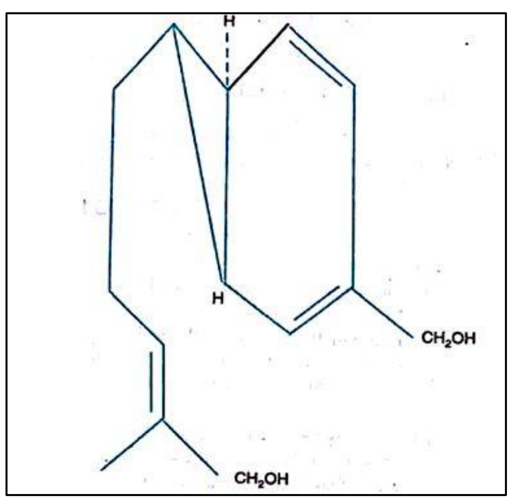

Figure 1.10: Chemical formula of Sirenin and its species specific. Although both D- and L- forms have been isolated only L- form is biologically effective

2. Antheridiol and Oogoniol:

Raper (1939-1959), on the basis of his classical studies on sex hormones in *Achlya*, demonstrated the presence of multi hormonal regulatory system in *A. ambisexualis* and *A. bisexua*lis.

He envisaged the presence of four hormones A, B, C and D but now it has been conclusively proved that only two hormones named as Antheridiol and oogoniol are involved. Hormones A and C are antheridiols and hormones B and D are oogoniols.

Antheridiol is a crystalline compound having empirical formula as C29 H42 O5 and molecular weight as 470. The hormone was isolated by Mc Morris and Barksdali (1967) and its structure was proposed by Arsenault et al (1969).

Antheridiol (Figure 1.11):

It is reported to stimulate four types of reactions:

(a) initiation of antheridial hyphae on male plant,

(b) chemotropic stimulation of antheridial hyphae,

(c) stimulation of male hyphae for production of oogoniol and

(d) delimiation of antheridia.

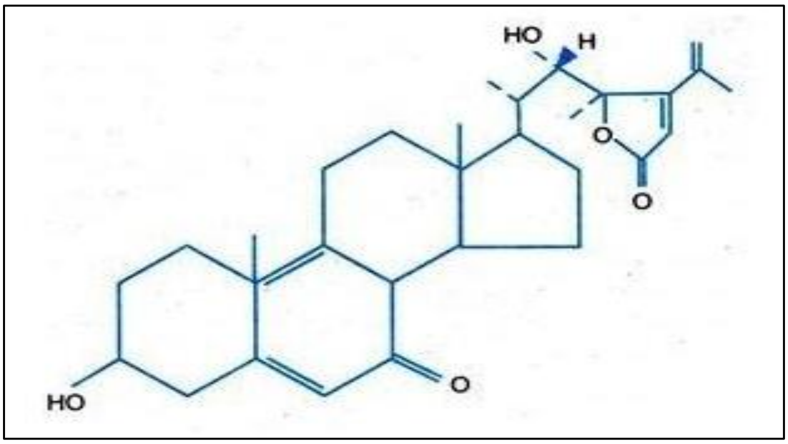

Figure 1.11: Antheridiol

Oogoniol:

The hormone is synthesized by male hyphae of *Achlya ambisexualis* only in the presence of antheridiol. However, Barksdali et al. (1974) reported that oogoniol is synthesised by some hermaphrodite strains without the stimulus of antheridiol.

Two crystalline compounds, possessing hormone B activity have been isolated from culture filtrates of Achlya heterosexualis by Mc Morris and his coworkers (1975). These have been named oogoniol-1 and oogoniol-2.

Oogoniol **(Figure 1.12)** is a crystalline steroid with molecular weight as 500. The hormone stimulates the development of oogonium on female hyphae.

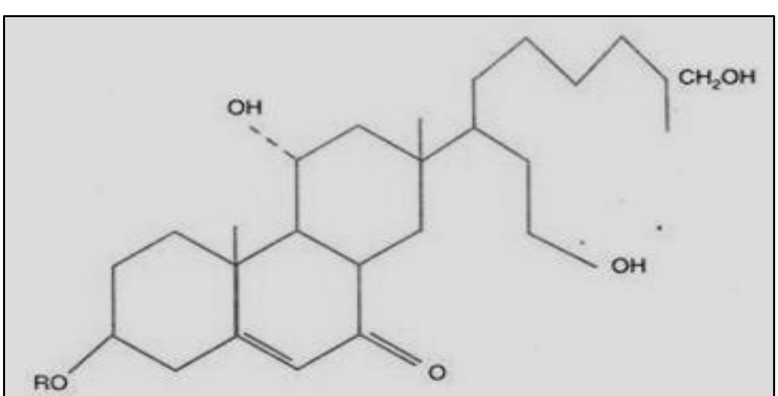

Figure 1.12: Oogoniol

3. Trisporic Acid:

Trisporic Acid is a sex hormone which has been isolated from *Blakeslea trispora* and *Mucor mucedo*. It has been found to play active role in sexual reproduction of several members of the order Mucorales. Though the concept of sex hormone in mucorales was developed in 1924 by Burgeff, it was only in 1956 that Burgeff could isolate a sex hormone in cell free extract and this sex hormone was named as Trisporic Acid.

It is an unsaturated and oxygenated form of trimethyl cyclo-hexane. Three kinds of trisporic acid have been identified, trisporic acid A, B and C.

Trisporic acid C plays the major role (80%) as a sex hormone, followed with trisporic acid B with 15% activity and trisporic acid A is least active with 1-2% activity. It appears that trisporic acid A does not have the functional group in the acid chain (Figure 1.13).

Empirical formula of trisporic acid is C18 H26 O4 and the molecular weight is 306.

The role of sex hormones in Mucor mucedo was studied by Plempel et al. (1957-61). The sex hormone trisporic acid, present in this species is synthesized from B-carotene.

In the heterothallic mycelia, trisporic acid B and C stimulate the development of zygophores. This hormone is synthesized only when the mycelia of (+) and (-) strains grow in a normal continuous diffusable medium.

The hormone trisporic acid synthesized in (-) strain induces the development of progametangium in (-) strains and vice-versa.

The zygophores of (+) and (-) strain are attracted towards each other due to chemotropic response of a volatile substance which also promotes the synthesis of trisporic acid in two opposite mating types.

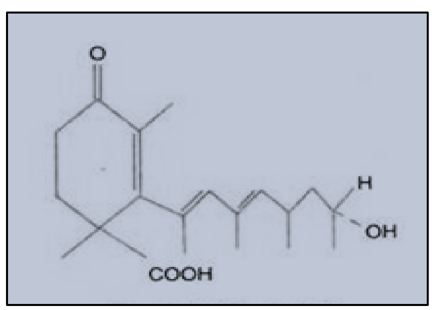

Figure 1.13: explains the role of trisporic acid and its collaborative synthesis by the compatible mating types of *Mucor mucedo*

It is believed that synthesis of trisporic acid as described for *Mucor mucedo* takes place in other members of Mucorales as well **(Figure 1.14)**.

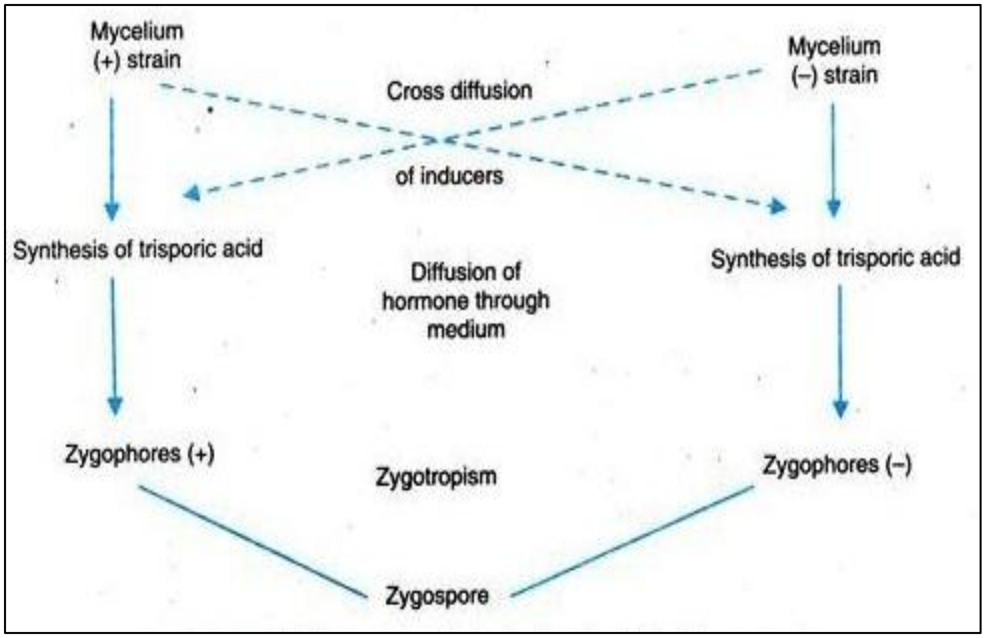

Figure 1.14: Collaborative synthesis of trisporic acid in *Mucor mucedo*

4. Yeast α Factor:

The presence and the involvement of some hormone in the sexual reproduction of *Saccharomyces* cerevisiae was suggested by Levi in 1950. In this fungus, the haploid cells are of two mating types a and α which conjugate to form diploid cells. In 1956, Levi showed that the α haploid cells produce a diffusible chemical which induces the formation of copulatory process by compatible a cells.

These a cells, due to influence of the chemical substance produced by α cells, stop their growth and reproduction by budding. Instead, these a cells swell in size and form giant cells of various shapes. These giant cells are 30 or more times heavy in dry weight in comparison to normal haploid cells. The α factor acts only on a cells and has no effect on α cells.

The α factor is reported to inhibit DNA replication in the α cells. Duntze (1970 – 1973) isolated the α factor in pure form. It is peptide complexed with copper ion and has molecular weight of 1400.

SAQ.10

a. Parasexual cycle was first discovered by Pontecarvo and Ropar in 1952 in ________.
b. New and better strains of these fungi are obtained by mutation through ___________.
c. The sex hormones may be defined as a diffusible substance playing a specific role in the_________________that produces it.
d. Sirenin is a sperm attaching hormone produced by water mould_____________.
e. Antheridiol is a crystalline compound having empirical formula as___________.
f. The hormone is synthesized by male hyphae of *Achlya ambisexualis* only in the presence of________________.
g. ______________is a sex hormone which has been isolated from *Blakeslea trispora* and *Mucor mucedo.*

h. The α factor is reported to inhibit________________in the α cells.

Importance of Fungi in Human life

Although we often think of fungi as organisms that cause disease and rot food, fungi are important to human life on many levels. They influence the well-being of human populations on a large scale because they are part of the nutrient cycle in ecosystems. They also have other ecosystem uses, such as pesticides.

1.10.1. Biological Insecticides

As animal pathogens, fungi help to control the population of damaging pests. These fungi are very specific to the insects they attack; they do not infect animals or plants. Fungi are currently under investigation as potential microbial insecticides, with several already on the market. For example, the fungus *Beauveria bassiana* is a pesticide being tested as a possible biological control agent for the recent spread of emerald ash borer.

1.10.2. Farming

The mycorrhizal relationship between fungi and plant roots is essential for the productivity of farm land. Without the fungal partner in root systems, 80–90 percent of trees and grasses would not survive. Mycorrhizal fungal inoculants are available as soil additives from gardening supply stores and are promoted by supporters of organic agriculture.

1.10.3. Food

Fungi figure prominently in the human diet. Morels, shiitake mushrooms, chanterelles, and truffles are considered delicacies. The meadow mushroom, *Agaricus campestris*, appears in many dishes. Molds of the genus *Penicillium* ripen many cheeses. They originate in the natural environment such as the caves of Roquefort, France, where wheels of sheep milk cheese are stacked to capture the molds responsible for the blue veins and pungent taste of the cheese.

Fermentation of grains to produce beer and of fruits to produce wine is an ancient art that humans in most cultures have practiced for millennia. Ancient humans acquired wild yeasts from the environment and used them to ferment sugars into CO_2 and ethanol under anaerobic conditions. It is now possible to purchase isolated strains of wild yeasts from different wine-making regions. Louis Pasteur was instrumental in developing a reliable strain of brewer’s yeast, *Saccharomyces cerevisiae*, for the French brewing industry in the late 1850s.

Saccharomyces cerevisiae, also known as baker’s yeast, is an important ingredient in bread, a food that has been considered a staple of human life for thousands of years. Before isolated yeast became available in modern times, humans simply let the dough collect yeast from the air and rise over a period of hours or days. A small piece of this leavened dough was saved and used as a starter (source of the same yeast) for the next batch, much in the same way sourdough bread is made today.

1.10.4. Medicine

Many secondary metabolites of fungi are of great commercial importance. Fungi naturally produce antibiotics to kill or inhibit the growth of bacteria, limiting their competition in the natural environment. Important antibiotics, such as penicillin and the cephalosporins, can be isolated from fungi. Valuable drugs isolated from fungi include the immunosuppressant drug cyclosporine (which reduces the risk of rejection after organ transplant), the precursors of steroid hormones, and ergot alkaloids used to stop bleeding. Psilocybin is a compound found in fungi such as *Psilocybe semilanceata* and *Gymnopilus junonius*, which have been used for their hallucinogenic properties by various cultures for thousands of years.

As simple eukaryotic organisms, fungi are important model research organisms. Many advances in modern genetics were achieved by the use of the red bread mold *Neurospora crassa*. Additionally, many important genes originally discovered in *S. cerevisiae* served as a starting point in discovering analogous human genes. As a eukaryotic organism, the yeast cell produces and modifies proteins in a manner similar to human cells, as opposed to the bacterium *Escherichia coli*, which lacks the internal membrane structures and enzymes to tag proteins for export. This makes yeast a much better organism for use in recombinant DNA technology experiments. Like bacteria, yeasts grow easily in culture, have a short generation time, and are amenable to genetic modification.

1.10 Summary

- Fungi are achlorophyllous, which means they lack the chlorophyll pigments present in the chloroplasts in plant cells and which are necessary for photosynthesis.
- As they are achlorophyllous, therefore, they do not have the ability to make their own food.
- The vegetative body of the fungi may be unicellular or composed of microscopic threads called hyphae. Hyphae can grow and form a network called a mycelium.
- Yeasts are unicellular fungi that do not produce hyphae.
- Fungi are heterotrophic organisms. They obtain its food and energy from organic substances, plant and animal matters.
- Fungi digest the food first and then ingest it to accomplish this the fungi produce exoenzymes like Hydrolases, Lyases, Oxidoreductase, Transferase, etc. Fungi store their food as starch.
- Fungi are saprophytes (gets energy from dead and decaying matters), or parasites (lives in a host, attack and kill) or symbionts (mutually beneficial).
- Optimum temperature of growth for most saprophytic fungi is 20-30°C while (30-37)°C for parasitic fungi. Growth rate of fungi is slower than that of bacteria.
- Reproduction in fungi is both by sexual and asexual means. Sexual state is referred to as teleomorph (fruiting body), asexual state is referred to as anamorph (mold like).
- Asexual reproduction methods are: fragmentation, somatic budding, fission, asexual spore formation. Sexual methods are: gametic copulation, gamate-gametangium copulation, gametangium copulation, somatic copulation and Spermatization.
- Some fungi are macroscopic and can be seen by naked eyes. Mold or mushrooms are examples of macroscopic form of fungi.
- In 1991, a landmark paper estimated that there are 1.5 million fungi on the Earth. Only about 300 species of fungi are infectious to human.
- The classification of fungi is designed mainly for practical application but it also bears some relation to phylogenetic considerations.
- The fungi can be classified according to the various parameters including; Classification based on taxonomy hierarchy, Classification based on spore Production, Classification of medically important fungi, Classification based on route of acquisition, Classification based on virulence
- Alexopolous and Mims proposed fungal classification in 1979. They place the fungi including the slime molds in the kingdom mycetae. They divide the kingdom mycetae into

three divisions namely: Gymnomycota, Mastigomycota and Amastigomycota

- Martin (1965) proposed a classification according to the spore formation in fungi and divide the division mycota into two subdivision; Myxomycotina and Eumycotina.
- Classification based on medically important fungi divided the fungi into superficial mycoses, cutaneous mycoses, subcutaneous mycoses and systemic mycoses.
- Heterothallism is a device for achieving outbreeding, which is a genetic desirability. Homothallism brings in inbreeding and provides no chance for genetic change.
- The parasexual cycle involves the following steps: Formation of heterokaryotic mycelium, Nuclear fusions and multiplication of the diploid nuclei, Mitotic crossing over during division of the diploid cells, Sorting out of the diploid strains, Haplodization.
- Parasexual cycle is of importance in industrial processes. Several fungi which are used in various industrial processes belong to fungi imperfecti or Deuteromycetes and in these fungi only parasexual cycle operates. New and better strains of these fungi are obtained by mutation through parasexual cycle. Parasexuality can also be applied in the analysis of genetic and physiological processes of perfect and imperfect fungi.
- Sex hormones may be defined as a diffusible substance playing a specific role in the sexual reproduction that produces it.
- Fungi are currently under investigation as potential microbial insecticides, with several already on the market.
- The mycorrhizal relationship between fungi and plant roots is essential for the productivity of farm land.
- Fungi figure prominently in the human diet. Morels, shiitake mushrooms, chanterelles, and truffles are considered delicacies.
- *Saccharomyces cerevisiae*, also known as baker's yeast, is an important ingredient in bread, a food that has been considered a staple of human life for thousands of years.
- Valuable drugs isolated from fungi include the immunosuppressant drug cyclosporine (which reduces the risk of rejection after organ transplant), the precursors of steroid hormones, and ergot alkaloids used to stop bleeding.
- Psilocybin is a compound found in fungi such as *Psilocybe semilanceata* and *Gymnopilus junonius*, which have been used for their hallucinogenic properties by various cultures for thousands of years.

1.12 Terminal Question

Q.1 Describe the characteristics features of fungi.

Answer:---

Q.2 Describe the cell structure of fungi.

Answer:---

Q.3 Discuss the reproduction of fungi.

Answer:--

Q.4 What is Heterothallism?

Answer:--

Q.5 Explain the term parasexuality.

Answer:--

Q.6 Describe the different types of sex hormones in fungi.

Answer:--

Q.7 **Write short notes on:**

1. Adventitious septa
2. Blastopore
3. Heterogamy
4. Spermatization
5. Arthrospores

Q.8 **Multiple choice questions:**

1. Fungi synthesize lysine by only the-

(a) L-α-adipic acid pathway

(b) D- α-adipic acid pathway

(c) meso- α, ε- diaminopimelic acid pathway

(d) meso- β, ε-diaminopimelic acid pathway

2. In a fungal mycelium, hyphae organised loosely or compactly woven to form a tissue called-

(a) Sclerotia

(b) Rhizomorph

(c) Plectenchyma

(d) None of the above

3. The example of Sclerotia is-

(a) Claviceps

(b) Sclerotinia

(c) Only (a)

(d) Both (a) and (b)

4. Fusing gametes are morphologically similar and motile but physiologically dissimilar, the process is known as-

(a) Heterogamy

(b) Anisogamy

(c) Isogamy

(d) None of the above

1.13 Answers

Ques-8 1. (a) 2. (c) 3. (d) 4. (c)

Self-assessment questions

SAQ.1 Answers

a. Lysine **b.** Chitin **c.** Plasma membrane

SAQ.2

a. Yeast **b.** Mycelium **c.** Allomyces

d. Mastigomycotina, Zygomycotina

SAQ.3

a. Armillaria mellea **b.** Predacious **c.** $(C_{22}H_{54}N_{40}O_{21})^n$

d. Karyochoresis

SAQ.4

a. Pythium, Puccinea **b.** Symbiotic **c.** Arbuscular

d. Chlorophyll

SAQ.5

a. Homothallic **b.** Sclerotia **c.** Budding

d. Rhizomorphs

SAQ.6

a. Pleomorphic or polymorphic **b.**Zoospore,aplanospore

c. Vacuoles, two **d.** Singly **e.** Basipetal, Acropetal

f. the blue green**g.** Pycniospores **h.** Arthrospore

SAQ.7

a. Glucan synthases **b.** *C. albicans*

b. 1,8-dihydroxynaphthalene, L-3, 4-dihydoxyphenylalanine **d.** Lomasomes

SAQ.8

a. Uni or biflagellate **b.** Parasitic fungi **c.** Martin **d.** Oospore

e. Sexual

SAQ.9

a. Heterothallism **b.** Gametangia **c.** Two-Allele **d.** Outbreeding

SAQ.10

a. *Aspergillus nidulans* **b.** parasexual cycle **c.** Sexual reproduction

d. *Allomyces* **e.** $C_{29}H_{42}O_5$ **f.** Antheridiol

g. Trisporic acid **h.** DNA replication

Unit 2

Phycomycotina I

Structure

2.1 Introduction

Phycomycetes are known as the lowest class of true fungi. Phycomycetes organisms are located all over the world in soil, animal manure, and on fruits. Frequently, the fungi of this class are found in refrigerators and are commonly called bread molds.

Objectives

After studying this unit, you will be able to:

- To explain the life cycle of *Plasmodiophora*
- To know the characteristics feature of Myxomycota

2.2 Life Cycle of Plasmodiophora brassicae

Cook and Swartz (1930) showed that the life cycle of *P. brassicae* comprises two distinct phases, the haplophase (primary phase) and the diplophase (secondary phase). The former occurs in the root hairs and the latter in the cells of the main root cortex of the susceptible host plant.

Each phase includes a number of successive stages which are described below:

2.2.1. Haplophase:

The resting spores or sporangia (cysts) which are differentiated by meiosis from the diploid protoplast of the sporothallus (secondary Plasmodium) are pioneer structures of the haplophase which occurs in the root hairs **(Figure 2.1)**.

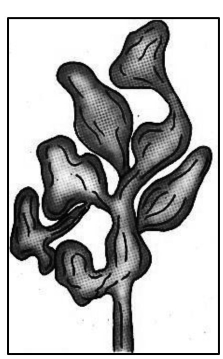

Figure 2.1: *Plasmodiophora brassicae*, Infected roots that have become swollen due to

hypertrophy

2.2.1.1. Fine Structure of Resting spore or sporangium:

It is a tiny hyaline, spherical, uninucleate, haploid structure up to 4.0 µ m in dia. According to Williams and Menabola (1967) the sporangial wall is differentiated into 3 layers (A) but in many cases it showed only 2 layers.

The outer layer is electrondense and granular. It included the surface spinules. The middle layer is less electrondense. Yukawa and Tanaka (1979) described a circular germ pore in the sporangial wall with the middle layer (inner in the 2 layered sporangial wall) thickened to form a circular electro-lucent plug-like structure in the region of the pore orifice (B).

It is surrounded by a ring of electron-dense material contiguous with the inner wall layer. Within the sporangial wall is the sporangial membrane which completely invests the cytoplasm replete with ribosomes. The other organelles present in the cytoplasm are mitochondria, endoplasmic reticulum and dictyosomes.

It has a single haploid nucleus. Numerous lipid globules of various sizes is another conspicuous feature of the spore (sporangial) cytoplasm. The mature spores are set free, when the clubs undergo decay. In the soil they germinate to initiate the life cycle **(Figure 2.2)**.

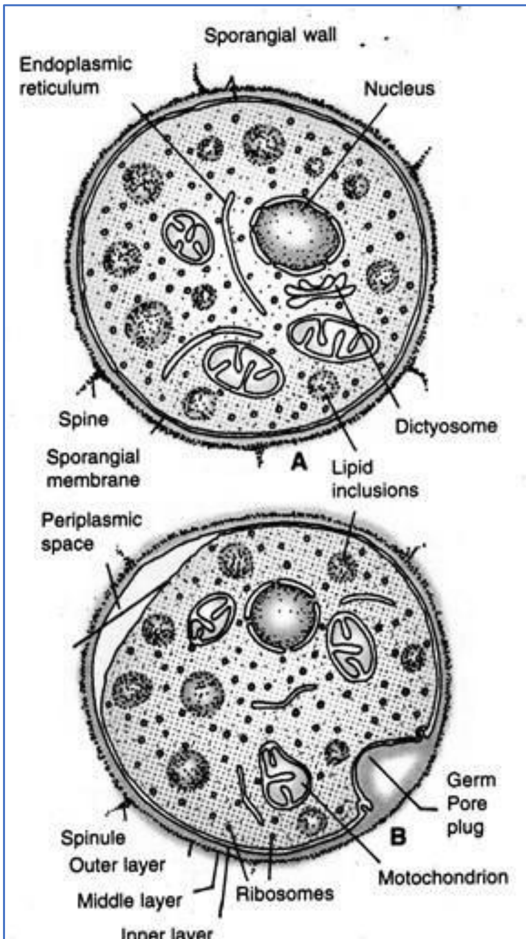

Fig. 5.2 (A-B) *Plasmodiophora brassicae*. Diagrammatic representation of the fine structure of resting spore or sporangium (A, Based on Williams and Menabola and B, on Yakawa and Tanaka.).

Figure 2.2 (A-B): *Plasmodiophora brassicae*. Diagrammatic representation of the fine structure of resting spore or sporangium (A, Based on Williams and Menabola and B, on Yakawa and Tanaka)

2.2.1.2. Germination of Resting Sporangium or Spore (cyst):

The spores of *P. brassicae* may germinate immediately or remain dormant in the soil for several years.

(a) Conditions affecting germination:

According to Hofing (1930), the most important factor for germination is maturity. Thus the spores or sporangia from older decaying galls germinate faster than those from the young galls. Ellison (1946) noted mutual stimulation of germination by resting sporangia (spores) in masses. Bremer (1924) reported that germination occurred more readily in wet acid than in limed soils.

The early suggestion of Chupp (1917) that the presence of host seedling stimulates germination, under certain conditions, has been substantiated by Macfarlane (1959, 67) and Bochow (1965) for *P. brassicae*. According to Macfarlane (1970) presence of host or metabolites secreted by them promote germination **(Figure 2.3)**.

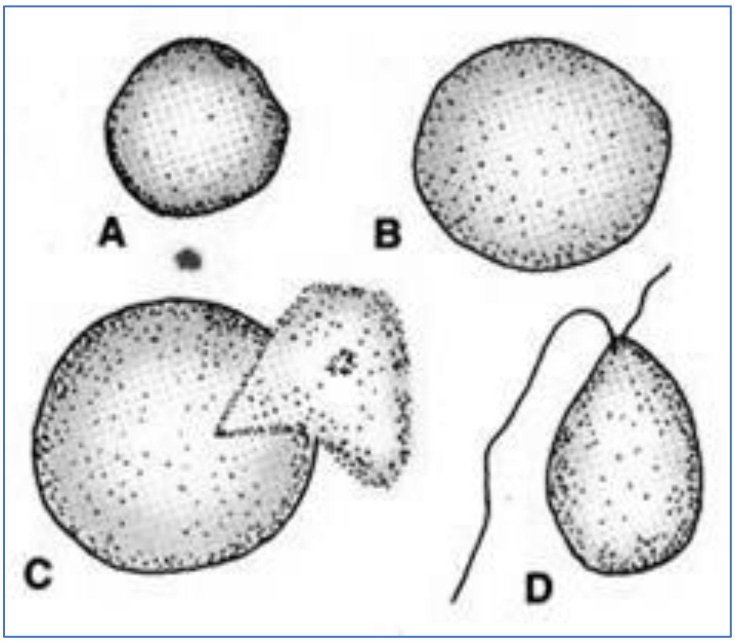

Figure 2.3 (A-D): ***Plasmodiophora brassicae*, Germination of resting spore in the soil**

(b) Process of germination:

Chupp (1917) and other early workers reported that the spore (A, sporangium) germinated in a favourable medium immediately. It absorbs water and swells considerably (B), particularly on one side along which a slit appears in the spore or sporangial wall. Through the slit, the uninucleate protoplasm emerges (C) as a single swarm cell or zoospore which is spherical or pear-shaped (D) in form.

Tommercup and Ingram (1971) observed a single, uninucleate, naked protoplast emerging from an isolated point on the spore wall. Macfarlane (1970) and Aist and Williams (1971) using interference optics observed a germination pore in the resting sporangium (or spore) wall through which the protoplast emerges slowly.

Recently Yukawa and Tanaka (1979) observed a circular germ pore in the sporangial or spore wall with a thickened pluglike structure in the pore orifice. In their view, this region undoubtedly constitutes the region of the germination pore of the resting sporangium (or spore) seen by

Macfarlane and Aist and Williams.

On germination, the plug dissolves to enable the zoospore to emerge through the germ pore. The refractile (lipid) globules in the sporangial cytoplasm gradually disappear as the germination begins. The spore contents become less viscous.

A small papilla emerges through the germ pore in the spore wall. It enlarges to form a thin vesicle as the spore contents flow into it. The flagella develop on the spherical or pearshaped zoospore as it completely emerges. It may also be termed as the primary or cyst zoospore.

Primary or Cyst Zoospore (D):

It is naked and extremely active after emergence for several minutes. Uptill 1934, it was assumed that the zoospore is furnished with a single flagellum inserted at the anterior end. It is of whiplash type and several times longer than the length of the zoospore. Ledinghan (1934) observed zoospores furnished with two unequal flagella.

Ellison (1945) confirmed that the zoospores of P. brassicae are biflagellate. Kole and Geilink (1962) observed with electron microscope that each zoospore is furnished with unequal, whiplash type flagella at its anterior end—a long one with an end piece and a short one arising by its side with a blunt end. The latter lacks the end piece.

2.2.1.3. Primary Infection of Host:

Infection takes place at the seedling stage in the host. The biflagellate, heterokont (with unequal flagella) primary zoospore (cyst zoospore) swims in a film of water in the soil or creeps over soil particles like an Amoeba.

According to Ayers (1944), on contact with the root hair of suitable host seedling (Cabbage or other crucifer seedling), the zoospore becomes attached and amoeboid, in this state it is called myxamoeba (A1).

The myxamoeba retracts its flagella and enters the root hair directly by a partial dissolution of the root hair wall (A2). According to Aist and Williams (1971), there is rapid injection of the parasite (encysted cyst zoospored) into the root hairs of the host by means of the special injection apparatus developed in the encysted zoospore.

The cyclosis of host cytoplasm sweeps the myxamoebae away from the penetration site soon after injection. The young myxamoebae in the root hairs are separated from the host cytoplasm by two kinds of simultaneously occurring intrafacial membrane arrangements. One of these is a 7-layered envelope of two closely appressed unit membranes and the second host parasite interface is also a 7 layered envelope.

2.2.1.4. Primary Plasmodium (Gametothallus, Fig. 2.4 A):

Within the root hair the uninucleate myxamoeba (A_2) enlarges to form a thallus. The protoplasm increases in size and the haploid nucleus divides repeatedly. The divisions are cruciform. The resultant small naked, multinucleate acellular mass of protoplasm constituting the thallus is called the primary Plasmodium.

It is a haploid structure and thus termed gametothallus. Many such thalli may be present in one root hair, if multiple penetration occurs, but these do not fuse.

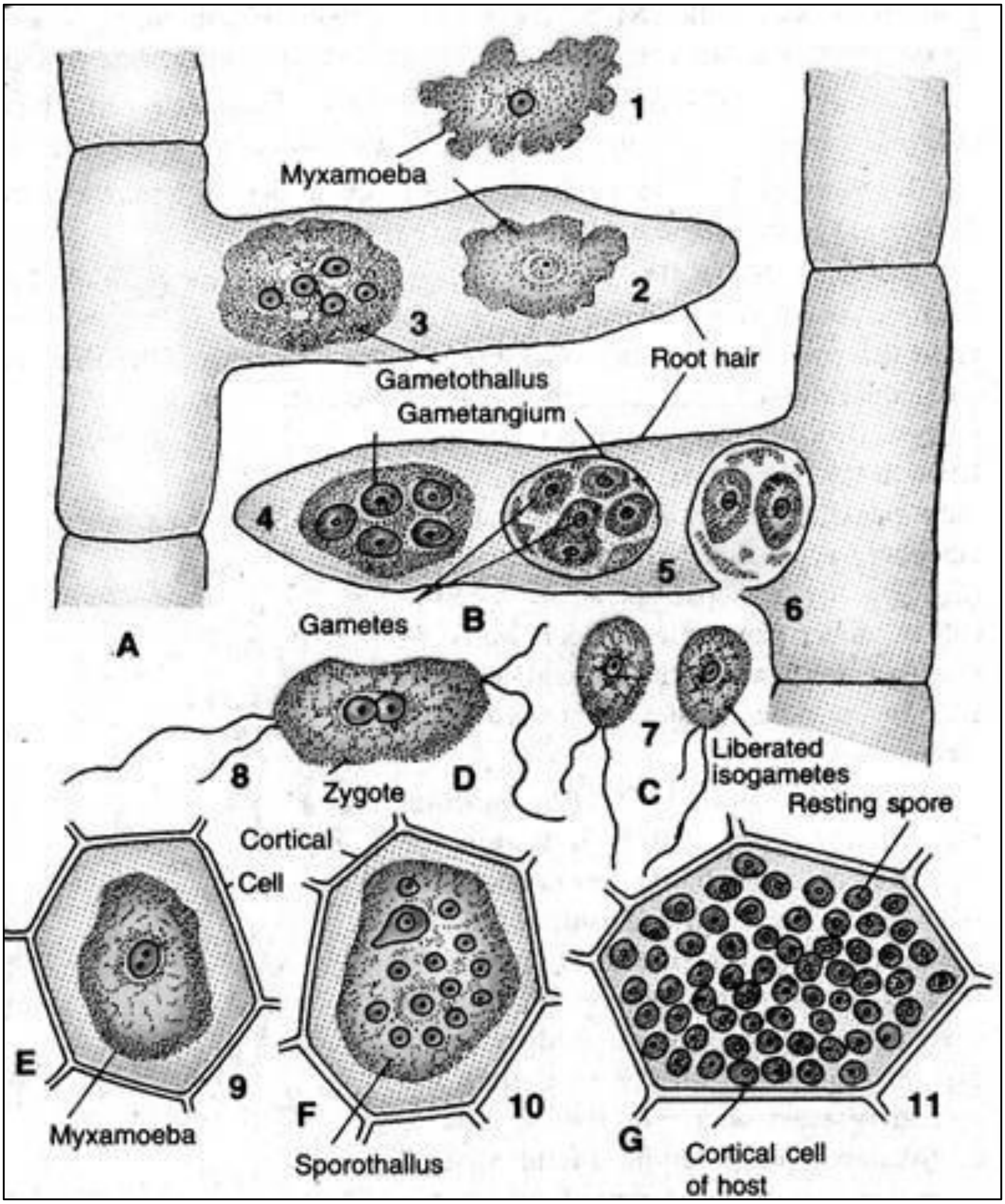

Figure 2.4 (A-G): *Plasmodium brssicae*, A1: Myxamoeba outside the root hair, A2: Myxamoeba within the root hair, A3: Gametothallus, B4: Differentiation of gametes in the gametangium, B5: Differentiation of gametes in the gametes in the gametangium, B6: Liberation of gametes in the soil, C7: Liberated isogametes, D8: Fusing gametes, E9: Zygote in the host cortical cell, F10: Sporothallus, G11: Resting sporangia or spores in the host cell

2.2.1.5. Sexual Reproduction:

The haploid primary Plasmodium (gametothallus) is concerned with sexual reproduction. After a certain period of growth, the cytoplasm of the gametothallus, while still lodged in the root hair, cleaves into as many uninucleate daughter protoplasts as there are nuclei (usually 4-10) in the Plasmodium (B4).

Each daughter protoplast secretes a membrane around it and functions as a gametangium. The gametangia are small spherical, thinwalled uninucleate structures. The haploid nucleus of the gametangium undergoes mitosis to form four to eight daughter nuclei (B5).

Each daughter nucleus gathers a small bit of cytoplasm around it and develops into a spindle-shaped motile, biflagellate, isogamete which is smaller in size than the zoospores (C6). The two flagella are of unequal size and of whiplash type inserted at the anterior end. Thus in one gametangium up to eight isogametes are formed (B5).

They have no cell walls. The whole process takes 2—8 days. The thin gametangium wall bursts (C6) and liberates the gametes in the root hair. All the stages (A—D) described above occur in the root hairs of the host. These constitute the haplophase.

Plasmogamy:

After liberation, the isogametes copulate in pairs. It has not been established whether gametes from the same gametangium or from different gametangia copulate. It is also not known definitely whether pairing of isogametes takes place in the root hairs or cortical cells after migration.

The most widely held view is that the isogametes are released in the soil outside the host through a pore formed at the point of contact of gametangium and the root hair cell wall. Pairing of gametes takes place outside the host in the soil. Pairing of gametes is soon followed by the fusion of their membranes and cytoplasms. This is termed plasmogamy. The latter thus results in the formation of binucleate fusion cell (D_8).

Karyogamy:

The fusion of two nuclei in the binucleate cell which is termed karyogamy is delayed. It takes place immediately before cyst formation.

2.2.2. Diplophase:

This phase in the life cycle begins with the formation of quadriflagellate zygotes (D8). The single nucleus in zygote is diploid.

2.2.2.1. Zygote:

The quadriflagellate zygotes are generally found in the cortical cells of the root. As mentioned above it is not definitely known whether the gametes fuse in the root hairs or in the cortical cells after migration. In the former case the flagellated zygotes perforate the epiblema cell walls and reach the meristematic zone of the root. When the quadriflagellate zygote is formed in the soil, it re-infects the root.

Once in the root cortex, the zygotes retract their flagella and become amoeboid. The amoeboid zygotes are called myxamoebae (E9). The myxamoebae spread from cell to cell by direct penetration of cell walls. At first they are found in the cortical cells and later in the other tissues of host root and stem.

2.2.2.2. Secondary Plasmodium (Sporothallus):

Within the invaded cortical cell, the myxamoeba by subsequent growth accompanied by repeated karyokinesis (mitosis) of its diploid nucleus but no cytokinesis, grows to form a relatively large, naked, multinucleate diploid Plasmodium.

It is called the secondary Plasmodium or sporothallus or cystogenous Plasmodium. In the mature state, it may occupy the entire lumen of the infected host cell and surround the host cell nucleus **(Figure 2.5 A)**. It lies immersed in the cytoplasm. The host cell may contain more than one plasmodia.

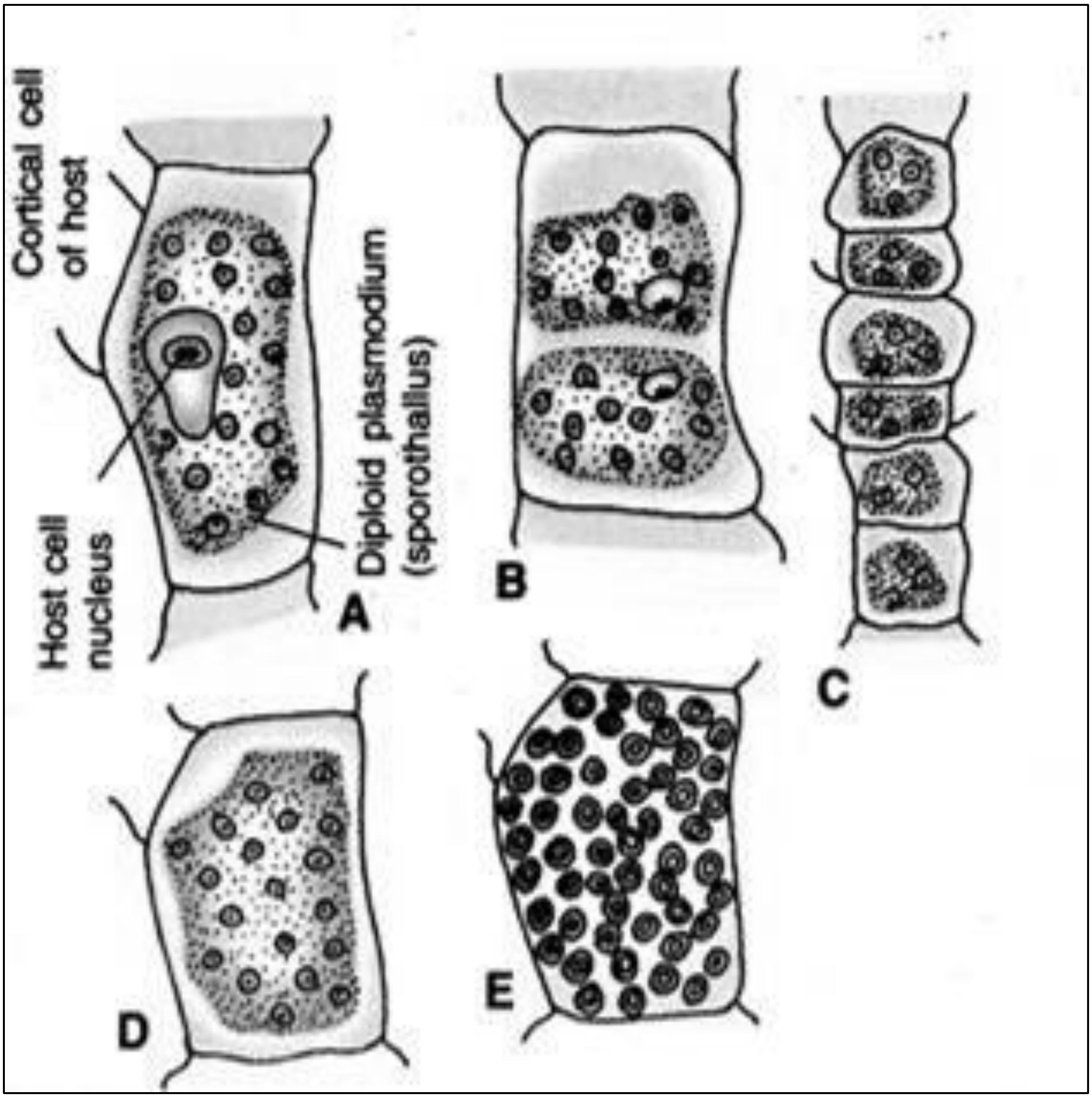

Figure 2.5 (A-E): ***Plasmodiophora brassicae*, A: Multinucleate sporothallus in the host cell, surrounding its nucleus, B: Sprothallus divides along with the host cell, C: series of invaded cells forming Krankheitscherd, D-E: Differentiation of resting sporangia or spores**

Ultrastructure of Secondary Plasmodium:

It was investigated by Willams and McNabola (1967). The plasmodium is bounded and thus separated from the host cytoplasm by a smooth, deeply staining osmophilic membranous envelope about 250A thick. It consists of two closely appressed osmophilic membranes. There is no cell wall within the membranous envelope; the growing plasmodial cytoplasm is replete with free ribosomes.

Besides, it contains abundant endoplasmic reticulum and several mitochondria, each with a few tubular cristae. Dictyosomes occur near the diploid plasmodial nuclei. The presence of numerous prominent lipid droplets of variable sizes is another conspicuous feature.

Each nucleus of the multinucleate plasmodial cytoplast is bounded by a perforated nuclear membrane and contains a single prominent nucleolus. A number of microtubules have been reported to occur near each diploid nucleus. The intracellular Plasmodium of *P. brassicae* lacks special feeding structures **(Figure 2.6)**.

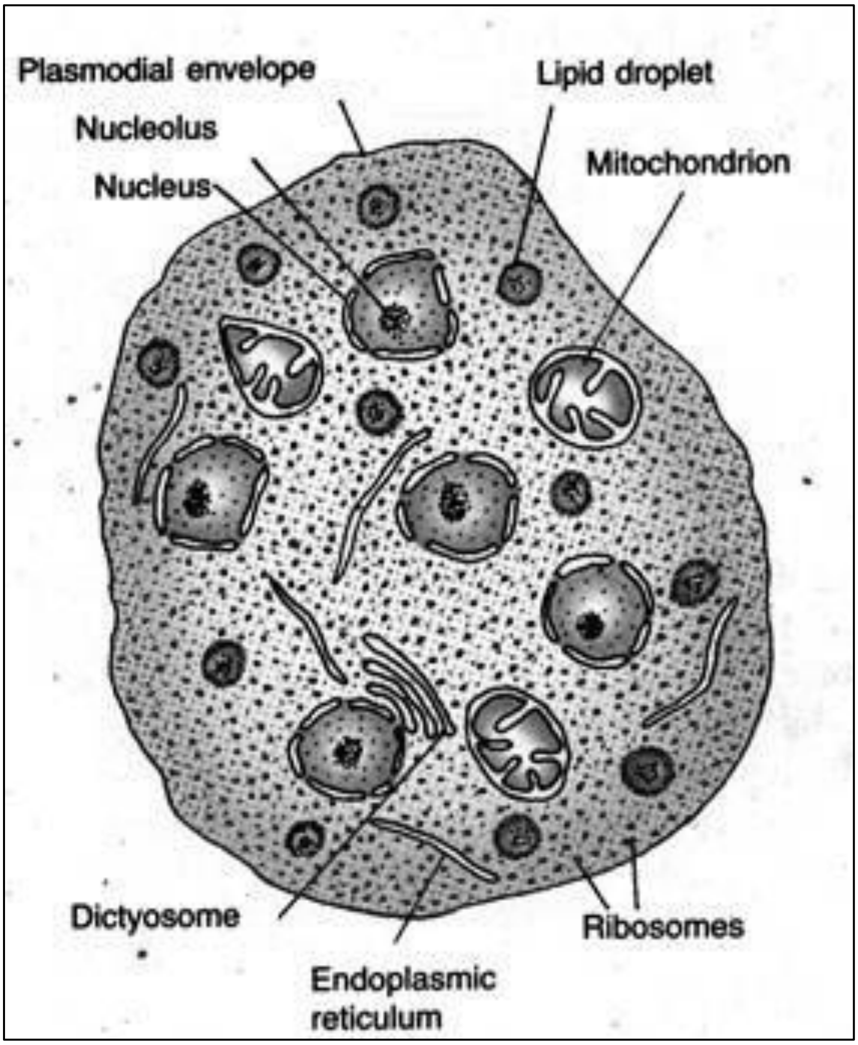

Figure 2.6: ***Plasmodiophora brassicae*, Diagrammatic representation of ultrstructure of sporothallus**

2.2.2.3. Formation of Clubs:

The presence of the secondary plasmodia in the cortical host cells elicits many metabolic responses in the infected cells. One of these is the excessive or abnormal increase in the size of the infected host cells. This is termed hypertrophy. Besides hypertrophy,' the presence of secondary plasmodia in the cortical cells stimulates them to have active and repeated division.

This excessive multiplication of infected or diseased host cells is termed hyperplasia. Hypertrophy and hyperplasia of the infected cells stimulates the neighbouring uninfected parenchyma cells of the host to divide and redivide.

Consequently, there is excessive proliferation of infected host cells in the form of tuberous swellings or malformations on the diseased roots. These malformations are called clubs or galls. This tumorous growth (galls or clubs) of roots and hypocotyl resulting from cell hypertrophy and hyperplasia is the most striking feature of Brassica plants infected with P. brassicae.

Williams, however, suggested that the stimulus for cell division and cell hypertrophy in the club root galls lies within the parasitized cells only and is not transferred to the adjacent cells. The infected roots act as sinks for growth materials produced in parts of the plant above the ground.

The club-tissue is thus likely to be invaded by soft rot bacteria or other rot producing organisms which bring about decay of clubs resulting in the formation of materials toxic to the plant and cause wilting of the tops. Subsequently it may result in permanent wilting or retarded growth.

2.2.2.4. Vegetative Multiplication of the Parasite:

At the time of division of infected or diseased host cells (hyperplasia), the secondary plasmodia may also divide (B), a part of it going to each infected daughter cell. The formation of new plasmodia by a vegetative method of fragmentation results in the spread and propagation of the disease.

Groups of infected hypertrophied cells become recognisable in the host tissues (C). Woronin (1878) called each such group of hypertrophied cells Krankhaitsherd (C). The secondary Plasmodium of each enlarged cell of Krankhaitsherd eventually becomes converted into a mass of resting sporangia or cysts (E).

2.2.2.5. Differentiation of Resting sporangia (Cysts) or spores also called cyst (Sporulation stage):

The mature multinucleate diploid secondary Plasmodium (sporothallus) practically fills the entire lumen of the hypertrophied cortical cell (D). It ceases to grow in size. With the cessation of vegetative growth, a new phase in the life cycle ushers in. During this phase, the diploid nuclei of the Plasmodium seem to lose their contents and disappear.

The chromatin fails to take the usual stain. It is the akaryote stage. Soon after the nuclei reappear and the protoplasmic mass of the Plasmodium cleaves around each nucleus. The entire Plasmodium is thus transformed into a large number of tiny uninucleate, spherical bodies each of which is surrounded by a wall of its own. These are termed the resting sporangia (Cysts) or spores (E).

Till recently the nature of the akaryote stage was an enigma. Lutman (1913) suggested that meiosis takes place during sporangial (Cysts) or spore differentiation. Milovidon (1931) claimed that akaryote stage represents prophase I of meiosis. Garber and Aist (1979) conclusively showed that the akaryote stage represents the meiotic prophase I and the subsequent divisions are remainder of meiosis I and meiosis II.

They thus confirmed previous claims both of Lutman (1913) and of Milovidon (1931). According to Garber and Aist's study, the akaryote stage marks the transition between the actually parasitic vegetative stage represented by the diploid Plasmodium and the dormant phase represented by the resting sporangia (Cysts) or spores which are haploid structures.

The vacuoles and long slender furrows which are absent in vegetative phase (secondary Plasmodium) appear in the plasmodial cytoplasm in the meiotic process. The vacuoles appear in the prophase I and furrows during metaphase I. The latter demarcate the boundary along which cleavage will occur.

Both the vacuoles and furrows become prominently conspicuous at the beginning of meiosis II. The plasmodium is still a single unit at this stage. By the end of meiosis II, the Plasmodium is divided into a number of tiny daughter protoplasts, each with 2 haploid nuclei.

The final step in cytoplasmic cleavage is the division and separation of the tiny binucleate blocks of plasmodial cytoplasm into uninucleate, irregularly-shaped haploid daughter protoplasts which later round up to take on the shape of mature haploid resting sporangia (Cysts) or spores.

Each young sporangium or spore is invested by a membranous envelope known as the sporangial membrane. The entire secondary plasmodium is thus converted into a sporangial or spore mass.

The spores or sporangia (Cysts) in the mass are free from one another but the entire mass of sporangia or spores is surrounded by the common plasma membrane of the host cell. A fine fibrillar matrix termed the inter-sporangial matrix remains between the sporangia or spores in the mass.

According to Williams and Mc Nabola (1967), granular aggregates of the inter-sporangial matrix are deposited along the sporangial or spore membrane as small spines termed the spinules. Towards maturity, sporangial or spore wall is deposited between the sporangial or spore membrane and the spines.

Ultra-structurally, the cyst spore wall is formation of resting differentiated into 5 layers.

These are:

(i) An outer layer of loose proteinaceous fibres (l_1),

(ii) A layer of similar fibres but with lipid granules enmeshed (l_2),

(ii) A prominently chitinous wall (l_3),

(iv) An inner phospholipid containing region (l_4) and

(v) An inner spore membrane.

The chemical analysis of cyst wall shows that the principal components are chitin, protein and lipid. The mature sporangia of spores (Cysts) are set free in the soil when the club roots undergo decay and decomposition by soft rot microorganisms.

The chitinous nature of the sporangial or spore (Cysts) wall enable them to withstand adverse conditions. The resting spores or cysts (sporangia) thus perennate in the soil.

They germinate to produce zoospores on the offset of suitable conditions to continue the fresh life cycle. Macfarlane (1970) reported that the spore or cyst germination is stimulated by the presence of susceptible host seedlings or by certain of their metabolities **(Figure 2.7 and 2.8)**.

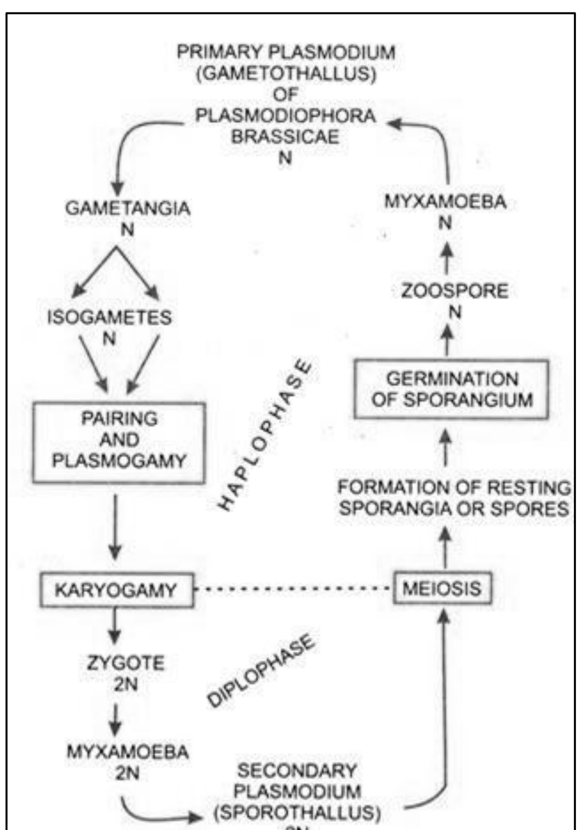

Figure 2.7: *Plasmodiophora* sp. Graphic representation of the life cycle

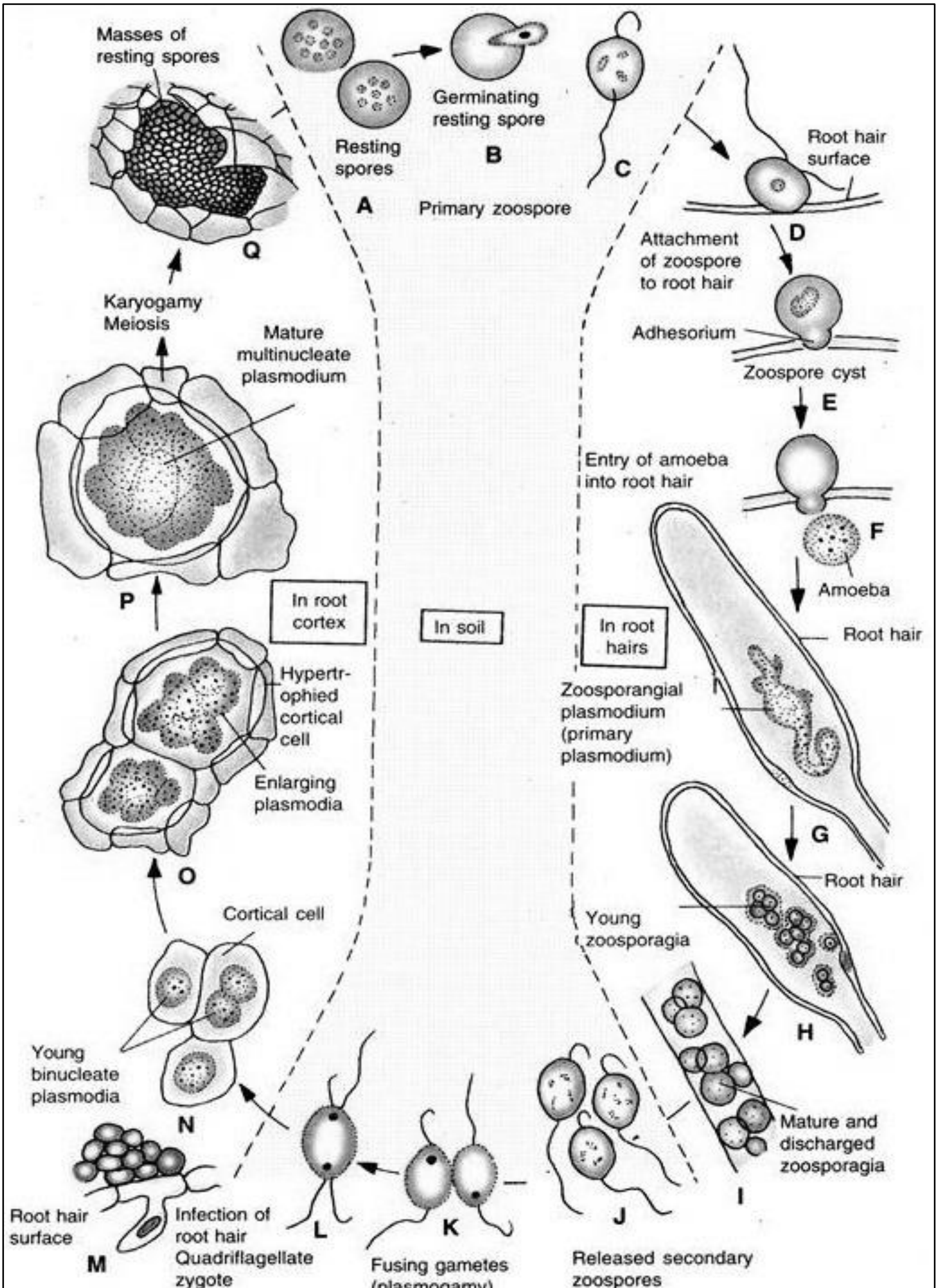

Figure 2.8: Pictorial Diagram of the life cycle of *Plasmodiophora brassicae*

2.2.2.6 Alternation of Generations of *Plasmodiophora Brassicae*:

There is distinct alternation of generations in the life cycle of *Plasmodiophora*. The zygote and the secondary plasmodium (sporothallus before spore formation) represent the sporophyte generation or diplophase. The resting spores, the zoospores, the haploid primary plasmodium (gametothallus), the gametangia, and the isogametes represent gametophyte generation or haplophase.

The two crucial points in the life cycle are meiosis at the time of differentiation of spores (meiospores) and karyogamy (fusion of gametic nuclei). At these critical points, the life cycle switches on from one generation to the other.

With meiosis the diploid or sporophytic phase ends. The gametophyte phase starts. At the time of karyogamy, the gametophyte phase terminates and the sporophytic phase is initiated with the formation of diploid zygote.

These two generations occur regularly one after the other in the life cycle. This is called alternation of generations. The life cycle characterised by alternation of generations with sporogenic meiosis is called haploid-diploid or diplohaplontic (diplobiontic life cycle).

SAQ.1

a. Secondary plasmodium are______________structures of the haplophase which occurs in the root hairs.

b. The____________globules in the sporangial cytoplasm gradually disappear as the germination begins.

c. _____________confirmed that the zoospores of *P. brassicae* are biflagellate.

d. Infection of *P. brassicae* takes place at the_____________stage in the host.

e. The haploid nucleus of the gametangium undergoes mitosis to form_____to_____ daughter nuclei.

f. The fusion of two nuclei in the binucleate cell which is termed___________.

g. Diplophase in the life cycle begins with the formation of_________________zygotes.

h. The intracellular Plasmodium of *P. brassicae* lacks special______________structures.

i. The life cycle characterised by alternation of generation with___________meiosis is called diplobiontic life cycle.

2.3 Myxomycota

The division Myxomycota includes the organisms like cellular slime molds, the plasmodial slime molds and the net slime molds. DeBary (1887), the Father of Plant Pathology and also the founder of modern mycology, termed the group Mycetozoa (Cr. mykes — mushroom, i.e., fungus and zoon — animal) i.e., fungus animal due to presence of their naked cell and phagotrophic i.e., holozoic mode of nutrition.

This was followed by different scientists for long time. Macbride (1899) was the first to name the group as Myxomycetes (Gr. myxa, slime and myketes, mushrooms or fungi). Martin (1960) also treated slime molds as Myxomycetes under fungi and which according to him has a protozoan ancestry.

Olive (1975) classified the group under the Kingdom Protista and divided them into seven classes: Protosteliomycetes, Ceratomyxo- mycetes, Dictyosteliomycetes, Acrasiomycetes, Myxomycetes, Plasmodiophoromycetes and Labyrinthulomycetes.

Later, Hawksworth et al. (1983) kept the above seven classes under the division Myxomycota of the kingdom Fungi. Alexopoulos and Mims (1979) kept these organisms under the division Gymnomycota along with other two fungal divisions namely, Mastigomycota and Amastigomycota. We have followed the classification of Ainsworth (1973) who placed them within the division Myxomycota.

The Myxomycota differs from true fungi because their vegetative body consists of only protoplast bounded by membrane and devoid of cell wall and also for their phagotrophic mode of nutrition. Economically, they have little importance, but are very useful as experimental tools in the study of molecular biology, biochemistry, cytology, genetics etc.

2.3.1. Characteristics of Division Myxomycota:

The important characteristics of the division Myxomycota are:

1. Presence of trophic phase which may be of myxamoeba (simple uninucleate amoeboid cell), a pseudoplasmodium (aggregation of uninucleate amoeboid cells) or the plasmodium (a free-living multinucleate mass of protoplasm).
2. The mode of nutrition is phagotrophic.
3. The vegetative part consists of protoplast covered by plasma membrane and devoid of cell wall (cell wall is present on the spore if produced by them).
4. They resemble the primitive fungi in their mode of reproduction by producing spores within sporangia.
5. They are either holocarpic or eucarpic.
6. They exhibit variable colouration.

2.3.2. Classification of Division Myxomycota:

The classification of Myxomycota by Ainsworth (1973) is:

Key to Classes:

A. Assimilative phase tree-living amoebae which unites as a pseudoplasmodium before reproduction Acrasiomycetes.

AA. Assimilative phase a plasmodium.

B. Plasmodium forming a network (net-plasmodium) ……… Hydromyxomycetes.

BB. Plasmodium not forming a network.

C. Plasmodium saprophytic, tree- living Myxomycetes.

CC. Plasmodium parasitic within cells of the host plant………………………. Plasmodiophoromycetes.

A. Class: Acrasiomycetes:

Acrasiomycetes are commonly known as cellular or amoeboid slime molds, and are found profusely in the upper layer of humus in deciduous forests and also in cultivated lands.

The characteristic features are:

1. Somatic phase commonly consists of amoeboid cells or myxamoebae.

2. Myxamoebae aggregate to form a pseudoplasmodium, which develops fruit body.

3. Lack of flagellated cells, except in *Pocheina rosea*.

4. Spore wall contains cellulose.

5. Fruit bodies may be sorocarps (in *Dictyostelium*) or sporocarp (in *Protostelium*).

Raper (1973) has given the outline of classification of this group and expressed that the organisms may not represent natural group and it is also uncertain whether this group is related to fungi or to protozoa. He divided the class into 3 subclasses: Protostelidae, Acrasidae and Dictyostelidae.

Later, Olive (1975) raised the rank subclasses into classes as Protosteliomycetes, Acrasiomycetes and Dictyosteliomycetes.

B. Class: Hydromyxomycetes:

This group shows uncertain affinities. The thallus forms net plasmodium or filoplasmodium. They are commonly aquatic and saprobic, but rarely parasitic.

The characteristic features are:

1. The thallus consists of uninucleate spindle shaped cells, forming extensive filaments.
2. The filaments are tubular and form net-like structure, the net-plasmodium or filoplas-modium.
3. Reproduction by cyst formation, zoospore formation or by congregation.

The class consists of two orders Hydro- myxales and Labyrinthulales. But Hawksworth et al. (1983) excluded Hydromyxales from fungi and included it in Protozoans. The members of Labyrinthulales are parasitic on higher plants and also on marine algae. *Labyrinthula macrocystis* is a very common species, found as parasite on *Zostera* marina, the eel-grass.

C. Class: Myxomycetes:

This group is commonly known as true slime molds or plasmodial slime molds. They are commonly found in damp places, especially on old wood and other decomposing plant parts.

The characteristic features are:

1. The vegetative body is a freeliving plasmodium.

2. They feed on yeast cells, protozoa, fungal spores and other substances.

3. Reproduction takes place by asexual and sexual means.

(a) Asexual reproduction takes place by fragmentation of plasmodium or binary fission in myxamoebae.

(b) Sexual reproduction takes place by fusion between flagellated zoospores or myxamoeba to form zygote, from which multinucleate plasmodium develops by mitotic divisions. They develop different types of fructification. These are sporangium, aethalium and plasmodiocarp. Meiosis takes place during spore formation in the fructification **(Figure 2.9)**.

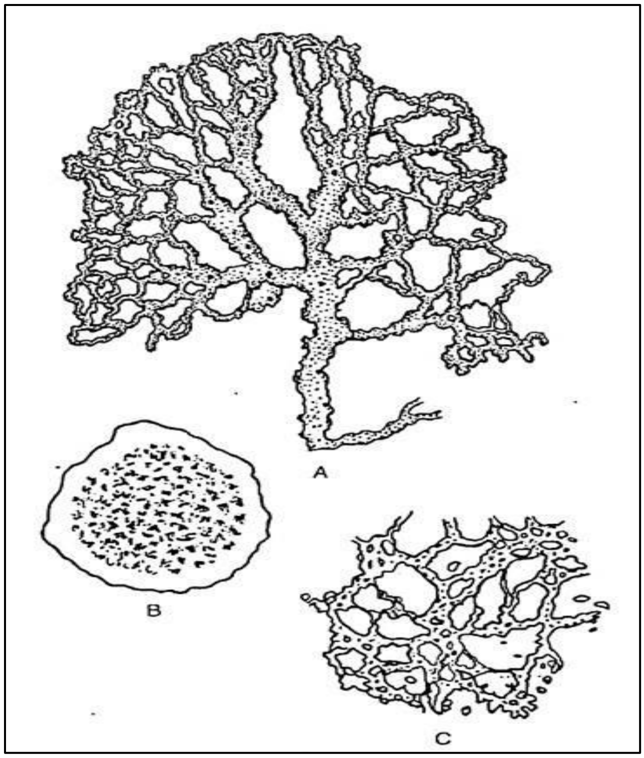

Figure 2.9: Three types of Plasmodia in the Myxomycetes; A. Aphanoplasmodium, B. Protoplasmodium and C. Phaneroplasmodium

Alexopoulos (1973) divided the class Myxomycetes into three subclasses: Ceratio- myxomycetidae, Myxogastromycetidae and Stemonitomycetidae.

D. Class: Plasmodiophoromycetes:

This group is commonly known as endo- parasitic slime molds. They are obligate parasites, grow on algae, aquatic fungi and higher plants (commonly in the roots).

The characteristic features are:

1. Members of this class are obligate (i.e., biotrophic) parasites of fresh water algae, aquatic fungi and higher plants (commonly in the roots) **(Figure 2.10)**.

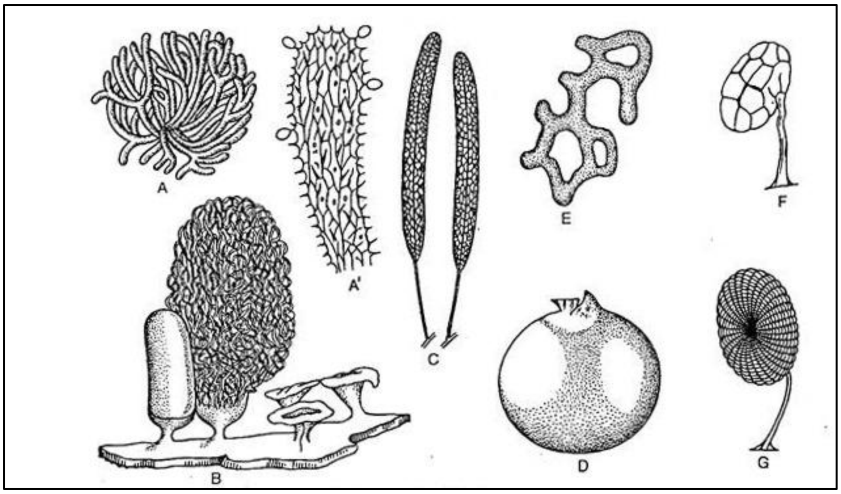

Figure 2.10: Different types of fructification in Myxomycetes: A-A'. *Ceratiomyxa fructiculosa,* A. Columnar structure composing fructification. A'. Details of single column showing attachment of sporangia, B. Sporangia in different stages of maturity in *Arcyria sp*. C. Sporangia bearing hypothalli in *Stemonitis*, D. Aethalium of *Lycogala* sp., E. Plasmodiocarp of *Hemitrichia sp.,* F-G. Sporangia in peridium on a slender stalk of *Physarum* (F) and *Dictydium* (G)

2. Somatic body consists of a naked holocarpic plasmodium.

3. Plasmodia are of two types in their life cycle: sporangiogenous plasmodium (form sporangia) and cytogenous plasmodium (gives rise to cysts i.e., resting spores).

4. Zoospores biflagellate, having unequal flagella of whiplash type, situated in opposite direction, the shorter one in anterior and longer one in posterior side.

The class consists of a single order Plasmodiophorales with a single family Plasmo diophoraceae. The class consists of 16 genera and 45 species. Some like *Plasmodiophora brassicae* causes club-root of crucifer; *Spongospora subterranea* causes powdery scab of potato.

SAQ.2

a. ______________was the first to name the group as Myxomycetes.
b. Myxomycota exhibit_____________variable colouration.
c. Myxamobae aggregate to form a_____________, which develop fruit body.
d. Fruit bodies may be______________in *Dictyostelium.*
e. Plasmodia are of two types in their life cycle:______________and______________ plasmodium.

2.4 Summary

In this unit you have learnt that:

The life cycle of *Plasmodiophora brassicae* summarises-

- It comprises two distinct generations or phases namely the gametophyte generation or haplophase and sporophyte generation or diplophase. The former occurs in the root hairs and the latter in the cortical cells of the host root (Brassica sp.).
- The gametophyte generation (haplophase) is initiated by the differentiation of resting spores

(sporangia) or cysts by meiosis from the diploid protoplast of the secondary plasmodium in the club roots of the host cortex. The mature cysts or resting sporangia or spores which are haploid are released into the soil when the club roots undergo decay and decomposition by soft rot microorganisms.

- After liberation, they perennate or germinate immediately if the conditions for growth are favourable. On germination, each resting spore or cyst produces a biflagellate, heterokont, haploid zoospore.
- The released zoospore swims in a thin film of water in the soil of creeps over the soil particles like an amoeba. Coming in contact with the root hairs of a suitable host it becomes attached and amoeboid. In this state, it is called a myxamoeba. It then retracts its flagella and enters the root hair.
- Within the root hair it is swept away from the penetration site by host cytoplasmic cyclosis. By growth and repeated cruciform nuclear division, the uninucleate myxamoeba becomes converted into a naked multinucleate thallus like mass of protoplasm. It is acellular haploid and is called the primary plasmodium (or gametothallus).
- Reaching a certain stage of maturity, the haploid protoplast of gamete thallus cleaves into 4-10 small, spherical, thinwalled, uninucleate gametangia. The haploid nucleus of each gametangium undergoes repeated mitosis to form 4-8 nuclei. Each daughter nucleus gathers a bit of cytoplasm around it to become a spindle-shaped mobile biflagellate isogamete.
- All the above mentioned haploid stages namely, the resting meiospores (sporangia or cysts), the zoospores, the primary plasmodium (gametothallus), the gametangia and the isogametes (which occur in the root hairs of the host) constitute the gametophyte generation or haplophase.
- The second phase of the parasite life cycle commonly called as the diplophase or sporophyte generation starts with the formation of zygotes. The zygotes are found in the cortical cells of the root. It is not definitely known whether the isogametes fuse in the root hairs or in the cortical cells after migration.
- The consensus favours the view that the isogametes are released in the soil outside the host where pairing followed by plasmogamy takes place. Karyogamy is delayed. A binucleated quadriflagellate zygote thus formed reinfects host root.
- Within the root cortex, the zygote retracts its flagella and becomes amoeboid in form. It is called myxamoeba. Within the invaded cell the myxamoeba by subsequent growth accompanied by repeated cruciform division grows to form a naked, multinucleate diploid mass of protoplasm called the secondary plasmodium or sporothallus.
- It fills the lumen of the cortical cell. It then ceases to grow in size and its diploid protoplast undergoes meiosis.
- As a result, the multinucleate diploid protoplast of the secondary Plasmodium is converted into a large number of uninucleate spherical haploid bodies each of which is surrounded by a wall of its own. These are the resting spores (sporangia) or cysts.
- The resting spores when mature are set free in the soil by the decay of club by rot microorganisms. In the soil the resting spores or cysts germinate under favourable conditions to continue the fresh life cycle. The zygote and the secondary plasmodium constitute the diplophase or sporophytic generation.

- The two crucial points in the life cycle are meiosis at the time of differentiation of spores (meiospores) and karyogamy (fusion of gametic nuclei). At these critical points, the life cycle switches on from one generation to the other.
- The division Myxomycota includes the organisms like cellular slime molds, the plasmodial slime molds and the net slime molds. DeBary (1887), the Father of Plant Pathology and also the founder of modern mycology, termed the group Mycetozoa

2.5 Terminal Question

Q.1 Discuss the haplophase of *Plasmodiophora brassicae.*

Answer:--

Q.2 Explain the cyst zoospore of *Plasmodiophora brassicae.*

Answer:--

-------------------------------- --

Q.3 Describe the sexual reproduction of *Plasmodiophora brassicae.*

Answer:--

-------------------------------- --

Q.4 Define ultrastructure of secondary plasmodium.

Answer:--

-------------------------------- --

Q.5 Give detail account of alternation of generation of *Plasmodiophora brassicae*.

Answer:--

-------------------------------- --

Short Questions

Q.6 Write short notes on:

1. Characteristics features of Acrasiomycetes
2. Salient features of Hydromyxomycetes
3. Characteristics features of Plasmodiophoromycetes

Q.7 **Multiple choice questions:**

1. *Plasmodiophora brassicae* causes the club root disease of crucifers can be controlled by-

(a) Raising PH of soil

(b) Decreasing PH of soil

(c) Both (a) and (b)

(d) None of the above

2. *Plasmodiophora brassicae* survives in soil in the form of-

(a) Oospore

(b) Resting spore

(c) Chlamydospore

(d) Perithecium

3. *Plasmodiophora brassicae* causes-

(a) Bulb root

(b) Club root

(c) Root rot

(d) Collar rot

4. Club root is more serious in-

(a) Alkaline soil

(b) Neutral soil

(c) Acidic soil

(d) None of the above

2.6 Answers

1. (a) 2. (b) 3. (b) 4. (c)

Self-assessment questions

SAQ.1 Answers

a. Pioneer **b.** Refractile **c.** Ellison **d.** Seedling **e.** Four, Eight **f.** Karyogamy
g. Quadriflagellate **h.** Feeding **i.** Sporogenic

SAQ.2 Answers

a. Macbride **b.** Variable **c.** Pseudoplasmodium **d.** Sporocarps
e. Sporangiogenous, Cytogenous

Unit 3

Phycomycotina II

Structure

3.1 Introduction

3.1.1. Mastigomycotina

- **G.C. Ainsworth's system** of classification includes Mastigomycotina which is a subdivision under **Eumycota.**
- It is known to be the first subdivision under eumycota.
- It is a motile **fungus.**
- These consist of large heterogenous fungi
- 75000 species have been reported under this category.
- These are majorly known by the presence of motile flagellated spores called **zoospores** (spores which show motility). This feature is unique to this subdivision known as zoosporic fungi.

3.1.2 Zygomycotina

- These are the second kingdom of **fungi** known as the **conjugated fungi.**
- They majorly include the bread mold, *Rhizopus stolonifer*.

- Approximately 1060 species are known.

Objectives

After studying this unit, you will be able:

- To know the classification of Mastigomycotina and Zygomycotina.
- To study the Characteristics features of Mastigomycotina and Zygomycotina.
- To Know the economic feature of Mastigomycotina and Zygomycotina.
- To study the life cycle of *Synchytrium endobioticum*

3.2 Classification

3.2.1. Mastigomycotina

These are further subdivided into 4 classes based on the type of flagellum, the position of the flagellum, and the number of flagellum attached.

1. **Chytridiomycets** Single Posterior flagellum – Whiplash type, aquatic, parasitic or saprophytic in nature.
2. **Hypochytridiomycetes** Single Anterior flagellum- Tinsel type, aquatic or terrestrial, parasitic in nature.
3. **Oomycetes-** Biflagellated zoospore- Anterior Tinsel type and posterior whiplash-type, freshwater or marine water, saprophytic or parasitic in nature.
4. **Plasmodiophoromycetes** Biflagellated zoospore- Anterior Tinsel type and posterior whiplash-type, aquatic or marine, parasitic in nature.

3.2.2. Zygomycotina

Zygomycotina is subdivided into 2 classes

1. **ZygomycetesOrders**

   Order Mucorales:

   Chiefly Saprophytes, some weak parasites on plants, a few endoparasites of vertebrates; mycelium extensive, asexual reproduction by sporangiospores or rarely by conidia Zygospore wall may be formed by modification of gametangial walls.

   Order Entomophthorales:

   Typically, parasitic on animals; rarely saprophytes, mycelium- limited. Asexual reproduction by sporangia turned conidia or true conidia; conidia discharged forcibly, gametangial wall not transformed to Zygospore wall.

   Order Zoopagales:

   Typically parasite on animals, rarely saprophytes, mycelium present with complicated haustoria. A sexual reproduction by conidia which are passively discharged; gametangial wall not transformed to Zygospore wall. Of these, Mucorales have been discussed in some detail.

2. **Trichomycetes**

SAQ.1

a. ________________showssingle anterior flagellum which is Tinsel type.

b. In order_______________,mycelium present with complicated haustoria.

c. Oomycetes shows____________zoospore which is anterior Tinsel type and posterior whiplash type

d. In zoopagales, gametangia wall not transformed to____________wall..

3.3 General Characteristics Features

3.3.1 Mastigomycotina

- They have aseptate and coenocytic mycelium.
- The septae formation may take place in old hyphae during the reproductive stage.
- The cell wall is made up of chitin and cellulose.
- The protoplast is vacuolated and has numerous nuclei.
- The protoplasm have oil droplets that act as food reserves.
- The reproduction may be vegetative, sexual, and asexual.
- They may be saprophytic, parasitic.

3.3.1.1. Distribution

- These are found in a variety of habitats such as Aquatic habitat, freshwater or marine, and soil
- The aquation fungi are known as water molds.
- They live either saprophyte on plant/animal debris or parasite on algae, fungi, and plants
- A few species live on the damp soil and these survive as saprophytes and may be responsible for few diseases like root rot
- A few are responsible for destructive diseases in plants/crops.

3.3.1.2. Types of Zoospores

There are 3 types of zoospores **(Figure 3.1)**.

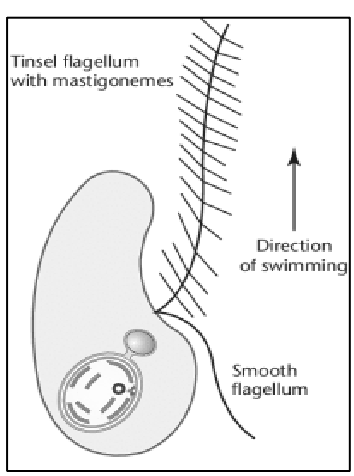

Figure 3.1 Zoospores

1. Single Anterior flagellum- Tinsel type
2. Single Posterior flagellum – Whiplash type
3. Biflagellated zoospore (Reniform or kidney-shaped) – Anterior Tinsel type and posterior whiplash-type

3.3.1.3. Reproduction

The reproduction may be vegetative, asexual or sexual.

- ***Vegetative***

1. **Fragmentation-** The vegetative mycelium or hyphae break into several fragments that have the capability to grow into new mycelium under favourable conditions.
2. **Clamadospores-** Hyphal tips are mostly swollen and they get separated by a septum and then germinate to form mycelium.

- ***Asexual***

1. **Through Zoospores-** ie. the difference is by type of flagellum, the position of the flagellum, and a number of flagellum attached. uniflagellate posterior type or uniflagellate tinsel type or biflagellated.

- ***Sexual***

Gametic Copulation or Planogametic copulation involves the fusion of two naked gametes

1. **Gametangium Copulation** The conjugation between the gametangia that leads to protoplasm fusion and ultimately nucleus forming spores.
2. **Gametangial contact** The conjugation tube is formed between the gametangia and the transfer of nucleus takes place leading to meiosis and formation of spores that form new hyphae.

3.3.1.4. Life Cycle (Chytridiomycetes) (Figure 3.2)-

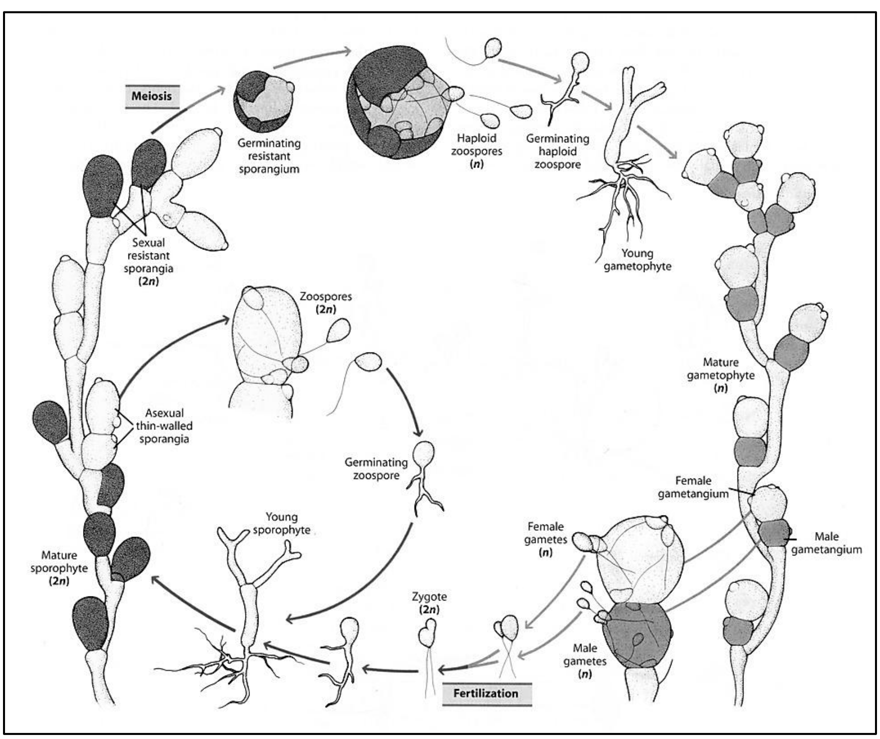

Figure 3.2

3.3.2 Zygomycotina

- These are true fungi.
- They have a well-developed and haploid filamentous thallus
- This consist of branched mycelium and coenocytic multinucleate hyphae due to the absence of septum.
- The septum is not present in early stage but formed during the reproductive stage
- A few mycelia produce rhizoids.
- The cell wall is made up of chitin.
- The mode of nutrition may involve parasitic or saprophytic associations
- Also, there are certain destructive plant pathogens causing disease.
- The **zygospore** formation is the characteristic feature in this fungus that contains **sporopollenin** which is present in the outer wall of spores.
- This protects them from desiccation and other unusual conditions
- They are mostly terrestrial in habitat, living in soil or on decaying plant or animal material.
- They show sexual and asexual reproduction

3.3.2.1. Hyphae

There are 3 types of hyphae present in this fungi-

1. **Stolon-** This grow horizontally
2. **Rhizoids-** These are root-like structures present in tufts. They help in attaching mycelium to the substratum.
3. **Sporangiospores-** These are present on the specialized hyphae. These are majorly erect, Aerial and unbranched hyphae which also grow as tufts. These are reproductive in nature as they bear sporangium.

3.3.2.2. Habitats

- They are found mostly in terrestrial habitat ie on soil or decaying plants and animals or may be aquatic
- They may be parasites on arthropods, plants or on fungal hosts
- They may also have symbiotic associations

3.3.2.3 Reproduction

They show sexual and asexual reproduction

- ***Asexual***

They majorly reproduce by asexual reproduction.

1. **Sporangiospores-** They reproduce by sporangiospores when they have all the required nutrients available i.e. they search for favourable conditions. They produce by forming a sac-like structure called sporangium around the sporangiophore. They are then passed by the wind current as the rupture takes

place and the sporangiospores are placed into other suitable growing conditions.

- ***Sexual***

Sexual reproduction occurs in adverse conditions.

1. **Gametangial Copulation-** The two opposite mating strains fuse their hypha to form diploid zygosporangia. A thick wall is formed between the two hyphae and there are zygospores inside it. That's why it is known as conjugated fungi. Also, the meiosis takes place once they got proper nutrition and development conditions.

3.3.2.4. Life Cycle

It occurs in three phases **(Figure 3.3)-**

1. Haploid Phase (n)
2. Diploid Phase (2n)
3. Dikaryotic Phase (n+n)

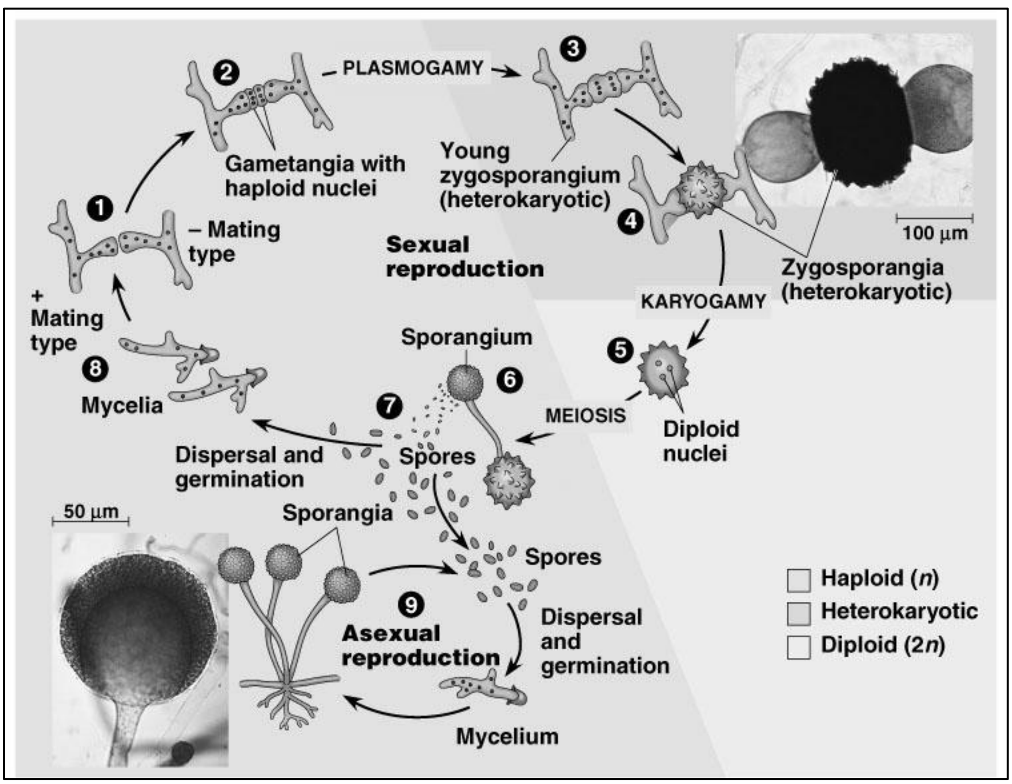

Figure 3.3

1. **Plasmogamy-** The protoplasm of two mycelia fuses together without the fusion of nuclei, forming two haploid nuclei in the same cell.
2. **Karyogamy-** It occurs when two opposite strains of fungi fuse together to form one diploid nucleus. Later they undergo meiosis and form zoosporangia. It is the final step and form **<u>sporangiospores</u>** when conditions are favourable.

SAQ.2

a. The two opposite mating strains fuse their hypha to form diploid_______________.

b. Gametangial copulation is a type of____________reproduction.

c. Zygomycotina show three types phases namly____________, diploid and____________.

d. Planogametic copulation involves the fusion of two________gametes.

3.4 Economic Importance

3.4.1. Mastigomycotina

- Chytrids cause wart disease of potato, wart diseases in roots of crucifers, crown wart of alfalfa, a brown spot of maize,
- Oomycetes are responsible for late blight of potato, downy mildew, damping-off, fruit rot (*Pythium species*), foot rot (*Pythium species*), white rust (*Albugo*),
- Few have been reported as biocontrol agents.
- Hypochytrids form an important group in marine or freshwater biodiversity.

3.4.2. Zygomycotina

- These are opportunistic human pathogen that rarely causes human disease.
- They are saprophytic in nature that depends on dead and decaying plants and animals, dung which ultimately helps in the **carbon cycle.**

3.5 Life Cycle of Synchytrium endobioticum

Synchytrium is represented by about 200 species reported from all over the world, occurs as parasite on aquatic alga, bryophytes (mosses), pteridophytes (ferns) and mostly on flowering plants.

About 80 species have been reported from India, of which *S. rytzii* on the members of Lamiaceae, *S. trichosanthoides* and *S. laginariae* on the members of Cucurbitaceae, S. taraxicola on *Taraxacum officinale*, *S. sisamicola* on *Sesamum indicum* and *S. endobioticum* is a well known species which causes wart disease or black wart of potato, available in the main potato growing regions of the world, mostly in mountains with moist and cold climate. In India, this disease was first recorded at Rangbul in Darjeeling district of West Bengal in 1953.

Symptoms of Disease Caused by *Synchytrium*:

The disease is characterised by cauliflower-like black warty growth on tubers, stolons and stem bases **(Figure 3.4)**. Sometimes, the size of the warts are more than the size of the tuber.

Life History of *Synchytrium*:

The life history of the most common species i.e., *S. endobioticum* has been studied by Miss K. M. Curtis, 1921; followed by Kohler (1923, 1931). The representation of the life cycle has been given in the figure.

Vegetative Structure of *Synchytrium*:

The vegetative body of *Synchytrium* consists of minute endobiotic holocarpic thallus, represented by naked uniflagellate zoospore with whiplash flagellum.

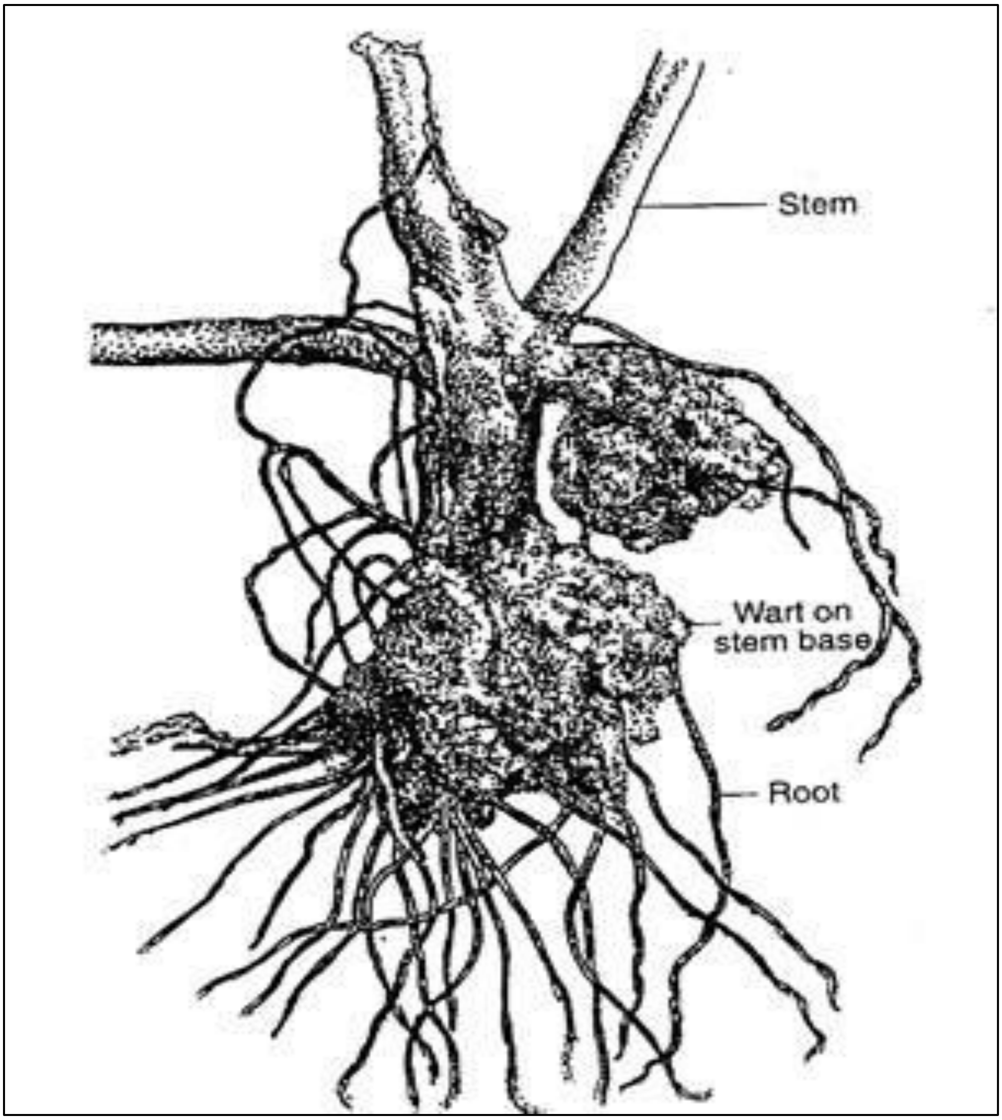

Figure 3.4: Symptom on stem base and stolon of potato

Reproduction in *Synchytrium*:

Synchytrium *endobioticum* reproduces both asexually and sexually. Vegetative reproduction is absent. During reproduction, the entire thallus transforms into a reproductive unit i.e., holocarpic.

1. Asexual Reproduction:

Asexual reproduction generally occurs during favourable condition, i.e., in spring season. Duiing this period, minute naked uninucleate and uniflagellate zoospores that are released from the resting sporangium (which torms during unfavourable condition i.e., in winter season) after water soaking.

The zoospores are capable of swimming for about two hours. After coming in contact either with the potato ‘eye’ or stolon or young tuber, they come to rest and withdraw their flagella. The content of the zoospore cyst enters into the host cell through the wall by minute pore in amoeboid movement, keeping the cyst membrane outside.

The protoplast of zoospore, after entry in the host epidermal cell, absorbs food and becomes spherical in shape. The infected host cell also enlarges in volume. The host cell surrounding the infected cell becomes stimulated and starts swelling (hypertrophy) resulting into the formation of tumour or wart-like structure **(Figure 3.5)**.

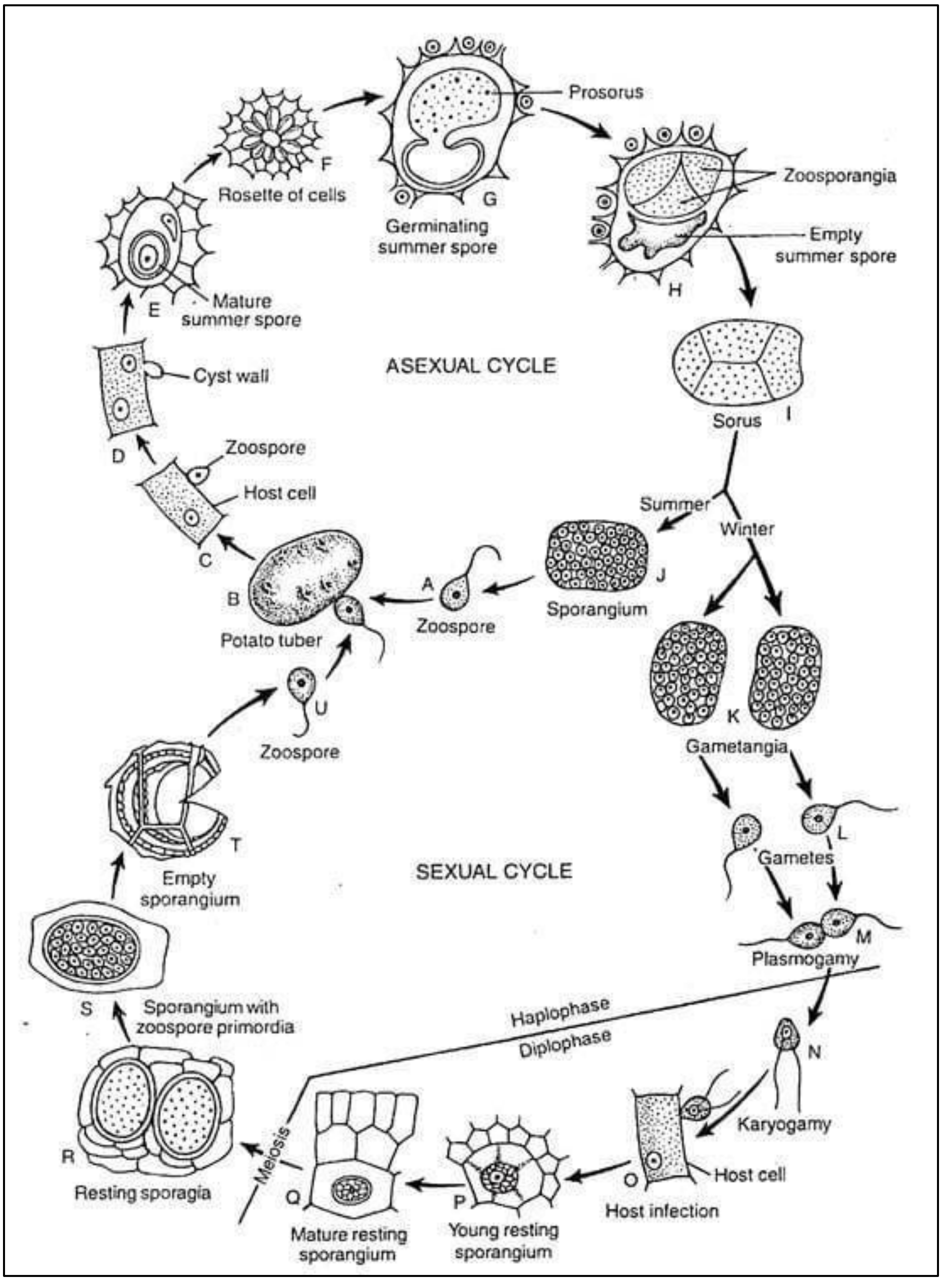

Figure 3.5: Life cycle of *Synchytrium endobioticum*

The infected cell dies and remains in the middle of the wart. The pathogen along with its nucleus enlarges considerably, rounds off and develops two layered walls, consisting of a thick golden brown exospore and a thin hyaline endospore. This is the summer spore.

The summer spore germinates within the infected host cell. Before germination, the nucleus enlarges and the inner wall protrudes out through a minute pore on the outer wall and forms a vesicle towards the upper portion of the infected host cell. The total content of the summer spore is transferred to the vesicle.

The nucleus of summer spore then undergoes repeated mitotic divisions and forms about 32 nuclei. This multinucleate vesicle is known as prosorus. The protoplast of the vesicle becomes cleaved into 4-9 segments, covered by thin hyaline wall. Each segment is known as summer sporangium or zoosporangium. The total aggregated structure of the zoosporangia is known as Sorus.

The nuclei of each zoosporangium undergo repeated mitotic divisions and form generally 200 to .300 nuclei (their number may go up to 500 or more in large sporangium). The protoplast then divides into many uninucleate segments.

The mature sporangium swells up by absorbing water and creates pressure on the host wall to burst. After bursting, the zoospores get released through a small slit on the sporangial wall. The zoospores are uninucleate and uniflagellate. They swim actively in water and infect again the new host or different regions of the same host.

The behavior of the zoospore varies with the environmental condition. If the condition is favourable (i.e., summer continues), the zoospore causes infection to a new host or different region of the same host and continues the asexual cycle again. During unfavourable condition they behave as gamete and undergo sexual reproduction.

2. Sexual Reproduction:

During unfavourable condition (if winter comes), the multinucleate segment of prosorus instead of behaving as zoosporangium behaves as gametangium which produces many gametes, those are smaller in size than the zoospores.

The gametes coming from different gametangia of a same or different sorus may fuse, but not from same gametangia of a sorus. The planogametes after union form diploid biflagellate zygote. The planogametes are similar in size and shape therefore; copulation is isogamous.

The zygote swims for sometime and encysts on the surface of the host epidermis and penetrates the host cell by a process similar to zoospore penetration. The surrounding host cell then undergoes hyperplasia i.e., repeated cell division. The infected cell is then buried into the deeper layer of host cells.

The effect on the surrounding tissue varies between zoospore and zygote infection. Hypertrophy (i.e., enlargement of cells) takes place on zoospore infection, but the zygote infection causes Hyperplasia (i.e., repeated cell division).

During this development, the zygote enlarges and becomes surrounded by two layered wall formed by itself and then a third wall is developed from the host content after its death. It is now called winter sporangium or resting sporangium. The resting sporangium remains dormant throughout the winter season.

The resting sporangia are released into the soil after decaying the host tissue and are capable to germinate within about two months.

With the onset of favourable condition i.e., in spring season, the resting sporangium becomes active and its nucleus undergoes repeated nuclear division of which first one is meiotic, followed by many mitotic divisions. The protoplast, along with a single nucleus, divides into many uninucleate segments.

After absorbing water, the wall of resting sporangium bursts open and releases the zoospores. The zoospores are like the asexual zoospores, which on coming in contact with a suitable host cause infection and repeat the cycle again.

Indian Species:

*Synchytrium endobioticum, S. brownii, S. ajrekari, S. colapsum, S. cookie*potato.

SAQ.3

a. The vegetative body of *Synchytrium* consists of minute______________thallus, represented by naked uniflagellate zoospore with whiplash flagellum.

b. The total aggregated structure of the zoosporangia is known as_______.

c. Hypertrophy takes place on___________infection, but the zygote infection causes____________.

d. Hyperplasis is formed by repeated______________,

3.5 Summary

After studying this unit, you have learnt that:

- **G.C. Ainsworth's system** of classification includes Mastigomycotina which is a subdivision under **Eumycota.**
- Zygomycotina are the second kingdom of **fungi** known as the **conjugated fungi.**
- Mastigomycotina are further subdivided into 4 classes based on the type of flagellum, the position of the flagellum, and the number of flagellum attached which are **Chytridiomycets, Hypochytridiomycetes, Oomycetes, Plasmodiophoromycetes.**
- Zygomycotina is subdivided into 2 classes: Zygomycetes and Trichomycetes.
- 3 types of zoospores formed in mastigomycotina: Single Anterior flagellum- Tinsel type, Single Posterior flagellum, Biflagellated zoospore.
- In Mastigomycotina, the reproduction may be vegetative, asexual or sexual. Vegetative reproduction through**Fragmentation,** Clamadospores Asexual reproduction through **Zoospores.** Sexual reproduction through **Gametic Copulation or Planogametic copulation** involves the fusion of two naked gametes.
- In Zygomycotina, the reproduction may be asexual or sexual. Asexual reproduction through **sprongiospores.** Sexual reproduction through **Gametic Copulation.**
- Chytrids cause wart disease of potato, wart diseases in roots of crucifers, crown wart of alfalfa, a brown spot of maize,
- Oomycetes are responsible for late blight of potato, downy mildew, damping-off, fruit rot (Pythium species), foot rot (Pythium species), white rust (*Albugo*),
- Zygomycotina members are opportunistic human pathogen that rarely causes human disease. They are saprophytic in nature that depends on dead and decaying plants and animals, dung which ultimately helps in the **carbon cycle.**
- S. endobioticum is a well-known species which causes wart disease or black wart of potato, available in the main potato growing regions of the world, mostly in mountains with moist and cold climate. In India, this disease was first recorded at Rangbul in Darjeeling district of West Bengal in 1953.
- The vegetative body of Synchytrium consists of minute endobiotic holocarpic thallus, represented by naked uniflagellate zoospore with whiplash flagellum.
- Synchytrium endobioticum reproduces both asexually and sexually. Vegetative reproduction is absent. During reproduction, the entire thallus transforms into a reproductive unit i.e.,

holocarpic.

3.6 Terminal Question

Q.1 Discuss about the general characteristics features of Mastigomycotina.

Answer:---

Q.2 Describe the salient features of Zygomycotina.

Answer:---

Q.3 Write the economic importance of Mastigomycotina..

Answer:---

Q.4 Write the classification of Zygomycotina along with orders.

Answer:---

Q.5 Define the term Hypertrophy and Hyperplasia.

Answer:---

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Short Questions

Q.6 Write short notes on:

1. Gametangial contact
2. Life cycle of chytridiomycetes
3. Reproduction in *Synchytrium*
4. Asexual reproduction in Mastigomycoitina

Q.7 **Multiple choice questions:**

1. Wart disease caused by Synchytrium occurs in-
   (a) Cabbage
   (b) Pea
   (c) Tomato
   (d) Potato

2. Zygomycetes have which type of mycelia?
   (a) Non-septate
   (b) septate with uninucleate
   (c) Septate with multinuclei
   (d) White, non-septate
3. Mastigomycotina is divided into-
   (a) 2 classes
   (b) 3 classes
   (c) 4 classes
   (d) 5 classes
4. Single posterior flagellum is-
   (a) Tinsel type
   (b) Whiplash type
   (c) Reniform type
   (d) None of the above

3.7Answers

1. (d) 2. (d) 3. (c) 4. (b) 5. (b)

Self-assessment questions

SAQ.1

a. Hypochytridiomycetes **b.** Zoopagales **c.** Biflagellated **d.** Zygospore

SAQ.2

a. Zygospore **b.** Sexual **c.** Haploid, dikaryotic **d.** Naked

SAQ.3

a. Endobiotic holocarpic **b.** Sorus **c.** Zoospore, Hyperplasia **d.** Cell division

Unit 4

Ascomycotina

Structure

4.1 Introduction

- It is the largest group of **fungi** having more than 32,000 species in 3,400 genera
- it is also known as **Sac Fungi**
- askos bag or bladder and mykes fungus
- It is characterized by the formation of an **ascus**
- This consists of molds that have septated hyphae and some yeasts

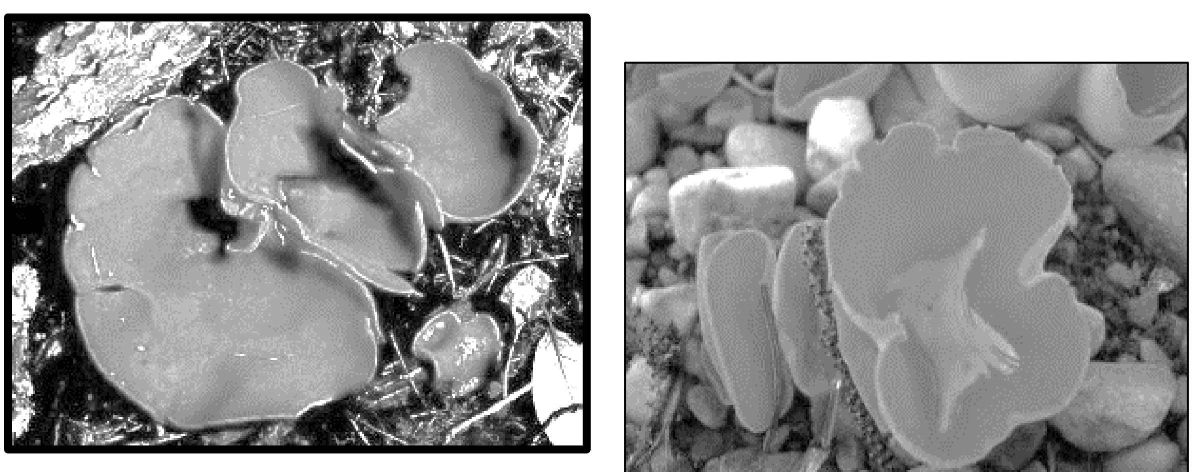

Figure 4.1

Objectives

After studying this unit, you will be able:

- To study the classification of Ascomycotina
- To know about salient features of Ascomycotina
- To understand economic importance of Ascomycotina.

4.2 General Characteristics

- The spore formed by these fungi is known as **ascospores** which are sexually produced and are present within a sac
- They consist of both parasitic and saprophytic species
- They may be symbiotic
- The majority species are terrestrial but few are aquatic ie. marine and freshwater
- It is responsible for a few diseases like powdery mildew.
- They show both sexual and asexual reproduction.
- They produce the sexual ascospores and asexual conidiospores.

4.2.1 Thallus structure

- It may grow either as yeasts, i.e. unicells multiplying by budding or fission or as mycelia which consist of septate hyphae
- Mycelium is well developed with branched and septate hyphae
- Mycelium may be homokaryotic or heterokaryotic
- Some fungi may be dimorphic i.e. they can switch from the yeast to the filamentous state or vice versa. e.g. Candida

4.2.2 Reproduction

Reproduction may occur sexually or asexually.

- ***Asexual***

1. **By Formation of Conidia-**

- These are exogenous and non-motile spores which are produced on the tip of conidiophores. They may be branched or unbranched and unicellular or multicellular
- Conidiogenesis occurs in two ways which appear to be distinct: **blastic and thallic**
    i. **Blastic** The conidium develops by the blowing-out of the wall of a cell, mostly from the tip of a hypha
    ii. **Thallic** This occurs by conversion of a pre-existing hyphal element in which terminal or intercalary cells of a hypha become cut off by septa.

2. **Other spore formations like Oidia or Chlamydospores-** This may occur in some species.

- ***Sexual***

Ascomycota have male and female gametangia in their haploid stage ie. **antheridium** and **ascogonium** respectively.

1. **Gametangial copulation**
2. **Gametangial contact**
3. **Plasmogamy**– A single cell with two haploid nuclei. This creates a binucleate, dikaryotic condition in the ascogonium leading to karyogamy
4. **karyogamy**– At the tip of the hyphae the nuclear fusion takes place

Diploid nucleus immediately undergoes meiosis followed by mitosis resulting in **8 haploid nuclei**. Each nucleus accumulates cytoplasm, secrete a wall around it develop into an ascospore.

4.2.3. Life cycle (Figure 4.2)-

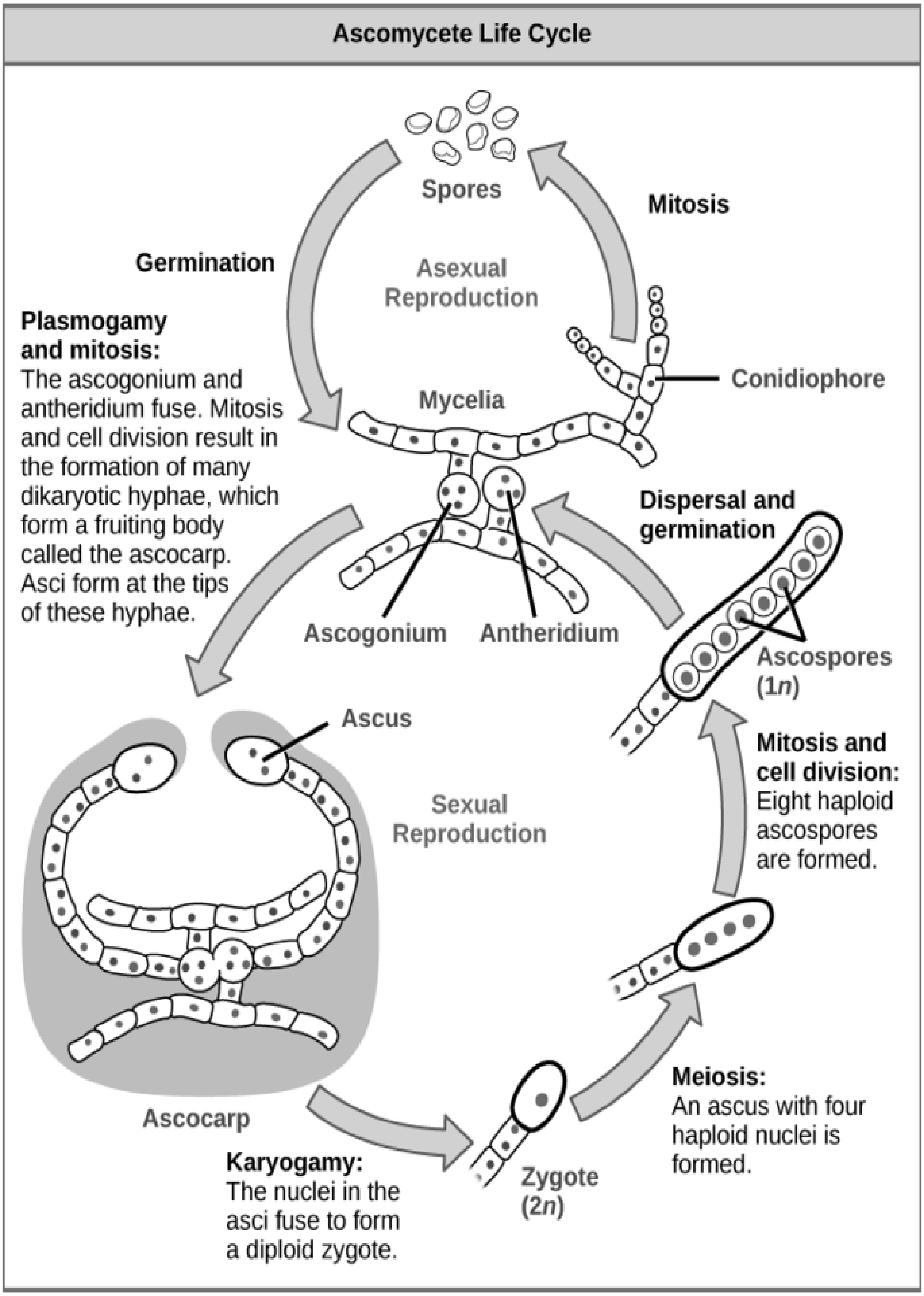

Figure 4.2

SAQ.1

a. The spore formed by these fungi is known as________________which are sexually produced and are present within a sac.

b. Mycelium is well developed_____________ and septate hyphae.

c. ______________may be homokaryotic or heterokaryotic.

d. Peach leaf curl disease is caused by______________.

4.3 Classification

It is subdivided into 6 classes-

1. **Hemiascomycetes-** Mycelium is poorly developed or absent, No ascocarp formation
2. **Plectomycetes-** Mycelium is well developed, branched and septate, Ascocarp is formed
3. **Pyrenomycetes-** Mycelium well developed and septate, ascocarp are produced
4. **Discomycetes-** Well developed mycelium, Sex organs are lacking
5. **Laboulbeniomycetes-** Thallus is reduced, Ascocarp is formed
6. **Loculoascomycetes-** Thallus is mycelial, Ascocarp is formed

Orders

- **Taphrinales**

  This order includes a variety of fungus, all parasitic fungi on vascular plants, causing an increase in the growth of infected tissues. The disease symptoms appear on infected plants such as wrap leaves, which affects leaves of trees peach and almond, this order includes two families-

Family: Taphrinaceae- This family includes about 118 species of Genus Taphrina sp. which grow as yeasts by budding during one phase of their life cycles, then infect plant tissues in which typical hyphae are formed this condition called Dimorphic. *Taphrina deformans* is one of the most important fungi of this family, which causes Peach Leaf Curl disease **(Figure 4.3)**.

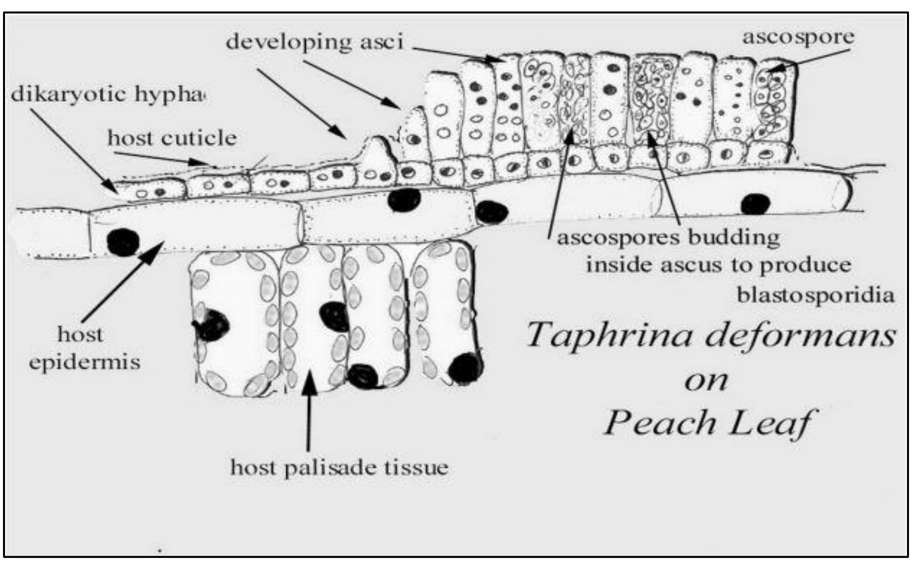

Figure 4.3: ***Taphrina deformans*** **on peach of leaf**

Family: Protomyctaceae- The most important species of this family is the fungus Protomyces macrospores, which causes Life gall disease of a group of plants belonging to the Umbelliferae family such as metal, celery, carrots and coriander.

- **Schizosaccharomycetales**

Family: Schizosaccharomycetaceae Ex : Schizosaccharomyces sp. is a genus of fission yeasts. The most well studied species is *S. pombe*, At present four *Schizosaccharomyces* species have been described (*S. pombe*, *S. japonicus*, *S. octosporus* and *S. cryophilus*), is a significant model organism in the study of eukaryotic cell biology. This yeast has contributed to the knowledge of many genetic information that has been reported in reaching a cure for many diseases, especially cancer, Yeasts reproduce by budding or forming spores called Blastospores **(Figure 4.4)**. Sometimes the bud is not separated from the mother forming pseudohypha which is a chain of linked buds.

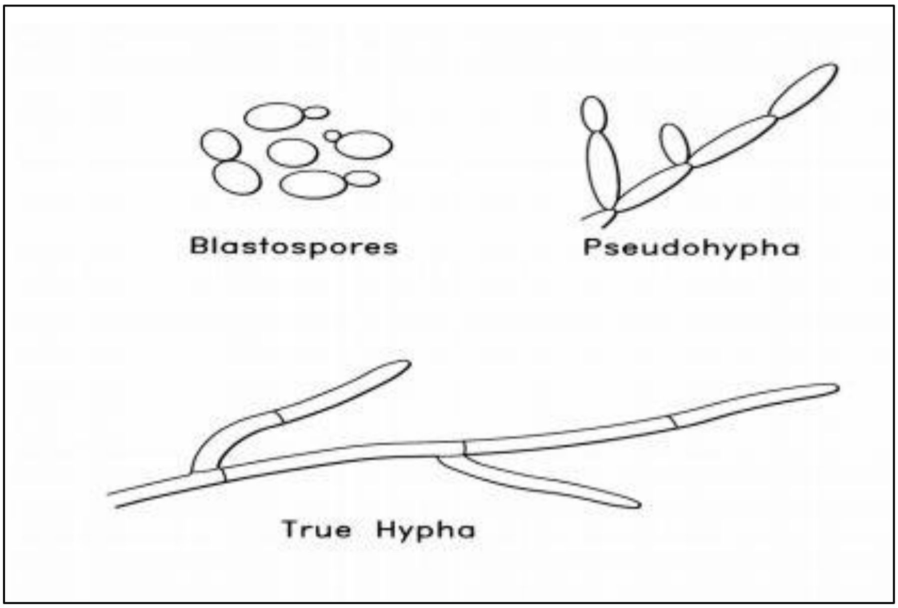

Figure 4.4: Blastopore, Pseudohypha and True hypha

Ex- *Pneumocystis sp.*

Is not commonly found in the lungs of healthy people, but, being a source of opportunistic infection, it can cause a lung infection in people with a weak immune system. *Pneumocystis* pneumonia is especially seen in people with cancer undergoing chemotherapy.

- **Saccharomycetales**

Ex: ***Saccharomyces cerevisiae*** It is species of yeast, the microorganism behind the most common type of fermentation. *S. cerevisiae* cells are round to ovoid, 5–10 µm in diameter. It reproduces by a division process known as budding or forming spores called Blastospores.

- **Pezizales**

This order *consists* of a group of fungi whose fruit bodies are Disc shape or Apothecium, which are open from the beginning or closed from the beginning and then open later. The fruiting body is relatively large, sometimes up to 10-15 cm in size, bright colours and is a large genus of saprophytic cup fungi that grow on the ground, rotting wood, or dung. Most members of this genus are of unknown edibility and are difficult to identify as separate species without use of microscopy. The genus has been estimated to contain over 100 species.

- **Eurotiales**

This order consists of fungus characterized by the formation of closed fruit bodies Cleistothecium composed of pseudo histological tissue fungal and asexual reproduction by the formation of conidia, containing seven families, including the most important E*urotiaceae, which* *includes several species, most notably Aspergillus sp, Penicillium sp.*

*Example 1 : Penicillium sp. was known in 1809. Penicillium includes a list of 227 species worldwide, isolated from environments such as air, soil, food waste, fruits, vegetables, fodder, and enclosed environments. and have ability to attack food products, fruits and fodder because of their ability to grow in severe conditions, including growth in oxyg*en Low levels and high levels carbon dioxide, even at low temperatures.

***Penicillium digitatum* (Green Mold)** is an important and common species that causes green fruit rot. The most common post-harvest diseases, causes major economic losses, usually affecting most types of fruits, especially citrus.

***Penicillium expansum* (Blue Mold)** is one of the most important causes of blue rot of post-harvest fruits and causes major economic losses annually. This type is known to cause the production of carcinogenic Mycotoxins. Patulin has been found in many samples of apple fruit Infected with this species.

Example 2: *Aspergillus sp*. Aspergillus is an opportunistic pathogenic fungus that cause of the aspergillosis disease, this genus has about 200 species that grow in different environments. This fungus is common and all species of *Aspergillus* generally produce spores Conidia, which is best germinated at a temperature close to 35 ° C, has some species of *Aspergillus* that High ability to resist Inappropriate environmental conditions through the production of sexual phases or stone objects. *Aspergillus niger* is one of the most important fungal species which is characterized by spores of black color and is called black mold (Black Mold). Aspergillus flavus is a widespread fungal species in tropical and subtropical regions that causes damage to poorly stored crops. *A. flavus* produces aflatoxins, the most Mycotoxins dangerous, either lethal or carcinogenic to the liver.

- **Hypocreales**

This order includes three families-

1- Hypocreaceae: the type of body fruit is Perithecium inside *Ascostroma, Cordyceps capitata* is the most important species of this family.

2- Nectriaceae: the type of body fruit is Perithecium and without Ascostroma. *Necteria sp.* is one of the most important members of this family, which contains 27 genera which causes cancer disease of shade plants.

3- Hypomycetaceae: the type of body fruit is Perithecium inside Ascostroma , *Hypomyce sp.* is the most important species of this family.

- **Erysiphales**

Family: Erysiphaceae Is divided into species according to appendage type and the number of ascus on the surface of the fruiting body, members causes Powdery mildew diseases included (**Figure 4.5)**

1. More than one asci and appendage like the Mycelium. e.g.: *Erysiphae sp.*

2. One asci and appendage like the Mycelium. e.g.: *Sphaerotheca sp.*

3. More than asci and appendage Branch e.g. : *Microsphera sp.*

4. One asci and appendage Branch e.g. : *Podosphaera sp.*

5. Appendage that globular base e.g. : *Phyllactinia sp.*

6. Appendage shape is Hockey e.g. : *Uncinula sp*

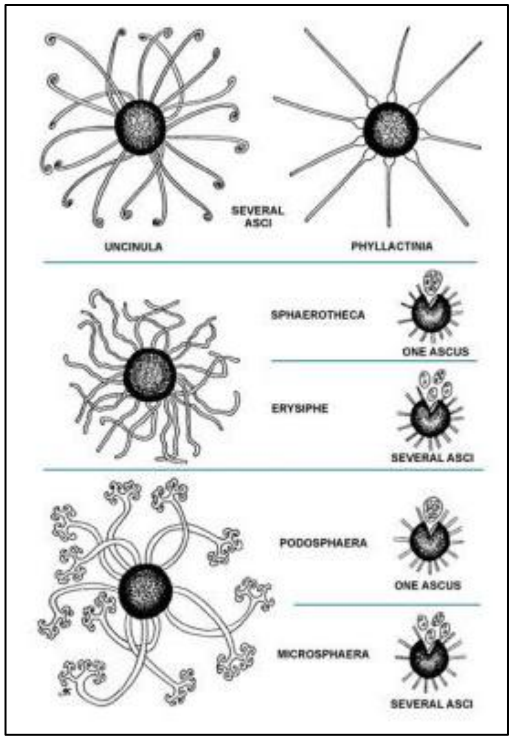

Figure 4.5

- **Helotiales**

The fruiting body is Disc shape or Apothecium above the soil. It has Inoperculate ascus. Ascospore is cup shaped. The most members of this order living saprophytic on wood plant. **Family: Sclerotinaceae** includes *Monilina sp*. cause Brown rot on trees have stony endocarp. *Sclerotina sp*. cause White rot on herbaceous, flowers and vegetables.

- **Pleosporales**

The fruiting body is Perithecium and it is called Pleosporatype. Sterile threads like Pseudoparaphysis. The most important family pleosporaceae include:

Sporomia sp. living on Dung animals herbivorous.

Pleospora sp. It is a plant pathogen infecting several hosts including alfalfa, apples, tomatoes, citruses and chickpea. It has a cosmopolitan distribution, and is common in temperate and subtropical regions.

Family: Venturiaceae e.g., *Venturia inaequalis* causes the Apple scab disease which lead to deformation of fruits.

4.4 Economic importance

- The species Neurospora crassa has been the subject of intensive genetical research.
- Alcoholic fermentation by yeasts as the basis of the wine and brewing industries
- Antibacterial antibiotics such as **penicillin** from *Penicillium chrysogenum* and *cephalosporin* from *Acremonium* spp.
- Food production as in breadmaking by **yeast**, cheese ripening by *Penicillium roqueforti* and *P. camemberti*
- Food spoilage may result from ascomycete contamination. e.g., *Claviceps purpurea*.

SAQ.2

a. Yeast reproduce by budding or forming spores called______________.

b. Green fruit rot disease is caused by______________.

c. Aspergillus is an opportunistic pathogenic fungus that cause of the____________ disease.

d. ____________ produces aflatoxins, the most dangerous, either lethal or carcinogenic to the liver.

4.6 Summary

- The spore formed by these fungi is known as **ascospores** which are sexually produced and are present within a sac
- Taphrinales order includes a variety of fungus, all parasitic fungi on vascular plants, causing an increase in the growth of infected tissues.
- *Saccharomyces cerevisiae* is yeast, the microorganism behind the most common type of fermentation.
- Pezizales order consists of a group of fungi whose fruit bodies are Disc shape or Apothecium, which are open from the beginning or closed from the beginning and then open later.
- Eurotialesorder consists of fungus characterized by the formation of closed fruit bodies Cleistothecium composed of pseudo histological tissue fungal and asexual reproduction by the formation of conidia.
- *Penicillium digitatum* (Green Mold) is an important and common species that causes green fruit rot. The most common post-harvest diseases, causes major Economic losses, usually affecting most types of fruits, especially citrus.
- *Penicillium expansum* (Blue Mold) is one of the most important causes of blue rot of post-harvest fruits and causes major economic losses annually. This type is known to cause the production of carcinogenic Mycotoxins.
- The most members of Helotiales order living saprophytic on wood plant.
- *Pleospora sp.* is a plant pathogen infecting several hosts including alfalfa, apples, tomatoes, citruses and chickpea. It has a cosmopolitan distribution, and is common in temperate and subtropical regions.
- The species Neurospora crassa has been the subject of intensive genetical research.

4.7 Terminal question

Q.1 Write the salient feature of Ascomycotina.

Answer:--

-------------------------------- --

Q.2 Discuss the classification of Ascomycotina.

Answer:--

------------------------------ ---

Q.3 Describe the characters of Pezizales order.

Answer:---

------------------------------ ---

Q.4 Discuss the Erysiphales order with respect to number of asci and appendages.

Answer:---

------------------------------ ---

Q.5 Explain the characteristics features of Erysiphales order.

Answer:---

Short Questions

Q.6 Write short notes on:

1. Ascogenous hyphae
2. Role of *Penicillium* in medicinal field
3. Role of *Aspergillus*
4. Aflatoxins

Q.7 **Multiple choice questions:**

1. Apergillosis disease caused by-

   (a) *Aspergillus*

   (b) *Penicillium*

   (c) *Saccharomyces*

   (d) *Peziza*

2. More than one asci and appendages like the mycelium found in-

   (a) *Erysiphae sp.*

   (b) *Sphaerotheca sp.*

   (c) *Uncinula sp.*

   (d) *Microsphera sp.*

3. *Apergillus nigur* is-

   (a) Black mold

   (b) Green mold

(c) Blue mold

(d) None of the above

4.8 Answers

1. (a) 2. (a) 3. (a)

Self-assessment questions

SAQ.1

a. Ascospore **b.** Branched **c.** Mycelium **d.** *Taphrina deformans*

SAQ.2

a. Blastopores **b.** *Penicillium digitatum* **c.** Aspergillosis **d.** *A. flavus*

Unit 5

Basidiomycotina and Deuteromycotina

Structure

5.1 Introduction

- **G.C. Ainsworth's system** of classification includes Basidomycotina which is a subdivision under **Eumycota**
- This is also known as **Club Fungi**
- This is also nonmotile fungi.
- These group of fungi are known to be true fungi.
- Major edible fungi belong to this Phylum
- It is a large group of fungi having around 30000 species.
- They include mushrooms and toadstools, bracket fungi, puffballs, earth stars, stinkhorns, false truffles, jelly fungi, earth balls and some less familiar forms **(Figure 5.1).**

Figure 5.1

Objectives

- To study the General characteristics of Basidiomycotina
- To explain the classification of Basidiomycotina
- To discuss the economic importance of Basidiomycotina
- To study the General characteristics of Deuteromycotina
- To explain the classification of Deuteromycotina
- To discuss the economic importance of Deuteromycotina

5.2 General characteristics of Basidiomycotina

- These have septate and multinucleate mycelium while some are yeast-like and others are dimorphic
- They are known as club fungi due to the presence of club-shaped basidium.
- Fruiting bodies are called basidiocarps.
- These are found in the tip of the stalks called sterigmata.
- Cell wall made up of chitin.
- They have well developed filamentous mycelium.
- Adjacent cells are separated by **dolipore septa.**
- The transverse septa which divide both monokaryotic and dikaryotic hyphae into segments contain a central pore which allows cytoplasmic continuity between adjacent segments. The septal pore is surrounded by a barrel-shaped flange of thickened wall material called dolipore septa which are a characteristic feature of Basidiomycotina.
- They are found in terrestrial regions but some grow in freshwater or marine habitats.
- They may be saprotrophic and are involved in litter and wood decay.
- The fruit bodies of many mushrooms are edible e.g. Agaricus bisporus, Pleurotus spp, Lentinula edodes.
- They possess both sexual and asexual reproduction.
- Basidiomycota are known to be related to Ascomycota.

5.2.1. Reproduction

It undergoes vegetative, asexual and sexual reproduction.

Vegetative

1. **Fragmentation**
2. **Budding**

Asexual

1. **Conidia formation**– It may develop on monokaryotic or dikaryotic mycelia. In rusts, smuts, etc
2. **Oidia-** It may develop on monokaryotic and dikaryotic mycelia
3. **Chlamydospores-** They are formed terminally on aerial branched conidiophores which

develop from a mycelium lacking clamp connections.

Sexual

- It also involves plasmogamy, karyogamy and meiosis.
- Plasmodium forms the dikaryotic mycelium
- Karyogamy and meiosis leads to the formation of basidiospores

Basidiospores

- These are small, haploid, thin walled and uninucleate cells produced exogenously on the basidium.
- The number of basidiospores produced by a single basidiocarp can be extremely high.
- They are transported by the wind current, insect or rain etc. and later start germinating.
- These are considered sexual spores as they combine the genetic material from both the strains.

5.2.2. Life cycle

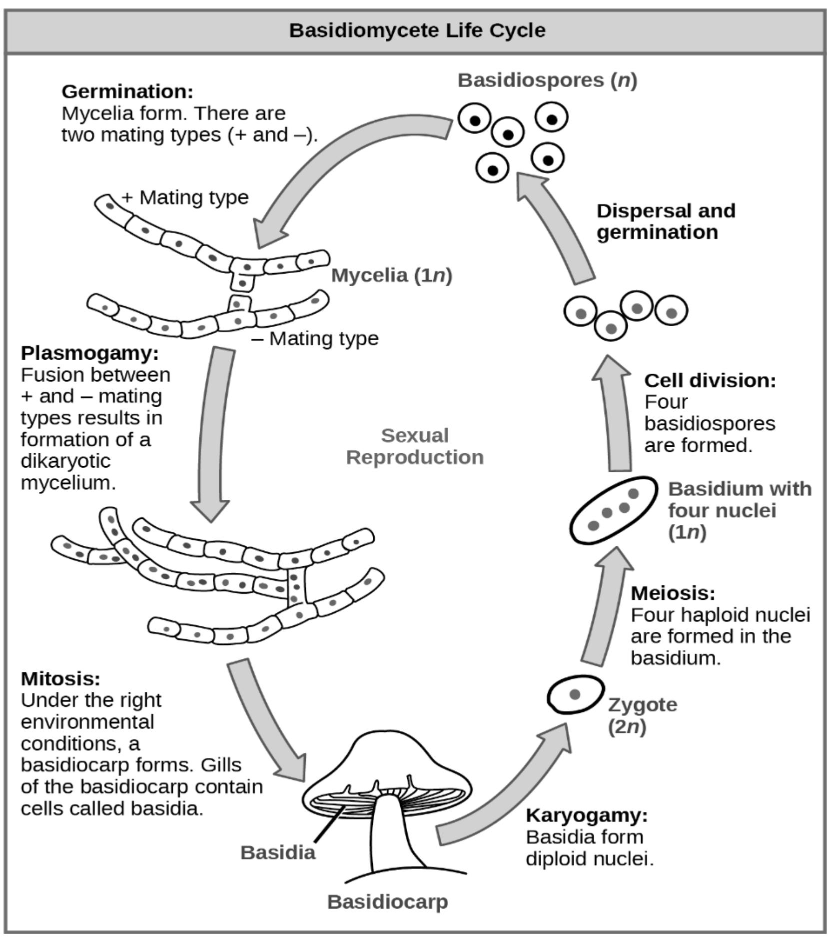

Figure 5.2: Lifecycle of a basidomycotina

- It includes alternation of generations
- It takes place in the fruiting body in basidia

- The basidia are formed by plasmogamy
- Many of these fungi in this group have a dimorphic life cycle.
- The life cycle continues in 3 phases

1. **Plasmogamy-** The haploid donor cell nucleus penetrates cytoplasm of the recipient cell
2. **Karyogamy-** Two strains of nuclei fuse together
3. **Meiosis-** The diploid nucleus produces haploid nuclei

5.3 Classification of Basidiomycotina

1. **Teliomycetes**
2. **Hymenomycetes**
3. **Gastromycetes**

Orders

- **Agaricales**

It is Called as Gill Fungi. This order includes about 7,000 species distributed in about 200 genera. Members live in the soil rich in organic matter and the remains of dead trees, many of which enter into the relationship of Takaful Mycorrhizae with trees. Includes Mushrooms(Edible) and Toadstool (poisonous). Sporophores have Stipe Solid and strong compared with other fungi. This order includes a groups of families:

Family: Agaricaceae e.g., Agaricus sp is a genus of mushrooms containing both edible and poisonous species, with possibly over 300 members worldwide.

Family: Amanitaceae e.g., Amanita sp. the most important genus of mushrooms. It is believed to contain a poisonous substance called Muscarine. and Its one Basidiocarp is poisonous enough to kill 12 or more people.

Family: Boletaceae . e.g.: Boletus sp. The genus Boletus contains many members which are edible and tasty such as *Boletus edulis* and *B. aereus*.

- **Lycoperdales**

Thisorder of (typically) terrestrial fungi in which the mature fruit body occurs above ground although its development may begin below ground. The fruit body is typically more or less spherical. The spores are contained within a peridium which is usually composed of at least 2 layers: the exoperidium and endoperidium. There are many genera. The order includes the puffballs and earth stars.

- **Nidulariales**

The Nidulariales are commonly known as ‘bird’s nest fungi’, also known as fungi with ‘Worchestershire Corn bell’ or ‘fairy purse’. They are socalled because in them the basidiocarp is cup shaped and contains several tiny lenticular bodies resembling a bird’s nest with eggs. These lenticular bodies are the peridioles which are formed by the breaking of gleba.

The cup is the peridium. In this order the large basidiocarps are external, not subterranean. The Nidulariales comprise two families: Nidulariaceae and Sphaerobolaceae. In the family Nidulariaceae several peridioles are formed in each cup-shaped basidiocarp. Whereas, in the Sphaerobolaceae the number of peridioles has been reduced to one. Here the entire gleba is transformed into a single peridiole.

Family Nidulariaceae: The members of this family are characterized by the presence of several peridioles. The epigeous basidiocarps arising from mycelial strands become differentiated into a cupshaped peridium and numerous peridioles borne inside the cup.

Each peridiole is a segment of the gleba. It becomes separated from other peridioles by hyphal gelatinization but remains attached to the inner surface of the peridium by a long stalk known as funiculus. The lenticular body of the peridiole has a thick walltunica which encloses basidia with basidiospores and mass of coiled and twisted hyphae.

The number of basidiospores may be four or more and may or may not be borne on sterigmata. The peridioles are completely enclosed by the peridium and a thin membranous layer, the epiphragm which at maturity breaks exposing the peridioles. The peridioles are disseminated by splashing of raindrops. Brodie (1948-1951) working on a number of species of the Nidulariaceae show all species that worked out, were tetrapolar. The principal genera are: Nidula, Nidularia, Cyathus, and Crucibulum.

Cyathus is similar to Crucibulum in many respects. But the basidiocarps of Cyathus are larger in height than those of Crucibulum. The peridium is differentiated into three layers in Cyathus, but in Crucibulum is two-layered. The peridioles of Cyathus are dark grey to black. Whereas, in Crucibulum the peridioles are white. Both these two genera have basidiocarps with epiphragm and each peridiole is attached to the peridium by a funiculus. In *Nidula epiphragm* the peridiole is not provided with a funiculus. Whereas, in *Nidularia* both epiphragm and funiculus are lacking.

- **Phallales**

The Phallales are commonly called stinkhorns because of the strong foetid odour of decaying meat they possess in their exposed glebal tissue. These are some of the most beautiful fungi. They grow where there is ample organic matter such as humus, rotted tree stumps, or decaying sawdust and often in damp soil of bamboo grooves. The young basidiocarps arise as terminal swellings of rhizomorphs.

They are spherical to ovoid masses known as eggs surrounded by a firm, somewhat leathery peridium. At first the young basidiocarps are completely or partially subterranean. They contain the fertile tissue or gleba and a specialized structure known as receptacle or receptaculum with maturity of the basidiocarp, the receptaculum elongates.

The pressure caused by the elongation of the receptacle finally ruptures the peridium elevating the gleba above ground. The gleba at maturity deliquesces to a slimy evil smelling mass with spores borne on a specialized receptacle. The receptacle may be a long, spongy pileate stipe, or a wide meshed lattice-like structure with or without a stipe.

The evil-smelling slimy gleba filled with spores attracts flies which serve to carry the spores far and wide. Two families are recognized: Phallaceae and Clathraceae. They are distinguished on the nature of receptacle.

Family Phallaceae: The members of the Phallaceae are distinguished by a stout, hollow stipe. At the top of the stipe is the pileus with viscid mass of spores. The pileus may or may not be adherent to the stipe. The stipe may also develop from below the pileus, a white skirt-like net work known as indusium.

The Phallaceae include 10 genera, of which *Phallus, Mutinus* and *Dictyophora* are best known. In Phallus, the stipe elongates rupturing through the peridium.

The apex of the stipe is covered with bell shaped pileus bearing gleba. Mutinus is very similar in structure to Phallus, but the basidiocarp is smaller, and the pileus is adherent to the stipe. Whereas, Dictyophora has in addition to stipe and pileus, a beautiful skirt-like indusium originating between the pileus and the stipe and encircling the stipe. Both *Phallus* and *Dictyophora* have a bell-shaped pileus free from the stipe except at the top.

- **Phyllophorales**

It called pores Fungal to the presence of pores, and the absence of lamella and most of the fungus belonging to this order are the Basidiocarp large size, the form of colonies or coral form of dishes or shelves, mostly fungal parasites or rather an analyst as they attack the trees alive or dead and analyzed and therefore Reduce their economic value. This order includes several families. The most important family-

Family: polyporaceae E.g., Polypores sp. this genus known from Japan to grow on the ground on the living or dead roots.

- **Tremellales**

It is known as the Jelly fungi because the Basidiocarps is often Gelatin take yellow color, Basidium type Phragmo basidium divided into longitudinal to four cells of each cell carrying a Basidospores on one Strigma , This order includes one family :

Family: Tremellaceae e.g., *Tremella sp* . All *Tremella* species are parasites of other fungi and most produce anamorphic yeast states. Basidiocarps (fruit bodies), when produced, are gelatinous. Over 100 species of *Tremella* are currently recognized worldwide. Two species, *Tremella fuciformis* and *Tremella aurantialba,* are commercially cultivated for food.

- **Auricularales**

Basidium type Phragmobasidium divided into longitudinal to four cells of each cell carrying a Basidospores on one Strigma. This order includes one family:

Family: Auriculaceae e.g., *Auricularia* sp. called (Ear Jelly fungi) because of shape. Basidiocarps is being ear-to shell shaped or forming narrow, imbricate brackets, Most Auricularia sp. are edible.

- **Uredinales**

It is called Rust fungus an estimated 168 rust genus and approximately 7000 species, more than half of which belong to the genus *Puccinia*, Rust fungi are highly specialized parasites, the infection is limited to plant parts such as leaves, petioles, tender shoots, stem, fruits may cause deformities such as growth retardation, witch's broom, stem canker, hypertrophy of the affected tissues or formation of galls. Include many families:

Family Pucciniaceae E.g., *Puccinia graminis* causing black stem rust in wheat Life cycle The members of this group pass either a long or short cycle:

1- Microcyclic life cycle: in this life cycle the Teliospores is the only spore.

2- Macro cyclic life cycle: in this life cycle there is more than one single spore.

- **Ustilaginales**

It is called Smut Fungi includes 1100 Different species all are obligate parasitism and these are the most common types of Basidiomycota Primitive fungus. This order includes several families:

Family: Ustilaginaceae*Ustilago sp.* smut fungi parasitic on grasses

Family: Tilletiaceae*Tilletia sp.* Species in this genus are plant pathogens that affect various grasses. *Tilletia indica,* which causes smut wheat, and *Tilletia horrida*, responsible for rice smut.

5.4 Economic importance of Basidiomycotina

- Most edible fungi fall in this group
- Many of these fungi are also pathogenic in nature
- *Sporobolomyces roseus basidiospores* is a cause for respiratory allergens which is found on moribund leaf surfaces.
- Another is *Cryptococcus neoformans*, which grows commonly on old "weathered" bird droppings, and which can cause a fatal systemic infection of immunocompromised people. Its air-borne basidiospores initiate infection via the lungs, leading to the disease termed cryptococcosis.

SAQ.1

a. The peridium is differentiated into__________layers in Cyathus, but in Crucibulum it is____________layered.

b. Both_____________and______________have a bell-shaped pileus free from the stipe except at the top.

c. *Tilletia horrida*, responsible for__________smut.

d. In micro life cycle the_____________is the only spore.

5.5 Deuteromycotina

- **G.C. Ainsworth's system** of classification includes Deuteromycotina which a subdivision under Eumycota.
- It is also known as **Fungi Imperfecti** as it lacks a perfect or a sexual stage and also **asexual fungi, anamorphic fungi, and conidial fungi.**
- It has around 17 000 species.
- These are non-motile structures.

Figure 5.3 Fungi imperfecti

5.6 General Characteristics of Deuteromycotina

- It is a polyphyletic group where many species are closely related to organisms in other phyla like in Ascomycotina and Basidiomycota and hence it is not a true phylum.
- They might be terrestrial or aquatic.

- In a fungus that has both an ascus (or basidium) stage and a conidial one, the former is known as the 'perfect' and the latter as the 'imperfect' state. This is why these fungi are commonly called **Fungi Imperfecti.**
- Also, it may happen that the fungi might have more than one imperfect stage.
- Members of these classes might have septate mycelium.
- The mycelium might be inter or intracellular having many nuclei
- Hyphae might be a heterokaryotic type.
- The reproduction mostly occurs by conidia, however, a few are purely mycelial, developing no spores.
- Sexual reproduction is absent in these members.

5.6.1. Reproduction

Reproduction might be vegetative or asexual.

- ***Vegetative***

It might occur by budding.

- ***Asexual***

1. **Conidiospores-** Reproduction majorly takes place by spores (conidia) which is produced mitotically (asexually) or by hyphae (conidiophores).

- ***Sexual***

Sexual reproduction is entirely absent in the life cycle of fungus, so its life cycle is incomplete in nature.

5.6.2. Life cycle (Figure 5.4)

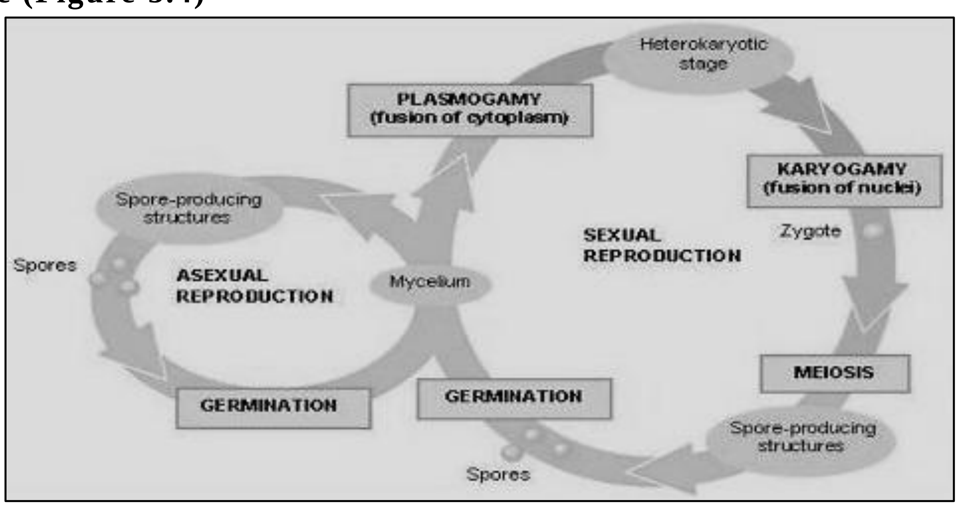

Figure 5.4

5.7 Classification of Deuteromycotina

It is divided into 3 classes.

1. **Blastomycetes-** It majorly forms single yeast-like cells from budding.
2. **Hyphomycetes-** This group contains the fungal species which have the potential as microbial insecticides. This has naked conidia **(Figure 5.5)**.

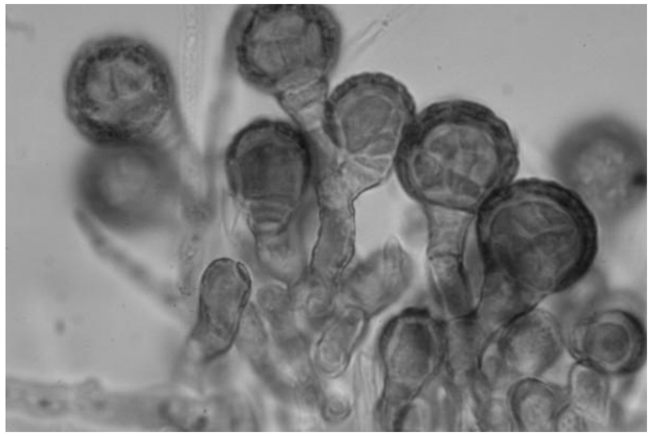

Figure 5.5

- Hyphomycetes are asexual reproductive structures produced directly on their substrate without any kind of enclosing tissues. For example, *Epicoccum nigrum*, the fungus in the picture at left, grows directly on the surface of dead leaves and grass stems where it is exposed to the environment and can have its conidia (spores) carried away by air currents. Because of this its conidia are abundant in the air and are commonly found by people investigating airborne fungi. Mycologists working with fungal cultures in Petri dishes commonly get *E. nigrum* as an uninvited guest.

- The most common function of hyphomycetes is reproduction and dispersal, although in some species the conidia may act as gametes or "spermatia" that can fertilize an incipient dikaryon. If this is so they are not likely to germinate and produce hyphae as happens in the great majority of hyphomycetes.

- Hyphomycetes come in a staggering variety of forms. This immense diversity reflects the role these forms play in the dispersal of the fungus producing them. Each species grows in a particular habitat. When the nutrients in this habitat are exhausted the fungus must ensure that its offspring find their way to a similar source of nutrition. Getting their conidia to this new place, often a very small target, requires precise dispersal mechanisms.

- **Air dispersal (Figure 5.6)**

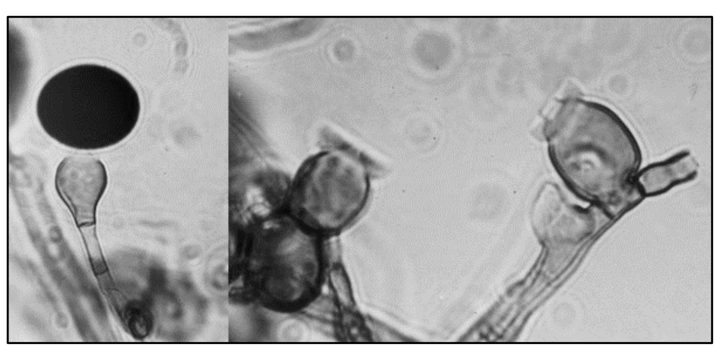

Figure 5.6

- *Epicoccum nigrum* and *Nigrospora sphaerica*, are examples of fungi that actually propel their conidia into the air using mechanisms that force the conidium away from its subtending cell. This mechanism is especially clear in *N. sphaerica*, the fungus pictured at right. In the left panel of the picture the large black conidium is still attached to its cell awaiting lift-off. In the right panel there are two cells that have already discharged their conidia; here we can clearly see the tube that directed water pressure up against the bottom of the conidium, shooting it away. We can also see the thin collar that originally held the conidium in place **(Figure 5.7)**.

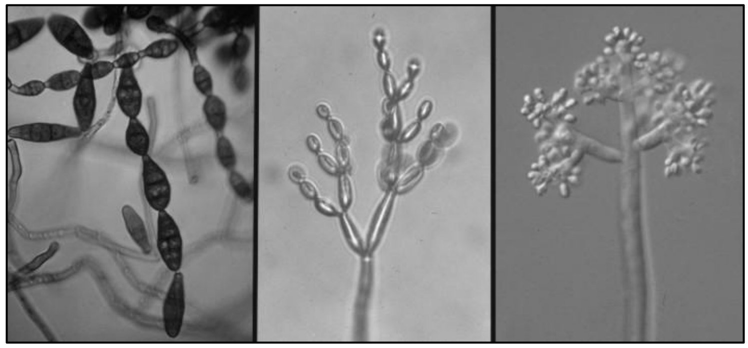

Figure 5.7

- Most air-dispersed hyphomycetes do not have forcibly discharged conidia. Instead they have very loosely attached conidia that can be disloged by the slightest air current. Fungi of this type often have long hyphae that extend the conidia well away from the substrate, thus escaping the dead air (boundry layer) that surrounds them. At left are three species that occur commonly in samples of airbore fungi. These are, left to right, *Alternaria, alternata, Cladosporium cladosporioides* and *Botrytis cinerea*. These three species are unrelated to one another yet often share the same habitats and have similar modes of dispersal.
- **Water dispersal (Figure 5.8)**

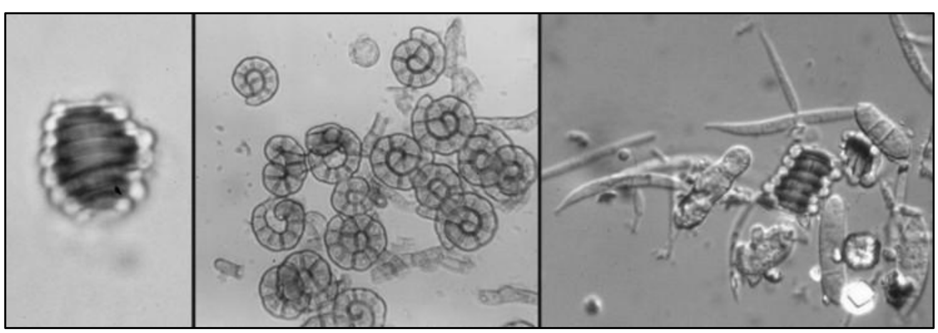

Figure 5.8

- Many hyphomycetes are dispersed by water rather than air. Some of these species actually live out their lives in water while others only use water as a means of dispersing their conidia. The three photos above illustrate species using freshwater for their dispersal. At left is a species of *Helicodendron,* characterized by conidia forming a tight barrel-shaped helix. Such hyphomycetes are often called "aeroaquatic hyphomycetes" referring to the fact that the conidia, although dispersed by water, are able to trap air and float along on the surface. Such fungi often grow in habitats that are periodically flooded but are usually dry. When water levels rise the conidia are able to float away. The species of *Helicoma* in the middle panel also produces coiled conidia but these are spiral, not helical, and are thus produced in only two dimensions. These conidia are not as likely to trap air but will become attached to bubbles of foam. Spiral conidia often straighten out when they get wet, although that is probably not what happens with this species of *Helicoma*.

- Conidia of aquatic hyphomycetes are easy to collect and observe under the microscope. They often collect and concentrate in the foam of running streams. To observe them, just collect the foam in a zippered plastic bag and bring them back for examination. The foam may gradually convert back to a liquid in the bag, but the spores will remain in abundance. Another way to observe these fungi, especially the aeroaquatic species, is to take a sample of forest litter that we suspect of being periodically wet and shake it up in a container of water. Then collect the very top layer of water with its floating debris and examine it under a microscope. Conidia will be abundant. The third panel in the photo above shows a sample taken from forest litter. An aeroaquatic *Helicodendron* species is clearly visible at the centre along with some other spores and unidentifiable debris. Also visible at upper middle is a narrow spore oriented horizontally and having a nearly vertical "arm", resembling a narrow canoe with a mast. This is a conidium of a *Tricladium* species, a good example of what are called "In goldian fungi", named in honour of Dr. C.T. In gold, a pioneer in the study of aquatic fungi. Ingoldian fungi have conidia that are narrow, straight or loosely helical and often have radiating arms like the one in the picture **(Figure 5.9).**

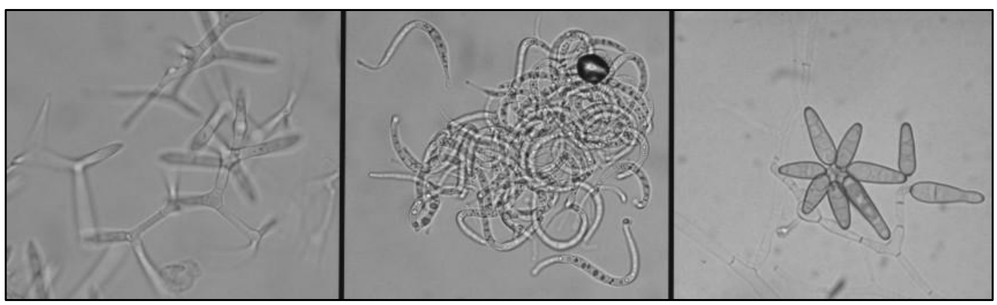

Figure 5.9

- Aquatic hyphomycetes are also found in marine waters and can be observed in sea foam in much the same way they can in freshwater foam. The picture above illustrates three common marine species. At left is *Varicosporina ramulosa*, a species common on decaying seaweed and other debris in warmer climates. It does not occur in our cold New Brunswick waters but can be found a day's drive away on the south shore of Cape Cod, particularly in the summer. It is in every way a typical Ingoldian fungus. The middle panel shows a species that occurs commonly in New Brunswick. This is *Sigmoidea marina*, another Ingoldian fungus because of its lazily helical conidia. In the right panel is *Asteromyces cruciatus*, a species commonly encountered on decomposing seaweed in temperate climates but not yet found in New Brunswick. At first glance *A. cruciatus* would not appear to be a species having aquatic dispersal. However, the dark conidia remain connected in star-shaped masses that function as typical Ingoldian fungi.

  - **Dispersal by insects and other small animals**

  Insects, mites and other small invertebrate animals live among fungi and share many common difficulties. Such organisms, including fungi, have fairly precise nutritional and environmental requirements and may be separated from acceptable habitats by considerable distances. Reaching a precise habitat, especially one that is not large, may require more than just casting some spores to the wind. Insects, of course, can fly well and have eyes and sensitive chemical detectors to aid them get where they need to go. Fungi, lacking such abilities often solve the problem by hitching a ride on an insect. This solution to a difficult problem of dispersal is so successful that nearly all groups of fungi have made use of it. The hyphomycetes are among the most adept **Figure 5.10)**.

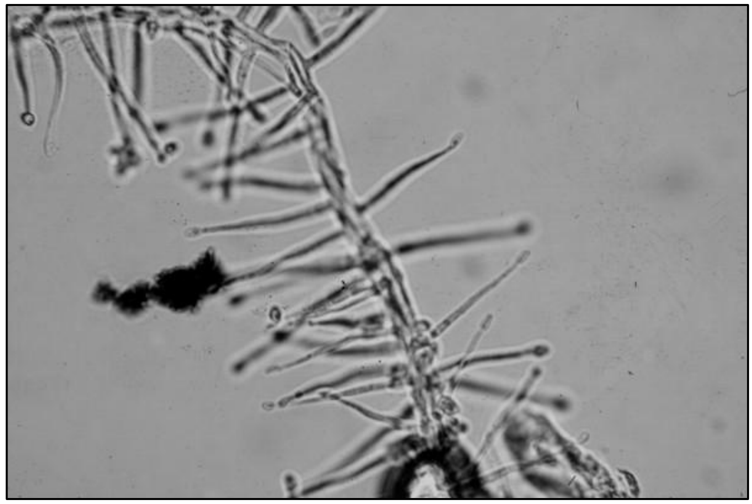

Figure 5.10

- The hyphomycete shown at right may be an excellent exploiter of insects for its dispersal. This fungus, a species of *Acremonium* produces its conidia at the tips of the small "spines" along the hyphal strand. The cells, called phialides, produce a continuous succession of conidia at their ends, and these conidia collect there in glistening drops of liquid, unfortunately not seen here because they flowed away when the microscope slide was prepared. Air currents do not dislodge the conidia nor are they likely to come in contact with water. Instead they stick to the bodies of insects and mites that are moving about in their habitat. The conidia are sticky because of the liquid they are borne in. Eventually the animal will move on to a new habitat and the fungus with be rubbed off and begin to grow there. Since many fungi live in enclosed places with few air currents to move them it is not surprising that many have taken the insect route.

  - **Organization of hyphomycetes (Figure 5.11)**

Figure 5.11

The photo above presents two hyphomycetes growing on a log, *Haplotrichum conspersum* at left and *Bactridium* sp. at right. Note how different they are in their growth habit: *H. conspersum* forms an almost continuous carpet on the log, irregular in places but nevertheless all one surface of conidia. On the other hand, the *Bactridium* species has produced its conidia in discrete little cushions, well separated from one another. Species of *Bactridium* are said to produce their conidia in **sporodochia**, a term denoting a dense cluster of conidium-bearing hyphae or conidiophores. The conidiophores in *Haplotrichum* are said to be solitary because they do not form distinct clusters **(Figure 5.12)**.

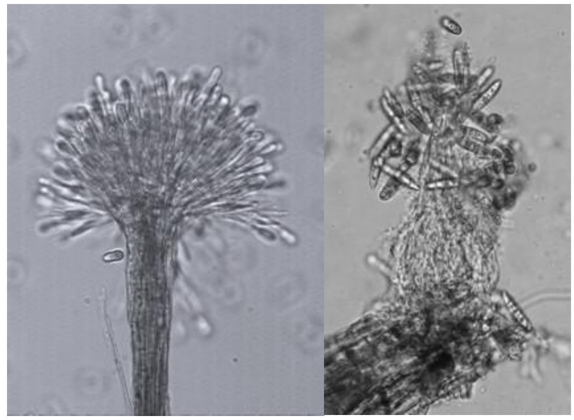

Figure 5.12

- In the two photos at left we see yet another variation. Here the conidiophores have united to form an elongated compound structure called a **synnema** (plural, synnemata). Synnemata are often associated with dispersal by insects. *Pesotum ulmi*, a synnematous form associated with the infamous Dutch elm disease, is well-known to transfer its spores to bark beetles, the vectors of the disease. The two photos represent the *Graphium* state of *Pseudallescheria boydii* at left and at right *Arthrosporium albicans*, an inhabitant of dead birch branches still covered by loose bark. Both occur in habitats frequented by insects and mites but not exposed to air currents. In *Graphium* species the conidia are borne in a droplet of liquid at the top of large dark synnemata. In *A. albicans* the conidia are borne on the upper part of the synnema but also occur along the sides.

3. **Coelomycetes-** The fruiting structures might be spherical with an apical opening or saucer-shaped. The production of conidia takes place within the fruiting body.

- Coelomycetes are asexual Dikarya that produce their conidia inside some kind of enclosing structure. If this structure completely surrounds the conidia it is called a **pycnidium**; if the conidia are borne in a more open structure with a wall only around the lower part, it is an **acervulus**. The large round structure in the picture at right is a pycnidium of the fungus *Sphaerellopsis filum*. This fungus is a parasite of rust fungi and occurs within their spore-bearing structures. In the picture you can see the urediniospores of the rust as numerous oval bodies surrounding the pycnidium of the *Sphaerellopsis*. The pycnidium here is very light coloured where it is sunken in the host tissues but dark on top. This is a common phenomenon among pycnidial fungi. Most pycnidia release their spores in a wet mass that is extruded out through the apical pore (ostiole). These often collect in large amounts and are either transported away by insects or will flow along with rain water **(Figure 5.13)**.

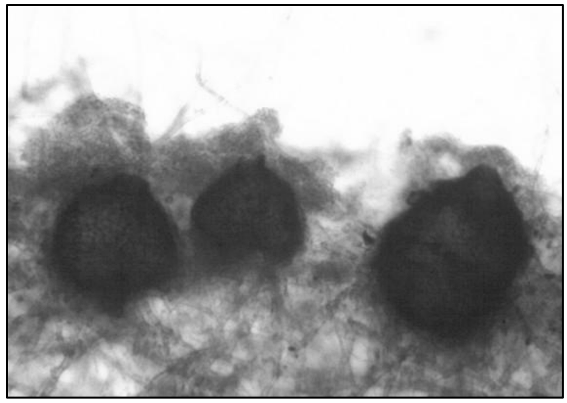

Figure 5.13

- Growing as a parasite on rust fungi is a rather unusual place to find a coelomycete. More commonly these fungi grow on living and dead plants. Some can become a nuisance to humans when they grow where they are not wanted. The specimen of *Phoma herbarum* pictured at left was orginally found embedded and growing in silicone sealant used to waterproof a meat-packing establishment near Toronto. All of the sealant had to be removed and replaced. Species of *Phoma* regularly turn up on materials in indoor environments and may be responsible for some of the dark brown to black mould growth seen on painted surfaces subject to moisture, such trim around showers and bathtubs and on window frames and sills **(Figure 5.14)**.

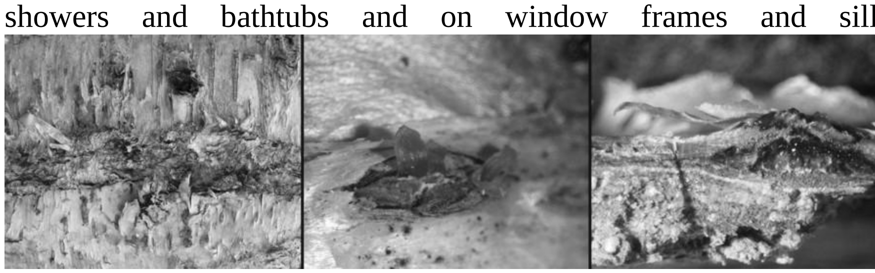

Figure 5.14

- The pycnidia considered so far have been simple flask-shaped structures with a single internal cavity. However, some pycnidia and acervuli can be highly complex and be composed of several cavities. The picture above is an example of one of these. This fungus, *Libertella betulina* commonly occurs on recently-killed birch logs. The first signs that it is there will be the small orange tendrils arising through small breaks in the bark, as figured in the left panel. A closer examination (centre panel) reveals that these tendrils have oozed out like toothpaste from its tube. In the right panel the structures have been cut in half with a razor blade to reveal what is below the bark. Here we can see that there are several chambers each producing orange conidia in massive numbers. These are then extruded out through one or more ostioles **(Figure 5.15)**.

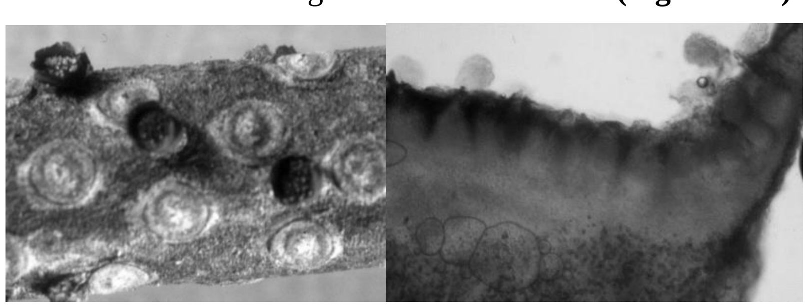

Figure 5.15

- *Bothrodiscus berenice*, the species figured above, produces yet another sort of compound structure. Here the pycnidia are embedded together inside small goblet-shaped structures on the surface of balsam fir twigs. The picture at far left shows three of these "goblets" while the one to the right presents a cross section through the goblet to reveal the layer of pycnidia on its surface.

5.3 Economic importance of Deuteromycotina

- The food industry like the cheese industries uses these members for ripening purposes.
- The blue veins in Roquefort cheese and the white crust on Camembert are the results of fungal growth.
- It has also contributed to the discovery of the antibiotic penicillin.
- These are a cause of a few diseases in both plants and humans and are also known to be the producers of potentially toxic compounds, like aflatoxins released by fungi *Aspergillus*.

SAQ.2

a. _______________and_________________, are examples of fungi that actually propel their conidia into the air using mechanisms that force the conidium away from its subtending cell.

b. In________________, the fruiting structures might be spherical with an apical opening or saucer-shaped.

c. This fungus,__________________ commonly occurs on recently-killed birch logs.

d. The potentially toxic compound aflatoxins released by fungi____________.

5.4 Summary

- **G.C. Ainsworth's system** of classification includes Basidomycotina which is a subdivision under **Eumycota**
- The transverse septa which divide both monokaryotic and dikaryotic hyphae into segments contain a central pore which allows cytoplasmic continuity between adjacent segments. The septal pore is surrounded by a barrel-shaped flange of thickened wall material called dolipore septa which are a characteristic feature of Basidiomycotina.
- It undergoes vegetative, asexual and sexual reproduction.
- Vegetative reproduction-Fragmentation, Budding
- Asexual reproduction -Conidia formation, Oidia, Clamydospores
- Sexual reproduction -involves plasmogamy, karyogamy and meiosis.
- Basidiospores are small, haploid, thin-walled and uninucleate cells produced exogenously on the basidium. The number of basidiospores produced by a single basidiocarp can be extremely high. They are transported by the wind current, insect or rain etc. and later start germinating. These are considered sexual spores as they combine the genetic material from both the strains.
- Life cycle includes alternation of generations. It takes place in the fruiting body in basidia. The basidia are formed by plasmogamy. Many of these fungi in this group have a dimorphic life cycle.
- Agaricales is Called as Gill Fungi. This order includes about 7,000 species distributed in

about 200 genera. Members live in the soil rich in organic matter and the remains of dead trees, many of which enter into the relationship of Takaful Mycorrhizae with trees.

- Lycoperdales order of (typically) terrestrial fungi in which the mature fruit body occurs above ground although its development may begin below ground. The fruit body is typically more or less spherical.
- The Nidulariales are commonly known as ‘bird’s nest fungi’, also known as fungi with ‘Worchestershire Corn bell’ or ‘fairy purse’. They are so-called because in them the basidiocarp is cup-shaped and contains several tiny lenticular bodies resembling a bird’s nest with eggs.
- The Phallales are commonly called stinkhorns because of the strong foetid odour of decaying meat they possess in their exposed glebal tissue. These are some of the most beautiful fungi.
- Phyllophorales called pores Fungal to the presence of pores, and the absence of lamella and most of the fungus belonging to this order are the Basidiocarp large size, the form of colonies or coral form of dishes or shelves, mostly fungal parasites or rather an analyst as they attack the trees alive or dead and analyzed and therefore Reduce their economic value.
- Tremellales is known as the Jelly fungi because the Basidiocarps is often Gelatin take yellow color, Basidium type Phragmo basidium divided into longitudinal to four cells of each cell carrying a Basidospores on one Strigma.
- In Auricularales Basidium type Phragmobasidium divided into longitudinal to four cells of each cell carrying a Basidospores on one Strigma.
- Rust fungi are highly specialized parasites, the infection is limited to plant parts such as leaves, petioles, tender shoots, stem, fruits may cause deformities such as growth retardation, witch's broom, stem canker, hypertrophy of the affected tissues or formation of galls.
- **Ustilaginales** is called Smut Fungi includes 1100 Different species all are obligate parasitism and these are the most common types of Basidiomycota Primitive fungus.
- *Sporobolomyces roseus basidiospores* is a cause for respiratory allergens which is found on moribund leaf surfaces.
- **G.C. Ainsworth’s system** of classification includes Deuteromycotina which a subdivision under Eumycota. It is also known as **Fungi Imperfecti** as it lacks a perfect or a sexual stage and also **asexual fungi, anamorphic fungi, and conidial fungi.**
- Hyphomycetes are asexual reproductive structures produced directly on their substrate without any kind of enclosing tissues.
- The most common function of hyphomycetes is reproduction and dispersal, although in some species the conidia may act as gametes or "spermatia" that can fertilize an incipient dikaryon.
- Most air-dispersed hyphomycetes do not have forcibly discharged conidia. Instead they have very loosely attached conidia that can be disloged by the slightest air current.
- Hyphomycetes are often called "aeroaquatic hyphomycetes" referring to the fact that the conidia, although dispersed by water, are able to trap air and float along on the surface.
- Conidia of aquatic hyphomycetes are easy to collect and observe under the microscope. They often collect and concentrate in the foam of running streams.
- The hyphomycete shown at right may be an excellent exploiter of insects for its dispersal. This fungus, a species of *Acremonium* produces its conidia at the tips of the small "spines"

along the hyphal strand. The cells, called phialides, produce a continuous succession of conidia at their ends, and these conidia collect there in glistening drops of liquid, unfortunately not seen here because they flowed away when the microscope slide was prepared.

- Coelomycetes are asexual Dikarya that produce their conidia inside some kind of enclosing structure. If this structure completely surrounds the conidia it is called a **pycnidium**; if the conidia are borne in a more open structure with a wall only around the lower part, it is an **acervulus**.
- The blue veins in Roquefort cheese and the white crust on Camembert are the results of fungal growth.
- It has also contributed to the discovery of the antibiotic penicillin.

4.5 Terminal question

Q.1 What is acervulus?

Answer:--

-------------------------------- ---

Q.2 Discuss the characteristics features of Basidiomycotina.

Answer:--

-------------------------------- ---

Q.3 Give a detail account of salient feature of Deuteromycotina.

Answer:--

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Short Questions

Q.4 Write short notes on:

1. Imperfecti fungi
2. Economic importance of basidiomycotina
3. Economic importance of *Penicillium*

Q.5 **Multiple choice questions:**

1. The number of basidiospores in basidium-

(a) Two

(b) Three

(c) Four

(d) None of the above

2. Tremellales is known as-

(a) Jelly fungi

(b) Sac fungi

(c) Rot fungi

(d) None of the above

3. Loose smut of wheat is caused by

(a) *Ustilago tritici*

(b) *Ustilago hordei*

(c) *Puccinia graminis tritici*

(d) *Colletotrichum fulcatum*

5.6 Answers

1. (d) 2. (a) 3. (a)

Self-assessment questions

SAQ.1

a. Three, Two **b.** *Phallus*, *Dictyophora* **c.** Rice **d.** Teliospores

SAQ.1

a. *Epicoccum nigrum*, *Nigrospora sphaerica*, **b.** Coelomycetes **c.** *Libertella betulina* **d.** *Aspergillus*

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Block-II

This block covers the field of plant pathology in seven units (6,7,8,9,10,11 and 12) and comprises both the science of learning and understanding the nature of disease art of diagnosing and controlling the disease and importance of plant diseases. The units of this block are as follows:

Unit-6 has concept of plant diseases and various symptoms produced by fungal, bacterial and viral pathogens.

unit-7 has pre-existing and inducted morphological and biochemical defence mechanism in host.

Unit-8 has dissemination of plant pathogens and environmental factors which affects disease development.

Unit-9 has information about epidemiology and disease forecasting.

Unit-10 has various methods applied for disease control.

Unit-11 has disease cycle and control measures of Green ear disease of bajra, Rust of Linseed, Rust of wheat, Covered smut of Barley, Tikka disease of groundnut and Loose smut of wheat.

Unit-12 has diseases cycle and control measures of early blight and late blight of potato, stem gall of coriander, downy mildew of cucurbit, wilt of arhar and blast of rice.

Objectives:

After studying this block you will be able to:

- Identify various disease of plants by their symptoms.
- To know various defence mechanism preset in plant to defend them against pathogen.
- To understand dissemination of pathogen, epidemiology and disease forecasting .
- To know various methods of disease control for reducing economic loss of agriculture.

Understand disease cycle of some importance crop plants.

Unit6

Concept of Plant Diseases

Structure

6.1 Introduction

The term pathology is derived from the Greek words pathos = suffering and logos = study, hence pathology is the "study of the suffering". Phytopathology (phyton- plant: pathos – suffering : logos – knowledge) is the "study of suffering plant and deals with the study of nature, development and control of plant diseases. The diseased plant is the central theme to which are interlinked the pathogen, the environment and the time period. According to modern concept, disease is an interaction among the host, pathogen and environment. Diseased plants can be distinguished by change in their morphological structure or physiological processes which are brought about by unfavorable environment or by parasitic agencies. Stakman and Harrar (1957) defined plant disease as, "physiological disorder or structural abnormality that is harmful to the plant or to any of its part or products that reduces the economic value".

A plant disease is defined as "anything that prevents a plant from performing to its maximum potential. Plant disease is an impairment normal state of a plant that interrupts or modifies vital functions. A plant disease can also be defined as any problem with the plant that leads to a reduction in yield or appearance. Many plant diseases are caused by pathogens. Disease causing agents are called pathogens. A plant is said to be diseased when there is a harmful deviation from its normal functioning of physiological processes. So plant diseases is defined as the state of local or systematic abnormal physiological functioning of a plant, resulting from the continuous, prolonged, irritation caused by phytopathogenic organisms (infectious or biotic disease agent)

Objectives:-

After studying this unit you will be able to know:

- History and significance of plant pathology.
- Koch's postulates for pathogenisity test .
- Classification of plant diseases.
- Various terms required for phytopatholgical studies.
- Classification of plant diseases.
- Conditions necessary for pathogenic diseases.
- Identification of various Fungal, Bacterial and Viral diseases of plants by their symptoms.

6.2 History of Plant Pathology:

The advent and progress of human civilization is intimately associated with the progress of agriculture. But ever since man started depending on plants to fulfill his nutritional needs. The enemies of plants have been causing much harm and economic losses. Fossil records of parasitic fungi date back to Devonian period which suggests that diseases originated along with the plants.

In India mention of plant disease has been made in *Rigveda, Atharveda* (1500-500B.C.), the *Artha Shashtra* (321-186 B.C.), *Sushruta Samhita* (200-500A.D.), *Agnipurana* (500-700 A.D.) etc. In Europe, Theophrastus, while describing trees, cereals and pulses also recorded the harmful effects of wind, weather and location and believed that diseases originated from plants or from the environment. But the invention of the microscope changed the entire concept. Micheli in 1729 made an extensive study of fungi and their reproductive structures and experimentally proved that the fungi originated from spores.

Tillet (1755) demonstrated that wheat seeds dusted with bunt diseases of wheat was caused by transmission of black powder (bunt) and was contagious.

The foundation of modern plant pathology as a science was established by the French scientist Prevost (1807) who demonstrated that micro-organisms are disease causing. Working with *bunt of wheat,* he studied the germination of spores and described the life cycle of the bunt fungus in detail. An important discovery made by Prevost was the fungicidal and fungistatic properties of certain chemical. But due to the firm belief of scientists in the theory of spontaneous generation, Prevost's discoveries were acknowledge 40 years later.

The devastating *'potato disease'* in the middle of the 4th century which swept over the whole of Europe and Ireland was one of the most tragic events in human history, but it was a blessing in diguise as it compelled attention of scientists on the importance of plant diseases. The causal organism of the potato disease was identified by Speerchneider and De Bary as Phytophthora infestans, but it was believed that the fungus developed from the disease rather than that the fungus caused the disease. Few scientists, like Berkeley (1846), Morren (1845) and Van Martius (1842), however, firmly believed that the late blight of potato was caused by Phytophthora infestans.

The German scientist Anton de Bary is credited for establishment of modern experimental plant pathology. He confirmed the findings of Prevost and gave the detailed description of potato late blight fungus, it's nomenclature and pathogenic nature. De Bary's outstanding contributions are his studies with rusts, smuts, downy mildew fungi, heteroecious nature of rusts and their pathogenic role. The role of enzymes in tissue disintegration was demonstrated by De Bary and the physiological era in plant pathology was initiated.

The role of fungi in disease development and the observations of the various scientists was recorded by Kuhn in 1858 in the first book of plant pathology.

A big jump in the field of plant pathology was made by Brefeld of Germany (1875) who developed modern techniques of inoculation and artificial culture of micro-organisms. Parasitic fungi were now being cultured in sterile synthetic media to study their physiology, nutritional requirements, sporulation and genetics.

Grape cultivation was the main industry in France for wine making. In 1878, the *downy mildew of grapevine* wiped out the crop, Professor Millardet of Bordeaux discovered that a mixture of copper sulphate and lime when sprayed on grapevine prevented the mildew disease and the Bordeaux mixture was invented. Thus, the method of chemical control of plant diseases, initiated by Prevost in 1805 was firmly established.

The variability of parasitism in pathogens and the existence of physiological races in the rust fungus was discovered by Swedish scientist Erikson in 1894. In the first decade of the 20th century, scientists studied the importance of genetics in plant disease resistance and selection of resistant lines was introduced to obtain resistant varieties (Biffer, 1903 and Orton, 1909). At the same time, Ward (1903) and Salmon (1903) discovered physiological specialization in rust and powdery mildew of cereals.

Blakeslee in 1904 reported that dissimilar nuclei take part in the life cycle of fungi. Fusion between dissimilar nuclei within a cell was demonstrated by Burgeff (1912-1914) and the term *heterokaryosis* was given to this phenomenon. Hansen and Smith (1923) established the theory of origin of physiologic races through heterokaryosis.

Flor (1955) advocated the important *gene to gene* hypothesis of disease resistance and susceptibility which stated that disease susceptibility depends on compatibility of genes between the host and pathogen.

In the early developmental stages of plant pathology scientists concentrated only on fungal diseases and bacterial association with disease was not taken into consideration. But Louis Pasteure and Robert Koch in 1876 proved that anthrax disease of cattle was caused by a bacterium. Later in 1878, Burrill reported that the fire blight of apple and pear was caused by a bacterium and by the year 1900 E.F. Smith firmly establish bacteria as important disease causing pathogens.

The discovery of the tobacco mosaic virus by Meyer in 1886 was the birth of the study of viruses as pathogenic agents. He demonstrated that the mosaic disease could be transmitted from diseased plant to healthy plants by infecting the sap of leaves showing mosaic symptoms. Ivanowski and Bijerinck are credited for starting study on the nature of viruses. In 1892, Ivanowski demonstrated that tobacco mosaic virus could pass through those filters that retained bacterial cells and suggested that viruses were smaller than the smallest bacterium. In 1998, Beijerinck coined the term contagium vivum fluidum (infectious living fluid) and observed that new growing tissues were more easily infected than old tissues.

In 1935, Stanley experimentally proved that viruses could be chemically treated and crystallized and still remain viable. The following year Bawden and his co-workers found that the crystalline powder of the virus contains nucleic acid and protein and in 1956 Gierrer and Schramm demonstrated that the nucleic acid fraction of the virus is actually the infectious agent.

Needham in 1743 A.D. for the first time reported the disease causing nature of nematodes, but a century later Berkeley and Schacht discovered root knot nematodes and cyst nematodes of sugar beet. Now almost every crop is known to be attacked by one or more of nematodes. The nematology has become a major branch of plant pathology.

Nocard and Roux (1898) discovered another group of disease incitants which was similar to viruses in size but could not be cultured. This group was known as mycoplasma: Japanese scientists (1967) discovered that mycolplasma like organisms could be responsible for most of the *yellowing diseases* supposed to be caused by viruses.

Plant pathology in the twentieth century

In the latter half of the century plant pathology progressed in several directions:

1. **Physiology of plant diseases-** The studies on physiological aspect of plant diseases was initiated by De Bary and pursued by Jones, Brown, Gaumann, Walker and others. The important role played by fungal enzymes and toxins was established.
2. **Genetics of the host plant and the pathogen-**Inheritance of resistance and virulence is related to the genetical constitution of the pathogen. Flor (1955) explained host parasite relationship in flax rust by the *gene for gene* relationship between rust reaction in the host and pathogenicity in the parasite.
3. **Fungicide research-** Several biochemists and organic chemists joined plant pathologists in evolving new fungicides. Sisler, Cox, Ludwig and other workers explored the mechanism of fungicide reaction and in 1934, Tisdale and Williama discovered alkyldiothiacarbamates, the most widely used fungicide. The Discovery of gliotoxin by Weinding and Emerson from *Trichoderma viride,* that prevented damping off of citrus seeding opened the field of antibiotics. Most antibiotics are bactericidal, however, **gliotoxin,petulin** and **griseofulvin** are used against pathogenic fungi.
4. **Environment in relation to disease development-**Environment is an important factor influencing disease development and includes climatic, edaphic and biotic factors.
5. **Nature of disease resistance-** Disease resistance is associated with phenols possessing antibiotic properties, Muller proposed the post infection formation of *Phytoalexin* chemicals which produced in non-hosts toward the pathogenic fungus and provide infection by other fungus.
6. **The Biochemistry and Physiology of the diseased state of the host-** The various metabolic processes of the infected plant have been investigated to determine the sequence and extent of pathogenesis. In the diseased state, the tissues of the host disintegrates, water becomes deficient, growth and reproduction are adversely affected. Host starves and respiration rate is altered. Hence the entire physiology and biochemistry of a diseased plant changes.
7. **Tissue culture-** The technique of tissue culture enabled plant pathologists to grow organs, tissues free cells and to study the transformation of a normal cell into a tumour cell as a result of infection. The first artificial cultures of a rust fungus and microbe free culture of viruses and nematodes were done by this method.
8. **Ecological studies of plant pathogens-** Waksman (1932) emphasized the important role of fungi in soil economy and decomposition of organic matter, Reinking and Manns (1933) coined the terms *soil inhabitants* to fungal forms occurring in all types of soil and *soil invaders* to forms restricted to few localities only. The interesting field of *rhizosphere* study was initiated by Hiltner in 1904 and Lockhead (1940) demonstrated that rhizosphere flora affected the resistance and susceptibility of plants to root infection.

In the twentieth century, plant pathology had developed into a multi-branched science, embracing all segments of biology and the entire human race is obliged to the plant pathologists for their important contribution in ensuring disease free nutritional food supply.

Heinrich Anton de bary- German surgon, botanist microbiologist and mycologist is considered FATHER OF PLANT PATHOLOGY as well as founder of MODERN MYCOLOGY.

Some important plant pathologist of India are E J Butler, B B Mundkur, K C Mehta, T S Sadasivan, R N Tandon, S P Raychaudhari, G. Rangaaswamy, S N Das Gupta etc. Sir Edwin John Butler an Irish mycologist and plant pathologist is considered father of modern plant pathology in In**dia**. He stayed in India for about twenty years and made scientific studies of most of the diseases known in India at that time. Butler left India in 1920, BB Mundkar started work on cotton wilt and started Indian Phytopatholgical Society in 1948. Sir K C Mehta and R Prasada worked on epidemiology of cereal rust in India. T S Sadasivn established the school of Mycology and plant pathology at Madras University and laid the foundation of research on soil borne pathogen in India.

SAQ 1.

- **a.** Bordeaux mixture was discovered by ………………………
- **b.** Father of Plant Pathology is ……………………………..….
- **c.** Father of modern Plant Pathology in India is ………………

6.3 Significance of Plant Pathology

Plant diseases are important as they cause damage to plants and plant products. The extent of the harm caused varies with plant, the pathogen, locality, environment etc. Plant pathology is concerned with all the aspects and features of plant diseases, caused by fungi, bacteria, viruses, nematodes, parasitic higher plants etc. The study of plant pathology is of special significance as it makes us knowledgeable not only about the various kinds of diseases infecting plants but also explains about the measures of control and prevention to be taken against those diseases.

Plant pathology is not an isolated subject but is intimately associated with botany, mycology, virology, bacteriology, plant anatomy, plant physiology, genetics, biochemistry, soil science and other branches of science.

6.4 Pathogenicity

Pathogenicity refers to the ability of an organism to cause disease (i.e. harm the host). This ability represents a genetic component of the pathogen and the overt damage done to the host due to host pathogen interactions. It is the quality of state of being pathogenic, the potential ability to produce disease. The potential capacity of infection of any pathogen is called its pathogenicity. The index of the quantitative nature of pathogenic micro organism is called the degree of pathogenicity or virulence.

On the molecular and cellular level, microbes can infect the host and divide rapidly, causing disease by being there and causing a homeostatic imbalance in the body, or by secreting toxins which cause symptoms to appear. All pathogens are parasite but all parasites are not pathogen. The parasite which cause disease on the host are called pathogen.

The host pathogen interaction begins when pathogen (in the form of inoculums) comes in contact of host and ends with the expression of disease in the form of symptoms.

The inoculum causes infection when the host is susceptible and environmental conditions are favourable.

When pathogen come in contact of a susceptible host pathogensis take place.

Pathogensis is the process of infection of disease development in a plant. Infection is the establishment of a pathogen within the host, followed by entrance.

Thus pathogenesis is the sum of sequence of biological process in disease development from initial contact between a pathogen and its host to the appearance of first symptom of disease. A number of external and internal factors are involved in the process

The process of pathogensis can be studied under following three phases:

(1) Prepenetration Phase

(2) Penetration Phase

(3) Post Penetration Phase.

(1) **Prepenetration Phase:-** It is the host pathogen interaction before penetration of pathogen into the host. The prepenetraction important only in the case of fungal inoculums and not in the case of viral and bacterial inoculum because, prepenetration involves germination of propagule and growth of germ tube which is a phenomenon of fungal inoculums.

Various type of spores like sporangia, conidia, oidia, chlamydospores, uredospores, ascospores etc. are produced by fungal pathogen. Some of them germinates immediately where as other germinates after a resting period.

Various **environmental factors** like moisture, pH, temperature, light, CO_2 and O_2, **Chemical factors** like host exudates, residues and biological factors like microorganisms present around the rhizosphere and phyllosphere influence the germination of spores by antagonism, competition and micro parasitism.

After encountering above factors, fungal propagule germinates by germ tube and penetraters directly into the host or it grows profusely over the host surface and form infection cushion. The tip of the germ tube then form **aspersorium** from which infection thread arise and enter into the host.

Penetration Phase: It is the actual entry of pathogen into the host. The pathogen enters into the host either indirectly or directly.

Indirectly pathogen enters into the host either through natural openings present on the host surface such as stomata, lenticel, hydathodes or through the wounds.

Directly pathogen penetrates through culticularised epidesmis. In this penetration pathogen has to cross morphological, biological and chemical barriers. The direct penetration is first mechanical then chemical. The germ tube of fungal hyphae develop appresorium which exert a strong mechanical pressure on the wall. As a result epidermis is streached and becomes thin. The penetration take place through this thin area.

The penetraction of cuticle is purely mechanical. The appresorium exerts a presscune at the thin area due to which cuticle breaks and pathogen comes in contact of epidermal wall of the host which has pectin and cellulose. These are penetrated by enzymatic action of the hyphae due to which the cell wall become soft and pathogen penetrates into the host tissue.

At the same time pathogen has also to neutralize many toxic substances secreted by host.

Post Penetration Phase:- In this phase pathogen successfully establishes them self into the host tissue which is must for the appearance of symptoms. Various internal factors try to inhibit the growth of pathogen inside the host. The pathogen establishes themselves after over coming the internal barriers which may be morphological or biochemical. The establishment of pathogen in the host involves a close bio-chemical relationship between the two (host-pathogen). Various enzymes, toxins and growth regulaters are secreted by pathogen inside the host. It brings various morphological, anatomical and physiological disturbance in the host tissue.

The physiological process, such as membrane permeability, photosynthesis, respiration and nitrogen metabolism are affected. The above disturbance are expressed on the host surface in the form of symptoms of the disease. On the basis of infection the symptom may be local in which pathogen infect the host organ or part of organ or may be systemic in which entire plant is affected. The factor that establishes infection is quantitative. Larger the dose of the infective pathogen greater are the chances of infection.

6.5 Koch's Postulats: The Pathogenecity Test

Roert Koch was a German Physician who confirmed the germ theory of disease and formulated four postulates known as Koch's Postulates. These postulates are four criteria designed to establish relationship between a microbe and disease. Koch's postulates have been critically important in establishing the criteria where by the scientific community agrees that a microorganism causes a disease.

Koch first laid down in 1882 a three step series which he said, must be fulfilled before the organism can be confirmed as the real cause of the disease. Later on a fourth step was appended to Koch's series of conditions by E.F. Smith in 1905. These four conditions are four postulates known as Koch's Postulates universally accepted to establish a relationship between microorganism and disease. These postulates are as fallows:

1. The organism must be found associated with the disease in all the diseased host examined.
2. The organisms must be successfully isolated and grown in pure culture on nutrient media. Its growth characteristics be recorded.
3. The organisms should be isolated from pure culture and must be innoculated on the healthy host on which the disease appears and it must cause the same disease on the inoculated healthy host.
4. The organism must be isolated from experimentally diseased host during the step 3 and grown in pure culture again, the organism grown in pure culture must show exactly the same characteristics of its growth which it showed during the step 2.

If all above steps of Koch's Postulates are proved to be true, the isolated organism is identified as the real pathogen responsible for the disease.

6.6 Classification of Plant Diseases:-

The plant diseases are classified in various ways on the basis of:

1. Host plant affected
2. Causal organism
3. Part of the plant affected
4. Occurrence of disease
5. Nature of dispersal medium.

1. **Classification of Plant Diseases on the basis of host plant affected:**

   The disease is of two types:

   a. **Systemic Disease** In this case whole plant is affected by pathogen and the symptom of disease appears in the whole plant.

   b. **Localised Disease** When certain organ such as root, stem, leaf etc. or part of organ of the host plant is affected then it is called localized disease. In this disease the symptoms produced by pathogen on host surface are also localized.

2. **Classification of Plant Diseases on the basis of Causal Organism:** On the basis of nature of Causal organism, the disease is of two types:

   a. Non Parasitic disease:

   This disease is not caused by living organism. It is due to environmental conditions like low and very high temperature, unfavourable soil moisture, pH, presence of toxic gases in the atmosphere. Excess and deficiency of minerals in the soil also cause non parasitic disease. As there is no involvement of living organism it can not be transmitted from one diseased plant to another healthy plant. Thus the disease is non infectious.

   Tip-rot or necrosis of Mango is an example of non parasitic disease. It is caused by deficiency of Boron.

   b. Parasitic Disease

   Parasitic disease is due to parasitic organisms like algae, fungi, bacteria, virus and nematodes. The disease is infectious and transmitted from diseased plant to healthy plant in the same field, from one field to another field and from one place to another through various agencies. White rust disease in crucifer caused by *Albugo candida* is an example of parasitic disease.

3. **Classification of Plant Diseases on the basis of part of the plant affected:** On the basis of part of the host plant affected disease may be classified as:

   a. **Foliage Disease** when leaf of the host plant is affected by pathogen.

   b. **Stem Disease** When stem of the host plant is affected by pathogen.

   c. **Root Disease** When root of the host plant is affected by pathogen.

   d. **Vascular Disease** When vascular region of the host plant is affected by pathogen.

   e. **Fruit Disease** When fruits of the host plant are affected by pathogen.

4. **Classification of Plant Diseases on the basis of occurrence of disease:** The study of plant diseases in relation to their occurrence (interaction of populations of plants, pathogens and environment) is known as epidemiology

There may be infectious disease and contagious disease. A disease which spreads slowly and is incited by transmissible pathogen is known as infectious disease, and that which spread rapidly is a contagious disease.

On the basis of occurrence diseases are classified as:

a. **Endemic Disease**

A disease which constantly occur from year to year in moderate to severe form is an endemic disease. For example, the wart disease of potato caused by *Synchytrium endobioticum* is endemic to Darjeeling. In plant pathology, this term is applied to simple interest disease which are either indigenous or of ancient introduction.

b. **Epidemic or Epiphytotic Disease**

The disease occur widely, but periodically in a destructive form. The pathogen may be present in the locality, but the environment favourable for development of disease occur only periodically. Thus the disease is very responsive to variation of environmental conditions which actually control its incidence. Cereal rust, Powdery mildew are example of epidemic disease.

c. **Sporadic Disease**

The sporadic disease is rather an epiphytic disease except that it occurs only here and there at irregular intervals. In a sporadic disease pathogen affects only a few plants in a large population of host plants and others remain unaffected. Angular leaf spot is an example of sporadic disease.

d. **Pandemic Disease**

The disease occurs all over the world and result in mass mortality. Late blight of potato is an example of pandemic disease.

5. **Classification of Plant Diseases on the basis of dispersal medium of the pathogen:** On the basis of the dispersal medium of the pathogen diseases are classified as:

a. **Soil Borne Disease**

The pathogen survives in the soil and disease spread through soil. Wilt of Arhar is an example of soil borne disease as *Fusarium* sp, the pathogen of wilt disease survives in soil.

b. **Seed Borne**

The pathogen of disease survives in the seed therefore disease spreads through infected seed. Loose smut of wheat is an example of this disease as, the pathogen *Ustilago tritici* spreads through seed.

c. **Air or Wind Borne Disease**

The pathogen of disease survives in air therefore spread of disease take place through air. For example, the uredospores of *Puccinia* comes through air, infects the wheat crop and cause Black Rust disease.

On the basis of causal agent the plant diseases are classified as:

(i) **Non Infectious Plant Diseases:** They are not associated with any animate or pathogen, so they cannot be transmitted from an infected plant to a healthy one. They are due to disturbances in the plant body caused by lack of certain inherent qualities, by improper environmental conditions of soil and air and by mechanical influences e.g.:-

1. Low/High temperature

2. Unfavourable O_2 level
3. Unfavourable water level
4. Rain
5. Wind
6. Air Pollution toxicity etc.

(ii) **Infectious Plant Diseases:** These are the diseases caused by pathogenic organisms or Virus, under a set of environmental conditions. Fungi, bacteria, viruses and nematodes are some pathogen. They obtain nutrients, water and everything. They need to reproduce from their host. Fungal and Viral pathogens causes many plant diseases; bacterial and nematode pathogens cause a few. Some pathogens can infect several kinds of plants; others require a specific type of host. Pathogens such as fungi and bacteria differ in their ability to survive, spread and reproduce.

SAQ 2.

a. Koch's postulates were given by……………………………..

b. In systemic disease…………………………plant is affected.

c. Parasitic disease is due to ………………………...organisms.

d. Pandemic disease occurs…………………………. the world.

6.7 Conditions Necessary for Pathogenic Disease

Three conditions are necessary for pathogenic plant disease:

- A susceptible host plant.
- An active, living pathogen must be present.
- A suitable environmental for disease development.

Sign: A sign of plant disease is physical evidence of the pathogen.

Disease Symptoms: The symptom of plant disease is a visible effect of disease on the plant. Symptoms may include a detectable change in colour, shape or function of the plant as it respond to the host.

6.8 Symptoms of Fungal Diseases.

Symptoms are visible effect which pathogen induces on the host plant. Symptoms can be divided into two categories:

(A) Symptoms due to external appearance of pathogen or some part of pathogen on the host are:

1. Mildew
2. Rust
3. Smut and Bunt
4. Sclerotia

5. White blister

1) **Mildew:-** The pathogen is seen as a superficial growth on the host surface in the form of patches of varying size. It is of two types:

(a) Downy Mildew **(b)** Powdery Mildew

(a) Downy Mildew	(b) Powdery Mildew
Pathogen is internal obligate parasite. The mycelium and sporangiophore are produced on the lower surface of leaves giving cottony appearance.	Pathogen is external obligate parasite. White powdery masses scattered over the surface of plant parts. The powdery appearance is due to formation of numerous conidia in the form of a coating on the host surface e.g. Powdery mildew of cucurbits caused by *Sphaerotheca* sp.

Fig.6.1.b. Symptoms of Powdery Mildew

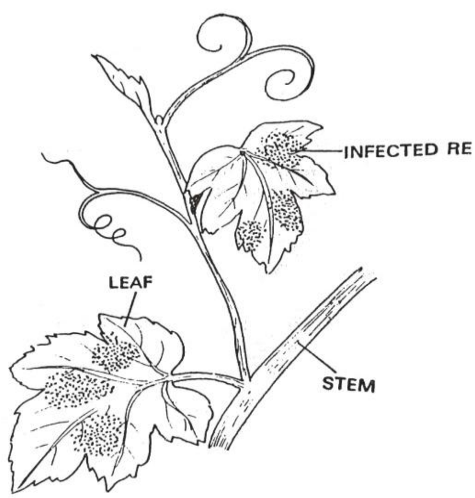
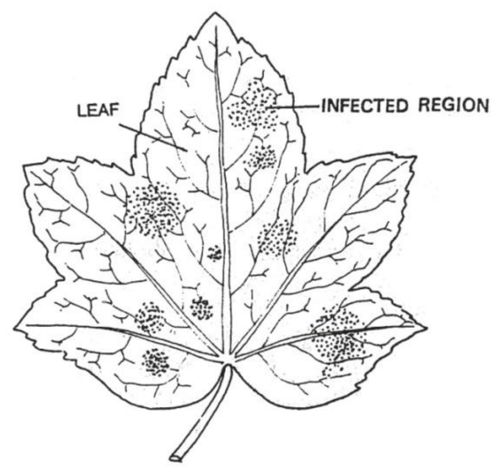


Fig.6.1 .a. Symptoms of Downy Mildew



2. Rust:- Symptoms appear as small coloured pustules on host surface. Colour may be red, yellow, black, brown and orange. These symptoms are produced due to exposure of underlying mass of spores because of ruptured epidermis. e.g. ***Black rust of wheat caused by Puccinia graminis tritici.***

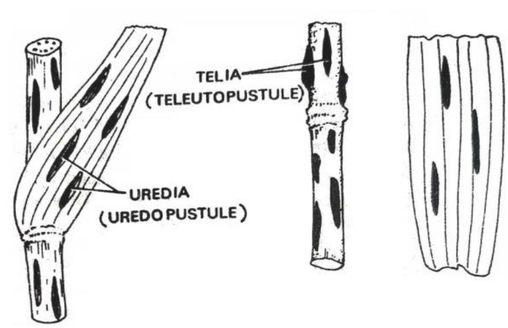


Fig. 6.2. Symptoms of Rust

3. Smut & Bunt:- Symptom of smut appears on the floral organs particularly in ovaries. The infected ear look charcoal like as the ovary has black powdery mass of smut spores instead of grain. The smut is of two types-

(a) Loose Smut (b) Covered Smut

<table>
<tr><th>(a) Loose Smut</th><th>(b) Covered Smut</th></tr>
<tr><td>The smut spore remain covered by thin membrane in the beginning but soon it ruptures and smut spores get exposed and disseminated e.g. Loose smut of wheat caused by- Ustilago tritici

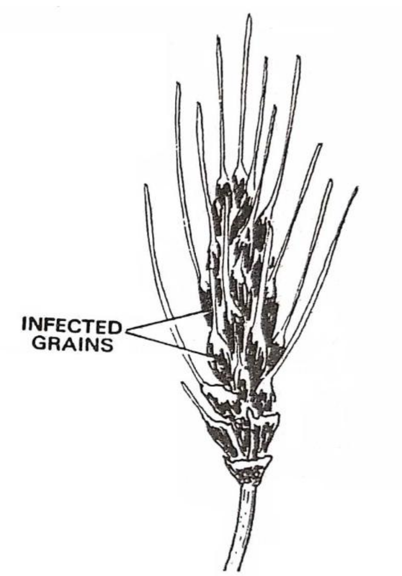
Fig.6.3.a. Symptom of Loose Smut</td><td>The smut sposes remain coved by wall of the grain and glume. They get exposed only at the time of threshing. e.g. Covered smut of Barley caused by Ustilago hordei.


Fig.6.3.b. Symptom of Covered Smut</td></tr>
</table>

In case of sugar cane the whole floral axis is transformed into a black dusty whip eg. Whip smut of sugarcane is caused by *Ustilago scitaminae.* In case of bunt the smutted ear has a thick Pericarp and ear given a stinking smell e.g. Bunt of wheat is caused by *Tilletia foetida*

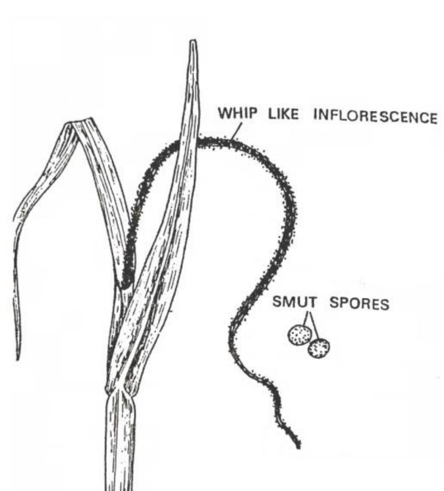


Fig. 6.4. Whip smut of sugarcane

4. Sclerotia:- It is a compact hard mass of dormant fungal hyphae which may be brown, black, gyeish, violet or purplish. In some case e.g. Ergot of rye, the selerotia are formed in the position of Kernel in the spike.

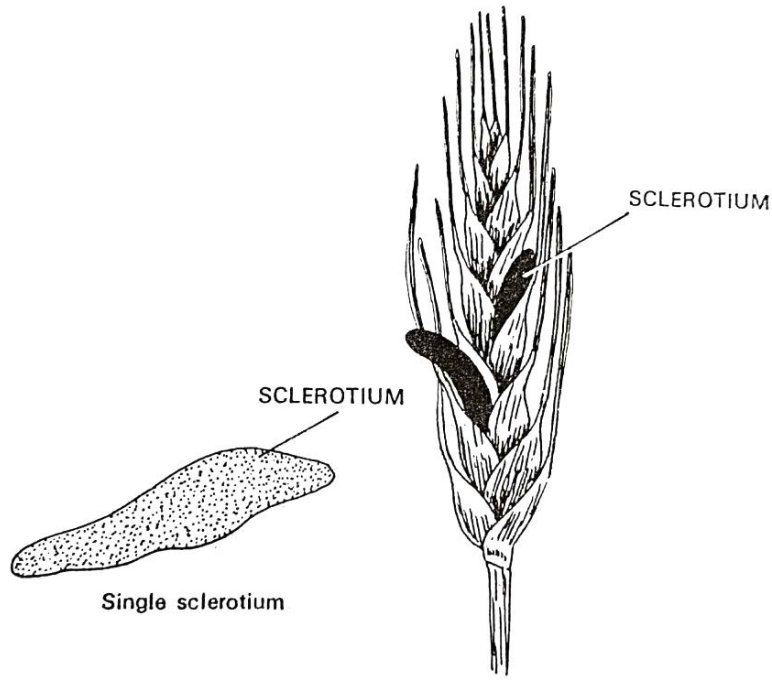


Fig. 6.5. Symptom of Sclerotia

5. White Blister:- White shiny blister like pustules are produced on the lower surface of the leaf of *Brassica* due to exposer of white powdery masses of conidia as a result of rupture of epidermis. e.g. White blister or Rust of Crucifer is causes by *Albugo candida.*

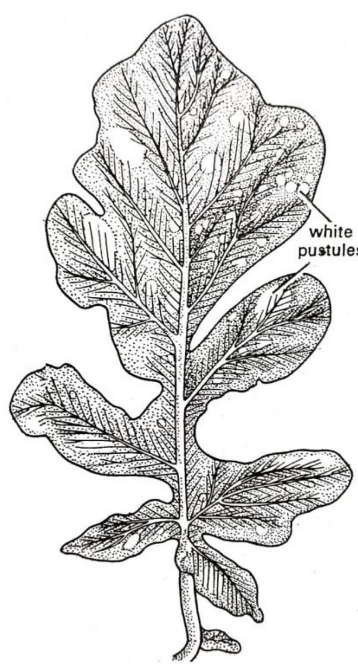


Fig. 6.6. Symptom of White Blister

B. Symptoms which are visible effect induced by pathogen on host are:

1. Necrosis

2. Overgrowth

3. Undergrowth

1. Necrosis:- The death of host tissue take place which is induced by attack of pathogen Necrotic symptoms are as fallows:-

- **Lesions or Leaf Spot**:- In many cases necrosis is confined to small area and is called *Local Lesions* which may be big or small, circular, oval or irregular in shape and variously coloured.

  In many cases dead tissue of the spot may fall out leaving a hole. This is called *Shot Hole.*

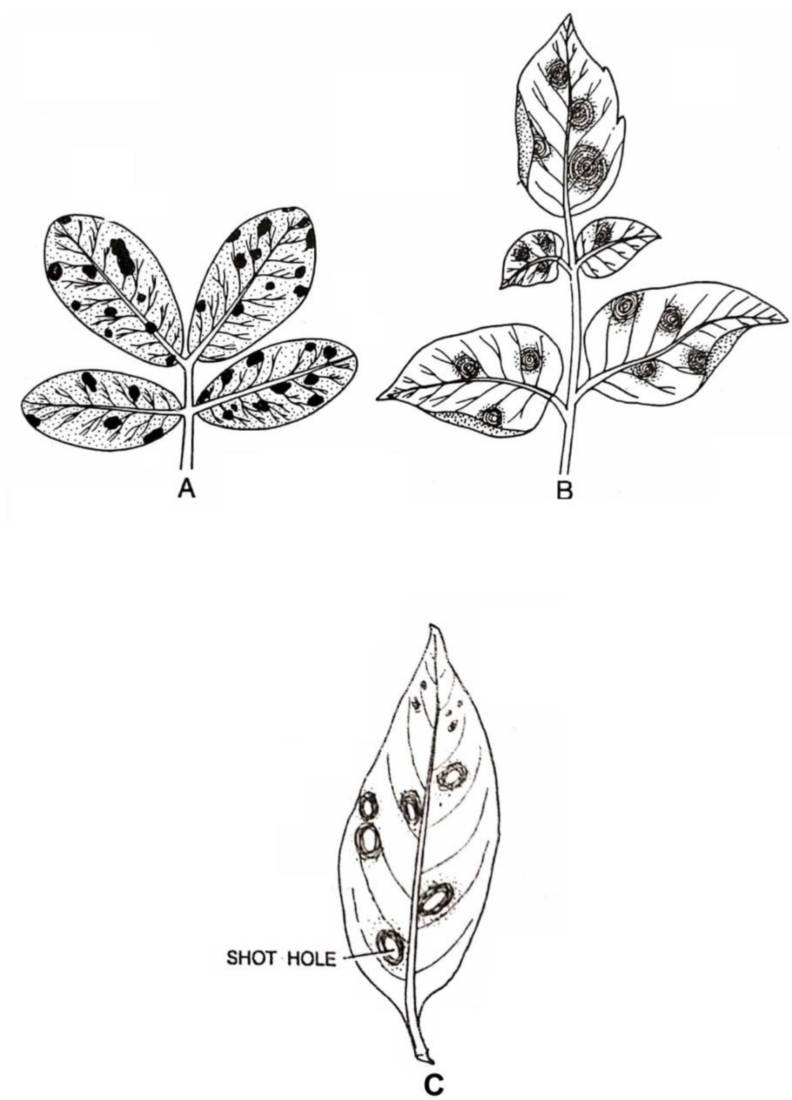


Fig. 6.7. A to C Symptoms of Lesions or Leaf Spot

- **Wilt:-** Plant show dehydration and drought. Symptom first appears firstly on shoot and leaves. The leaves become flaccid due to loss of turgidity and result in dropping of entire plant. Pathogen attacks the root of the plant and get accumulated in the vascular tissues of stem and root. It causes obstruction to the movement of water. Tyloses are also formed in the lumen of vessel. Besides this, pathogen secreates some toxic substance such as gum, gel, pectins and polysaccharides.

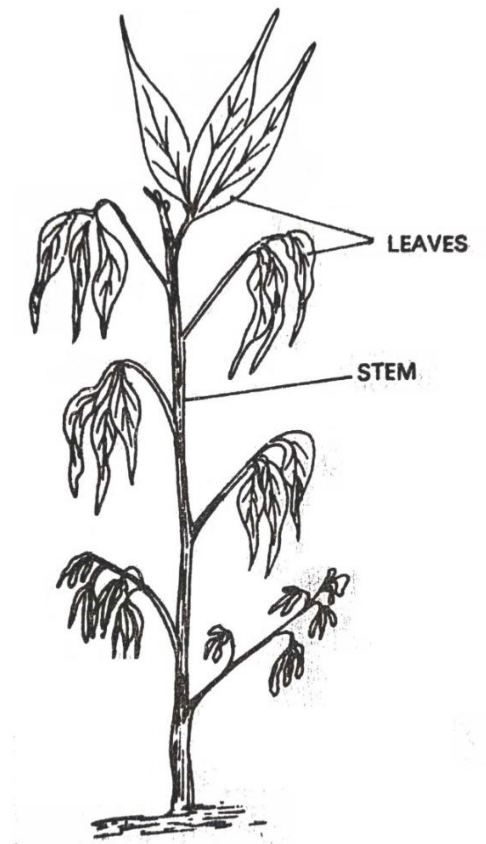


Fig. 6.8. Symptom of Wilt

- **Damping off**:- Young seedings are killed either before their emergence from the soil or after emergence. When they are killed before emergence it is called *Pre emergence Damping off* in which young radical and plummule get rot and finally die.

  When newly emerged seedings are killed at ground level it is called *Post emergence damping off*. In this the pathogen attacks the base of stem (hypocotyle) usually just below the soil line. The infected tissue becomes soft and water soaked as a result the seedling topples over or collapse.

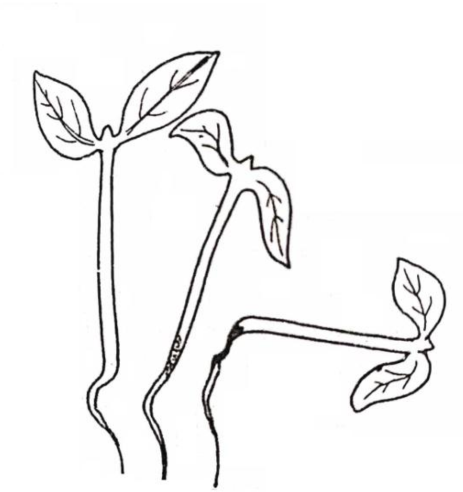


Fig. 6.9. Symptom of Damping off

- **Rot**:- In Rot the affected tissue die and undergo decay. The Rot diseases may be classified on the basis of the organ attacked such as leaf, stem, root, bud and fruit rot. In rot the death and decay is due to disintegration of cells and middle lamella by the action of enzymes. It turns black to brown. Rot may be soft and dry. When symptom is watery it is called soft rot.

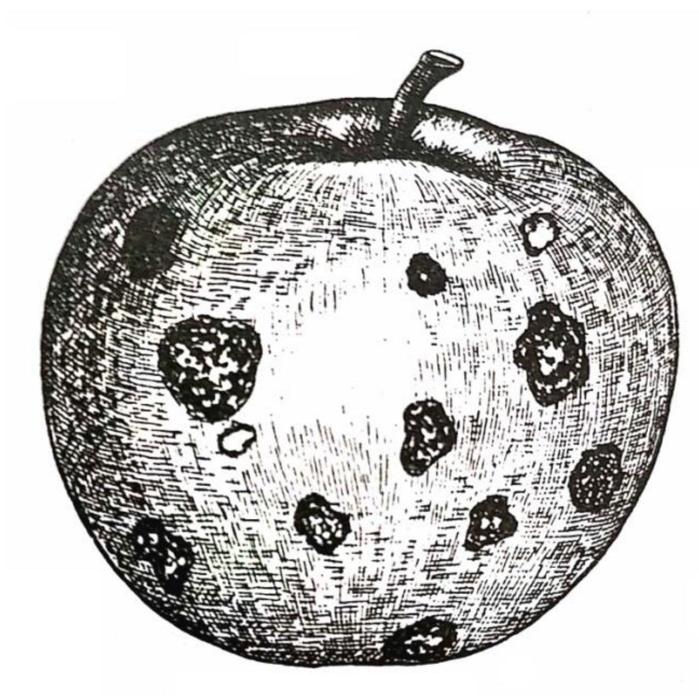


Fig. 6.10. Symptom of Rot

- **Blight**:- The symptoms give a burnt appearance due to sudden and extensive damage to the leaves and other part of plant in response to attack of pathogen. Initially symptom appear in the form of circular or irregular spot on the leaf gradually. It increases in size and cover the entire leaf. The affected tissue become necrotic and gives burnt appearance. In severe attack leaves shrivell and fall down e.g. Late Blight of Potato caused by *Phytopthora infestens.* Early Blight of Potato caused by *Atternaria solani.*

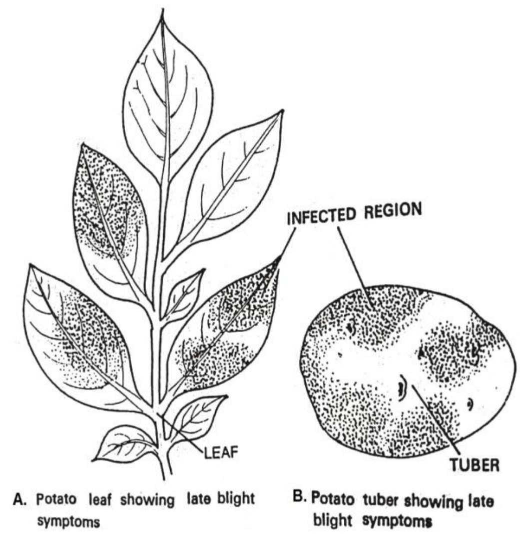


Fig. 6.11. A-B, Symptoms of Blight

2. Overgrowth:- Sometimes over growth in the host tissues are induced which may be either due to *Hypertrophy* or due to *Hyperplasia* or due to both.

In **Hypertrophy** the abnormal increase in size of one or more organ of a plant is due to increases in cell size of host plant induced by pathogen.

In **Hyperplasia** the abnormal increase in size of one or more organ of a plant is due to increase in no. of cells of host plant induced by pathogen.

Hypertrophy and Hyperplasia causes distortions, swellings, Leafcurls and gall. e.g Hypertrophy of *Brassica* caused by *Albugo.*

Fig. 6.12. Symptom of Overgrowth Showing Hypertrophy

3. Undergrowth (Atrophy):- Symptoms are characterised by undergrowth or under development of tissue. It produces *Dwarfing Symptom* in which,, size of leaf reduces, nodes and internodes become short. Plant fails to produce flower and fruit and finally die e.g. Little leaf of Brinjal caused by *Mycoplasma*.

SAQ 3:-

a) Black rust of wheat is caused by ………………………………………..

b) Symptoms of smut appears on the floral organ particularly in ………………….

c)*Albugo candida* causes …………………….. in crucifer.

d)*Phytopthora infestens* causes ………………….. of Potato.

6.9 Symptoms of Bacterial Diseases:-

All plant pathogenic bacteria are rod-shaped and majority are flagellated. Only two genera among the six e.g. *Corynebacterium*and *Streptomyces* are Gram positive while the rest are Gram negative .

The Pathogenic bacteria enter into the plant through: (1) Root hairs, stigmas (2) Natural openings such as stomata and (3) incidental wounds. After entering into the suitable host, the bacteria may establish themselves interacellulary, intravascularly or in more than one combination and exhibit following types of disease symptoms;

Local Lesions:-

Local lesions or spots appear on the leaf blade in the petiole, stem etc. when such spots occur on fruits, resulting in the discolouration of fruits. The spot first appear as minute water soaked specks spreading rapidly to form irregular, angular or Circular spots. The lesions or spots become necrotic (dead).

Soft Rots-

In this case softening of host tissue occurs due to disintegration of cells and dissolution of middle lamella as a result of enzymatic action and oozing of watery secretion from the affected part. It is followed by plasmolysis and death of host cell. The bacteria grow upon this dead plant tissue.

Cankers and Scabs:-

Cankers and scabs are Corky outgrowths formed on above ground parts of the host such as leaves, twigs, fruits. These outgrowths are the result of the reaction of host tissue to the pathogen. The Canker are deeply seated, local and dead lesion result in open wound sunken in the stem surrounded by living tissue. Scab on the other hand are not deep seated because it is formed by epidermal infection. Such infections are common in citrus, mango and many other fruit and forest trees e.g. Citrus Canker disease is Caused by *Xanthomonas campstris p.v. citri.*

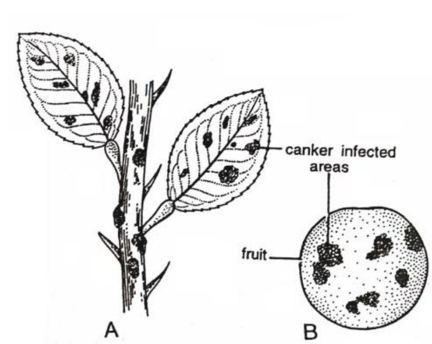


Fig. 6.13. A-B. Symptoms of Cankers

Tumours and Galls :-

In some cases, invasion of bacterial pathogen result in the hypertrophy and hyperplasia of invaded tissues. This hypertrophy and hyperplasia is due to some chemicals produced in the vicinity of the host cell as a result of chain of reactions caused by pathogen. Due to this, tumours and galls develop on the affected organs. Crowngall disease caused by *Agrobacterium tumefaciens* is the best example of this.

Vascular Disease:-

In some of the bacterial leaf spots, pathogen moves into the vascular tissues and becomes systematic. In others, the invasion is concentrated in the vascular tissues, resulting in typical wilt of the affected plants. Pathogenic infection obstructs movement of water in the vessels due to depositions of gum and formation of tyloses in the lumen of vessel. The collapse of vessel also contribute to wilting.

SAQ 4:-

a) Canker is a …………………………lesion.

b) Crown gall disease is caused by ……………………….

6.10 Symptoms of Viral Diseases.

(1) Leaf Curl:- Curling, distortion and reduction in the size of leaf is produced by virus. e.g. Leaf curl of papaya is caused by *Tabacco virus 16.*

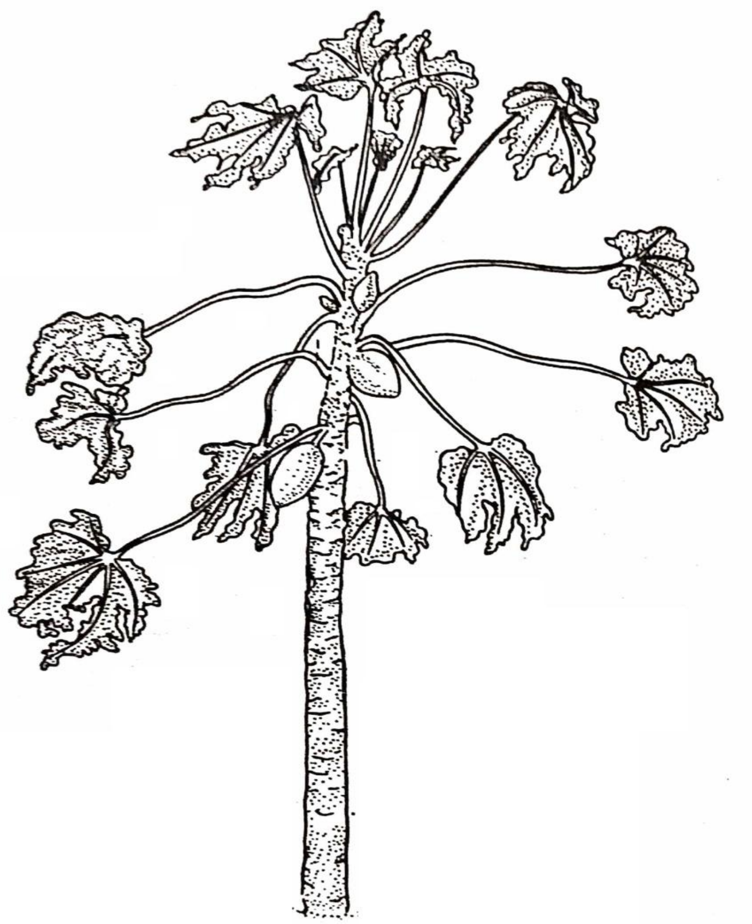


Fig. 6.14. Symptom of Leaf curl of papaya

(2) Colour Changes:- Natural colour of the plant changes due to attack of virus which are of following type-

(a)Mosaic:- Characteristic light and dark green pattern accompanied by blistered appearance of leaves due to more rapid growth of dark green tissues. It is caused by viruses. e.g. Tabacco Mosaic disease is caused by *Nicotiana virus*

Fig. 6.15. Symptom of Mosaic

(b)Chlorosis:- In this yellowing take place in the leaf.

(c) Vcin Clearing:- In this yellowing of vein and veinlets take place as a result a yellow network of vein is formed. e.g. Yellow vein mosaic of bhindi is caused by *Hibiscus vircus* I. In this veinclearing is followed by veinal chlorosis of the leaves.

(d) Vein Banding:**-** The tissue close to vein remain green but the remaning tissue undergo chlorosis.

3. Local Lesion:- Symptom appear in the form of chlorotic or necrotic small area Necrosis is killing of cells and tissues and area where necrosis occur is called lesion.

4. Distortion:- The infected plants show attraction in the symmetry of leaf arrangement. Crinkling of their edges rolling and resetting of leaves by redundant growth of veins. In some cases the leaves get cleaved & wiry then called *witche's broom.*

5. Ring Spot:- Rounded spot which appears on the leaf either singly or in cluster of 4-6. The spot enclosed necrotic tissue with chlorite area against the dark green back ground.

6. Outgrowth and Tumours: In certain cases plants parts develop out growth due to attack of virus. e.g. Secondry leaves are developed on the midribs of leaves or root develop tumours.

7. Colour Break: Some viral diseases produce colured spot or streaks on floral petals and furits. These are called *Colour Breaks'*

1. Yellow streaks in tulip
2. Pink flower garnish
3. Chlorotic spots on fruits of tomato.

SAQ 5:-

a) Leaf curl of Papaya is a ………………………..diseases.

b) Tobacco Mosaic is caused by …………………………

c) In chlorosis ……………….take place in the leaf.

6.11 Some Important Fungal, Bacterial and Viral Diseases.

Disease	Pathogen (causal organism)	Symptom
FUNGAL DISEASES		
Damping off of seedings	*Pythium debaryanum*	The young seedling rot from the base and topple over
Downy mildew of curcifers	*Perenospora brassicae*	Small or large purplishbrown spots on the ventral surface of leaf
Downy mildew of bits cucurbits	*Pseudoperanospora cubensis*	Pale yellow, angular patches on leaves.
Downy mildew of bajra	*Sclerospora graminicola*	The whole infloresce infected into leafy bearded structures with out bearing any grains.
Powdery mildew of wheat	*Erysiphe graminis*	A greyish-white powdery growth occurs on the leaf.
Powdery mildew of peas	*Erysiphe polygoni*	The powdery whitish spots completely cover the leaves, petioles, stem and even the pods.
White rust of crucifers	*Albugo candida*	White or cream-yellow coloured pustules appear on the leaves.
Black stem rust of wheat	*Puccinia graminis tritici*	Black coloured lesions or pustules appear on stem, leaves and leaf sheaths.
Brown rust of wheat	*P. recondita*	Bright orange coloured pustules appear in small clusters or irregularly distributed on the leaves.
Yellow rust of wheat	*P. striiformis*	Lemon-yellow coloured oval pustules appear arranged end to end in a series, chiefly on the leaves.
Rust of linseed	*Melampsora lini*	Brown or black coloured pustules (telial stage) or orange coloured pustules (uredial stage) appear on both the surface of the leaf.
Rust of bajra	*P. penniseti*	Black coloured pustules appear on both the surfaces of the leaf, leaf sheath and stem
Loose smut of wheat	*Ustilago tritici*	The symptoms appear on the inflorescence only, the diseased ear consists of deformed spikelets filled with black, dry powdery mass of spores.
Loose smut of barley	*U. nuda*	Symptoms similar to loose smut of wheat.
Covered smut of barley	*U. hordei*	The symptoms appear on the inflorescence only. The smutted ear is shorter in length and every grain is replaced by a black spore mass which are held firmly by a persistent membrane.

Smut of bajra	*Tolyposporium penicillariae*	Bright green to dirty black coloured infected grains, enlarged in size and irregularly distributed in the ear.
Whip smut of sugarcane	*U. scitaminea*	The floral shoot gets transformed into a long, whip like, dusty, black shoot, which is covered by a thin membrane.
Die-back of chillies	*Colletoricum capsici*	The infection starts from the growing point of the branches and advances backward and downwards, the infected part of the stem assumes an enamel white colour sharply demarcated by a black line.
Mango anthracnose	*C. gloeosporioides*	On the leaves, dark brown necrotic area develop, on the twigs black necrotic areas whereas black spots appear on the older fruits.
Club root disease of cabbage	*Plasmodiophora brasicae*	The infected roots enlarge to form 'clubs' and their diameter increases 10-12 times the normal root, the leaves become pale green or yellowish in colour.
Wart disease of potato	*Synchytrium endobioticum*	The infected tubers bear dark brown, warty, tumerous out growths.
Wilt of pigeon pea	*Fusarium oxysporum f.sp. udum*	The seedling and adults wilt which is characterized by yellowing, withering and drying of leaves, branches and finally the entire plant.
Root rot of cotton	*Rhizoctonia bataticola*	The entire root system get completely rotted.
Leaf spot of groundnut	*Cercospora personata*	Dark brown to black spots, which are almost circular, 1-6 mm in size, occurring on leaves, stipules petioles.
Early blight of potato	*Alternaria solani*	In the necrotic spots, concentric rings appear on the older leaves and darkened areas on the stem giving a target-board like effect. A narrow chlorotic zone appears around the spots.
Late blight of potato	*Phytophthora infestans*	In the initial stage, purplish brown spots appear on the foliage, later the tubers get injected manifested by dry or wet rotting.
Leaf curl of peach	*Taphrina deformans*	The leafblades become thickened and puckered along midrib, resulting in the curling of the leaves downwards. The leaves become reddish, thick and fleshy and the upper surface is covered bloom of fungal spores.

Ergot of bajra	*Claviceps purpurea*	The inflorescence gets infected and the ovaries are converted into small dark grey, hard sclerotia.
BACTERIAL DISEASES		
Citrus canker	*Xanthomonas citri*	The diseases appears as dark green spots with a raised convex surface on the leaves branches and fruits.
Yellow ear rot of Tundu disease of wheat	*Corynebacterium tritici*	Twisting of the stem distortion of the earhead and rotting of the spikelets with profuse oozing of yellow liquid containing masses of bacterial cells.
Bacterial blight of rice	*Xanthomonas oryzae*	Drying and twisting of leaf tips which extends to leaf sheaths, culms and glumes. The bacterial mass oozes out and dries on the surface.
Crown gall of stone fruits	*Agrobacterium tumefaciens*	Small outgrowths known as galls appear on stem and roots which are soft in young condition, but become hard and knotty as they grow older.
VIRAL DISEASES		
Tobacco mosaic	*Nicotiana virus 1*	The leaves develop a characteristic light and dark green discolouration pattern known as mosaic
Leaf roll of potato	*Solanum virus 14.*	The margins or the tips of the leaves become yellow and roll up.
Leaf curl of papaya	*Tobacco virus 16.*	Crinkling and curling of the leaves accompanied by vein clearing and reduction in the size of the leaves In later stages, the leaves roll inwards and downwards and turn dark in colour.
Yellow vein mosic of bhindi	*Hibiscus virus I*	Vein clearing followed by veinal chlorosis of the leaves forming a yellow net work of veins.

6.12 Psychopathological Terminology

The term used in the study of plant pathology carry definite meaning. Some such terms are as follows:

Host- On which pathogen survive.

Pathogen - A living entity which causes disease.

Inoculum – The pathogen survives from one growing season to the other in the form of spores, selerotia, dormant mycelium or in various other forms. This constitute inoculum. For example, Inoculum in bacteria is the entire cell, in virus the entire particle, in Fungi vegetative hyphae and spores. Thus the part of a pathogen which enters the host cells and causes disease is known as inoculum.

The inoculums is of two types:

(1) **Primary Inoculum:** The form of pathogen through which initiation of disease take place is known as Primary inoculum. For example in white rust of crucifer disease, the primary inoculum is oospore present in the soil

(2) **Secondary Inoculum:** After infection on the host surface pathogen produces fresh crop of spores which causes secondary spread of disease. These are called secondary inoculum. For example in the disease cycle of white rust of crucifer *Albugo candida* (pathogen) produces conidia on mustard plant (host). These conidia are secondary inoculum as they cause secondary spread of disease.

Disease: Any deviation from the healthy conditions which interferes with the normal structure and performance of vital functions of a plant is called disease. The diseased plant can thus be spotted by changes in their structure or physiological process.

Symptom: The external sign on the plant which indicate disease is known as symptom.

Simple Interest Disease: Simple interest or monocyclic disease increased mathematically similar to simple interest on money. This disease develops from a common source of inoculum, that is, the capital which is constant. It is also known as monocyclic disease as there is one generation of infection in a season.

Compound Interest Disease: Compound interest disease is also known as polycyclic disease. This is mathematically analogus to compound interest on money and characterised by multiple generations of spores being produced in a year.

Etiology- It is the study of the living, non-living and environmental causes of plant disease.

Pathogenesis- It is the study of the mechanism of disease development by pathogens and is concerned with the processes of infection and colonization of host by the pathogen.

Epidemiology- It is the study of the spreading of the pathogen within crop areas during the growing season. Epidemiology has a wide meaning and is concerned with the interaction of crop, pathogen and environment.

Control- It is the study of the development of suitable methods of controlling the disease and reducing the losses caused by them.

Antagonism- The inhibition of growth of one organism by the other which may be due to production of antibiotics, for competition for food etc.

Biotrophs- Certain organisms obtain their nutrition from living organisms only and complete their life cycle within the living tissues are called *biotrophs* e.g. rust, smut, powdery mildew causing fungi etc.

Elicitors- Chemical signals generated by an organism to bring about metabolic shifts in another organism. The term **elicitor** is applied in phytoalexin production.

Fungitoxic- Antifungal substance which are harmful for the growth of fungi are known as fungitoxic, e.g. fungicides.

Fungistatic- Fungistats are compounds which prevent growth of fungus as long as fungus and fungistat are in contact.

Hypersensitivity- The extreme degree of sensitivity of the host plant to the pathogen, resulting in the death of the host cells in the vicinity of the invading pathogen, thus blocking the advance of pathogen.

Inoculum- The part of a pathogen which enters the host cells and is capable of causing disease. For example, Inoculum in bacteria is the entire cell, in virus the entire particle and vegetative hyphae and spores in fungi.

Infection- The establishment of nutritional relationship between the host and pathogen is known as infection. When the pathogen spreads throughout the plant in varying degrees and is associated with all phases of its life cycle. It is known as systemic infection.

Invasion and colonization- After entering or infecting the host cells, the pathogen slowly begins to attach or *invade* neighboring host cells and begins to establish itself within the host tissue by rapid division. This is known as *colonisaton.*

Incubation- The interval of time between infection and appearance of disease symptoms is known as *incubation.* Incubation period varies with host pathogens and environmental conditions.

Immune- A plant which can resist or overcome disease infection is said to be *immune.*

Latent infection- The dormant state in which a host is infected with a pathogen but does not show any symptoms.

Lesion- It is a localised area of discoloured, diseased tissue.

Mosaic- It is a viral diseased leaves characterized by intermingled patches of normal green and light green or yellow colour.

Necrotic- The term refers to tissues which are dead and discoloured.

Non-infectious disease- Disease caused by an environmental factor and not by a pathogen. This disease can not be transmitted.

Parasite- Organisms that obtain their nutritional requirements from living plants (host) are called *parasites.* Parasites may be *obligate* if restricted to living tissues only and *facultative* if growing in living or dead tissue.

Pathogen and pathogenicity- Any organism, part or entire, which can infect another organism (host) disturbing the host's metabolism is known as *pathogen* and the ability of the pathogen to cause disease is known as *pathogenicity.*

Resistance- The extent to which a plant prevents the entry, invasion and colonization of a pathogen is a measure of the plant's *resistance.* A plant is said to be *immune* when it shows *high resistance* and *susceptible* when it shows *low resistance* to the **pathogen.**

Recognition System- The earliest time when molecules of the host cell recognise the molecules of the pathogen and accept it for establishment.

Saprophytes- Organisms which derive their nutrition from dead organic matter.

Suscept- A plant that can be attacked by a given pathogen i.e. the host plant.

Susceptibility – The inability of a plant to resist the effect of a pathogen.

Symptomless carrier- A plant which produces no obvious symptoms inspite of being infected with a pathogen (usually a virus).

Systemic- A pathogen or a chemical which spreads internally throughout the plant body.

Syndrome- The set of varying symptoms characterizing a disease is termed as *syndrome.* For instance a disease may be characterized by necrosis of tissues, wilting and hypertrophy. All these symptoms collectively known as syndrome.

Phyllosphere- This term refers to the total above ground surface of plant when viewed as a habitat for microorganisms.

Rhizosphere- The soil surrounding the plant roots when viewed as a habitat for microorganism.

Antagonism- Antagonism refers to the action of any organism that suppresses or interferes with the normal growth and activity of a plant pathogen, such as bacteria or fungi.

Competition- An interaction between organisms or species in which both the organisms or species are harmed. Competition may be intra specific (among the members of same species) or intrespecific (between the individual of different species)

SAQ 6.

a. Pathogen is a ……………..entity which causes disease.

b. ………………………increased mathematically similar to simple interest on money.

c. Mosaic is a ……………….disease symptom.

d. Necrotic means……………………..and discoloured tissue.

6.13 Summary

- Heinrich Antonde Bary is considered FATHER OF PLANT PATHOLOGY as well as founder of MODERN MYCOLOGY.
- . Sir Edwin John Butler is considered FATHER OF PLANT PATHOLOGY in India.
- Sir K C Mehta and R Prasada worked on epidemiology of cereal rust in India.
- T.S. Sadasivan established the school of mycology and plant pathology at Madras University and laid the foundation of research of soil brone pathogen in India.
- Prof. Millardet of Bordeaux discovered Bordeaux mixture which is a mixture of copper sulphate and lime. This mixture was used to control the mildew disease of grapevine.
- The discovery of tobacco mosaic virus by Meyer in 1886 was the birth of the study of virus as pathogenic agents.
- In the twentieth century major tends in the areas like Physiological plant pathology, Genetics of host and pathogen, Fungicides, Environment in relation to plant disease, Disease resistance in plants, Biochemistry and physiology of diseased state, Tissue culture in plant pathology as well as Ecological studies of phytopathogens.
- All pathogens are parasite but all parasites are not pathogen.
- The parasite which cause disease on the host are called pathogen.
- The potential capacity of infection of any pathogen is called its pathogenicity.
- The process of pathogensis has three phases: Prepenetration phase, penetration phase and post penetration phase.
- Symptoms of disease appears on the host surface after pathogenesis.
- Four criteria of Koch’s postulates are necessary in establishing relationship between a microbe and a disease (The pathogenicity Test)

- The diseases may be classified as Systemic and Localised, Epidemic or Epiphytotic, Sporadic, Pandemic, Soil Borne, Seed Borne and Air or Wind Borne.
- Host is the plant on which pathogen survives.
- Pathogen is a living organism which causes disease. Symptoms are external sign on the host plant which indicates disease.
- Symptoms are visible effects which pathogen induces on the host plant.
- Some fungal symptoms are due to external appearance of pathogen or some part of pathogen on the host, e.g. Mildew, Rust, Smut and Bunt, Sclerotia, white blister.
- Some fungal symptoms are visible effect on the host induced by pathogen e.g. Necrosis, Overgrowth and undergrowth.
- Local lesions, softrot, Canker and Scabs, Tumours, Galls and Vascular disease are bacterial symptoms.
- Leaf Curl, colour changes, Local lesions, Distortion, Ring spot, Outgrowth and Tumours and Colour break are viral symptoms.

6.14 Terminal Questions

Long Answer Questions:

1. Write a brief account of history of plant pathology.

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2. What is plant pathology? Discuss its progress achieved in twentieth centaury.

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3. Describe classification of plant Diseases.

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4. Write an essay on symptoms of various plant diseases produced by fungi.

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5. Write a brief account of various symptoms produced in plants by fungi, bacteria and virus.

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6. Describe various symptoms of diseases produced in plants by bacterial and viral pathogen.

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Differentiate Between:

a) Host and suscept

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……………………………………………………………………………………………
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b) Simple interest disease and compound interest disease.

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c) Non parasitic and parasitic disease.

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d) Primary inoculum and secondary inoculum.

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e) Fungitoxic and Fungistatic

……………………………………………………………………………………………
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Differentiate Between:

a) Powdery mildew and Downy Mildew

b) Rust and Smut

c) Loose smut and Covered smut

d) Hypertrophy and Hyperplasia.

Write Short Notes on:

a) Significance of plant pathology

b) Koch's postulates

c) Inoculum

d) Symptoms of bacterial diseases

e) Symptoms of viral diseases.

Define the following terms:

(a) Pathogenesis (b) Epidemiology

(c) Disease (d) Hypersensitivity

(e) Necrotic (f) Symptom

(g) Parasite (h) Saprophyte (i) Syndrome

6.15 Answers

SQA 1:

a) Millardet b) Heinrich Anton de Bary c) BB Mundkur

SQA 2:

a) Robert Koch b) whole c) parasitic d) all over

SAQ 3:

a) Puccinia graminis tritici b) Overy c) White rust

d) Late blight

SAQ 4:

a) Dead b) Agrobacterium tumefaciens c) Xanthomonas citri

SAQ 5:

a) Viral b) Tabacco virus I c) Yellowing

SQA 6:

a) living b) simple interest disease c) virald) dead

Unit7

Defence Mechanism in Host

Structure

7.1 Introduction

Stakman and Harrar (1957) stated that all plants have resistance to some pathogen under certain conditions. By active or passive processes, the host is capable of warding off the pathogen, thereby inhibiting or totally disrupting the hostparasite relationship. The capacity or ability of a plant to protect itself against the invasion or establishment of pathogen is known as defence mechanism of the plant. Plant defence mechanisms consist of a variety of preformed barriers like cell walls bark and cuticles. The barriers give to protecting the plant from pathogen invasion plants howe evolved different mechanisms for defence against and resistance to invading pathogens. such as bacteria, viruses and fungi in different patho system. Resistance to disease and development of defence mechanism is not the an exception but rather the rule in nature. The genetic constitution of a plant and the environmental conditions under which the genes operate determine the capacity or ability of a plant to defend itself against pathogen. The defence mechanism of plants may be categorized under two heads-

(i) Morphological or structural defence mechanism.

(ii) Biochemical defence mechanism.

Objective:

After studying this unit you will be able to know:

- About various defence mechanism present in host plant against pathogen.
- Morphological or structural defence mechanism present in host either before infection or after infection.

- About pre existing and induced biochemical defence mechanism.
- Plant bodies or immunization of plants.

7.2 Morphological or Structural Defence Mechanism

Certain structural features act as natural barriers for the entry of pathogens. Such morphological structures may be present before infection or may develop afterwards as a result of infection.

I. DEFENCE STRUCTURES PRESENT BEFORE INFECTION

The first line of defence in plant is their surface which includes quality of wax over the cuticle, thickness of cuticle, structure of the epidermal cell walls, size, shape and location of stomata and lenticels. These may be summarised as follows:

1. **Thick walled epidermis**- The thick and tough outer wall of the epidermis functions as a natural obstruction, but some times entry of the pathogens take place through the epidermis. Yoshii (1936) reported that the outer epidermal walls of rice plants are lignified and penetration of the rice blast fungus *Pyricularia oryzae* occurs through the thin walled pectinified motor cells, similarly resistance to pathogen inoculation is provided by the suberized cells as in potato.
2. **Cutin and wax depositions-** Martin (1964) emphisized the importance of cuticle as a defence mechanism against pathogens. The outer, non-cellular, membranous layer covering the epidermis consisting of cutin and waxes is one of the most effective physical and chemical barriers. The hydrophilic nature of wax acts as an excellent water repellent and prevents water retention by plant surfaces, a condition, negative for invasion by pathogen. For instance, infection in *Linum usitatissimum* by *Melampsora lini* and in coffee by *Colletotrichum coffianum* is checked by the heavily cutinised cuticle. Melander and Craigic (1927) reported that disease resistance of Berberry leaves to *Puccinia graminis* is due to the thick cuticularized epidermis.

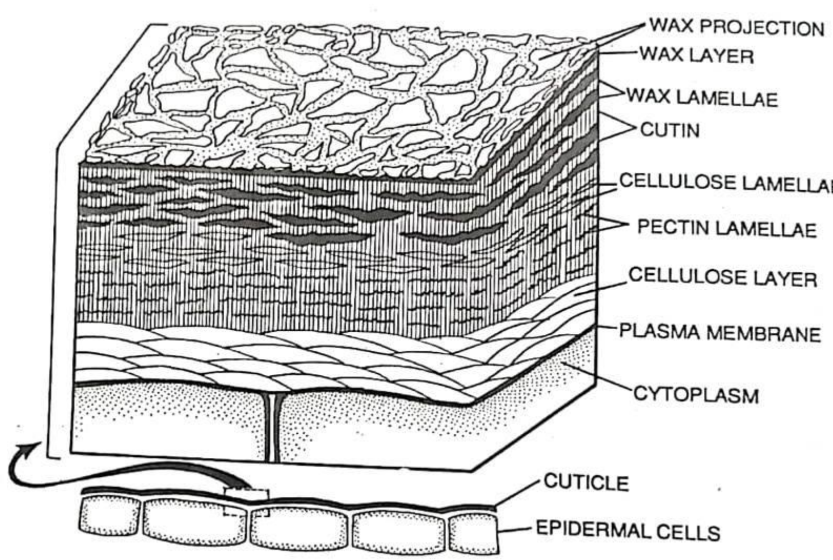

Fig 7.1 : The Epidermis, Cutin and Wax as defence structures.

3. Natural openings- Entry of pathogens into the host leaves is through the natural openings- the stomata. Resistance offered by natural openings may be of two types.

(i) ***Structural resistance***- The structural adaptations of stomata provide resistance to normal entry of pathogen, e.g. the orange variety, Szinkum is resistant to infection by *Xanthomonas citri* causing citrus canker disease due to its stomatal structure. The stomatal opening has a broad projecting cuticular ridge and a narrow slit leading to the stomatal cavity, so that the rain drops containing fungal spores and bacteria can rarely reach the leaf mesophyll.

(ii) ***Functional resistance-*** The resistance offered as a result of the stomatal functioning is known as functional resistance. In case of wheat varieties in which the stomata open late in the morning, Infection by *Puccinia graminis tritici* is checked because of the dessication of the germ tubes of the spore germination in the night dew, which evaporate before the stomata begin to open.

SAQ-1

1. Thick walled………………..defence plant against pathogen.
2. Cuticle layer covering epidermis act as …………………….. against pathogens.
3. ……………. acts as water repellent and defend host for invasion by pathogen.

II. DEFENCE STRUCTURES FORMED AFTER INFECTION

When pathogen manage to overcome the defence structures present before infection, the plants responds by forming some structures that help them to defend from further invasion by the pathogen. Such adaptive mechanisms can be summarised as follows:

1. **Formation of cork layers around infected area-** As a response to infection, three to four layered deep cork cells are produced by the host just below the infected area. These cork layers form an impervious zone that prevents the further spread pathogen as well as stops the flow of water and nutrients from the healthy parts to the infected areas, thereby killing the pathogen by starvation. Speedy formation of this *cork barrier* is of vital importance to check the diffusion of toxic substances from the diseased area of potato tubers, anthracnose disease of grapes and in *Prunus domestica* leaves, attacked by *Cocomyces prunophorae.*

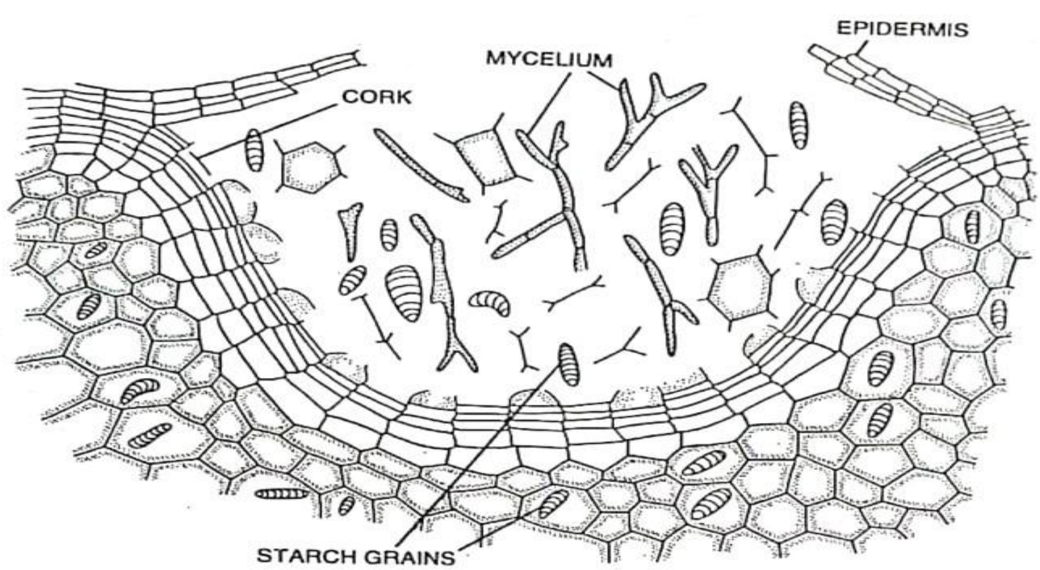

Fig 7.2 : Formation of Cork as defence structure.

2. **Formation of sheaths around fungal hyphae-** Hyphal penetration of the epidermal cells often stimulates the formation of sheaths, cell wall swellings and callus formation to check further invasion by the pathogen. The sheath may be of cellulose or granular nature and the pathogen usually outgrow such sheaths, hence their formation is of little significance.

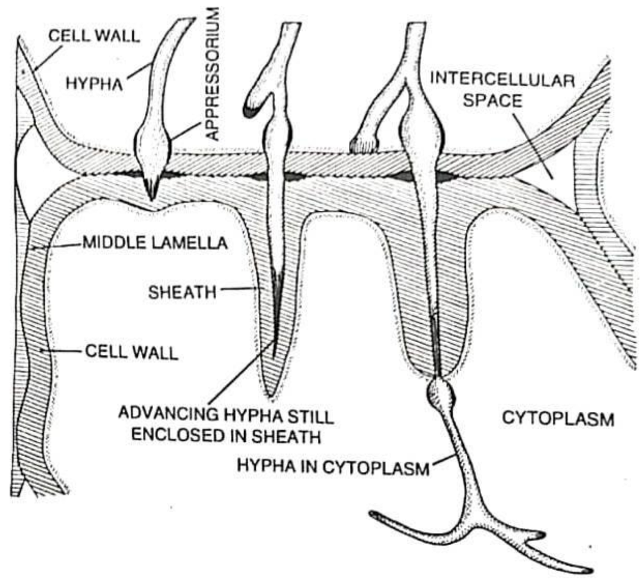

Fig 7.3 : Formation of sheaths around fungal hypha as defence structure.

3. **Formation of abscission layer-**In young leaves of stone fruits like cherry, peach etc, fungal, bacterial or viral infection causes the formation of abscission layers. Cells abjacent to the infected region become thin walled and the middle lamella (pectic materials) dissolves forming an abscission layer extending from the upper to the lower epidermis, causing the infected portion to fall out, e.g. *cladosporium carpophilum* causing shot hole disease of peach.

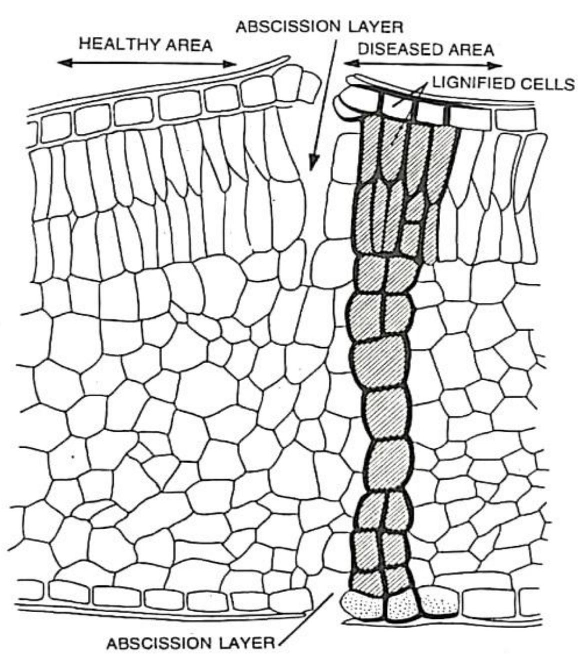

Fig 7.4 : Formation of abscission layer as defence structure.

4. **Formation of Tyloses-** Protoplasmic outgrowths formed by the neighbouring parenchymatous cells, which protrude into the lumen of the xylem vessels are known as tyloses. Toxic substances secreted by pathogens stimulate tyloses formation. The time and speed of formation of tyloses is an important factor in determining their effectiveness against pathogen spread, e.g. *Fusarium oxysporum* sp. *batatas* causing sweet potato wilt can be effectively checked by the abundant and early formation of tyloses.

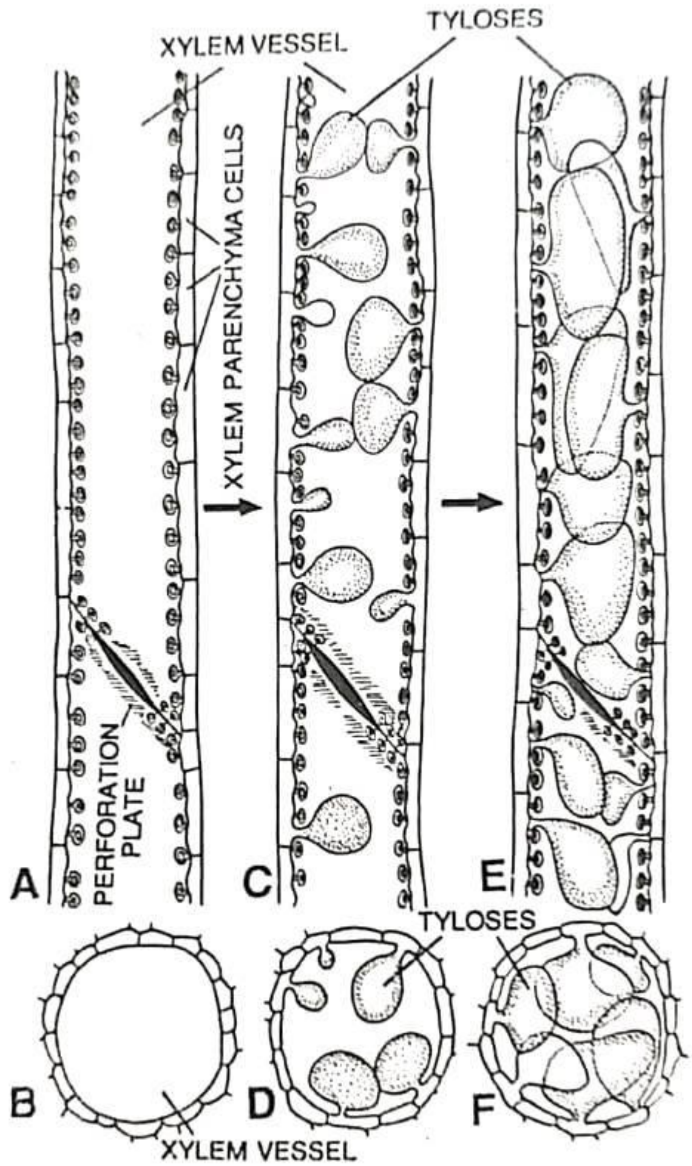

Fig 7.5 : Formation of Tyloses as defence structure.

5. **Formation of gum deposits-** Deposition and accumulation of gum in the intercellular spaces as a result of infection help in restricting the spread of the pathogen. Gum deposited along the margins of the infected spots act as a protective demarcation and offers mechanical resistance, e.g. an impenetrable gum barrier is formed in the *silver leaf disease* in plums caused by *Stereum purpureum* which prevents the spread of the disease. Similar formation of gum barriers in the diseased part of the apple twig infected with *Physalospora cydoniae* was reported by Hesler (1916).

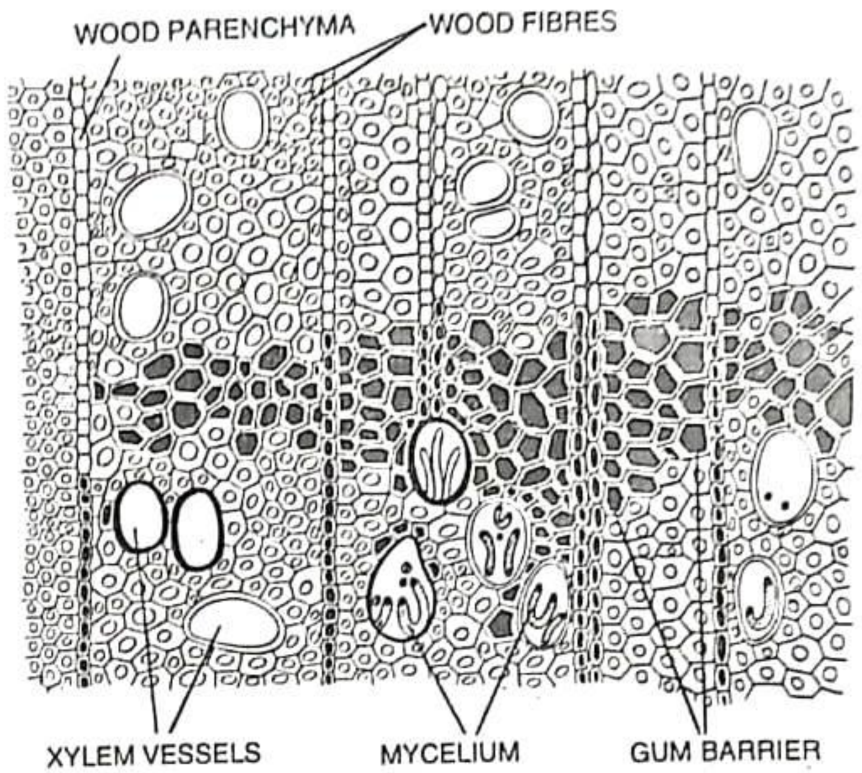

Fig 7.6 : Formation of gum deposits as defence structure.

SAQ-2

1. Cork layer is formed in host around .... area as defence mechanism.
2. …………………….layer is formed after infection to defend host against pathogen.
3. ………………produced in the lumen of xylem vessels are effective against wilt pathogens.
4. Deposition and accumulation of ………….in the intercellular spaces of host tissue restrict the present of pathogen.

7.3 Biochemical Defence Mechanism

Chemical substances present in the plant which check the growth and multiplication of the pathogen is known as biochemical defence mechanism. These substances may be present before infection or may be secreted by the host parasite interaction. Which is categorised as:

I. Pre existing Biochemical Defence Mechanism

II. Induced Biochemical Defence Mechanism

(I) Pre existing Biochemical Defence Mechanism

The chemical substances produced in plant cells before infection play an important role in defence mechanism. These are as follows:

1. **Defence through inhibitors released by the plant in the environment-**

   Root exudates offer excellent protection against infection. The resistant variety of flax secretes exudate, containing glucoside which is toxic for soil bacteria but not for

Trichoderma viride. T. viride produces a volatile antibiotic known as *trichodermin* which helps the resistant varieties of flax to resist 'wilt' caused by *Fusarium oxysporum f. sp. lini.* The blight resistant varieties of Cicer *arietinum* secrete malic acid on the leaves which inhibits spore gemination and retards the hyphal growth of the fungus.

2. **Defence through inhibitory substances present in the plant cells before infection-** Certain plants possess inhibitory compounds in their cells which resist infection by pathogen. In potato tubers, higher concentration of chlorogenic acid protects them from *potato scab* caused by *Streptomyces scabies.* Leaves and roots of oat contain a glucoside, *awenacin* which inhibits the growth of several fungi.

3. **Defence through phenolic substances present in the plant cells-** The presence of high concentrations of fungitoxic phenolic substances and their oxidation products and increased polyphenolicoxidase (PPO) activity, cause of resistance to plants against to fungal pathogen. Scott et al. (1957) reported that the resistance of barely plants to *Erysiphe graminis* is associated with phenol production, which accumulates around the haustoria of the pathogen and inhibits pathogen development. Some of the important phenolic compounds are **caffeic acid, ferulic acid, chlorogenic acid** and various **phytoalexins.**

   Polyphenoloxidase (PPO) activity is important because it can oxidize phenols to quinones which are more fungitoxic.

4. Defence through pH of the host cells- Many physiological processes in plants and pathogens are influenced by the pH of the plant tissues such as enzymatic activities and resistance of pH sensitive pathogens. Gardner and Vendrick (1921) reported that the resistance of ripe tomatoes to *Xanthomonas vesicatoria* may be attributed to the pH (pH=4—4.5).

5. Defence through permeability effects and osmotic pressure- Intercellular diffusion of water is governed by osmotic pressure and it has been observed that the cell sap of the pathogen have a higher osmotic pressure than the host cells, thus facilitating movement of water from cells of the host to the pathogen. Cells of resistant varieties of lettuce have a higher osmotic pressure than the cells of the susceptible varieties to infection by *Erysiphe cichoracearum* causing lettuce mildew.

Permeability of cell wall is an important factor influencing water movement from host cells to the cells of the pathogen (wheeler and Hackey, 1968)

6. **Defence through absence of nutrients essential for pathogen growth-** The growth and successful parasitism of the pathogen depends upon the availability of amino acids, proteins, vitamins and enzyme systems. If the host tissue fails to supply any of these nutrients, spread of the pathogen will be checked. Mutant forms of *Venturia inaequalis* deficient in choline and riboflavin were unable to cause scab disease unless these substances were supplied artificially.

Ressistance to infection is linked with nutritional factores as well as concentratrion of nutrients in the host tissues. Horsfall and Dimond observed that high suger content of the host tissue favoures the growth of certain rusts and powdery mildews whereas low sugar content favours early blight of potato (*Alternoria solani*) and Dutch elm disease (*Coratostomellalmi*).

SAQ-3

1. Certain plants possess ………………. ………………..in their cells which resist infection by pathogen.

2. …………….. substances present in the host cells defend them against pathogen.

3. ……..of the plant tissues defend them against pathogen.

4. …………………of nutrients essential for pathogen growth play their role in defence ……………….

(II) Induced Biochemical Defence Mechanism

This kind of defence mechanism involves the production of chemical substances in response to pathogen attack. These substances may either have toxic effect on pathogen or may counter act the effect of pathogen toxins. These are as follows:

1. **Defence through synthesis of Phytoalexins-** Humans and animals are known to be immune to certain viral disease but virus infected plant usually die. Wingward (1928) for the first time observed that plants infected with tobacco ring-spot disease were capable of recovery and acquired immunity to the disease. Later in 1940, Wallace gave evidence that tobacco plants infected with sugar-beet-curly-top disease produced certain protective substances which helped the infected plants to recover. This was followed by the startling discovery of a compound **phytoalexins** in *Phytophthora* infected potato tubers. The term phytoalexin coined by Muller and Borger is derived from the words phyton=plant and alexin=warding off compound. Phytoalexins are antibiotics produced as result of host parasite metabolic interaction and inhibit the growth of micro-organisms, insects or nematodes. The biological steps leading to phytoalexin synthesis was given by Cruickshank (1966).

Host plant surface+water

↓

Diffusion of host nutrients

↓

Host lechate+fungal spores

↓

Germination and growth of fungus

↓

Mycoantigen+viable host cell

↓

Stimulation of intermediary host metabolism

↓

Phytoalexin

The phytoalexin theory, proposed by Cruickshank, is as follows:

1. Synthesis of phytoalexin takes place only when host cells comes in contact with the parasite.
2. The speed of phytoalexin formation decides the resistance or susceptibility of the pathogen.
3. They are antifungal compounds with a wide spectrum.
4. Phytoalexin synthesis influenced by factors such as inoculums concentration, age of the host, temperature and aeration.
5. Phytoalexins are incapable of translocation from one site to another and are confined to the tissue colonized by the fungus.

6. They are non-specific in their toxicity towards fungi.

   A number of phytoalexin compounds identified in plants are Ipomeamarone, Pisatin, Phaseolin, Trifolirhizin, Orchinol, Isocoumarin, Gossypol etc.

2. **Defence through substrate formation resisting the enzymes of the pathogen-** As a response to the enzymes secreted by the pathogen, the host produces certain chemical substances which increase the resitance of the host, to the pathogen. Green unripe apples are more resistant to infection by several fungi than ripe apples due to the presence of pectin proteinpolyvalent cation complex present in them and which resists hydrolysis by fungal hydrolytic enzymes.

3. **Defence through induced synthesis of proteins and enzymes-** An important factor of disease resistance is the synthesis of protein and enzymes induced by pathogen infection. Dease and Stahmann reported that pectic enzyme formation by *Fusarium* was greatly reduced when the pathogen were grown on tissues from resistant varieties as compared to that from susceptible varieties. Peroxidase activity has been reported to be greatly increased in incompatible host parasite relationship as compared to compatible ones.

4. **Defence through change in rate of respiration-** It has been suggested that increased respiration is necessary for development of disease resistance in the host plant. Hypersensitive defence reactions are accompanied by increased oxygen uptake as well as accumulation and oxidation of phenolic compounds, thereby indicating that substances inhibiting respiration also decrease resistance power in host plants.

5. **Defence through detoxification of pathogen toxin-** Pathogen secrete substances that are toxic for the growth of the plant. Resistant varieties of the host in turn produce chemical substances which act as detoxicants and inhibit the toxic effect of the pathogen. Fusaric acid produced by *Fusarium* infecting cotton and tomato plants, is detoxified and converted to a non-toxic compound N-methyl fusaric acid amide. Mori (1962) observed that resistant varieties of pear contain more dehydroascorbic acid and ascorbic acid oxidase than the susceptible varieties and these were responsible for inhibiting the toxin produced by *Alternaria kikuchiana.*

6. **Defence through hypersensitive reaction-** A significant and common form of defence reaction occurring only in incompatible host parasite combination is the hypersensitive reaction. As soon as the pathogen comes in physiological contact with the hypersensitive host, the neighbouring cells collapse and the pathogen is isolated from the host cells. Hypersensitivity reaction is an interesting case of extreme resistance being accomplished by extreme susceptibility. The size of the lesions formed as a result of collapsing of the host cells depends upon the degree of resistance of the host.

Hypersensitive reaction is caused by imbalance between the oxidative and reductive processes in the cells. Rapid accumulation of phenols in the infected cells occur and these are oxidized to toxic quinines by polyphenol oxidase and peroxidase enzymes.

7. **Defence through tolerance to disease-** Cobb (1984) observed that wheat plants, heavily infected by rust (*Puccinia graminis*) produced fairly good crops thereby proving that disease does not always result in damage. Such plants which yield economically important produce, inspite of heavy infection, are said to be ‘tolerance’ to the disease. Tolerance is exhibited when the symptoms of the disease appear on the parts which are not economically important. In rusts, the symptoms (pustules) appear on the leaf and stem but the grains remain unaffected, but in case of smuts the infection symptoms appear on the grain, hence economically the host is damaged. Tolerance, like other forms of resistance is a relative phenomena and differs from plant to plant.

SAQ-4

1. ………………are synthesized in resistant host after infection as .... mechanism.
2. In resistant host synthesis of ……………… and enzymes is induced by pathogen infection.
3. As the pathogen comes in physiological contact with the hyper sensitive host, …………. reaction defend host against pathogen

7.4 Plant bodies (Immunization of plants)

Plants do not produce antibodies therefore, do not have an immune system like animals and humans. Plant bodies produce antibodies by genetically modified plants.

Genetically- Engineered disease- Resistant plants

Disease- resistant transgenic plants can be developed by genetic engineering.

For example genes that encode proteins capable of breaking down mycotoxins or inhibiting the activity of cell- wall degrading enzyme can be introduced into plants. Plants can be engineered synthesize and secrete antimicrobial colonization. Essential defence hub regulatory genes can be reprogrammed to fine time defence responses.

The transgenic plants may have either plant derived gene or pathogen derived genes.

- **Plant- derived gene**

The first plant R gene was Hml which was isolated from corn in 1992. This gene codes for an enzyme that detoxifies the HC-toxin produced by *Cochliobolus carbonum*. The R genes are used extensively genetically engineered transgenic plants. For example tobacco plants transformed with a chitinase gene from bean became resistant to *Rhizoctonia solani*. Transgenic tobacco plants expressing a PRI protein gene were resistant to blue mold fungus *Pernospora tabacina.*

- **Pathogen-derived gene**

Plant virus causes many important disease and are responsible for huge losses in crop production and crop quality in all parts of the world. Therefore the concept of pathogen-derived resistance has stimulated research on obtaining virus resistance through genetic engineering which protects plant from diseases. For example. When coat protein gene of TMV was introduced into tobacco plant by genetic engineering, the transgenic plant express the coat protein gene of TMV showed resistance to subsequent infection with the same virus. Similarly a number of crop plants like tomato, pepper, alfalfa, barley, corn, oat, rice, cucumber, papaya etc. were transformed with the coat protein gene of ,one or more viruses that infect them. In most resistance, transgenic plants show high level of resistance to the virus from which coat protein gene was derived.

Thus genetic engineering inhanced disease resistance in plant and play their role in defence mechanism. It provides an excellent additional tool for the control of plant diseases.

SAQ-5

1. …………………..are antibodies produced by genetically modified plants.
2. The transgenic plants may have either …….. derived gene or pathogen derived gene.

7.5 Summary

- The defence mechanism of plants may be categorized under two heads- (i) Morphological or structural defence mechanism. (ii)Biochemical defence mechanism.
- Certain structural features act as natural barriers for the entry of pathogens. Such morphological structures may be present before infection or may develop afterwards as a result of infection.
- The defence structures present before infection can be summarised as:, thick walled epidermts, Cutin and wax deposition, Natural openings
- the defence structures formed after infection can be summarised as: formation of cork layers around infected area, formation of sheaths around fungal hyphae, formation of abscission layer, formation of Tyloses, formation of gum deposits.
- Chemical substances present in the plant which check the growth and multiplication of the pathogen is known as biochemical defence mechanism. These substances may be present before infection or may be secreted by the host parasite interaction. Which is categorised as: (i) Pre-existing Biochemical Defence Mechanism (ii) Induced Biochemical Defence Mechanism
- Pre-existing Biochemical Defence Mechanism may be, through inhibitors released by plant in the environment, through inhibitory substances present in the plant cells before infection, through pH of the host cells, through permeability effects and osmotic pressure, through absence of nutrients essential for pathogen growth
- Induced Biochemical Defence Mechanism may be through synthesis of Phytoalexins, through substrate formation resisting the enzymes of the pathogen, through induced synthesis of proteins and enzymes, through change in rate of respiration, through detoxification of pathogen toxin, through hypersensitive reaction, through tolerance to disease
- Plants do not produce antibodies therefore, do not have an immune system like animals and humans. Plant bodies are antibodies produced by genetically modified plants
- Disease resistant transgenic plants can be developed by genetic engineering. The transgenic plants may have either plant derived gene or pathogen derived genes.

7.6 Terminal Questions

1. Write a brief account of different types of defence mechanism in plants to protect them from disease.

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2. Give an account of various structural defence mechanism present in plant.

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Describe pre existing and induced bio-chemical defence mechanism in plants to protect them from diseases.

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Write short notes on:

1. Defence structures present before infection

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2. Defence structures formed after infection.

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3. Pre existing Biochemical defence mechanism

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4. Induced Biochemical defence mechanism

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5. Phytoalexins

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7.7 Answers

SAQ-1

(1) Epidermis (2) defence mechanism (3) wax

SAQ-2

(1) infected area (2) Abscission (3) Tyloses (4) gum

SAQ- 3

(1) Inhibitory compounds (2) phenolic (3) pH (4) absence, mechanism

SAQ-4

(1) Phytoalexins, defence (2) protein (3) hypersensitive

SAQ-5

(1) Plant bodies (2) plant, pathogen

Unit8

Dissemination of Plant Pathogen

Structure

8.1 Introduction

The development of disease is a dynamic interrelated process between the pathogen, host, environment and time. In the presence of the pathogen and the host, the environment plays important and decisive role. Some diseases are prevalent in certain areas and their appearance is restricted to specific time of the year, although all pathogens, all perennials and many annual plants are present, in the field throughout the year. Hence, becomes imperative to conditions decide the host pathogen interaction and appearance of disease.

The environment is a dynamic, everchanging sum total of the interaction of all the variables operating in nature. The plants with their roots embedded deep into the soil and the shoot system above the ground, encounter two kinds of environment influences root-linked diseases while diseases that initiate in the leaves or stem (aerial) are affected by the climate factors.

The various environmental factors affect disease development in multifarious ways. The survival of the pathogen from one crop season to another, dispersal and germination of inoculum, the growth and vigour of the host plant and the resistance of the host are all environment dependent. Even after establishment of the inoculum, sudden change in the environment may retard or stop the disease process.

Dissemination or dispersal or transmission is the transport of spores or infectious bodies acting as inoculums, from one host to another host at various distances resulting in the spread of the disease. If displacement occurs on a susceptible host and environmental conditions are suitable, the pathogen grows and multiply. This is called effective dispersal. When the plant pathogen does not get any medium for it’s survival it is called ineffective dissemination. The pathogen disseminate for food, nutrition, survival and to complete their life cycle.

Objectives:-

After studying this unit you will be able to know:

- How temperature, moisture, wind and light affects dissemination of pathogen.
- That O_2 and CO_2 concertation affects dissemination of pathogen.

- Role of Host plant nutrition and herbicides on diseases development.
- How plant pathogen disseminates in nature.

8.2 Environmental factors which affects disease development

The environmental factors which affect development of infectious, plant disease can broadly be classified into following groups:

Temperature, moisture, wind, Light, soil pH, O_2 and CO_2 concentration, host-plant nutrition and herbicides of the environment are factors which affects disease development-

1. **Temperature-** Different pathogen have different temperature requirements for growths, sporulation and infection and greatly differ in the their choice of low or high temperatures. For instance, some species of *Fusarium and Typhula* grow well in low temperatures. *Phytophthora infestans* is active only during winter, where as fusarial wilts and *Phymatotrichum* root rots prefer warmer regions, the effect of temperature on the development of a particular disease after infection depends upon the host pathogen relationship. For stem rust of wheat (*Puccinia graminis tritici*) the complete cycle from inoculation with uredospores to new uredospores formation takes about 22 days at 5^0C, 15 days at 10^0C and 5-6 days at 23^0C. If the minimum, optimum and maximum temperature requirements for the pathogen, the host and the disease are same, the effect of temperature on disease development is affected. Temperature determines seasonal appearance of symptom in various viral diseases.

   Most viral diseases are virulent when the temperature ranges between 200C- 250C. These include the tobacco mosaic virus, potato mosaic virus, cabbage virus, potato yellow dwarf etc.

2. **Moisture-** The most important influence of moisture is on the germination of fungal spores and on penetration of host by pathogen germ-tube. The various bacterial, fungal and nematodal pathogens are also activated by moisture. The distribution and dispersal of many pathogen on the same plant or from one plant to another is affected by splashing rain and running water. The succulence of host tissues increases by moisture effect, thus facilitating penetration by inoculum.

   The occurrence of many diseases is closely correlated with the amount and distribution of rainfall within a year. Regions with high rain fall or high humidity during and growing season has high incidence of disease such as late blight of potatoes, apple scab, downy mildew etc, most of the pathogens require humid conditions only during the spore germination, whereas a few like late blight of potatoes and downy mildew require high humidity for their development. But powdery mildew can develop in the driest of climate, probably due 70% of water contained in the spores.

   Soil moisture does not have the same controlling effect on the development of diseases as soil temperature has, but a number of soil characteristics combine and tend to create a microclimate which influences the disease course.

   A continuous film of water is essential for bacterial pathogens to develop, viral infections are, however, inhibited by ions, mainly phosphate ions, which are necessary for blinding the virus particles to their inoculum sites.

3. **Wind-** The dispersal of infectious spores of pathogens depends mainly on the wind factor. Wind also helps in speedy drying of wet plant surfaces and facilitates inoculation. A strong wind helps in releasing the fungal spores and bacteria from the infected regions and disperses

them through air to be deposited on a fresh plant. e.g. uredospores of rusts and conidia of *Albugo* are dispersed by wind action. The plant of leaf surface may be injured by strong wind action, thus exposing them to viral, bacterial and fungal infection.

4. **Light-** The virulence of pathogen is not significantly affected by light. Light deficiency adversely affects the vigour of plants and makes them more susceptible to disease. Fungal diseases like root rots, cankers and leaf spots are favoured by low light intensities. The germination of rusts is much greater in light than in darkness. Powdery mildews though more prevalent in shady habitats, germinate better in strong light.

   In case f viral infections, if the plants are kept in darkness, just after inoculation, the number of lesions increases. Bawden and Roberts (1947) observed that keeping the plants in shade increases the fragility of the leaves thereby making them more susceptible to infection, They proposed that some photosynthetic product formed in the presence of light may be inhibiting infection. Later Wiltshire (1956) confirmed this observation and reported that light treatments in the absence of carban di oxide (photosynthesis checked) increased the susceptibility of plants to infection.

   Dark treated plants caused reduction in carbohydrate level and nitrate nitrogen and this may somehow be related to the increase in susceptibility of the plants.

5. **Soil pH-** Soil borne diseases are greatly influenced by the pH of the soil. The growth and reproduction of some pathogens and disease development is affected by soil reaction (acidic or alkaline) directly or indirectly by influencing certain biological and chemical processes in the soil. The biological balance between plant parasites, host plant and soil microfloara may be affected by soil pH. The soil pH greatly influences the uptake of catonic plant nutrients. In acidic soils potassium uptake is reduced whereas alkaline soils produce negative effect in the uptake of calcium, manganese and boron.

   The pH requirement of pathogens varies widely and this character is exploited to control pH sensitive diseases. For instance *club root of cabbage* (*Plasmodiophora brassicae*) is favoured at pH 5.7 and decreases with increase in pH (5.7-6.2) therefore adding lime to the soil and increasing the soil pH helps to control the disease.

   On the other hand *scab of potatoes*(Caused by *Streptomyces scabies*) develops significantly between pH 5.2 and 8.0. The disease can be successfully controlled by acidifying the soil with sulphur or sulphuric acid.

   However, pathogen which have a wide range of pH sensitivity e.g *Fusarium* can not be controlled by this method.

6. **Oxygen and Carban dioxide concentration-** The balance between O_2 ad CO_2 in soil is highly variable and affecting the development of root diseases. Free O_2 of soil influences the activity of microorganisms, growth of plant roots, nutrient uptake and other biochemical activities in soil. Pathogen differ in O_2 requirement for their growth and reproduction. For the development of soil diseases the increased concentration of CO_2 inhibits growth of *Rhizoctonia solani, Sclerotia minor, Fusarium culmorum* pathogen in soil.

SAQ-1.

1. Different pathogen have different ……………………………requirement for growth, sporulation and infection.
2. The most important influence of moisture is on the ………………. of fungalspore.
3. The uredospores of rusts are …………………………by wind.

4. Deficiency of light affects the ……………..vigour of plants and make them more …………………….to disease.
5. ……………………………..disease are greatly in fluenced by the pH of the soil.
6. The balance between ……………….. and ………………….. in soil affects the development of root diseases.

7. **Host plant Nutrition-** Nutrition affects plants to defend themselves against diseases. Excess nitrogen delay maturity of host and make them more susceptible to pathogen eg. Excess of nitrogen delay maturity of host and make them more susceptible to pathogen e.g. excess of nitrogen increases susceptibility of wheat to rust (Puccinia) and powdery mildew (*Erysiphae*) etc. other elements such as phosphorus, potassium, calcium and micronutrients also have similar effects on disease development. Plants receiving balanced nutrients are more capable to defend themselves from new infection.

   Potassium reduces severity of diseases of barley. Potassium reduces severity of many diseases like rust of wheat, early blight of potato. Calcium reduces, the severity of many diseases caused by pathogen like *Rhizoctonia, Fusarium, Botrytis* etc. Similarly manganese reduces potato scab, late blight of potato etc. diseases. The application of molybdenum reduces late blight diseases of potato.
8. **Herbicides-** Herbicides increases the severity of some diseases on one hand for example *Fusarium* wilt of cotton and tomato and *Sclerotium* stem rot of various crops decreases severity of some diseases and on the other hand for example *phytophthora* collar rot to various crops.

SAQ-2

1. ………………….affects plants to defend themselves against …………………………………….
2. ………………………………….makes the host more …………………………to pathogen.
3. Herbicides decreases severity of …………………………..collor rot.

8.3 Dissemination of plant pathogen

Transport of inoculums from one host to another at various distances results in the spread of disease. This is called dissemination, dispersal or transmission of plant pathogen. The plant pathogens disseminate in two ways:

I. Direct transmission or Active dispersal

II. Indirect transmission or Passive dispersal

8.4 Direct transmission or Active Dispersal

If the pathogen is transmitted with seeds or any other vegetative part of the plant is known as direct transmission or active dispersal. It occurs as germinative vegetative and adherent transmission in following way:

(i) **Germinative Transmission:**

The pathogens are transmitted along with the seeds or propagule in the specific parts of the seeds such as endosperm and embryo. It remain viable and dormant inside the seed for several years. These seeds apparently look healthy. They get mixed with healthy seeds during harvesting of the crop and sown in the field. Then pathogen of disease is disseminated along with seeds. The pathogen of loose smut of wheat and barley are example of germinative transmission .

(ii) Vegetative Transmission:

The pathogens are also transmitted through the vegetative parts of the plant used as a seed such as tuber, bulb, rhizome, cutting of the plant etc. The infected vegetative parts disseminate pathogen e.g. *Phytopthora infestens* causes late blight diseases in potato. This disease is transmitted through infected tubers used as a seed for sowing. Similarly other pathogens like *Ustilago scitaminae* causal organism of whip smut of sugarcane diseases and *Collatotrichum fulcatum* causal organism of red rot of sugar cane are transmitted through infected cane sets used as a seed.

(iii) Adherent Transmission:

The pathogens are carried over the surface of seeds or vegetative part of the plant used as seed. The sclerotia of ergot diseases, smut spores, bacterial cells get lodged on the surface of seed coat and transmitted to a long distance. For example *Telletia foetida* pathogen of bunt of wheat disease, *Ustilago hordei* pathogen of covered smut of barley and spp of *Cleviceps* pathogen of ergot diseases are transmitted over the surface of seed.

SAQ 3.

a. Transmission of pathogen with seeds and vegetative parts of the plant is ………………………

b. In germinative transmission pathogen establish themselves in the …………………. and ……………….. of the seed.

c. The pathogen of late blight of potato is transmitted through infected ……………

d. Pathogen of covered smut of barley is an example of ………………..

8.5 Indirect transmission or Passive dispersal

Transmission of pathogen occurs through some other agency like it may be autonomous by wind, by water, by insects, mites and nematodes, by cattle and birds and by man. The indirect transmission occurs in following way:

(i) Autonomous Transmission:

Autonomous transmission of pathogen has been discussed by Muskett in 1960. In this the dispersal of pathogen take place independently without involvement of any external agency. Diseases spread to short distance by this method. For example *Fusarium* the pathogen of wilt diseases is transmitted independently. Such infection occurs usually through roots of the plant and disease spreads from plant to plant in the same fields or from field to field in the same locality.

(ii) Transmission by Wind:

It is the most common method of transmission of plant pathogens and termed as anemochory. The pathogens of wind borne diseases like fungi and bacteria are transmitted by wind or air. Fungal pathogen disseminated by wind have some special qualities like they are produced in large number, light in weight, very small in size and discharged with sufficient force. The uredospores of *Puccinia graministritici* has been trapped in the air by means of aerospores and transmitted to very large distance through wind. They can move as high as 14,000ft above the infected grain field and travel as long as 600km distance without causing infection to other grain field. The pathogens of powdery mildew, downy mildew and smut are also disseminated by wind. The effect of air current on dispersal of spores are complex and varied. The irregular air movements are often more effective in bringing about multidirectional spread of pathogen than the strong sturdy winds.

(iii) **Transmission by water:**

Water as an dissemination or transmission agent is less important as compared to air but is an important agent of local dissemination. The plant pathogens are disseminated by water in two ways – (1) as a medium in which actively motile organisms or spores may swim about and (2) by the mechanical action of run off rain; the flowing of irrigation water or by the stream flow. The surface flow of water, heavy rain or irrigation water carry pathogen to short distances. The wilt fungus *Fusarium* and blight fungus *Phytopthora infestens* are disseminated by surface flow of water.

Splashing drops of rain and dew also help in short distance transmission. The rain drops falling on infected plant part may splash pathogen propagules in small droplets which lands on neighbouring healthy susceptible host or may be carried to long distances by air currents eg. *Xanthomonas* pathogen of black rot of crucifer. The spread of infections in red rot of sugarcane caused by *Collato- trichumfalcatum* and the dissemination of sclerotial bodies of *Sclerotium rolfsii* through soil are mainly by irrigation water.

(iv) Transmission by insect, mites and nematodes:

Insects, mites and nematodes also serve as important means of transmission of plant pathogens either on or within their bodies. They are most effective in case where pathogen produces sugary and sticky substances. Honey dew stage of ergot of bajra attracts insects and conidia of pathogen get smeared on their body parts. The same insect when visits the flowers of other healthy plant causes dispersal of pathogens. The most common and important means of transmission of virus in the field is by insect vectors like aphids, white flies, leaf hoppers, the mealy bugs and tree hoppers. The insect vectors suck the sap from the diseased plants so that the viruses reach to their mouth parts. When such insects suck the sap from the healthy plants viruses are transmitted into them. Some plant viruses multiply also within the body of insect vectors. Thus the infectivity of vectors passes from generation to generations. Some viral bacterial and fungal pathogens are transmitted by nematodes. For example yellow ear rot of wheat caused by *Corynebacterium tritici* is transmitted by the ear cockle nematode.

(v) Transmission by Cattle and Birds:

Cattle and birds carry the pathogens either on their bodies or within their bodies. They ingest the viable fungul propagule into their intestine through contaminated fodder. The propagule pass out as such into the dung which is used as manure. when such dung is applied in the field it act as a source of inoculums and transmit the pathogen. For example pathogens of potato scab and potato wart diseases are transmitted by manures from the dungs of horses and cows fed on diseased tubers. Some times the spores of certain pathogenic fungi mingled with the soil may be carried from contaminated fields to diseases free fields on the feet of domestic animals e.g. potato wart, club root of cabbage and onion mildew. The smut fungi are carried from field to field through alimentary canal of farm animals.

(vi) Transmission by Man:

Man also play important role in the transmission of pathogen by his usual agricultural practices. Seeds are imported and exported. During this practice some times infected seeds many also get transmitted and thus pathogens move from one country to another. Plantation of contaminated tubers, bulbs, rhizome, bulbils etc. also helps in dispersal of pathogen. Usual farming practices such as weeding and pruning also helps in dispersal of pathogens. The workers working in the field carry the pathogen from plant to plant from field to field through their clothes, shoes, hands etc. Pathogens are also transmitted by sticking to the agricultural implements. Thus man is an agent of transportation of pathogens from continent to continent, from country to country and even from plant to plant on his own farm. In this way he repeatedly carried pathogens to the area which was initially free from pathogen.

(Table-1)

Example of some plant diseases introduced in India from other countries

Disease	Original home
Leaf rust of coffee caused by *Hemileia vastatrix*	Sri Lanka
Late blight of potato caused by *Phytophthora infestans*	England
Flag smut of wheat caused by *Urocystis tritici*	Australia
Downy mildew of grapes caused by *Plasmopara viticola*	Europe
Downy mildew of cucurbits caused by *Erysiphe cichoracearum*	Sri Lanka
Downy mildew of maize caused by *Sclerospora phillipinensis*	Jawa
Black rot of crucifers caused by *Xanthomonas campestris*	Jawa
Powdery mildew of rubber caused by *Oidium hevea*	Malaya
Black shank of tobacco caused by *Phytophthora nicotianae*	Holland
Crowngall of apples and pears caused by *Agrobacterium tumefaciens*	
Bunchy top of banana (viral)	Sri Lanka
Hairy root of apple (viral) **Bacterial leaf streak of chillies**	England

Onion smut caused by ***Urocystis eepulae***	Europe
Bacterial blight of paddy caused by ***Xanthomonas oryzae***	Philippines
Golden nematode of potato caused by ***Heterodera rostochiensis***	Europe

SAQ-4

1. In ……………………… ………………………… disease spread to short distance.
2. Transmission of pathogen wind is termed as ……………………………………
3. The surface flow of water, heavy rain or irrigation water carry pathogen to …………………………distance.
4. Cattle and birds carry the pathogens either ………………… their bodies or ……………………… their bodies.
5. The ……………………… is an agent of transportation of pathogens by his usual …………………………… practices.

8.6 Summary

- The development of disease is a dynamic interrelated process between the pathogen, host, environment and time.
- The environment is a dynamic, ever-changing sum total of the interaction of all the variables operating in nature.
- The various environmental factors affect disease development in multifarious ways.
- Temperature, moisture, wind, Light, soil pH, O_2 and CO_2 concentration, host-plant nutrition and herbicides of the environment are factors which affects disease development-
- Different pathogen have different temperature requirements for growth, sporulation and infection and greatly differ in the their choice of low or high temperatures.
- The most important influence of moisture is on the germination of fungal spores and on penetration of host by pathogen germ-tube.
- The occurrence of many diseases is closely correlated with the amount and distribution of rainfall within a year.
- The dispersal of infectious spores of pathogens depends mainly on the wind factor. Wind also helps in speedy drying of wet plant surfaces and facilitates inoculation.
- Light deficiency adversely affects the vigour of plants and makes them more susceptible to disease.
- Soil borne diseases are greatly influenced by the pH of the soil.
- The biological balance between plant parasites, host plant and soil microfloara may be affected by soil pH.
- The balance between O_2 ad CO_2 in soil is highly variable and affecting the development of root diseases.

- Nutrition affects plants to defend themselves against diseases. Excess of nitrogen delay, maturity of host and make them more susceptible to pathogen
- Transport of inoculums from one host to another at various distances results in the spread of disease. This is called dissemination, dispersal or transmission of plant pathogen.
- Dissemination of plant pathogens occurs in two ways: (1) Direct transmission or Active dispersal (2) Indirect transmission or Passive dispersal
- Direct transmission may be germinative, vegetative or adherent.
- The pathogens are transmitted along with the seeds or propagule in the specific parts of the seeds such as endosperm and embryo.
- The pathogens are also transmitted through the vegetative parts of the plant used as a seed such as tuber, bulb, rhizome, cutting of the plant etc.
- The pathogens are carried over the surface of seeds or vegetative part of the plant used as seed.
- Indirect transmission may be autonomous or by wind, water, insects, mites, nematodes, cattle, birds and man.
- In Autonomous transmission, dispersal of pathogen take place independently without involvement of any external agency.
- The pathogens of wind borne diseases like fungi and bacteria are transmitted by wind or air.
- The plant pathogens are disseminated by water in two ways – (1) as a medium in which actively motile organisms or spores may swim about and (2) by the mechanical action of run off rain; the flowing of irrigation water or by the stream flow.
- Insects, mites and nematodes also serve as important means of transmission of plant pathogens either on or within their bodies
- Cattle and birds carry the pathogens either on their bodies or within their bodies.
- Man play on important role in the transmission of pathogen by his usual agricultural practices.

8.7 Terminal Questions

1. Describe dissemination of plant pathogen.

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2. Discuss direct and indirect dissemination of plant pathogen.

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3. Discuss environmental factors which affects disease development in plants.

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4. Write short notes on:

(i) Direct transmission

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(ii) Indirect transmission

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Role of temperature and moisture in disease development.

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(iii) Role of wind and light in disease development.

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(iv) Role of pH, CO_2 and O_2 concentration in disease development.

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8.8 Answers

SAQ-1

(1) Temperature (2) germination (3) disseminated (4) vigour, susceptible

(5) soil borne (6) oxygen , carbondioxide

SAQ-2

(1) Nutrition, diseases (2) Excess of nitrogen , susceptible (3) phytophthora

SAQ 3.

(a) Epidemology or epiphytology (b) plants (c) epidemic (d) susceptible host, virulent pathogen, favourable

SAQ-4

(1) Autonomous transmission (2) anemochory (3) short (4) on, within (5) man, agricultural

Unit9

Epidemiology and Disease Forecasting

Structure

9.1 Introduction

The word epidemiology comes from the Greek word epi, meaning on or upon, demos, meaning people and logos, meaning the study of.... By definition, epidemiology is the study (scientific, systematic, and data-driven) of the distribution (frequency, pattern) and determinants (caused, risk factors) of health-related states and events (not just diseases) in specified populations (neighborhood school, city, state, country, global). Epidemiologic studies are the foundation for disease control and prevention through tracking the prevalence of the disease, characterizing the natural history and identifying determinants or causes of the disease.

When a pathogen spreads and affects any individual within a population over a relatively large area and within a relatively short time the phenomenon is called epidemic. Epidemiology or epiphytology is the study of the outbreak of epidemic diseases, its course, intensity, cause effects and the various factors governing it. Forecasting is the process of making predictions based on past ad present data. Forecasting of plant diseases means predicting for the occurrence of plant disease in a specified area ahead of time, so that suitable control measure can be undertaken in advance to avoid losses. The objective of forecasting is to accurately predict when the three factors – host, environment and pathogen all interact in such a way that disease can occur and cause economic losses. A good disease forecasting system must be reliable, simple, cost effective and applicable to many diseases. At the field scale forecasting is used by growers to make economic decisions about disease treatment for control. Disease forecasts are predictions of probable out breaks or increase in intensity of disease. In other words plant disease forecasting is a management system used to predict the occurrence or change in severity of plant disease. At the field scale, these systems are used by growers to make economic decisions about disease treatments for control.

Objectives:-

After studying this unit you will be able to know:

- About epidemic disease and various factors that influence them.
- Pattern and development of an epidemic.
- Forecasting of plant epidemic disease.
- How can farmers protect their crops from epidemic diseases?
- Rate and range of epidemic.

9.2 Rate and range of epidemics

Some diseases periodically out break covering a large area and large population of plants. It is called epidemic. The study of epidemics and various factors that influence them is called epidemiology or epiphytology.

Epidemic: Plant disease epidemics occur on most crops in many parts of the world. Some untold suffering to human due to epidemic are the Irish famine (1845, 1846) caused by late blight of potato (*Phytophthora infestans*) and Bengal famine (1943) caused by brown spot of rice D. *oryzae* (*Helminthosporium oryzae*) conidial state of *Cochliobolus miyabeanus.* Most epidemics are more or less localized and result in minor or moderate losses. Some epidemics appear suddenly extremely wide spread and become out of control.

The elements of an epidemic are susceptible host plant, virulent pathogen and favourable environmental conditions over a long period of time. The host, environmental factors and rate of multiplication of pathogen determines the capacity to spread a disease. The increase in epidemic is due to high birth rate and low death rate of pathogen. These epidemics spread very fast but can be controlled by fungicidal spray whereas the epidemic developing due to low death rate of pathogens spread slowly over a long period of time. This epidemic is dangerous because their eradication is difficult.

When an epidemic is periodic and appears after certain intervals of time it is termed cyclic. On the otherhand, when an epidemic extends over most of a continent and causes mass mortality, and also termed as pandemic. Every epidemic has a specific course. It changes, increases and becomes virulent, decline, become milder and has its own appearance and morphology. An epidemic may be in two forms quantitative and qualitative. The quantitative epidemic is incidence of the disease and qualitative epidemic is the severity of the disease. There are two extremes of epidemics i.e. explosive epidemics and tardy epidemics. The graph of explosive epidemic shows a steep rise, a short acute peak and a steep decline whereas the tardy epidemic graph shows slow progress.

Simple Interest Diseases

If the rate of increase of disease is mathematically analogous to the simple interest in money, it is known as simple interest disease. There is only one generation of the pathogen in the life of infected crop.The infections noticed in the field are from primary source of inoculums. In this disease the primary inoculum is soil borne and secondary infection is rare. The examples of simple interest soil borne disease are root rots and wilt and seed borne are loose smut of wheat, covered smut of barley etc. In wilt and root rot disease the primary inoculum is important and there are very remote changes of secondary spread.

Compound interest diseases

In this the rate of increases of disease is mathematically analogous to the compound interest in money. The infection cycle is repeated many times during cropping season because pathogen produces spores at a very rapid rate which are disseminated by external agencies and infect other plants in which it in turn, produces spores which are disseminated and infect further plants and so on. The incubation and sporulation period of pathogen is very short and environmental conditions also play an important role in such diseases. Thus there are several generations of pathogen in the life of crop. Wheat rust, late blight of potato and apple scab are example of compound interest disease.

9.2 Elements of an epidemic

Elements of an epidemic disease are susceptible host plant, virulent pathogen and favourable environmental conditions. The epidemic diseases develop as a result of timely combination of above elements over a fairly long period of time. The activities of human beings also help to initiate and develop epidemic. Humans can stop the initiation and development of epidemics by using control measures. Presence of susceptible host, virulent pathogen and favourable environmental conditions increases epidemics.

A diseases triangle formed by the three elements of epidemic can be expanded to include time and humans factors. The specific point in time at which a particular event in disease development occurs and the length of time during which the event take place affect the amount of disease. Thus adding time component to the disease triangle results into a tetrahedron or pyramid, in which each plane represents one of the components. If the four components of the disease tetrahedron could be quantified, the volume of tetrahedron would be proportional to the amount of disease on a plant or in a plant population.

The fifth components in epidemic diseases development is human which affects the kind of plants grown in a given area, the degree of resistance in plants, their number density and time of planting. He can modify environment by manipulating the time of planting and harvesting and can also affects the amount of primary and secondary inoculums by their cultural practices, biological and chemical control. Thus human component should be considered a distinct fifth component which influences plant disease development directly or indirectly.

9.4 Factors Affecting Establishment of An Epidemic

Establishment of an epidemic is affected by following the factors:

(i) Nature of the host.

(ii) Nature of the pathogen

(iii) Environment

(iv) Human activity

(i) Nature Of The Host: There are many external and internal factors of host plant which affects the development of an epidemic. These are as follows:

(a) Susceptibility and degree of genetic uniformity of plant: Usually plants have ability to fight and defend against disease due to various genetical, physiological and structural factors. Some times few of theses factors are missed and plant becomes susceptible. The accumulation of susceptible host over a large area in aggregation is the major cause of epidemic. The host plant with vertical resistance do not allow pathogen to become established, unless a new race of pathogen develops whereas plants with horizontal resistance become infected but the rate at which epidemic develops depend on the level of resistance and environmental conditions.

(b) Types of crop and age of plants: Type of crop and age of plant affects epidemic. The epidemics develop more rapidly i.e. in few weeks in annual crops, whereas slowly i.e. in several years in the perennial woody fruit and forest trees.

The susceptibility of diseases for plant changes with age. In some cases the hosts are susceptible during the growth period, become resistant when adult e.g. downy mildew, rusts, systemic smuts etc. The other plants are resistant while still young, become susceptible during their growth and again resistant before they are fully expanded. The diseases like late blight of potato, early blight of potato etc. there is a stage of juvenile susceptibility during the growth, followed by relative resistance in the early adult stage and then susceptibility after maturety.

(c) Introduction of new host in the area: New varieties of plants are brought into a new area from their place of origin and sown there. Some times these varieties of plants become more susceptible to other pathogen.

(d) Introduction of new alternate and collateral host in the area: Alternate host belongs to a different family that helps to complete the pathogen life cycle and its survival. A collateral host is an additional than the usual host on which the pathogen can complete its life cycle. Thus both alternate and collateral host are important in building up the primary inoculum for the new crop. Sometimes introduction of new alternate and collateral host causes epidemic.

(ii) Nature of the Pathogen: Nature of pathogen includes its virulence level and inoculums density, reproduction cycle, ecology and mode of spread. It affects development of an epidemic in the following way:

(a) Virulence level and Inoculum density: Virulent pathogens infect host rapidly. This results in production of large amount of pathogen at faster rates when the number of pathogen propagules such as bacterial cells, fungal spores etc. are in greater number near or within the field of host plant result in greater increase of an epidemic.

(b) Reproduction cycle of pathogen: The pathogens having short reproduction cycles are polycyclic pathogen because they can produce many generation in a single growing season. This causes sudden, catastrophic disease epidemic. The pathogens which have high birth rate cause rapid epidemic as the disease spread in a compound interest manner. The pathogens which have 2-4 reproductive cycles per seasons cause localized and slower epidemics. These pathogens have low deaths rate and cause simple interest disease.

(c) Ecology of pathogen: Inoculums of pathogen is mostly produced on the aerial part of the plant. Such inoculums is dispersed easily to longer distances and results in wide spread epidemics. The vascular pathogens reproduce inside the host plant and their inoculums spread only with the help of vectors. Thus the development of epidemic depends on the active vector. The dispersal of inoculums present on plant debris lying in soil is very slow. In this way ecology of pathogen affects epidemic.

(d) Mode of pathogens spread: Mode of pathogen spread may be seed, soil or air which affects epidemic. The seed and soil borne pathogen have several limitations and hardly cause sudden or widespread epidemic. The air borne inoculums such as uredospores of rust can be easily dispersed by air over long distance. This causes frequent and wide spread epidemics.

(iii) Environment:

The environment affects each component of the epidemic and has a controlling influence on the development of epidemics. The environment affects the availability, growth stage and genetic susceptibility of the host. It also affects survival, multiplication rate, vigour, sporulation, dissemination of the pathogen and germination of spore and penetration. Moisture and temperature are most important environmental factor which affect disease epidemics.

Moisture promotes growth of susceptible host, increase of sporulation in fungal pathogen, facilitate release and germination of spores. In presence of high moisture all such events occur constantly and repeatedly. This results in epidemics.

Temperature favour epidemics by affecting pathogens and every stage of pathogenesis: sproe germination, penetration, growth and reproduction of pathogen, invasion and sporulation. Within a favourable range of temperature and moisture a polycylic pathogen can complete its infection cycle within a few days. Thus pathogen can produce many infection cycles within a growing season. This results into severe epidemic due to presence of abundant inoculums.

(iv) Human Activities:

Human activities like cultural practices and control measures used either favour or reduce the rate and frequency of epidemics low-lying, poorly drained, aerated fields again to another infected fields, tend to favour epidemic. The propagative material having inoculums favours epidemic. Various cultural practices like continuous monoculture, planting of same variety of crop in large area, high nitrogen fertilizers, poor sanitation etc. increases the possibility of epidemics.

Various disease control measures such as chemical spray, rotation of crop use of resistant varieties reduce or eliminate the possibility of an epidemic. However, sometimes use of certain chemicals and planting of certain variety results into serious outbreak of an epidemic when if the pathogen has resistance against chemical or can attack the resistant variety.

The movement of seed, tubers, nursery stock and others propagative parts is world wide due to which new pathogens are introduced in other new areas. Such pathogens in the new area lead to severe epidemics e.g. citrus canker, chestnut blight.

SAQ. 1

(a) The study of an epidemic and various factors that influence them is called …………………...

(b) Epidemic diseases cover a large area and large population of …………………………….

(c) Type of crop and age of plant affects …………………………………

(d) Development of an epidemics require …………………………., ……………………… and ………………………… environmental conditions.

9.5 Assessment of Plant Diseases and Yield Loss

While measuring disease, we measure incidence and severity of disease and yield loss. For a farmer, severity and yield loss are more important than the incidence of the disease.

- **Incidence:** The incidence of the diseases is the number of proportion of plant units diseases. The disease incidence measurement is used in epidemiological studies to measure the spread of a disease through a field, region or country. In some diseases like cereal smut, vascular wilt of annuals disease incidence has a direct relationship with severity of disease and yield loss. In other diseases like leaf spots, root lesions disease incidence has a little relationship with the severity of disease and yield.

- **Severity:** The severity of the disease is the amount of plant tissue that is diseased.The strategy for loss appraisal involves assessment of the disease through surveys of a number of fields using appropriate assessment methods and actual calculation of yield loss from the data obtained on disease incidence and severity.
- **Yield loss:** The yield loss is the yield that farmer will not be able to harvest due to disease.

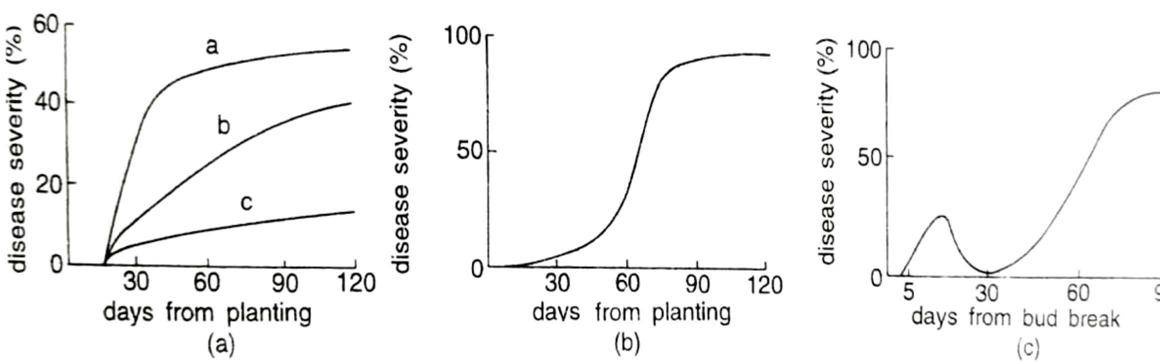
9.6 Measurement of Diseases Intensity

Pattern of an epidemic:-

The pattern of anepidemic is given by a curve called disease- progress curve that shows the progress of an epidemic over time. The disease progress curves are characteristic for some group of disease. A saturation type curve is characteristic for monocyclic disease (Fig. 9.1. a). Polycyclic diseases show sigmoid curve and disease affecting different organs show bimodal curve (Fig. 9.1. b, c) The rate of epidemic growth can be obtained from disease- progress curve.

Fig. 9.1. (a) Saturation type curve, (b) Sigmoid curve, (C) bimodal curve

The



pattern of an epidemic in terms of spread of disease over distance is given by another curve called disease gradient curve. The number of diseased plants and the severity of diseases decrease steepy within short distance of the source and less steepy at greater distance. (Fig. 9.2)

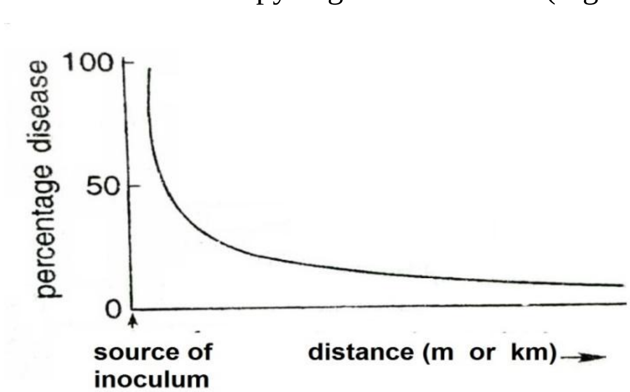


Fig. 9.2. Disease gradient curve

The following components are involved in the development of an epidemics:

- A large area planted with genetically uniform crop plant and the planted fields being close together.

- Presence of a virulent pathogen
- Combination of right sets of environmental conditions at appropriate stage of the host plant and the pathogen.
- In each new location the same set of favouralble environmental conditions must be repeated so that infection, reproduction and dispersal of the pathogen can occur as quickly as possible.

Some epidemic grow slowly while other develop rapidly. During early stage epidemics spread vigorously and after development of a saturation stage it shows decline by itself.

Percentage Scale

In this, usually the number of plants or organs falling into known percentage disease groups are recorded. The disease groups are the categories distinguished on the basis of per cent damage seen by human eye.

- A 12 grade scale was suggested by Horsfall and Baratt (1945) who took into the fact that the grades detected by the human eye are approximately equal divisions on a logarithmic scale and generally follow the Weber-Fechner law which states that visual activity depends on the logarithm of the intensity of the stimulus.
- In percentage disease assessment, the eye actually assesses the diseased area upto 50 per cent and the healthy area above 50 per cent.

The relationship between percentage damage and grade scale is as follows:

Grade Scale	Damage % due to disease
1	0
2	1-3
3	7-12
4	13-25
5	26-50
6	51-75
7	76-87
8	88-94
9	95-97
10	98-99
11	100.

This is a logarithmic scale and is satisfactory not only for disease measurement, but also for epidemiological studies, because pathogens multiply at logarithmic rate and also for loss appraisal.

Advantages of percentage scales :
The upper and lower limits of the scale are always well defined.

- The scale is flexible in that it can be divided and subdivided conveniently.

- It is universally known and can be used to record both the number of plants infected (incidence) and area damaged by a foliage or root pathogen.

Standard area Diagrams: It was developed by Nathan Cobb for leaf rust of wheat. It divides rust intensity into five grades representing 0, 5, 10, 20 and 50 per cent of leaf area occupied by the visible or sporulating rust pustules. The highest grade (50%) represented the maximum possible cover. A modified Cobb's scale was proposed by Melchers and Parleu (1922) for the estimation of stem rust of wheat. One of the most practical set of the area diagrams was prepared by James (1971). These diagrams represent the actual area of the leaves, stems, pods and tubers occupied by lesions in terms of per cent area covered. These area diagrams are in the form of loose plastic cards which can be conveniently used in the field. A common formula as follows is generally used to calculate the average infection or Infection Index, sometimes also known as Disease Index or Per cent Disease Index, which is calculated as follows:

$$\text{Per cent Disease Index (PDI)} = \frac{\text{Sum of all disease ratings}}{\text{Total number of ratings} \times \text{Maximum disease grade}} \times 100$$

- Severity estimates from fairly small areas can be combined to cover large areas,viz., village, district or state. This overall index can be obtained by using the formula:

$$\text{Per cent Disease Index (PDI)} = \frac{\text{Field rating class} \times \text{Number of hectares in the class}}{\text{Total number of hectares}}$$

Remote sensing

Remote sensing provides a powerful tool for detection and measurement of diseases. It is used for survey of large crop areas by means of aerial photography. Diseased plants can be identified as distinct patches in an otherwise uniform picture. It is useful for measuring diseases such as late blight of potato where early disease foci can be located and their subsequent spread is followed. Remote sensing is also useful when sudden disaster strikes and a rapid appraisal of the situation is required. In wheat crop, aerial photography can be used to determine the extent of damage by take-all or eye spot disease. Similarly, the incidence of Heterobasidion can be monitored in pine plantation covering undulating, boggy or rocky land.

Loss Measurement: The objective of loss measurement is to correlate disease severity to reduction in the crop yield. It helps in preparing standard tables which can be used to translate data of the disease severity into percentage loss in yield. Some models are designed by FAO (1971) for appraisal of loss of some disease. For example:

Loose smut of wheat caused by *Ustilago nuda triti*.

- Sampling is done at the stage of heading
- 50 plants are taken in each field from five sites of 1m^2 selected at random along a diagonal.
- Percentage of infected ears of plants is calculated and yield loss is estimated as given below;

$$\square\square\square\square \left(\frac{\square\square}{h\square}\right) = \frac{\square_{\square}}{100 - \square_{\square}} \times \square_{\square}$$

Where P_r = Percentage infected ear

P_a = actual yield (kg/hr)

In large scale surveys, 20 fields are assessed in a minimum of five locations in each district for each kind of cereals.

9.7 Information Required for Disease Forecasting

Forecasting of plant epidemic disease means prediction for the occurrence of disease in a specific area so that suitable control measures can be undertaken in advance to avoid heavy losses. Various informations regarding host, pathogen and environment are required for forecasting of disease. These are as follows:

(1) Information regarding host:

The information regarding host are presence of susceptible varieties of host plants in the given locality, response of host at different stages of its growth to the activity of pathogen. Density and distribution of host in the given area. The dense population of a susceptible variety invites the spread of an epidemic.

(2) Information regarding pathogen:

For forecasting of an epidemic disease, information of all stages of the diseases cycle or pathogen is required. These are initial inoculums, dispersal of inoculums, germination of spore, infection, incubation period, sporulation of pathogen on the infected host and redispersal of spores.

(3) Information regarding environment:

Temperature and moisture are two most important environmental factors needed for forecasting of disease. Besides this, light intensity, wind velocity during crop and intercrop period should be observed for a number of years in the field.

9.8 Forecasting of Plant Epidemic Diseases

The forecasting of plant epidemic diseases extremely useful to formers for the practical management of crop diseases. In managing the disease of their crops, farmers must always weigh the risks, costs and benefits of numerous decisions. The pathogens and weather factors are of different type: therefore forecasting is predicted in different ways.

On the basis of data collected on weather, disease cycle and pathogen cycle certain laboratory investigations are done and correlated. Then the forecasting of disease is done by the following methods:

- **Forecasting of disease based on primary inoculum:** Forecasting of disease is done on the basis of presence of primary inoculums, its density and viability in the area where susceptible host is present.
- **Forecasting of disease based on various weather factors:** Regular monitoring of weather factors like temperature, rainfall, humidity etc. during crop and intercrop period, local weather conditions above the crop and at the soil are considered for forecasting of disease. Weather data of several years are collected and correlated with the intensity of the disease.
- **Forecasting of disease based on computer:** Computerized warning system for diseases forecasting are in use since the mid 1970s such as BLITECAST. In BLITECAST, weather data collected on the farm by individual grower are transmitted to the centrally located computers. The computer then process the data, determines whether an infection period is imminent, likely to occur or cannot occur and makes a recommendation to the grower for applying control measures against epidemic disease.

In advanced countries like USA forecasting of disease is done by computer using various environmental data.

Computerized forecasting (BLITECAST, 1975) of late blight of potato disease can be done if:

- A night temperature is below dew point for at least 4 hours.
- The next day should by cloudy
- Minimum temperature 10^0C or above
- A least 1mm rainfall during the next 24 hours.

SAQ 2.

a. Prediction for the occurrence of an epidemic in an area is known as forecasting of …………………………..
b. Information regarding ……………, …………. and ……………………… are required for forecasting.
c. In advance countries forecasting of disease is done by ……………………………..

9.9 Disease Warning and Expert Systems

Plant diseases are one of the most important reasons that lead to the destruction of plants and crops. Detecting those diseases at early stages enable us to overcome and treat them appropriately. This process requires an expert to identify the diseases, describe the methods of treatment and protection.

Indentifying the treatment accurately depends on the method used in diagnosing the diseases. Expert systems help a great deal in identifying those diseases and describing methods of their treatment.

In some states computerized warning systems are in use for certain disease such as BLITECAST. After 1980, small computers have been developed for special purpose such as apple scab predictors monitor. They are mounted on a post in farmers field which collects data of the field on temperature, relative humidity, leaf wetness, rainfall. Analysis of the data helps in prediction of disease occurrence. It also helps in recommendation of disease control.

In plant pathology first expert system was developed in 1983 to diagnose nearly 20 soybean disease in Illinois. Many expert system are developed for the management of diseases like TOM for tomato diseases, Crops for grapes disease CONSELLOR for wheat disease, POMME far apple disease etc.

Expert systems are computers programmes which are frequently used in plant pathology for diagnosis of a plant disease. Several expert systems incorporate the decision making process of the expert and advise farmers on disease management. The expert systems utilize a band of data pertinent to the problem stored in the computer and knowledge base input by expert, followed by conclusion and finally a recommendation. These expert systems are revived and revised by other experts if necessary.

9.10 Summary

- Epidemic disease periodically out break covering a large area and large population of plants.
- Epidemiology is the study of various factors that influence an epidemic.
- Nature of host and pathogen, environment and human activity affects establishment of an epidemic.
- Susceptible host, virulent pathogen and favourable environmental conditions favour an epidemic.
- Some epidemic grow slowly other develop rapidly.

- During early stage epidemic spread vigorously and after development of a saturation stage it shows decline by it self.
- Prediction for the occurrence of an epidemic disease in the area is called disease forecasting.
- For disease forecasting, information regarding host, pathogen and environment is required.
- In advanced countries like USA forecasting of disease is done by computer using various environmental data.

9.11 Terminal Questions

5. What is epidemic? Discuss various factors responsible for an epidemic.

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6. Describe forecasting of plant epidemic disease.

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7. Discuss assessment of plant disease. How will you measure disease intensity and yield loss.

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8. Write short notes on:

(i) Diseases warning and expert system.

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Epidemic

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(ii) Nature of the host for an epidemic

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(iii) Pattern and development of an epidemic

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Information required for diseases forecasting.

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9.12 Answers

SAQ 1.

(a) Epidemiology or epiphytology (b) plants]

(c) epidemic (d) susceptible host, virulent pathogen, favourable

SAQ 2.

(a) Plant (b) host, pathogen, environment

(c) computer

Unit10

CONTROL OF PLANT DISEASE

Structure

10.1 Introduction

Plant disease play an important role in influencing the agricultural economy. Therefore, the main object of disease control is to prevent qualitative and economic losses of crops due to attack by pathogen. The aim of control measures is to save the population rather than a few individual plants. The cost of control measured used in disease control should be less than the economic value of the crop. Various types of pathogens are present in nature. Their complete eradication is impossible. Therefore plant disease control programmes are essential and should be operated in a large areas instead of smaller areas. Principles that characterize the modern concept of plant disease management should be viewed from three stand points.

(a) Reduction in the initial inoculums or the rate of disease development.

(b) Management of the pathogen population, the cure or induce defense of the suscept or modify the environment as it influences disease.

(c) Interruption of dispersal, survival or the course of disease development.

Objectives:

After studying this unit you will be able to know:

- Various methods of disease control.
- Prophylectic measures for protecting plants from diseases.
- Therapeutic measures for disease control after infection.
- The immunization measures for disease control.
- How can you reduce economic loss of agriculture due to diseases?

10.2 Out line of Various Methods of Diseases Control

Various methods adopted for control of plant disease can be classified in to following categories:

Methods of Diseases Control

- Prophylactic or Preventive measures
- Therapeutic or Curative measures
- Immunisation measures

Prophylactic or Preventive measures

1- Exclusion
(i) Ouarantin

2- Eradication
(i) Field Sanitation
(ii) Rouging
(iii) Eradication of alternate host
(iv) Eradication of collateral host

3- Protection
(i) Crop rotation
(ii) Selection of good quality of planting material
(iii) Condition for germination and emergence of growth

Therapeutic or Curative

1- Physical Therapy
(i) Sterilization of soil by heat
(ii) Hot water treatment
(iii) Hot air treatment
(iv) Low temperature treatment
(v) Treatment of radiation

2- Chemical Therapy
(i) Fungicides

Immunisation measures

1- Biological Control

2- Disease Resistance

10.3 Prophylactic or preventive measures

Prophylactic measures are measures designed to prevent the occurrence of an adverse event, of a diseases or its dissemination. Therefore these methods are applied in advance before the spread of disease. These measures are of following three types:

1. Exclusion
2. Eradication
3. Protection

1. **Exclusion:** It includes some regulatory measures to keep away the entry of pathogen in the areas where susceptible hosts are growing. This can be achieved by quarantines or quarantine regulation or Plant Quarantines.

Quarantines or Quarantine regulation or Plant Quarantines:-

Quarantine or Quarantine regulation or plant quarationes is the legal restriction at the national and international level on the movement of agricultural commodities. The purpose of this regulation is exclusion, prevention or delay in the spread of plant pathogens and diseases in uninfected areas. Quarantine measures are of three types: (i) domestic (ii) internal and (iii) total embargoes.

The first quarantine laws were enacted in USA (1912) and are known as Federal Quarantine Acts. In 1914 India had passed legislature the destructive insect and pest Act (DIPACT) which subsequently supplemented by other provisions. This act has been revised eight times from 1930 to 1956 and corrected upto 1967; but it still does not fulfill the needs under prevailing conditions. The DIP Act impose restrictions on import and export of diseased plant materials and pathogen. For this purpose there are quarantine station which works at sea ports and air ports. In India there are 16 quarantine stations operating under the Directorate of **Plant Protection** and **Quarantine**. Eight quarantine stations at sea ports, six at airports and two on land frontiers (Hussainiwals in Ferozepur and Sukhia pokri in Darjecling district).

DIP Act allows import of plant or plant material such as seed, tubers etc. from other countries only when it has a certificate from the ministry of agriculture of the exporting country stating that the plant or plant material is free from pathogen. The imported material is thoroughly checked by the trained staff at quarantine stations. In this way quarantine regulates entery of pathogen in uninfected area and prevents the disease.

Before the DIP Act following diseases are introduced in India (Table-1):

Disease	Introduced From
Leaf rust of coffee caused by *Hemileia vastatrix*	Sri Lanka
Late blight of potato caused by *Phytophthora infestans*	Europe
Flag smut of wheat caused by *Urocystis tritici*	Australia
Downy mildew of grapes caused by *plasmopara viticola*	Europe
Downy mildew of cucurbits caused by *Erysiphe cichoracearum*	Sri Lanka
Downy mildew of maize caused by *Sclerospora phillipinensis*	Java

Table-1

There are a number of lacunae in the DIP Act. As a result many diseases have been introduced in India after DIP Act. (Table-2):

Disease	Introduced From
Paddy blast caused by *Pyricularia oryzae*	Southeast Asia.
Powery mildew of rubber caused by *Oidium heveae*	Malaya
Black shank of tobacco caused by *Phytophthora nicotianae*	Dutch east
Crown gall of apples and pears (bacterial disease)	England
Hairy root of apple(bacterial disease)	England
Bunchy top of bananas (viral disease)	Sri Lanka
Wart disease of potato caused by *Synchytrium endobioticum*	Netherlands
Onion smut caused by *Urocystis cepulae*	Europe
Golden nematode of potato caused by *Heterodera rostochiensis*	Europe

Table-2

In India, so for, quarantine measures exist for two insect pests e.g. Fluted scales and San Tose scale and for three diseases e.g. wart of potato, bunchy top and mosaic of banana.

2. **Eradication:-**

The primary aim of eradication is to break the "infection chain" by eliminating the pathogen.

Thus the production of initial inoculums is reduced by destroying or inactivating the sources of initial inoculums. For this the knowledge of the life cycles of the pathogens, method of perennation, host range and habit of growth are essential prerequisites for division suitable measures to prevent the disease. Eradication is done by using following methods:

(i) Field Sanitation

(ii) Roguing

(iii) Eradication of Alternate host

(iv) Eradication of Collateral Host.

(i) **Field Sanitation:** Field sanitation is a very simplest method of disease control. Pathogens survive or perennate through dormant structures in plant organs and in the soil, which act as inoculums for diseases caused by them. Hence field sanitation is must in which diseased plants are eliminated and destroyed. Destruction of diseased plant is done either mechanically or chemically. Mechanically the plant debris having inoculums and infected plant parts are burned after removal. Chemically they are treated with suitable chemical to kill or inactivate the inoculums. Infact, sanitary conditions are helpful in almost all infectious diseases. Many infectious diseases like powdery mildew of wheat and pea, downy mildew of wheat and pea, wilt of cotton and arhar, red rot of sugarcane can be controlled successfully by field sanitation.

(ii) **Roguing:-** Rouging is careful removal and destruction of infected plant parts from the fields at an early stage. This method is applied in diseases like loose smut of wheat, red rot of sugarcane, ergot of bajara, wilt of arhar, loose and covered smut of barley etc.

(iii) **Eradication of Alternate Host:-** The heterocious pathogens complete their life cycle on two host; one the primary host and second the alternate host. This alternate host is generally wild and provides shelter to the pathogen during unfavourable conditions. The eradication of such a wild host plant breaks the chain in completing the life cycle of pathogen. For example *Puccinia graminis tritici* is a heteroecious pathogen and requires two host wheat and barberry to complete their life cycle. This pathogen causes black rust disease only on wheat plant. The eradication of barberry plant, the alternate host in temperate countries breaks the chain of life cycle of pathogen. It helps in the control of black rust disease of wheat. Similarly the yellow vein mosaic of lady's finger persists on wild hosts in nature and the systemic removal of these hosts help in control of disease.

(iv) **Eradication of Collateral Host:-** Some times pathogen survives on wild perennial plants or grasses. These are called collateral host. For example Blast of rice disease is caused by *Pyricularia oryzae.* This pathogen can infect and survive on several wild species of rice and grasses, such as *Panicum repens*, *Digitaria marginate* and *Setaria intermedia.* Removal of these collateral host from the area eradicates the pathogen and help in disease control.

SAQ. 1

a. Exclusion can be achieved by ………………………………………..

b. In India there are …………………….quarantine stations.

c. Field sanitation is a very simplest method of …………………………..

d. Heteroecious pathogen can be controlled by eradication of …………….

3. **Protection:-**

In protection preventive measures are applied to discourage the spore germination, penetration into the host and disease development. It is achieved by using following methods:

(i) Crop Rotation

(ii) Selection of Good Quality Planting material

(iii) Condition for Germination and Emergence of plant.

(i) **Crop Rotation:** Crop rotation is an ancient farming practice that has been used by farmers since the BC Centuries. Curl (1963) has reviewed the control of plant diseases by crop rotation. Crop rotation is the practice of planting different crops sequentially on the same plot of land to improve soil health. Continuous growing of the same crop or related, crops leads to the continuous increases of soil borne pathogens in the field. These soil borne pathogens of that crop easily perenate in the soil and increases their population. Ultimately the soil becomes so heavily infested with the pathogen that it no longer supports the growth of the crop. Such soil is called "sick soil". Similar crops tend to have the same pathogens; therefore crop rotation intercepts the pathogen life cycle and their habitat. It reduces survival rate of pathogen in the absence of the suitable host. Many soil-borne diseases such as wilt of arhar, wilt of pea, red rot of sugarcane, ergot and smut of bajra etc can be controlled by crop rotation. For example *Fusarium orxysporum* causes wilt disease in arhar. This survives in soil. To control this non susceptible other crops are sown in the field for the next 3 or 4 seasons. As a result the chain of pathogen cycle breaks due to absence of suitable host. Thus disease can be controlled. This method has also important hasr aspects. If the same crop is sown year after year in the same area, the particular essential elements of the soil will be exhausted with the accumulation of toxic substances and organic acids. Thus rotation of crop helps in disease control by increasing soil nutrients and limiting the concentration of pathogen in soil.

(ii) **Selection of Good Quality Planting Material:** The seeds, tubers, cutting of plant and grafts are used as planting material. Proper care should be taken during selection of above planting material because if planting material will be infected then the crop will be diseased.

(iii) **Condition for Germination and Emergence of Plant:** Plants should not be sown when the disease pathogen is prevelent in that area. Sowing of the seeds should be done at proper time and proper depth. The appropriate fertilizer should be given at proper time. All above result in vigorous seedling which has capability to fight the pathogens and protect them from disease. Injury in the plant should also be avoided during managing crop in the field to check the entry of pathogen. This will also protects crop from disease.

10.4 Therapeutic or Curative Measures

Therapeutic or Curative measures have been used much often to control plant diseases than in human or animal medicines. The therapeutants inhibits the development of a disease syndrome in a plant when applied for the treatment of diseased plant or plant parts. The therapy is of two types:

1. Physical Therapy
2. Chemical Therapy

1. **Physical Therapy:** In this diseased plants are treated with physical agents like temperature, radiation in the following way:

   (i) **Sterilization of Soil by Heat:-** In this method soil in the field is sterilized by steam at $82^{0}C$ or above for 30 minutes. This kills the soil pathogen. But it can not be applied in the fields of large areas. This method is effective as well economical for green houses and seeds beds where the area is small. Therefore soil pathogens of green houses and seed beds are killed by steam sterilization.

   (ii) **Hot Water Treatment:-** This method is used to eliminate seed borne diseases. The infected seeds are first soaked in the water of normal temperature. This result in activation of dormant inoculum of disease causing pathogen. Then seeds are immersed in hot water at 54^0C for 10 minutes only. This will destroy the pathogen but the embryo present in the seed remain safe. The treated seeds are dried before sowing. Thus the infected seeds become pathogen free and give rise healthy plants on sowing.

(iii) **Hot Air Treatment:** This treatment is given to the plants after harvesting to remove moisture and protect them from fungal and bacterial attack.

(iv) **Low Temperature Treatment:** It is given to control post harvest disease of fruits and vegetables.

(v) **Radiation Treatment:-** Many pathogens of post harvest diseases are killed by using radiations such as ultra violet, □, □, □ and x-rays.

2. **Chemical Therapy**

In chemical therapy chemical substances are used to kill the pathogen for diseases control. A variety of chemicals are available that have been designed to control plant diseases by inhibiting the growth of or by killing the disease causing pathogens. Chemicals used to control bacteria (bactericides), Fungi (fungicides) and nematodes (nematicides) may be applied to seed, foliage, flowers, fruits or soil. They prevent or reduce infection by utilizing various principles of disease control.

Enormous literature is available on chemicals used for control of plant disease like principles of fungicidal action by Horsfall (1956); Fungicides, An Advanced Treatise in two volumes by Torgeson (1967, 1969); plant diseases and their chemical control discussed by Evans (1968); Role of Fungicides in modernizing agriculture in India by Mehta (1971).

The use of chemical sprays, dusts or seed treatment for protecting plants from the ravages of the pathogens is not an innovation of the 20th century. In the past agriculturists used chemicals and fungicides to control plant diseases. The first recorded mention of plant disease control is in the writing of the Greek poet, Homer (1000 B.C.), who mention sulphur, which is still in use as fungicide.

Pierre Alexis Millardet (1985) showed that the downy mildew of grapes could be controlled by mixture of copper sulphate and lime. Copper sulphate had been in use even before that but its toxicity was reduced when mixed with lime in 1885. The Bordeaux mixture was used in Europe and USA for the control of many diseases. It was followed by lime sulphurs in the late 19th century and formalion, copper carbonate dusts and organomercurials as seed treatment (1913). An era of organic fungicides thiram, chloranil, dichlone were developed from the mid- 1930s on wards and captan the most successful fungicide was developed only two decades ago. Many groups of chemical compounds are now available for plant diseases control. These include heterocyclic nitrogen compounds, quinines, phenols and antibiotics.

SAQ 2.

(a) Soil borne diseases can be controlled by ………………………………

(b) Selection of good quality plant material helps in protecting plants from ……………………………

(c) Therapeutic measures inhibits the development of …………… in a plant.

(d) In physical therapy diseased plants are treated with physical agents like ………………….

(e) In chemical therapy ……………… are used in plants for disease control.

Fungicides: The fungicides are chemicals that kills or inhibits the development of the fungal spores or mycelium. On the basis of their uptake by the plant and mobility within plant tissues, the fungicides are classified as:

(a) Protectants

(b) Eradicants

(c) Therapeutants

Protectants: The protectant fungicides are prophylactic in their behavior and may be applied to seeds, plant surface or the soil. Fungicides of this category place a chemical barrier between the plant and the pathogen. These fungicides are not absorbed by or translocated through the plant. Thus they protect only those parts of the plant treated before invasions by the pathogen.

Eradicants: It eradicates the dormant or active pathogen from the host. Eradicants are designed to kill a pathogen that may be present in the soil, on the seeds or on vegetative propogative organs, such as bulbs, corms and tubers. They can remain effective on or in the host for some time and functions as protectant also. Therefore, this chemical can be protectant as well as eradicant.

Therapeutants:- It inhibits the development of a diseases syndrome in a plant when applied subsequent to invasion by a pathogen. Usually the chemo-therapeutants are systemic in their action. They enter the plants and affect deep-seated infections.

To be successful fungicide must have following characteristics:

- To be effective against rain and dew.
- Must be nearly insoluble in water, but at the same time they must be soluble enough to function as fungicide.
- Adhesiveness is needed to enable them to stick well and last for a longer period.
- Should not be phytotoxic.

On the basis of chemical nature fungicides are divided into two categories:

(A) Inorganic fungicides

(B) Organic fungicides

(A) Inorganic fungicides:- The inorganic chemicals used as fungicides are known as inorganic fungicides which may be copper compounds, mercury compounds and sulphur sprays.

(I) Inorganic Copper Compounds:-

(i) **Bordeux Mixture:-** It was discovered by Millardet in 1885 at university of Bordeux- France. It is a mixture of copper sulphate lime and water. In 1882 millardet was investigating disease downy mildew of vine caused by *Plasmopara viticola.* He observed that infected leaves had bore and get defoliated. But when the leaves were sprayed with Bordeux mixture the defoliation stopped. Then millardet in collaboration with a chemist Gayon was able to announce the successful use of copper sulphate, lime and water as fungicide against *Plasmopara viticola* (1882). The fungicidal action is due to the formation of soluble copper sulphate which is toxic to spores and sporelings in drops of atmospheric water. It is specific against downy mildew, late blight of potato, coffee rust and various leaf spot diseases. The Bordeaux mixture is sometimes phytotoxic to tender leaves and other parts and burn them.

The formulae for the Bordeaux mixture vary. The original mixture contained 15% copper sulphate and 8% lime (CaO). The proportion of these now varies according to the crop and the diseae. Higher concentrations are useful in the case of woody and tough tissues, while lower concentrations are used for succulent and softer parts. The following formula (5:5:50) is regarded as a good standard type:

Copper sulphate (blue stone)	5lb (2.268 kg)
Stone or hydrated lime	5lb (2.268 kg)
Water	50 gallons

The two solutions are prepared separately in wooden or earthen vessels and the diluted solution of $CuSO_4$ is slowly poured into a concentrated lime solution in a tub with constant stirring. The resulting mixture is neutral or slightly alkaline and is not injurious. The mixture is used almost immediately after preparation and deteriorates if left for some time. To avoid this, stock solution of the two ingredients can be prepared separately and stored in wooden vessels. These can be mixed when actually required.

(ii) **Burgundy Mixture:-** Burgundy mixture is a modification of the Bordeaux mixture. It is used in cases of tender foliages, since it is less phytotoxic. In this lime is substituted by sodium carbonate and hence is sometimes called 'soda bordeaux'. The composition of burgundy mixture is:

Copper sulphate (blue stone)	10lb (4.536 kg)
Stone or hydrated lime	12.2lb (5.666 kg)
Water	50 gallons

SAQ 3.

a. Bordeux mixture was discovered by ……………………..
b. Bordeux mixture is a mixture of ………………., ……………….. and water.
c. Bordeux mixture is an …………………………. fungicide.
d. Bordeux mixture was first time used against ……………. disease.

(iii) **Cheshunt Compound:** It contains two parts of copper sulphate and 11 parts of ammonium carbonate. It is used for the control of "damping off" diseases.

(iv) **Chaubattia Paste:-** The paste is prepared by mixing copper sulphate (800g) and red lead (800g) in one litre of lanolin or raw linseed oil.

(v) **Insoluble Coppers:-** The fungicidal and bactericidal properties of copper is used in the preparation of a variety of copper dusts and sprays such as Perenox, Blitox , Cuprocide and Fytolan.

(vi) **Inorganic Mercury Compounds:** Mercury compounds are highly effective as fungicides and bactericides but their use is limited because they are highly toxic to animals and human beings. Mercuric chloride ($Hg\ Cl_2$) and mercurous chloride (hg_2cl_2) are used as fungicide for seed, rhizomes, corms of vegetables and flowers to control certain bacterial and fungal diseases.

(ii) **Sulphur Sprays:-** The effective use of sulphur as a fungicide was discovered in the beginning of the 19th century. Sulphur is the earliest known and widely used fungicide. The preparation of elemental suphur or curde lime suphur were used to control powdery mildew on a variety of crops and leaf curl of peach. The sulphur sprays are:

(i) **Lime Sulphur:** Chemically lime sulphur is a mixture of calcium thio sulphate and calcium polysulphides. Besides fungicide it is an insecticide also. On the tender parts it is phytotoxic hence it has only limited use.

(ii) **Self-boiled lime Sulphur:** This is less toxic than lime sulphur and made by using 8lb of sulphur flour and 8lb of burnt lime with 50 gallons of water.

(iii) **Wettable Sulphur:** Wettable sulphurs also known as flotation sulphurs are very finely divided elemental sulphurs. It is extensively used fungicide because it causes less foliage injury.

(B) **Organic Fungicides:-** The organic chemicals used as fungicidies are known as organic fungicides . Some of them are as follows:

(i) Organic compounds

(ii) Quinone and Phenolic fungicides

(iii) Heterocyclic Nitrogen compounds

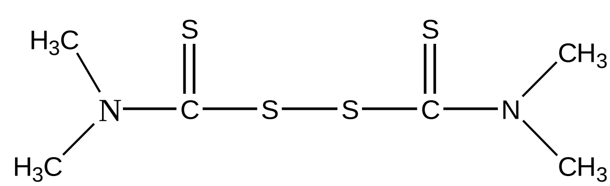
(iv) Benzene Compounds

(v) Systemic Fungicides

(vi) Antibiotics

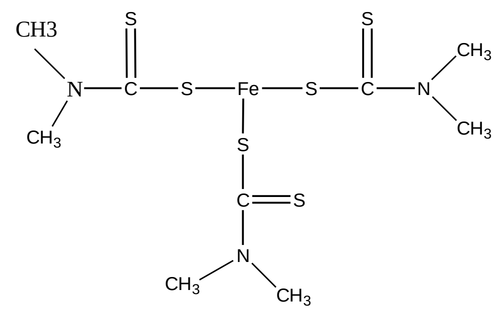
(i) **Organic compounds :-** Some organic compounds used as fungicides are:

- ***Thiram (Tetramethyl thiuram disuphides):*** Thiram is being sold under a variety of other trade names , such as 'arasan', 'tundas', 'terson', 'tulisan' etc. It is used for seed treatment. Thiram is also used for the control of foliage diseases and the soil born pathogens such as *Pythium, Rhizoctonia, Fusarium* and *Protomyces.*



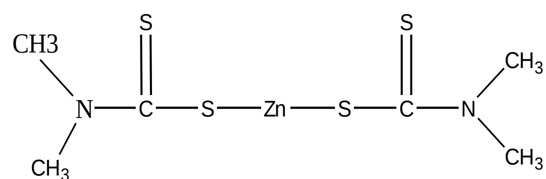
Thiram

- ***Ferbam (Ferric dimethyl dithiocarbamate):*** Its trade name is fermate or ferbam, karbam or coromet. Ferbam has been successfully used as a protectant fungicide, against a wild variety of fungal diseases of fruits and vegetables.



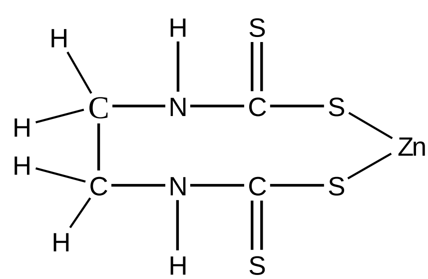
Ferbam

- ***Ziram (Zinc dimethyl dithiocarbamate):*** It's trade names are cumin, zerlate, karbam white, corozae, etc. In India, it is available under the trade name of Cuman and used against many foliar disease in field and orchard crops.



Ziram

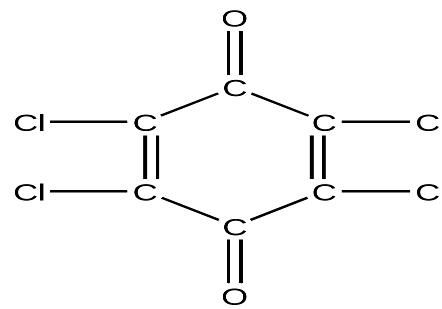
- ***Zineb (Zinc ethylene bisdithiocarbamate):*** Zineb is derived by the substitution of sodium in nabam with zinc. It is called Dithane Z-78, Parzate C or Linacol. Zineb is mainly used for foliar sprays against diseases, such as early and late blight of potatoes and tomatoes, blast of rice, leaf blight of rice.



Zineb

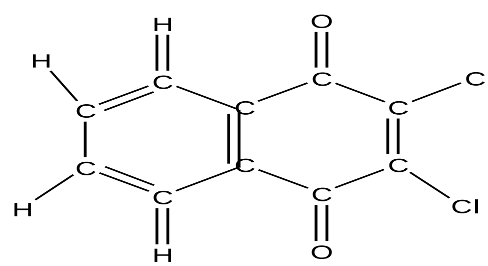
(ii) **Quinone and Phenolic Fungicides:-** Quinone and phenolic compounds are quite important as fungicides. Some important ones are:

- ***Chloranil (Tetrachloro-p-benzoquinone):*** It was reported by Cunningham and Sharvelle (1940) to give protection to lima beam seedlings from damping off. Chloranil is mainly used in seed and bulb treatment of legume flowers and vegetables.



Chloranil

- ***Dichlone (2,3 dichloro*-1,4 naphthaquinone):** It is used for seed treatment and also as a foliage spray against many plant disease.

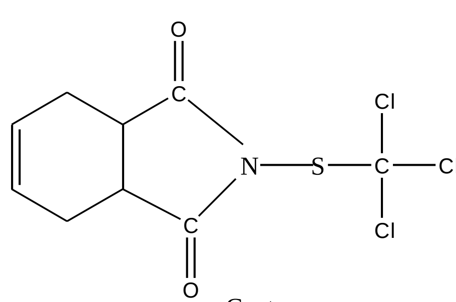


Dichlone

- ***Phenols:*** Phenols have shown exceptional qualities as bactericides, but as fungicides their use has been limited. It has been used as soil fungicides and in seed treatments.

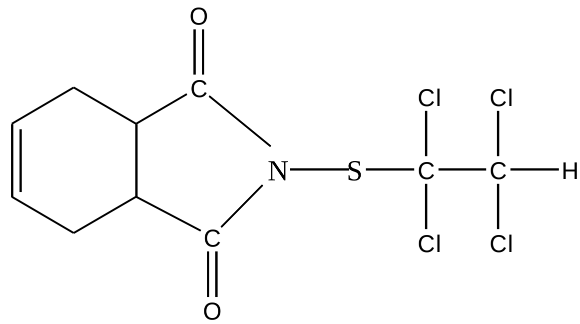
(iii) **Heterocyclic Nitrogen Compounds:-** These compounds have valuable fungicidal properties and are used as foliage protectant and eradicants of fruits and vegetables.

- ***Captan:*** Captan is the common name of N-trichloromethyl and thio-4-cyclohexene-1,2 dicarboximide. It is commercially sold as Captan 50 W and Esso fungicide 406, which acts systemically.



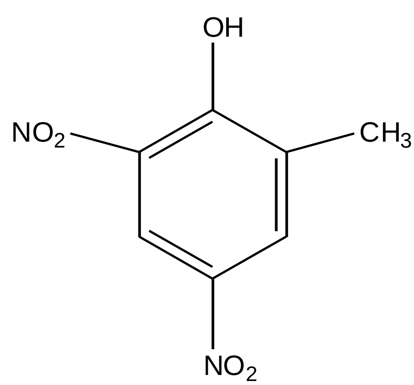
Captan

- ***Difolatan [N-***(1,1,2,2-**tetrachloro ethyl sulfenyl)-cis 4-cyclohexene 1,2-dicarboximide]** : Difolatan has properties similar to captan. It is good fungicide for the control of early and late blight of potatoes and tomatoes.



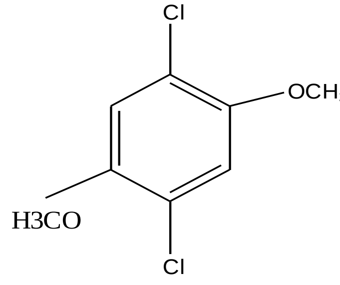
Difolatan

(iv) ***Benzene Compounds:-*** Many benzene compounds are toxic to micro-organisms and have been developed as fungicides. It is used as a dormant spray for the control of many diseases of fruit trees and ornamental plants.



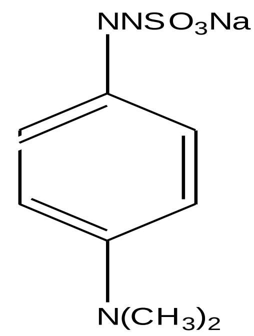
Dinitro-o-cresol

- ***Chloroneb:*** The fungicide, chloroneb, 1,4-dichloro-2,5 dimethoxy benzene, was introduced for the control of seedling disease of cotton. This is a systemic fungicide.



Chloroneb

- ***Dexon:*** This is p-(dimethylamino)- benzene-diazosodium sulfonate. It is used against soil-borne fungi causing root rot and damping off diseases of plants.

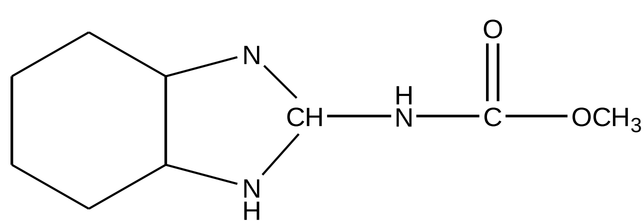


Dexon

(v) **Systemic Fungicides:-** The development of systemic fungicides such as benomyl, oxathins, terrazole etc are used to treat many plants after infection. Systemic fungicides are absorbed and translocated within the plant, restricting the spread and development of pathogens by direct or indirect toxic effects by increasing the ability of the host to resist infection.

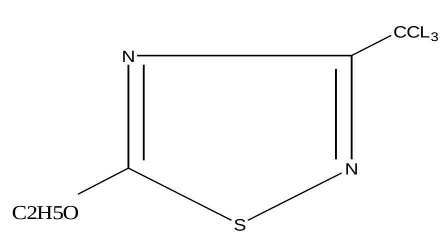
The systemic fungicides inactivate enzymes and toxins of the pathogen. Therefore, they are more specific in their action than non-systemic fungicides.

- **Benomyl:-** This is methyl- N (butyl carbomoyl)-2 benzimidazole carbamate and marketed as benlate. This fungicides is effective against a wide range of pathogens such as *Cercospora* leaf spot of sugar beet, rice, blast, apple scab, powery mildew on cucurbits, cereals and legumes. Many soil borne pathogens can also be controlled by benomyl.



Methyl Benzimidozole Corbamate (MBC)

- **Terrazole:** Terrozole-5-ethoxy-3trichloromethyl-1,2, 4- thiadiazole is systemic in action. It is toxic to phycomycetous fungi, such as *Pythium* and *Phytophthora*. It has a systemic action in plants (Al-Beldawi and Sinclair, 1969). Little is known about its fungitoxic action.



Terrozole

(vi) **Antibiotics:-** Antibiotics have been developed to control various plant diseases. Most of these drugs are absorbed by the plant and translocated like systemic fungicide. Streptomycin is used against a variety of bacterial pathogen. Tetracycline is able to control the growth of certain mycoplasmas and cycloheximides and are effective in the control of certain fungal diseases.

10.5 Immunisation measures

It is based on ability to exempt infection of disease by a pathogen. It is achieved by two ways- (1) Biological Control (2) Disease resistance

(1) **Biological Control:-** The control of disease by living organism is called biological control. In biological control the survival activity of a pathogen is reduced through the agency of any other living organism except man himself. This results reduction of disease incidence caused by a pathogen. Many micro-organism parasitise compete and antagonise other micro-organism. Biological control is based on these properties of micro-organism. It acts in following ways-

(i) **Antibiotics :** These are the chemicals secreated by the micro-organism which inhibits the growth and activity of pathogen and controls the diseases.

(ii) **Cross protection:** In this mild strain of pathogen is introduced into the host due to which resistance is developed against the strong strain of that micro-organism which can cause sever damage to the host.

(iii) **Hyper-parasitism:** Many pathogens parasitise other pathogen. That is called Hyperparasitism e.g. *Melampsora lini* (Pathogen of Rust of linseed) produces uredosposes. Which can be controlled by *Cladophora sp.* As it parasitise on uredospores of *Melampsora.* **:** In the above example one fungus is parasitized by another one, therefore it is also known as mycoparasitism. The parasitizing fungus is called hyperparasite whereas the parasitized fungus is termed as hypoparasite.

(iv) **Antagonism:** In this one organism inhibits the growth and activity of another micro-organism eg. *Trichoderma* is antagonistic against many soil borne pathogen. There fore it is used to control many soil borne disease.

(v) **Competition:** The microorganisms compete for space, mineral and organic nutrients for proliferation and survival in their natural habitat both, rhizosphere and phyllosphere, **Rhizosphese** is “the zone of soil around plant roots characterized with intense microbial activity”. **Phyllosphere** is “the niche of microbes on the surface of leaf landing from surrounding air”. For the successful completion of their life cycle or infection process, the pathogen has to compete for substrate and minerals as mineral nutrients are generally present in large quantity except nitrogen and iron in nitrogen-poor and iron-poor soils respectively. Therefore competition for substrate is most important factor than mineral nutrients. The fate of plant pathogens in competition depends on cellulolysis rate that mediates the speed of sporophytic tissue penetration. ***Trichoderma viride*** vs ***Fusarium roseum*** is an example of successful competitors competing for nutrients.

(2) **Disease resistance:-** It is the inherent ability of a plant to prevent the establishment of pathogen. If the resistance is against all the races of a pathogen it is called horizontal resistance and if it is against only few race of pathogen it is called vertical resistance.

New varieties are produced by breeders. when the new variety has resistance against disease then it is recommended to the formers.

Breeding of diseases resistance is achieved by following methods

(i) **Introduction:** The new variety of plant from its place of origin is introduced into a new locality and in new environmental conditions and if it still shows resistance then it is recommended to the farmers.

(ii) **Selection:** Plants having disease resistance are selected and grown along with the suceptible host and then only those plants are selected which exhibit resistance against disease. These plants are grown again for several years under different environmental conditions and when they show resistance against all conditions then they are recommended to the farmers.

(iii) **Hybridization:** The cross is made between susceptible and resistant variety and the plants of F_1 generation are grown. The plants which exhibit resistance are selected and recommended to the farmers.

SAQ 4.

a. Systemic fungicides inactivate ……………… and ………….. of the pathogen.

b. …………………….. is a systemic fungicide.

c. ……………………. are used to control certain fungal diseases.

d. The control of disease by living organism is called …………………………

e. ………………………. Is the inherent ability of a plant to prevent the establishment of pathogen.

10.6 Summary

- The main object of disease control is to prevent qualitative and economic losses of crops due to attack by pathogen.
- Prophylectic or preventive methods are applied in advance before the spread of disease.
- The aim of exclusion is to prevent new pathogen and diseases from reaching to uninfected area.
- Plant Quarantine is the legal restriction at the national and international level on the movement of agricultural commodities.
- The primary aim of eradication is to break the “infection chain” by eliminating the pathogen.
- Eradications is done by field sanitation, rouging, eradicating alternate and collateral host.
- In protection preventive measures are applied to discourage the spore germination, penetration into the host and disease development.
- Protection is achieved by rotation of crop, selection of good quality planting material and condition for germination and emergence of plant.
- Therapeutic or curative measures have been used to control plant diseases by physical or chemical therapy.
- Physical therapy is done by heat sterilization of soil, hot water treatment of infected seeds, hot air treatment of plants after harvesting, low temperature and radiation treatments.
- In chemical therapy chemical substances are used to kill the pathogen for disease control.
- The chemical may be inorganic and organic fungicides, quinines, phenols, heterocylic compounds, benzene compounds, systemic fungicides and antibiotics.

- Immunization measures are achieved by biological control and disease resistance.

10.7Terminal Questions

1. Comment briefly on the chemical control of plant diseases.

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2. What are plant quarantines? When and where was the first quarantine act enacted?

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3. Comment briefly on various methods of disease control in plant.

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4. Discuss prophylactic or preventive measures of diseases control.

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5. Discuss therapeutic or curative measures of diseases control.

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6. Discuss immunisation measures of diseases control.

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7. Write short notes on:

   (1) Quarantine

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   (2) Biological control

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Fungicides

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   (3) Crop rotation

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   (4) Systemic fungicide

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   (5) Disease resistance

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10.8 Answers

SAQ1.

(a) Quarantines

(b) 16

(c) disease control

(d) alternate host

SAQ 2.

(a) Crop rotation

(b) disease

(c) disease syndrome

(d) temperature, radiation

(e) chemical substances.

SAQ 3.

(a) Millardet

(b) copper sulphate, lime

(c) inorganic

(d) downy mildew of vine

SAQ 4.

(a) Enzymes, toxins

(b) Benomyl

(c) cycloheximides

(d) biological control

(e) Disease resistance.

Unit11

Plant Diseases 1

Structure

11.1 Introduction

Fossil evidences indicates that plants were affected by diseases 250 million years ago. The bible and early writings mention diseases, as rusts, mildews and blight.

Any deviation from the healthy condition which interferes with the normal structure and performance of vital functions of a plant is called a disease. The occurrence and prevalence of plant diseases vary from season to season, depending on the presence of the pathogen, environmental conditions, crops and varieties grown. Plant diseases are important to human beings because they are responsible for causing damage to plants and plant products. Millions of people all over the world depends on the plant products for their existence. Plant diseases can make the difference between a happy and a miserable life. During world war I, late blight damage to the potato crop in Germany may have helped end the war. This is an example of the consequences of plant diseases.

Objectives:-

After studying this unit you will be able to know:

- Pathogens and symptoms of various diseases.
- The hostpathogen relationship and environmental factors which favours disease development.
- Life cycle of various disease and their control measures.

11.2 Green ear Disease of Bajra

Host: *LinumUsitatisssimum*.

Pathogen: *Sckerisoira graminicola (sacc.) Schroet.*

Systematic Position

Class-Oomycetes

Order- Pernosporales

Family – Pernosporaceae

Occurrence: The green ear disease of Bajra is a common disease and has been reported form several countries including India, Iran, China, Fiji, Japan and the countries wherever Bajra crop in grown. In India the disease was first reported and studied by Butler (1907) who considered the disease to be sporadic in nature not causing much damage to the crop. Mitter and Tandon (1930) reported the disease from Allahabad, Uttar Pradesh and confirmed the observations of Butler (1907). Since then the disease of Bajra has been reported from the states wherever Bajra is cultivated as one of the crops of 'Kharif' season.

Symptoms:

Two stages of the symptoms of the disease have been recorded: the downy mildew stage prominent on the leaves and the green ear stage affecting the inflorescence (ears). The latter is more prominent than the former symptom since it has been reported that the strain of the pathogen occurring in India produces more oospores than the sporangia.

The growth of the plants affected is checked and the plants appear stunted and sick, pale yellow in colour. Even young plants show this symptom. Soon, the leaves begin to show chlorosis in streaks on the upper surface while the lower surface shows downy growth of the fungus.

After some time chlorotic areas turn brown and in advanced stages shredding of the leaves has also been observed. Since the plant is unbranched, the disease causes stimulation of nodal bud's and lateral shoots develop which is an abnormal character.

Associated with it, the leaves also show additional symptoms. Usually green colour of the leaves may change wholly or partly, to whitish or brown colour. Whitening of the younger leaves is evident along the streaks while in older leaves, the colour changes to brown.

In older plants, this occurs especially in those leaves from the axil of which the inflorescence develops. The change of the colour of leaves is associated with twisting, folding and shredding towards the tip.

In older plants where green ears have been formed the upper leaves are mostly brown and split. A large number of leaf buds develop into a large mass of white or twisted brown leaves. The axil of these buds produce green leafy human ear like structures.

The disease becomes prominent when the inflorescence gets converted into green leafy ears.

This is due to transformation of floral parts into twisted leafy structures, giving the ear an appearance of green leafy mass. Hence, the common name of the disease-'Green ear'.

Generally the following types of green ears have been observed:

(i) Entire ear (inflorescence) is transformed into green leafy mass.

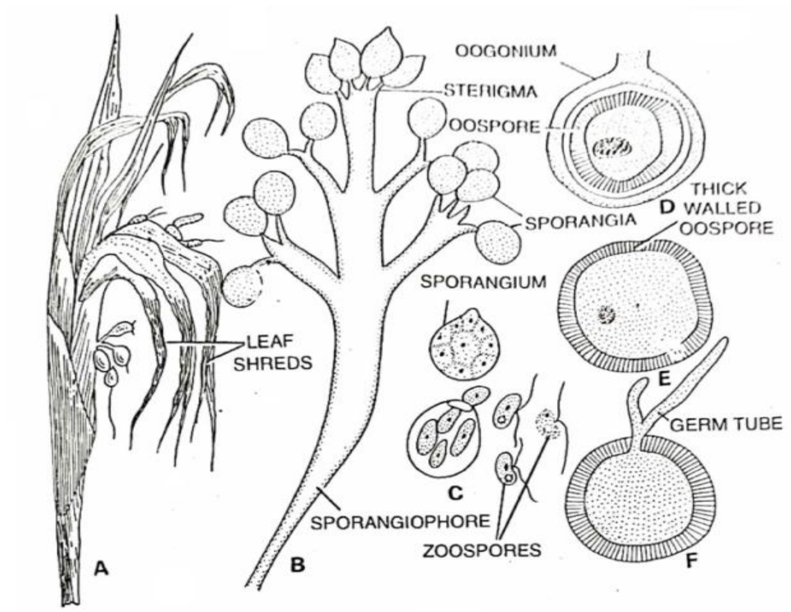
(ii) The lower part of the inflorescence is converted to green leafy mass but the upper part bears seeds.

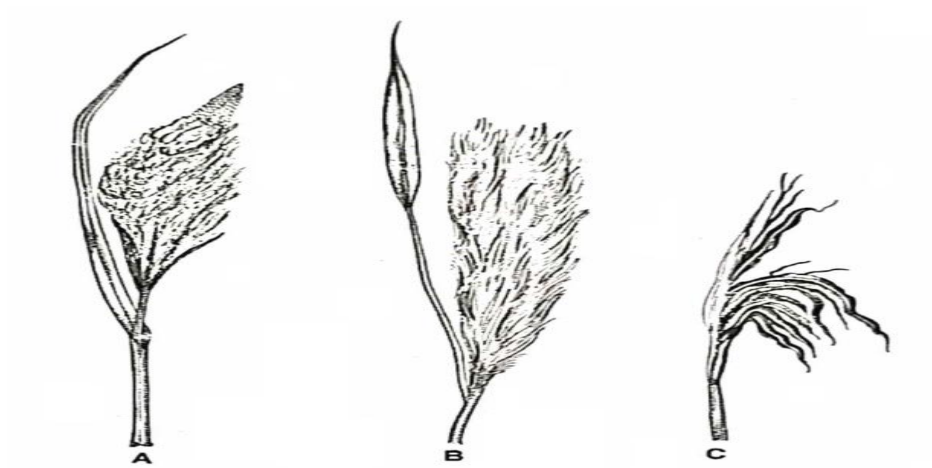
(iii) The development of inflorescence is completely suppressed and in its place is formed a small bunch of leafy structures.

The disease causes changes in the florets as well as floral parts. The bristles of spikelet's become contorted and hypertrophied. The number of spikelet's may change from one to two in the same pedicel. A very common feature is the increase in the number of florets in each spikelet.

The fertile parts especially the stamens and carpels usually become sterile, leaf like and suppressed to rudimentary peg like structures. Sometimes the stamens appear as brown leathery, pointed bodies without any differentiation into filament and anther.

In severely attacked plants,' the carpels rarely develop and is replaced by small, leafy shoots or horn like outgrowths. This may be attributed to hypertrophy and hyperplasia of the affected tissues.





A- Shredded Leaf, **B-** Sporangiophore with sporangia, C- Sporangium germination, **D to F** - Oospore

A- Partially infected ear, **B-** Wholly infected ear, **C-** Leaf shredding

Fig-11.1. Symptoms of Disease

Disease cycle:

Initially the diseases was regarded as sporadic in nature causing not much damage to the crop except in low lying fields where the loss could be quite significance. However, Rai and Sinha (1965), Mathur and Dalela (1971) and Nene and Singh (1976) have estimated the loss to be as high as 27-30 percent. The disease appeared in an epidemic form in Karnataka and Maharashtra during 1975 causing almost total loss of the crop.

The disease is primary soil borne. After the return of favourable conditions, the oospores present in the soil, germinate and enter the young seedlings of host through the underground parts and cause primary infection. The primary infection occurs through oospores or mycelium present in the seeds produced on diseased ears.

When seeds containing mycelium are sown in the fields, these germinate and grow and along with it the mycelium also grows and causes primary infection as well. The infection spreads systemically along with the growth and development of seedlings into mature plants.

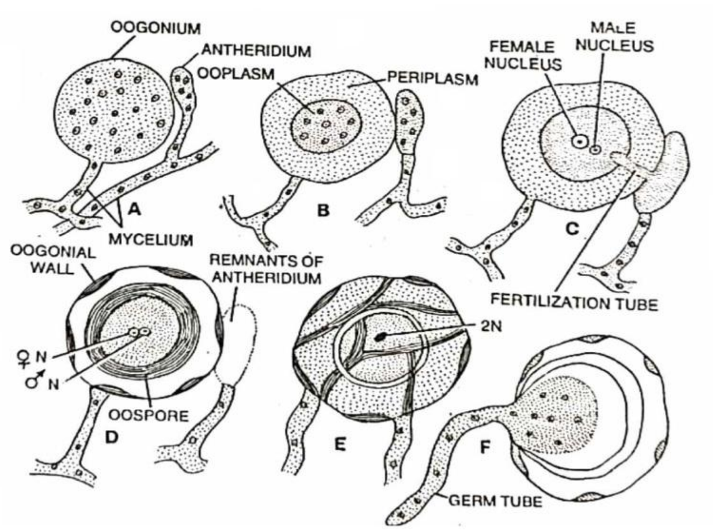
In early stages, symptoms appear on leaves as downy growth of the fungus on the lower surface of leaves. After some times the characteristic green ears appear on the diseased plants.

The secondary infection takes place through sporangiophores and sporangia produced on the host as a result of primary infection. These sporangia are disseminated by wind, water and insects, land on the susceptible parts of the host, and germinate producing zoospores.

These zoospores germinate by germ tube and cause secondary infection. Since the sporangia are reported to germinate only in the presence of enough dew on leaf surface, the chances of secondary infection are remote.

Towards the end of the growing season of the crop, the pathogen produces oospores through sexual reproduction. The oospores are thick walled and serve as resting spores, keeping the pathogen alive during the unfavourable conditions.

During harvesting of the crop, the oospores along with plant debris are left in the soil of the fields where the oospores perennate waiting for the favourable conditions to return back so that these can serve as the source of primary inoculum.



A - F . Fertilization and germination of Oospore

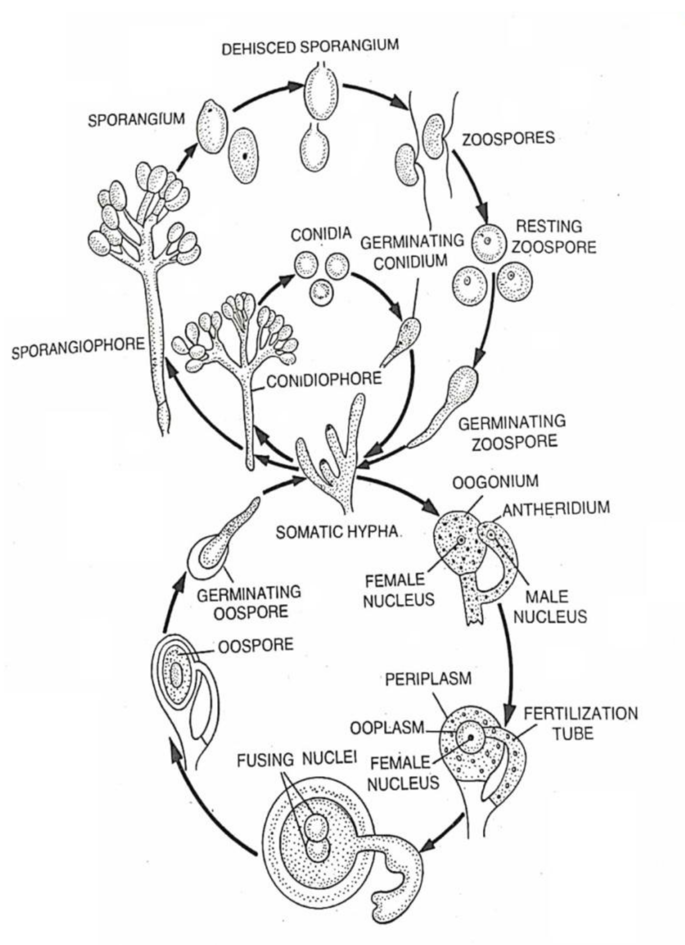


Fig – 11.2. Life Cycle Pathogen *Sclerospora graminicola.*

Control Measures:

- Rotation of crop, with nonhost types may check the disease.
- Removal of diseased plants and their burning within a month of the disease detection checks the disease to a large extent.
- Spraying with Dithane M-45 also helps in controlling the disease.
- Seed treatment with 0.1 percent Agrosan GN and 0.4 percent thiram has been reported to control the disease to 50 percent.
- Use of disease resistant varieties like HB-15, PHB-10 and PHB-14 has been recommended.

SAQ 1

(a) Green ear disease of bajra is caused by ……………………………………

(b) Primary inoculum of green ear diseases of bajra is ………………………..

(c) Green ear diseases of bajra is ………………….. borne disease.

(d) Secondary inoculum of Green ear diseases of bajra is ……………produced on host.

11.3 Rust of Linseed

Host: *Linum Usitatisssimum.*

Pathogen:*Melampsora Lini.*

Systematic Position

Class-Basidiomycetes;

Order- Uredinales;

Family – Melampsoraceae.

Occurrence: Rust of linseed is a common disease of flax growing areas of the world. In India flax is a major oilseed crop cultivated in almost all the states. The crop is generally cultivated during October-April. The disease generally appears in February or later but Butler has observed the disease in central India in early November. At the time of crop harvesting the affected plants get a fired appearance due to the presence of telial sori. The disease causes disastrous effects on the plants. Once the disease sets in a field, most of the linseed fields in the locality get affected with no time. The disease generally appears in epidemic form. Severely infected plants get mostly defoliated due to which starch formation is also reduced. Most of the food reserves of the host is consumed by the pathogen resulting in decrease in the yield of seeds and quality of fibres. Oil content of the seeds is also reduced.

Symptoms:

The leaves are the first to show the symptoms and gradually all the aerial parts of the plant get infected. Large, orange coloured pustules generally appear on the leaves. Small pustules are initially surrounded by chlorotic areas. Little necrosis of the leaves is at first observed but it grows, becomes more general and the leaves prematurely die.

Fig –11.3. Infected twig

Disease cycle:

In temperate countries, primary infection takes place through basidiospores which are produced as a result of germination of teleutospores prennating in the soil. But in tropical countries, the teleutospores, produced at the end of growing season i.e., April-May loose their viablility due to excessive heat of summers. Uredospores too are killed due to excessive temperatures. It is presumed that the uredospores produced on linseed at hills come down to plain to cause infection. Thus the primary inoculum, windblow fall on the host, germinate and cause infection. Because the transportation of uredospores from hills takes some time, the outbreak of the disease in plants takes place only after 2-3 months of the sowing of the crop. Uredospores produced as a result of primary infection cause secondary infection. Since the uredospores take very little time to germinate the secondary infection is caused within a short time. Secondary infection along with primary infection cause heavy damage to the seed crop. Teleutospores produced at the end of the growing season appear to have no role to play in the continuance of the life cycle of the rust.

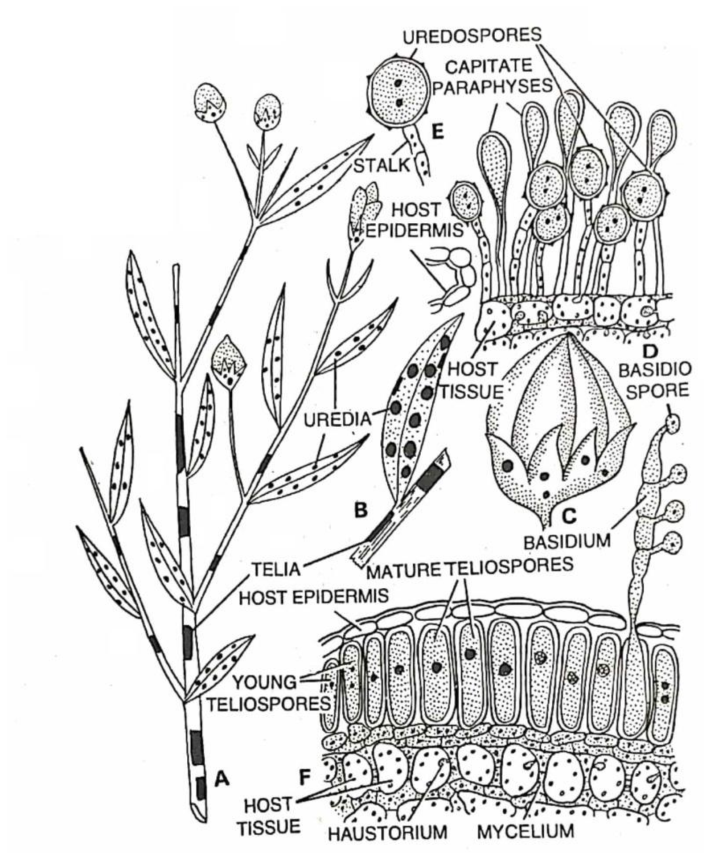


Fig –11.4. Disease cycle

Control Measures:

- Use of disease resistant varieties, like NP (RR) 9, 10, 56, 95. 218, 279B 279K 3, 368, 381, 389, 415 and 501 is the only effective method to control the disease.
- Seed treatment to kill the teleutospores in hills has also been suggested.
- Avoidance of excessive nitrogenous manures is recommended.
- Field sanitation by destruction of diseased crop debris and weed hosts of any, reduces the inoculum.
- Fungicidal sprays are also effective but not economical at field scale.

SAQ-2

(a) Rust of Linseed is caused by ……………………..

(b) Rust of Linseed is……………….. borne and ………………. borne diseases.

(c) The primary inoculum of soil borne diseases is …………………...

11.4 Rust of Wheat

Black Rust of Wheat

There are three different rust diseases that affect wheat plants.

1. Black rust (stem rust)
2. Yellow rust (stripe rust)
3. Brown rust or orange rust (leaf rust)

All the three rusts of wheat are most important destructive diseases of plant and causes enormous economic losses in all wheat are great enemy of the cultivators. Black and orange rusts are found all over the world while yellow rust is restricted, being absent, for instance from south Africa and Australia. In India all the above three different forms of rust attack the wheat plants. The three rust diseases are as follows:

1. **Black Rust (Stem Rust)**

   Pathogen: *Puccinia graminis tritici*

   Host : Wheat Plant

   Systematic Position of Pathogen:

   Class – Basidiomycetes

   Order – Uredinales

   Family – Pucciniaceae

Occurrence: The disease occurs in all wheat growing countries of the world. In different parts of India the disease appears at different times. In Northern India it appears in the month of march whereas in southern and Peninsular India it appears in the fourth week of November. The disease is very destructive and causes enormous losses in all wheat growing regions of the world.

Symptoms: Symptoms appear on the stem and leaf sheath in the form of long elongated pustules. Initially the pustules are brown in colour due to uredospores but become black coloured when teleutospores are produced. The uredospores are one celled, binucleated and are exposed by the rupture of the leaf epidermis. The teleutospores are two celled unnucleated and are exposed by the rupture of underlying epidermis. In severe infection plants look sick and fail to develop normal ears.

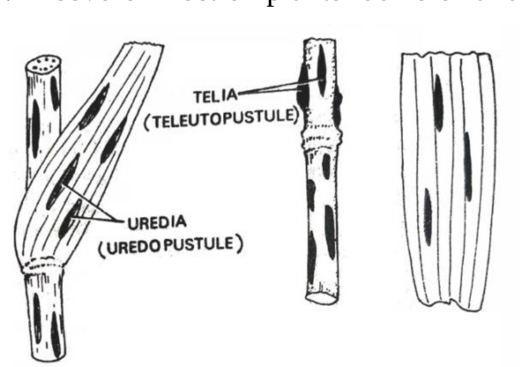


Fig. 11.5. Symptom of black rust of wheat

Host-pathogen relationship: The dikaryotic mycelium grows into the intercellular spaces of the host plant and produce button shaped intracellular haustoria by means of which absorb nourishment.

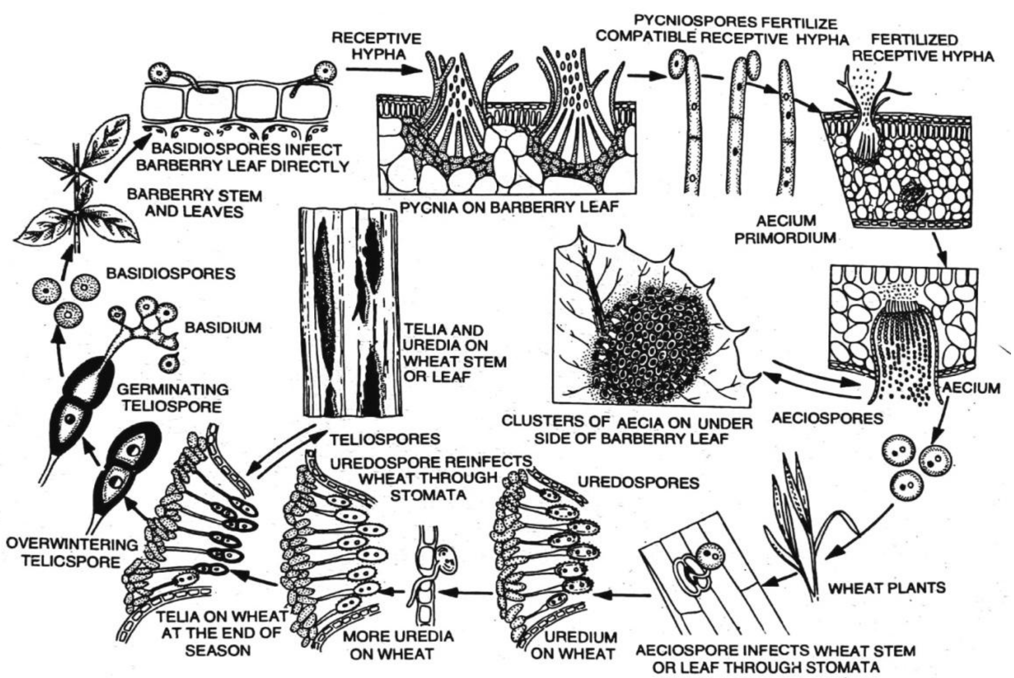
Environmental relationship: Moderate temperature and heavy rainfall favorers the disease.

Disease cycle: Puccinia graminis tritici is a heteroecious pathogen and requires two host wheat and barberry plant to complete their life cycle. The wheat is the primary host on which pathogen causes disease. Barberry is alternate host which is required to complete the life cycle of pathogen.

The disease is air born. The primary inoculum uredospores come to the plains of Northern India from the hills. The uredospores of the plains are killed by summer heat where as they survives on the hills due to low temperature. The uredospores when fall on the wheat plant germinates to produce mycelium and establish themselves in the intercellular space. After vegetative growth the pathogen produces uredospores in uredosori in the host below the epidermis. The epidermis ruptures and uredospores get exposed. At this stage brown streaks develop on the host surface.

The uredospores produced on the host act as secondary inoculum and are disseminated by wind. Thus secondary spread of disease occurs. After uredospores, teleutospores are produced in teleutosori on wheat plant and black streaked spots develop on host surface. After teleuto stage the life cycle of pathogen ends on wheat plant.

The teleutospore germinates in soil and forms basidium which bears four basidiospore (two of + strain and two of – strain). The basidiospores of + and – strain are dissaminted by wind and falling on alternate host barberry it germinates and produce Pycnia of + and – strain on the upper surface of leaf respectively. The + strain Pycnia has + strain receptive hypha (♀ reproductive organ) and + strain pycniospores (□reproductive organ). On the lower surface of leaf primordia of aecidial cup is formed in which aecidiospores are produced as a result of spermatization. These aecidiospores get exposed by rupture of epidermis and disseminated by wind. Thus the life cycle of pathogen is



completed.

Fig. 11.6. Disease cycle of Black rust of wheat

Control Measures:

1. Cultivation of resistant varieties of wheat like NP710, NP718, NP822 and NP825 helps in disease control.

2. Use of fungicides like dithane, zineb and actidione also control the disease.
3. Destruction and eradication of collateral host of hilly region on which uredospores survive there.

SAQ-3

a. *Puccinia graminis tritici* is a ………………………… fungus.

b. The primary host of *Puccinia graminis tritici* is …………….. plant.

c. Barberry leaf is the ………………………. host of *Puccinia graminis tritici*

d. Black rust of wheat is caused by …………….. …………………. ……………

2. **Yellow or Stripe Rust**

Pathogen: *Puccinia striiformis*

Systematic Position

Class-Basidiomycetes

Order- Uredinales

Family – Pucciniaceae

Occurrence: This disease is limited to North and East India and rarely in peninsular region of eastern India. The Disease is seen in the middle of January and appears like the other rust disease of wheat.

Symptom

Yellow rust appears earlier than black rust before the grains are formed. Uredinia are mainly occur on leaves, but under severe attack the leaf sheaths and stem, also get infected. Bright yellow pustules (Uredia) appear on leaves at early stage of crop and pustules are arranged in linear rows as stripes. The stripes are yellow to orange yellow. The teliospores are also arranged in long stripes and are dull black in colour.

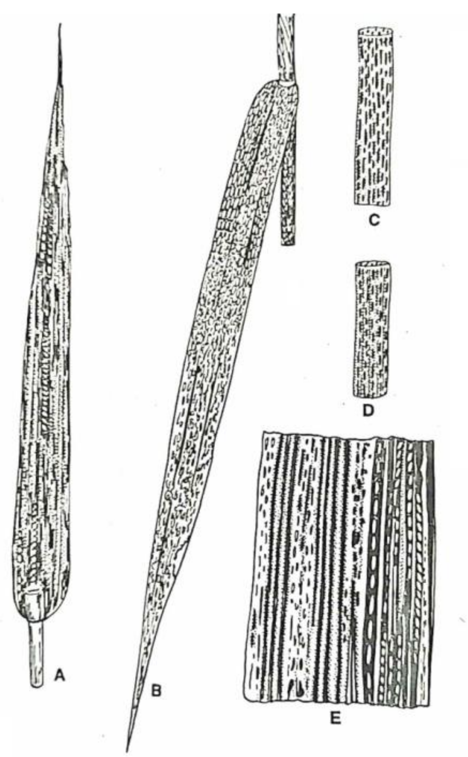


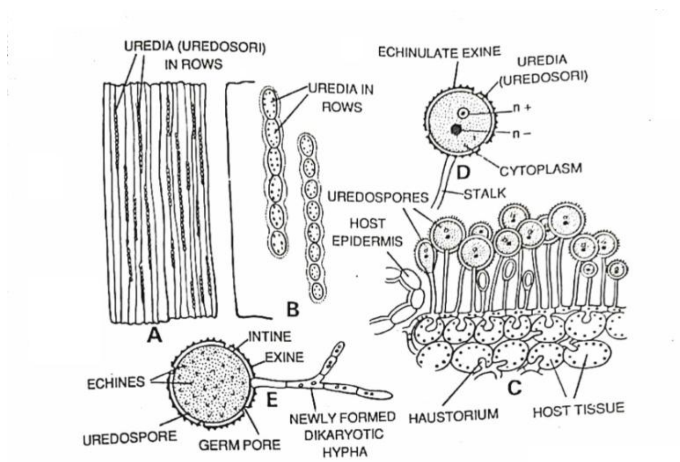
Fig – 11.7. A –E. Symptoms on Leaf and Stem

Disease Cycle

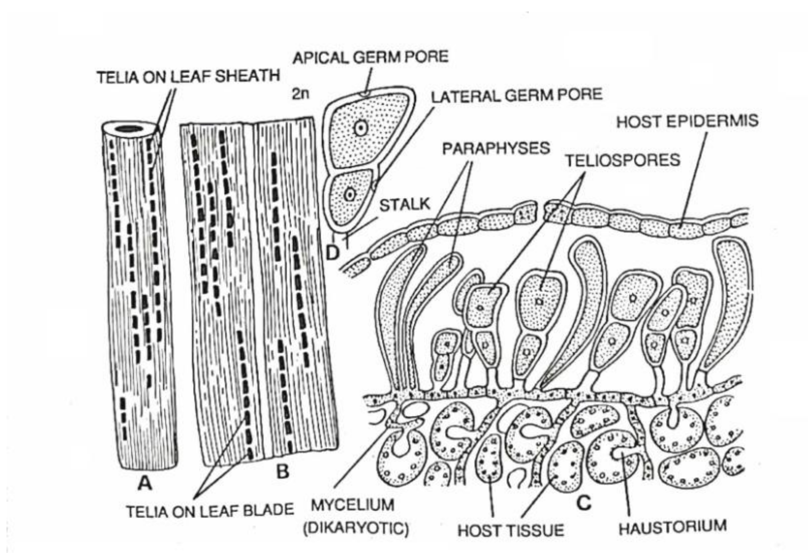
The disease is air-borne. Uredosori turn into teliosori as summer approaches. The inoculum survives in the form of uredospores / teliospores in the hills during off season on self sown crop or volunteer hosts, which provide an excellent source of inoculum. In India, role of alternate host (Barberis) is not there for completing the life cycle.

The fungus is inhibited by temperatures over 20˚C although strains tolerant of high temperatures do exist. The complete cycle from infection to the production of new spores can take as little as 7 days during ideal conditions. The disease cycle may therefore be repeated many times in one season. During late summer, the dark teliospores may be produced. These can germinate to produce yet another spore type, the basidiospore, but no alternate host has been found. Although the teliospores seem to have no function in the disease cycle they may contribute to the development of new races through sexual recombination. Temperature less than 10^0 favours yellow rust.

Uredospores and dormant mycelium survive on stubbles and straws and also on weed hosts and self sown wheat crops. Wind borne uredospores from hills are lifted due to cyclonic winds and infect the crop in the plains during crop season.



A-E . Uredial Stage



A-D. Telial Stage

Fig – 11.8.Disease Cycle

Disease Control:

- Mixed cropping with suitable crops help in disease control.
- Avoid excess dose of nitrogenous fertilizers.
- Spray Zineb at 2.5 kg/ha
- Grow resistant varieties like PBW 343, PBW 550, PBW 17

SAQ-4

(a) Yellow or strip rust is caused by ………………………..….

(b) Yellow or strip rust is ………………………..borne disease.

(c) Yellow rust appears earlier than …………………. rust before the grains are formed.

3. Brown or Orange Rust

Pathogen: *Puccinia* recondita

Systematic Position of pathogen

Class-Basidiomycetes

Order- Uredinales

Family – Pucciniaceae

Occurrence: The disease occurs throughout the world. Though it is found throughout India, yet more common in the northern and eastern regions. The disease prevails both in the hills and in the plains. In the northern region this disease appears earlier than black and yellow rust and causes much damage to the wheat crop.

Symptoms:

The symptoms of disease appear exclusively on the leaves because the uredosori or Uredia appear on the leaves. These uredia are sometimes grouped in small clusters or scattered irregularly. These uredia burst on the upper surface as points of bright orange colour and forms the most characteristic distinguishing features of brown rust. Telia are rarely formed and when present they are like those of yellow rust.

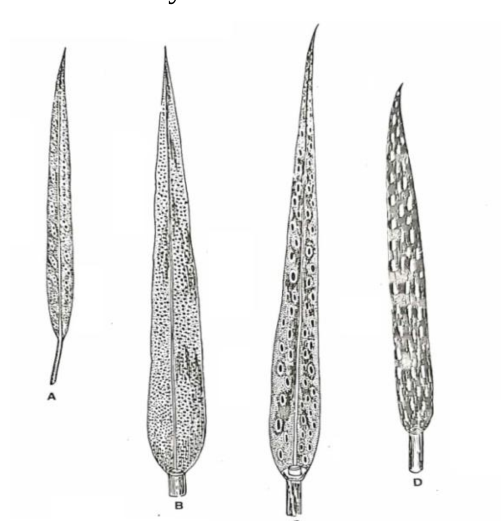
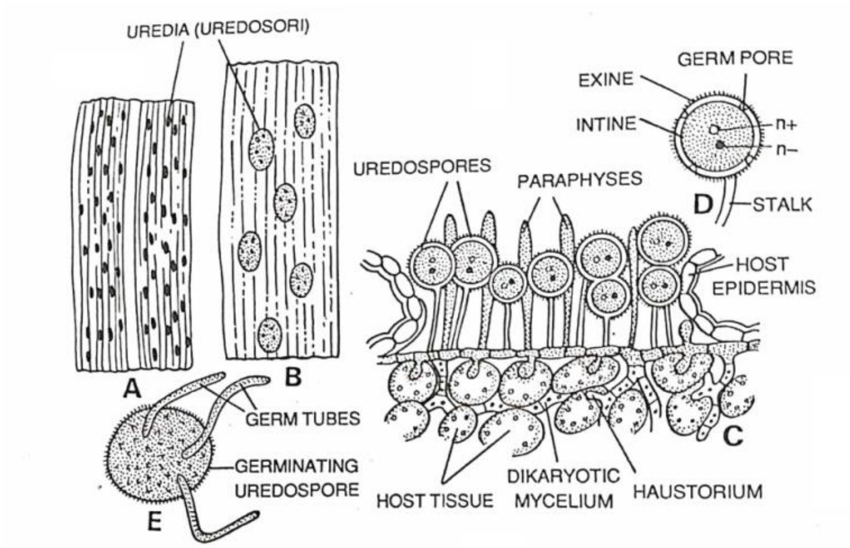


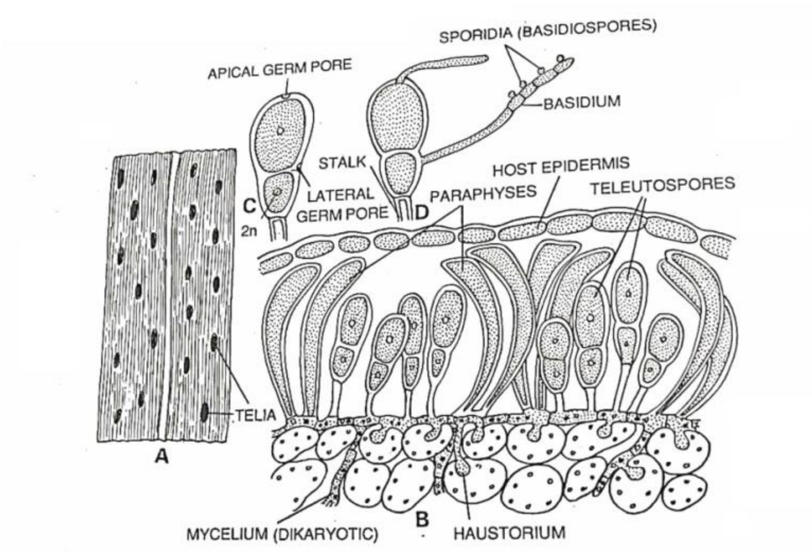
Fig – 11.9. A-D. Symptoms on Leaves.

Disease cycle:

The pathogen of brown rust in heteroecious and completes their life cycle on two host wheat and *thalictrum* but disease occurs only on wheat plant The uredia and teleia stages occur on primary host i.e. the wheat plant whereas the aecial and pycnidia stages of the pathogen appear on alternate host i.e. species of *Thalictrum.* In India, the role of alternate host has not be precisely determined. The disease is air-brone like other rust of wheat. Uredospores survive as an inoculum on the tillers and self sown plants in the hills. Every year these uredospores are carried by wind from hills to the plains and as they fall on the host surface germinate the germtube emerge through the germ-pores, which infect the wheat leaf through stomata.



A-E . Uredial Stage



A-D. Telial Stage

Fig -11.10. Disease cycle

Disease Control:

- Eradication of the alternate host is partly useful in the control of diseases.
- Eradication of collateral host present on hills during summer may greatly reduce the

incidence of outbreak of rust in plain during winter.

- Mixed cropping with noncereal crops minimizes the inoculum for secondry spread of disease.
- Chemicals like Dithane D-14, Dithane M-45, Zineb, Maneb, Vitavax, Plantavax etc are also used to control of disease.
- Use of resistant varities like 5227, 5307, 5308, 533, Lerma Rojo and Sonora 63 and 64 showed resistant to most races of the three rusts.

SAQ5.

(a) Brown or orange rust is caused by ………………….

(b) Brown or orange rust is ……………………..borne disease.

(c) The primary inoculum of brown orange rust is …………………………...

(d) The Uredospores are carried by wind from …………….. to the ……………….

11.5 Covered Smut of Barley

Causal Organism: *Ustilago hordei (Pers.) Langerheim.*

Systematic position:

Class-Basidiomycetes;

Order- Ustilaginales;

Family – Ustilaginaceae.

Occurrence: Disease is world-wide in its distribution and found in all those countries where the barley crop is grown. It is a common disease also in northern India. In Uttar Pradesh, it is one of the most important diseases of barley. The disease also causes much losses in the Punjab and Bihar.

Symptoms: As soon as ears of the infected plant emerge out, the first symptoms may easily be seen. The smutted or blackened ears of a diseased plant become infected and all the developing grains turn into smut sori. All the grains in a diseased ear are transformed into masses of spores which are held in place by persistent, tough, greyish-white membrane. The covered masses of spores are not released from their enclosing membranes until threshing time. Unless the membrane is broken accidentally.

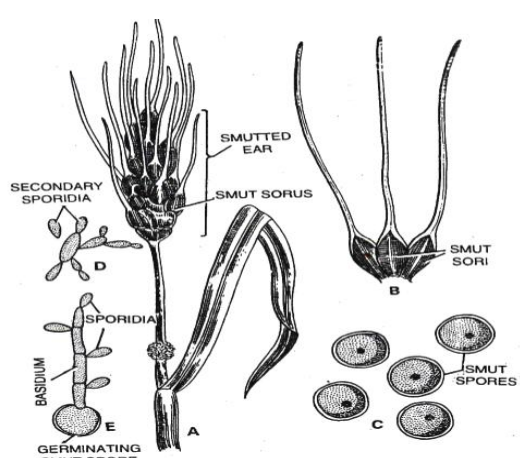


Fig –11.11. Symptom on Barley Ear

Disease cycle:

This is an eternally seed-borne and systemic disease. Every year the recurrence of disease takes place by the contaminated seeds.

Whenever, the contaminated grains of barley are sown and germinated, the smut spores adhering to them also germinate. On germination, every smut spore (teliospore) produces a promycelium or basidium. The diploid (2n) nucleus of smut spore divides meiotically forming four haploid (n) nuclei. The basidium becomes septate and basidiospores or sporidia are produced on the four cells of basidium. The basidium becomes septate and basidiospores or sporidia are produced on the four cells of basidium in chains. From two cells of the basidium, the basidiospores of + strain, and from the two cells, the basidiospores of – strain develop. Every sporidium or basidiospore is uninucleate and single-celled which produces secondary sporidia by means of budding. The two sporidia of opposite strains (+ and -) fuse together, and a dikaryotic hypha is formed. Now this dikaryotic hypha enters the coleoptile, and develops upwards in the seeding. The mycelium develops first in the stem and on the emergence of ears, it becomes most active in floral parts. The mycelium within the floral parts becomes closely septate, and thus the smut spores and formed. The smut spores remain covered by a thin, shining, white silvery membrane within ovary, and the structure is being termed as *smut sorus*. During threshing the smut sori break, the smut spores are released, and they make the seeds contaminated again.

Many of the spores lodge on healthy kernels and remain dormant until the seed is sown. When such infected barley seed begins to germinate the spores also germinate and infect the seeding along the epicotyl by dikaryotic infection hyphae. After fungus has entered the seeding, its hyphae continue to grow with the shoot and eventually replace the grains by masses of spores. A warm, moist, acid soil favours seeding infection. The greatest number of seedings are infected at a soil temperature range of 50^0F to 70^0F, during the germination period.

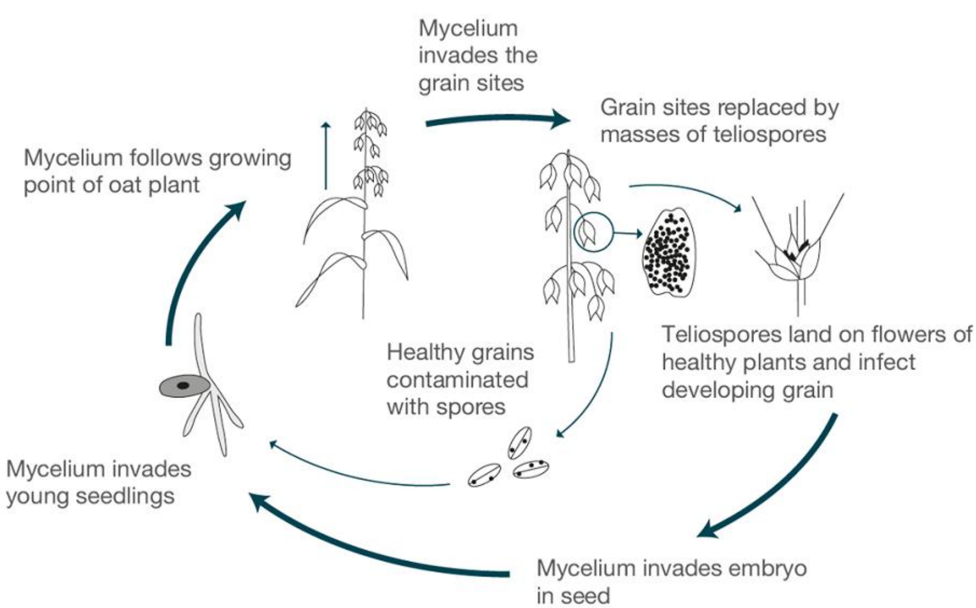


Fig -11.12. Disease cycle

Control Measures:

- Covered smut of barley is an externally seed-borne disease therefore most effective control measures will be seed treatment.

- Use of disease resitant varieties like (K 12, C.N. 294, C 84, BHS 4, BM 23, LB 873, EB 4003, EB 4032, and HBL 7 are highly resistant varieties, while K 18, K 19, C 50, CN 294, HBL 52, HBL 53, K 401-5, EB 4045, K 24 and NP 109)
- Sowing seeds in a moderately dry soil will aid in cheeking the disease, since moistsoils are favourable for infection.
- Rate of infection is reduced when barley is raised in a neutral or alkaline soil than in an acid soil.
- Rogueing- the infected plants may be uprooted and burnt.
- Seed selection- seeds must be taken from healthy crop.
- Seed treatment- the infected seeds may be treated with organomercuric compounds such as agrosan GN, and ceresan. About 5 kg seeds may be treated with 10 gms of seed disinfectant for about fifteen minutes.

11.6 Tikka Disease of Groundnut

Pathogen: *Cercospora arachidicola and C. personata*

Host: Groundnut

Systematic Position of Pathogen (Imperfect stage):

Class – Deuteromycetes

Order – Moniliales

Family – Dematiaceae

Occurance: Tikka disease is world wide in distribution and occurs in all those countries where the crop is grown. In India the disease occurs in all those states where the crop is grown. In Utter Pradesh disease is caused every year and locally known as chitwa or haldai due to characteristic symptoms on the leaves.

Symptoms: The symptom appears in the form of small pale area on the leaf surface which later on turned light brown when the causal organism is *C. arachidicola* or carbon black when the causal organism is *C. personata.*

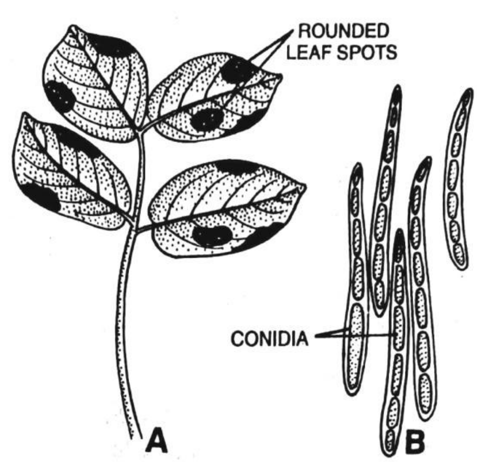


Fig. 11.13. symptom of tikka disease of groundnut (*Cercospora arachidicola*). A. Leaf showing

characteristic spots; B. Conidia

Host pathogen relationship: The mycelium grow in the intercellular spaces and do not produce haustoria. It kills the host tissue and then become intracellular.

Environmental relationship: Disease prevails in the month of September. Prolonged low temperature heavy dew and high humidity favors the disease development.

Disease cycle: Primary infection take place by conidia present in the infected plant Debris in soil and on seeds in the shell. The primary inoculum infects the plant when they are 2-3 months old. Mycelium establish themselves between the intercellular and intracellular spaces and produces long septate conidia which are disseminated by wind and causes secondary infection in the healthy host.

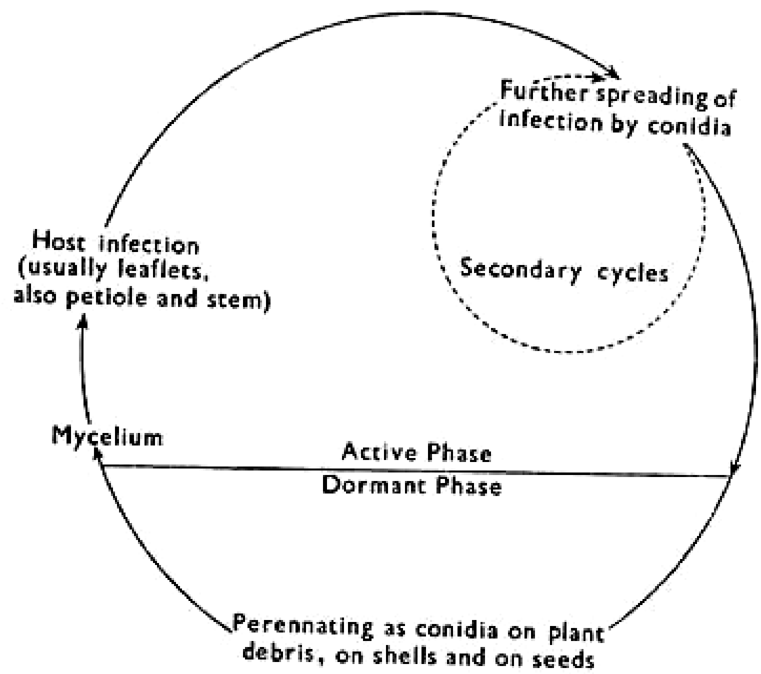


Fig. 11.14. Diagrammatic disease cycle of Tikka disease

Control Measures:

1. Rotation of crop can be used to control disease.
2. Treatment of seed and disposal of host debris by burning or burying also helps to control disease.
3. Plants are sprayed with fungicides like carbendazin, benomyl and bordeaux mixture.

11.7 Loose smut of wheat

Pathogen: *Ustilago tritici*

Host : Wheat Plant

Systematic Position of Pathogen:

Class – Basidiomycetes

Order – Ustilaginales

Family – Ustilaginaceae

Occurance: It is a common disease of India which occurs mostly in western districts of Utter

Pradesh. The distribution of disease is throughout the world.

Symptoms: The symptom appears in the inflorescence. The diseased ear has powdery mass of smut spores. In the beginning the smut spores remain covered by thin silvery membrane but later on the membrane ruptures and powdery mass of smut spores get exposed.

Fig. 11.15. Smutted ear of wheat

Host-pathogen relationship: Pathogen is an obligate parasite. Septate dikaryotic mycelium grow into the intercellular spaces in the part of the plant and absorbs nourishment with the help of intracellular haustoria. The spores are produced only in the floral parts specially ovary of the flower.

Environmental relationship: Cool and humid weather at the time of flowering favors the disease development.

Disease cycle: The disease is seed borne and primary infection comes from the infected seed. The secondary mycelium grow in all the part of the plants but symptom appears in the ear when teleutospores are produced. The telutospores act as secondary inoculum and disseminated by rain or wind. They fall on the stigma of healthy overy and causes secondary infection.

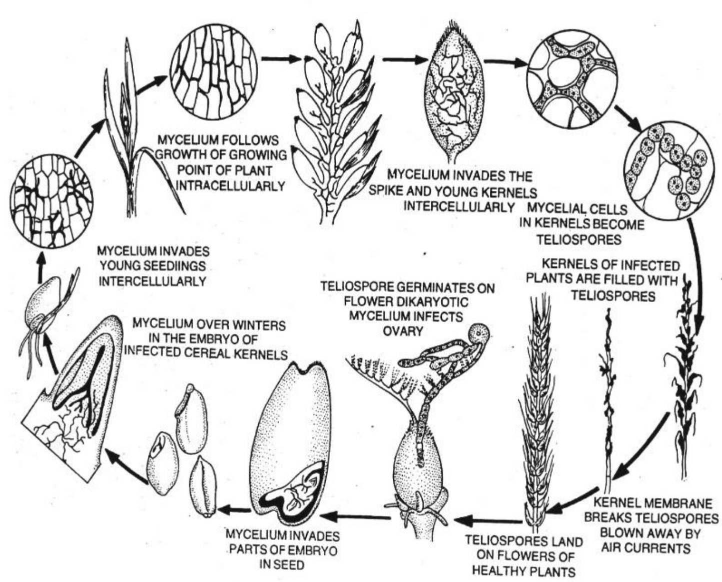


Fig. 11.16. Disease cycle of Loose smut of wheat

Control Measures:

1. Seeds are soaked in cold water for few hours then they are treated with hot water (temp. 52-54^{0}C) for 10 minutes. The seeds are then dried and sown.
2. Water soaked seeds are exposed to heat of direct sunlight for about 04 hours.
3. Use of resistant varieties like NP 710, NP 718, NP 761, NP 770, MP 108, MP 144 etc.

SAQ-6

a. The host of tikka disease is ………………………………

b. The pathogen of tikka disease is …………………. …………. and ………………..

c. Loose smut of wheat is caused by …………………………….

d. Symptoms of smut disease appear in the …………………………… of the plant.

11.8 Summary

- Plant diseases are important to human beings because they are responsible for causing damage to plants and plant products.
- *Puccinia graminis tritici* is a heteroceious pathogen and completes their life cycle on two host. The primary host wheat plant and alternate host is barberry plant. On wheat plant it causes a disease known as black rust of wheat.
- Tikka disease of groundnut is caused by *Cercospora arachidicola* and *C. personata.* The disease is soil borne.
- Loose smut of wheat is a seed borne disease caused by *Ustilago tritici.* The pathogen of disease grow in all the vegetative parts of the plant but symptoms of the disease appears only in the floral parts.
- Green ear disease of bajra is common disease caused by Sckerisoira gramminicola. The disease is primary soil borne.
- Rust of linseed is a common disease coused by Linum usitatissimum. The primary inoculum uredospose is windblow. There fare disease is air borne.
- Yellow or stripe rust is caused by *Puccinia striformis* in which bright yellow pustules appears on leaves at early stage of crop in linear rows as strips.
- Brown or orange rust is caused by *Puccinia rocondita* Bright orange colour symptom appears on the upper surface of leaf.
- Covered smut of barley is a systemic seed borne disease caused by *Ustilago hordei*. The symptom of disease appears in the ear which get transformed into masses of spore covered by tough, greyish white membrane.

11.9 Terminal Questions

1. Give a brief account of black rust of wheat caused by *Puccinia graminis tritici.*

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2. Give an account of loose smut of wheat.

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3. Describe pathogen symptom disease cycle and control measures of green ear disease of bajara.

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4. Give a brief account of rust of linseed disease.

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5. Describe life cycle of covered smut of barley.

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6. Write short notes on:

   (a) Yellow rust disease.

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   (b) Brown or orange rust disease.

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11.10 SAQ answers

SAQ-1

(a) Sckerisoira graminicola

(b) Oospore

(c) Soil

(d) Sprongia

SAQ-2

(a) *Melompsora lini*.

(b) Soil and air.

(c) teleutospore.

SAQ-3

(a) *heteroecious*

(b) wheat

(c) alternate

(d) Puccinia graminis tritici

SAQ-4

(a) *Puccinia* striformis.

(b) air

(c) black

SAQ5.

(a) *Puccinia recondite*.

(b) air

(c) uredospore.

(d) hills to the plains.

SAQ-6

(a) ground nut

(b) Cercospora personata,

(c) Arachidicoal

(d) ustilago tritici

Unit12

Plants DiseasesII

Structure

12.1 Introduction

Plant disease is defined as the state of local or systemic abnormal physiological functioning of a plant, resulting from the continuous prolonged irritation caused by phytopathogenic organisms.

Plant diseases, an impairment of the normal state of a plant that interrupts or modifieds its vital functions. All species of plant wild or cultivated alike are subject to disease. Although each species is susceptible to characteristic disease, these are in each case, relatively few in number. The occurrence and prevalence of plant diseases vary from season to season, depending on the presence of the pathogen, environmental conditions and the crops and varieties grown. Some plant varieties are particularly subject to the outbreak of diseases while others are more resistant to them.

The study of plant diseases is mot important as they causes loss to the plant as well as plant produce. The various types of losses occurs in the field, in storage or any time between sowing and consumption of produce. The diseases are responsible for direct monitory loss and material loss.

Objectives:-

After studying this unit you will be able to know:

- Pathogens and symptoms of various diseases.
- The hostpathogen relationship and environmental factors which favours disease development.
- Life cycle of various disease and their control measures.

12.2Early Blight of Potato

Pathogen: *Alternaria solani*

Host: Potato Plant

Systematic Position of Pathogen:

Class – Deuteromycetes

Order – Moniliales

Family – Dematiaceae

Occurance: The disease is world wide in distribution from Canda to New Zealand and Japan to

South Africa. In India disease occurs in the Indo-gangetic plain and the Nilgiris.

Symptoms: It is called early blight because disease appears in the early stage when the plants are 3-4 weeks old. The disease appears in the form of small isolated scattered pale brown to dark oval or angular shaped spot. The lower leaves are infected first. The spots are covered by deep greenish blue growth of the pathogen. In older spot the necrotic area is surrounded by series of concentric ridge which give target board effect. This is the characteristic symptom of the disease.

The spots are surrounded by chlorotic zone. In severe infection spot appears on petiole and stem as well as in the tuber in the form of dark, slightly sunken, irregular or circular lesions. In severe infection the whole plant collapse.

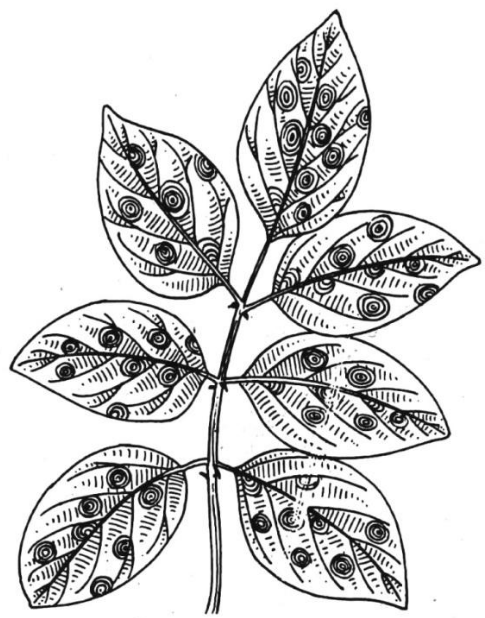

Fig.12.1. Potato leaf showing target board effect symptom

Host-Pathogen relationship- Septate branched mycelium grow in the intercellular spaces and then becomes intracellular.

The mycelium produces single conidium at the apex of conidiophore. Each conidia is muriform in shape and has transverse and vertical septa.

Environmental relationship: Heavy dew with frequent rains are essential for abundant production of conidia. The optimum temperature for germination of conidia is 28-30^{0}C. Abundant moisture and high temperature reduces the physiological vigor of the host plant and favors disease development.

Disease Cycle: The pathogen overwinters on infected plant debris in the form of mycelium or conidia. Thus disease is soil borne. Warm and humid environmental conditions are conducive to infection. The conidia present in plant debris germinates within 40 minutes under free moisture and 28-30^{0}C temperature. The germ tubes of conidia penetrates the leaf epidermis directly or through stomatal openings. Infection of potato tubers occur through wound in the tuber. Thus the primary infection in the host plant appears within 2-3 days. After infection pathogen produces conidia on conidiophores within 4-7 days.

The conidia produced on host surface act as secondary inoculum. They are disseminated mainly by wind and occasionally by splashing rain or overhead irrigation. When they fall on healthy potato plant germinate and causes secondary spread of disease. Thus early blight is polycylic with repeated cycles of new infection.

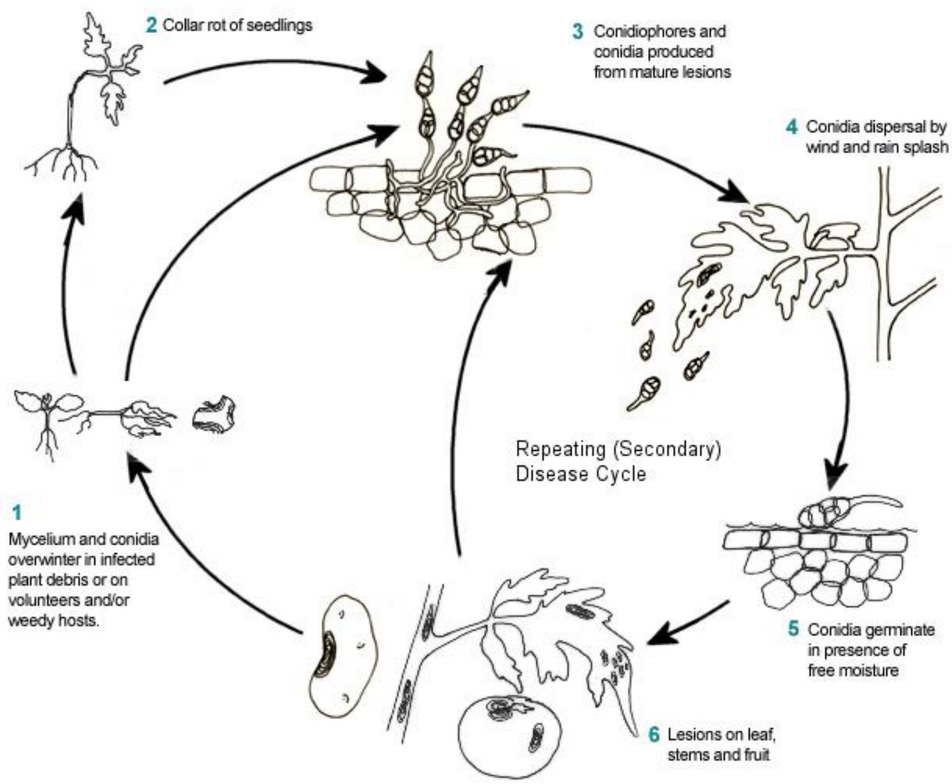

Fig -12.2. Disease Cycle

Control Measures:

1. Rotation of crop is a successful method to avoid primary infection from conidia present in the soil.
2. The plant debris should be collected and burned immediately after harvest.
3. Use of resistant varieties like: K. Naveen, K. sindhuri, K. Jeevan.
4. Timely and thorough spray of fungicides effectively controls the disease. Spray with Zineb or copper fungicide at 15 days intervals and weekly sprary of Bordeaux mixture is effective in disease control. Four to five foliar sprary of Dithane M-45, dithane Z-78, difoltan, captan and blitox-50 are also effective.

SAQ-1

(a) The pathogen of early blight of potato is …………………......

(b) The diseases is ……………………… is distribution.

(c) The disease appears in the ………………….. when the plants are 3-4 weeks old.

12.3Stem gall of coriander

Pathogen: *Protomyces macrosporus*

Host: Coriander (*Coriandrum sativum* L.)

Systematic position:

Class: Ascomycetes

Order- Tapherinales

Family- Protomycetacea

Occurrence: The disease has global distribution. It is prevalent in all the areas of the world, wherever the coriander is grown. The disease was first reported in Great Britain. In India, this disease was reported from Bihar, Uttar Pradesh, Madhya Pradesh and other part of India.

Symptoms: Symptoms of the disease appear as gall/tumor on the stems, peduncles and inflorescence. The galls are mostly elongated glossy and soft at the time of development, but become hard and rough in the older stems. Single gall is small up to 1.0 cm in length, but more than two galls coalesce and become longer up to 5 cm in length. The size of the galls varies according to the infected part, those on the stem usually being larger, than those of the leaf petioles and flower stalks. The infected plants show deformation in the fruits and severe infection kills the whole plant. The disease causes heavy loss in the annual yield of coriander.

Fig –12.3. Symptoms on Stem and Fruits

Disease cycle and epidemiology: The disease is seed-born. Primary inoculum of the disease is carried to the field of with the seed drawn from an infected crop, crop debris and/or uncleaned seed mixed with fruit galls. The hibernated thick-walled chlamydospores resist unfavorable dry environment and perennate summer, which may prolong for up to several years in absence of host. Chlamydospores germinate during the early winter in the host when immersed in water. The disease is favoured by prolonged cold temperature (8-22 °C and 65 % relative humidity) of the winter season. Longevity of the chlamydospore decreases with their age. On germination, they produce a vesicle which contains spores. At maturity the spores separated from each other, set free as the vesicle bursts. Released spores also multiply by budding and infect the host.

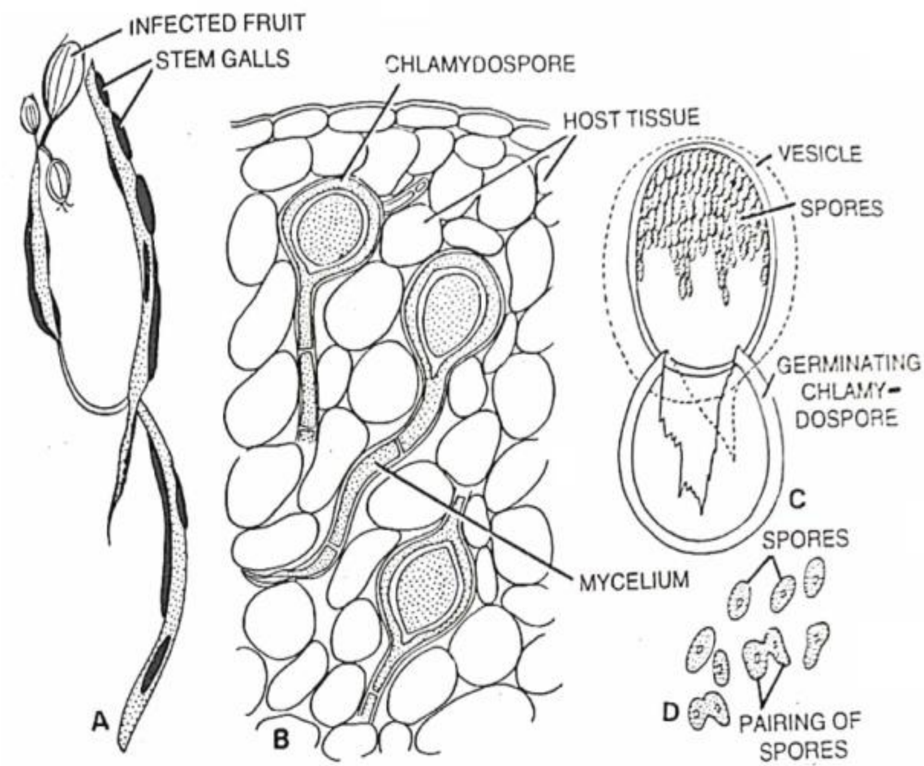

Fig- 12.4. A-D. Different Sttages of Spore formation in Disease cycle.

Control measures

- Stem gall of coriander is effectively suppressed by, treatment of seed, soil and foliar spray of Trichoderma viride and Pseudomonas fluorescens 40, 60 and 75 days of sowing reduce the disease up to 32 %.
- Seed treatment and foliar spray of 1.0 % neem oil is effective in reducing the disease.
- Seed treatment with chemical fungicides, e.g, thiram, ceresan and omnamycin effectively reduces the disease.
- Use of disease free field sanitation and rotation of crop are helpful in reducing the primary source of inoculum.

SAQ-2

(a) …………………………….. causes stem gall of coriander.

(b) Symptoms of the diseases appears as……………….. on the stem, peduncles and inflorescence.

(c) The disease is ………………. borne.

12.4 Downy Mildew of Cucurbits

Pathogen: *Pseudopernospora*

Host: Pathogen grows on members of Cucurbitaceae, such as gourds, melons, cucumbers etc.

Systematic position:

Class – Oomycetes

Order - Pernosporales

Family- Pernosporaceae

Occurrence: Disease is world-wild in distribution and was first discovered is vey common and causes serious damage in cucurbits during late rainy season.

Symptoms:

Symptom appears on leaf as several pale green areas separated by islands on dark green areas which look like mosaic mottling. In cucumbers, lesions are confined by leaf veins and appears angular in shape. In guards, pumpkins, lesions appears in irregular shape where as on watermelon leaves, the lesions tend to be smaller and rounded. Under humid conditions, a purplish downy growth begins to appear on the lower side of each such spot the whole leaf ultimately collapses, the entire plant becomes weak and wilted.

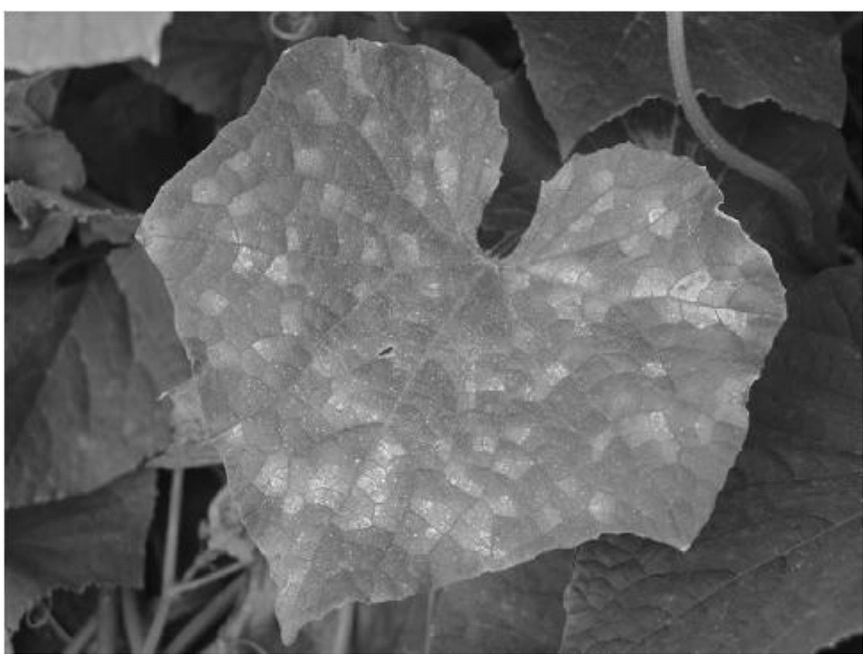

Fig –12.5. Symptoms on Leaf.

Disease Cycle:

The disease in soil borne. In areas where conditions are favourable for oospore formation, the fungus survives as oospore in the soil along with plant debris and serve as primary inoculum. This oospore causes primary infection on the host and produces sporangia and sporangiophore. The development of sporangia and sporangiophore is affected by light and temperature. The sporangia act as secondary inoculum, They are disseminated by wind and when fall on leaf surface of host germinates to produce zoospores. These zoospores infect the leaf by entering through stomata.

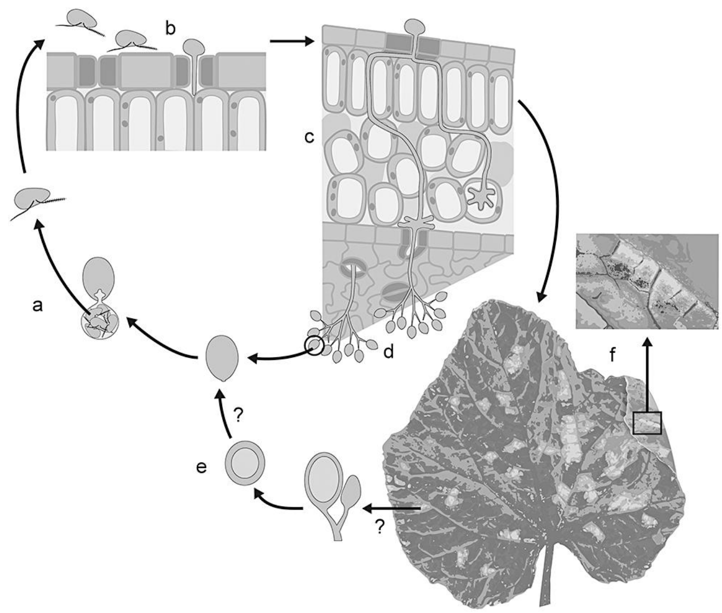

Fig-12.6. Disease Cycle

Control measures:

- Rotation of crop for two to three years is recommended for diseases control.
- Early sowing, proper nutrition (high N and P and low k level), moisture around plants helps in diseases control.
- Destruction of wild cucurbit host help reducing the disease incidence.
- Disease can also be controlled by spray of fungicides like mancozeb, zineb (Dithane M-45, Dithane Z-78) and Tricop-50 at 5-7 days interval.

SAQ-3

(a) The pathogen of downy mildew of cucurbits is ……………………….

(b) The downy mildew of cucurbits is ……………………… borne disease.

(c) The ……………………………. act as secondry inoculum.

12.5 Wilt of Arhar

Pathogen: *Fusarium oxysporum.*

Host : Arhar Plant

Systematic Position of Pathogen:

Class – Hyphomycetes

Order – Moniliales

Family – Tuberculariaceae.

Occurance: Wilt of arhar is the most severe threat to the arhar producing states in the country. This disease is responsible for severe losses in parts of Maharashtra, Uttar Pradesh, Madhya Pradesh and

Bihar. More than fifty percent of the plants are succumbed to the disease in the field.

Symptoms: The young susceptible host of about five to six weeks old are attacked by pathogen. The first sign of disease appears as premature yellowing of the leaves fallowed by withering. Gradually, the wilting occurs and plants dries up. In severe infection more than fifty percent plants in the field may fall due to this disease. This wilting is different from the wilting occurring in plant due to scarcity of water or by frost. In this wilting the vascular tissue of the stem and root of host plant are plugged by dense masses of pathogen mycelia and hyphae. Tyloses are also formed in the lumen of the xylem vessels. Besides this deposition of gum also occurs there. All this interrupt the free flow of water to the leaves of host plant. As a result drooping and wilting occurs in the leaves. The pathogen also produces some toxic substances which kill the plant cells concerned in the ascent of sap. If plugging in the vascular tissue of the host plant occurs on one side only the wilting is partial.

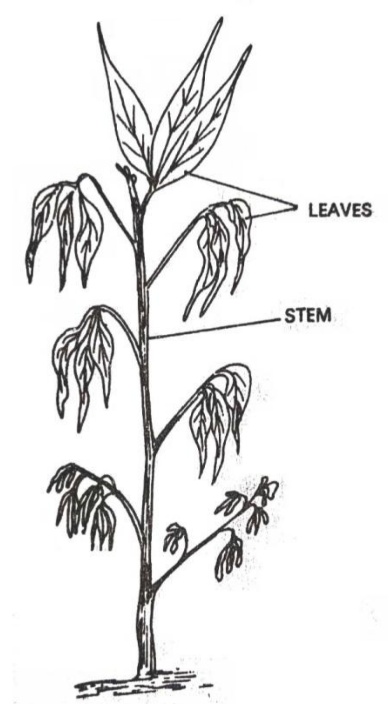

Fig. 12.7. Symptom of wilt

Host-Pathogen Relationship: The pathogen is facultative parasite and can survive in soil in the absence of host plants. The mycelium is septate, branched, colourless, intercellular and intracellular restricted to the vascular tissues of the host plant. The profuse growth of mycelium within the xylem vessels completely plugs the lumen of the vessels. Macroconidia, microconidia and chlamydospores are produced by the mycelium in the host tissues.

The macroconidia are long curved backward where as, the microconidia are small, oval or curved, unicellular or 1-2 septate. The chlamydospores are round, small, thick-walled produced in chain and remain viable for a long time.

Disease Cycle:

Wilt of arhar is a soil borne disease. The microconidia, macroconidia and chlamydospores produced by *Fusarium* remain viable in the soil. When arhar is sown in the soil having inoculum get infected. The spores of pathogen present in the soil act as primary inoculum and germinates in the soil in presence of susceptible host and suitable environmental conditions. The pathogen enters into the host through roots or rootlets and establishes themselves in the vascular system of the plant. Only the roots of the plant are being infected and the infection may be carried by roots to the new area.

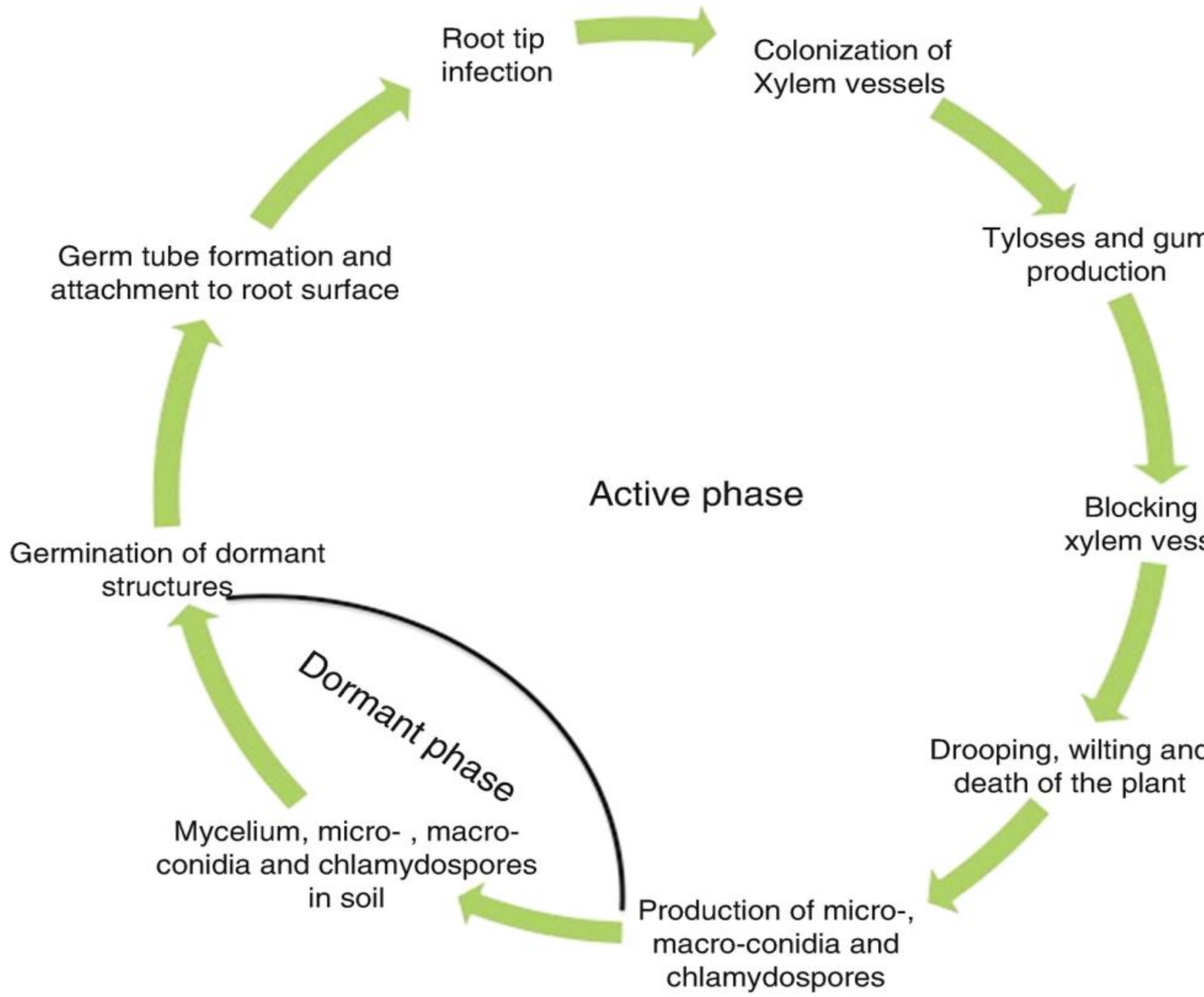

Fig. 12.8. Disease Cycle of wilt of arhar (Digrammatic)

Control Measures:

1. Wilt is a soil borne disease, therefore rotation of crop for 2 to 3 years is a best method of disease control. The pathogens are host specific and when the pathogen does not get their specific host it will die and field become pathogen free.
2. Use of resistant verities such as NP (WR)-15, (NP-24 X NP-51), 15-3-3 and DDN-1 developed at 1.A.R.A., New Delhi.

SAQ-4

(a) Wild arhar is caused by …………………………..

(b) Wild of arhar is a ……………………. borne disease.

(c) ……………………….. for 2 to 3 years is the best method of disease control.

12.6Blast of Rice

Pathogen: ***Pyricularia oryzae***

Hosts: **Rice (*Oryza sativa*).**

Systematic Position of Pathogen:

Class – Deuteromycetes

Order – Moniliales

Family – Moniliaceae

Symptoms

Fig – 12.9.A-D. Symptoms on Ear, Collar and Leaf.

The symptoms of rice blast include lesions that can be found on all parts of the plant, including leaves, leaf collars, necks, panicles, pedicels, and seeds. A recent report shows that even roots can become infected. However, the most common and diagnostic symptom, diamond shaped lesions, of rice blast occur on the leaves, whereas lesions on the sheaths are relatively rare.

The symptoms on leaves may vary according to the environmental conditions, the age of the plant, and the levels of resistance of the host cultivars. On susceptible cultivars, lesions may initially appear gray-green and water-soaked with a darker green border and they expand rapidly to several centimeters in length. On susceptible cultivars, older lesions often become light tan in color with necrotic borders. On resistant cultivars, lesions often remain small in size (1-2 mm) and brown to dark brown in color.

The collar of a rice plant refers to the junction of the leaf and the stem sheath. Symptoms of infection of the collars consist of a general area of necrosis at the union of the two tissues. Collar infections can kill the entire leaf and may extend a few millimeters into and around the sheath. The fungus may produce spores on these lesions.

The neck of the rice plant refers to that portion of the stem that rises above the leaves and supports the seed head or panicle. Necks are often infected at the node by the rice blast fungus and infection leads to a condition called rotten neck or neck blast. Infection of the necks can be very destructive, causing failure of the seeds to fill (a condition called blanking) or causing the entire panicle to fall over as if rotted. The rice blast fungus can also infect the panicles as the seeds form. Lesions can be found on the panicle branches, spikes, and spikelets. The lesions are often gray brown discolorations of the branches of the panicle, and, over time, the branches may break at the lesion.The fungus has often been isolated from the pedicels of the seeds. Seeds are not produced when pedicels become infected, a condition called blanking. Symptoms of rice blast on seeds themselves consist of brown spots, blotches and occasionally the classic diamond shaped lesion often seen on leaves. The process and the time during which infection of seeds by spores of the pathogen occurs has not been fully described but recent information shows that the fungus can infect seeds by infecting the florets as they mature into seeds, and it is believed that this is the main way seed infection develops.

Disease Cycle

Plant diseases are often severe during periods of warm temperatures and high moisture. In the United States, rice is grown in Arkansas, California, Florida, Louisiana, Mississippi, Missouri, and Texas. In the United States, rice is planted mechanically as seed, while in many other countries, rice seedlings are grown in beds and transplanted manually or by machine. Throughout the world, rice is normally grown partially submerged in water in paddies, although in some regions rice is grown as upland rice in much the same way as wheat. Generally, rice blast is favored by moderate temperatures (24C) and periods of high moisture that are 12 hours or longer, conditions readily attainable in flooded rice fields.

The overwintering sources of spores that comprise the primary inoculum consist of grasses, volunteer plants, infested refuse and infested seed on the soil surface after mechanical planting. Infested seeds left on the soil surface can readily produce spores of *P. oryzae* for more than several weeks after planting, well after seedlings have emerged. In the greenhouse, the fungus also sporulates on the dead or dying coleoptiles of plants grown from infected seeds.

Spores produced as the primary inoculum on the overwintering tissues produce the initial infections on young seedlings when the spores that are deposited on leaves, germinate and invade leaf tissues. Disease severity is often correlated with the amount of infested material. For example, in Arkansas, the first visible lesions often appear approximately 45 to 55 days after planting, but the disease is much more severe in plots receiving the highest amounts of primary inoculum found on infested seeds. Lesions on the young seedlings appear within a few days after infection. These secondary lesions produce more spores and these spores are readily wind disseminated to nearby healthy leaf tissues. The secondary cycles can be repeated many times during the growing season, with the potential for very high amounts of disease within the crop. The number of cycles and the number of spores that are produced on each individual lesion can be influenced by many factors, including the temperature, rainfall, the depth of the water in the paddy, the amount of nitrogen used to fertilize the rice, and the level of genetic resistance in the cultivar that is infected. Generally, the leaf phase of the disease is most severe when daily temperatures are moderate, and when rice is over-fertilized, or if it is being grown in flood waters below the recommended depths. Under these conditions conducive to disease, very high incidences of disease have been recorded on susceptible cultivars such as Newbonnet and RT7015 in comparison to cultivars genetically resistant to the fungus.

The amount of disease at the end of the vegetative phase of the growing season influences the amount of disease during the reproductive phase. Spores produced near the end of the growing season may infect the collar of the flag leaf producing symptoms called collar rot. They may also infect the neck when it emerges from the infected collar upon which the head will be supported to produce a condition called rotten neck or neck blast. Yield losses are significantly correlated with the extent of rotten neck. Infections of the neck are generally considered the most deleterious phase of the disease because infection at this location can reduce seed set on the entire panicle. In addition, the fungus can infect the panicle, the branches on the panicle, and the peduncles upon which the seeds are carried on these branches. Finally, new information shows that the seed also can be infected. Infections of the neck, panicle and branches of the panicle are usually relatively nondescript grayish discolorations of the tissues.

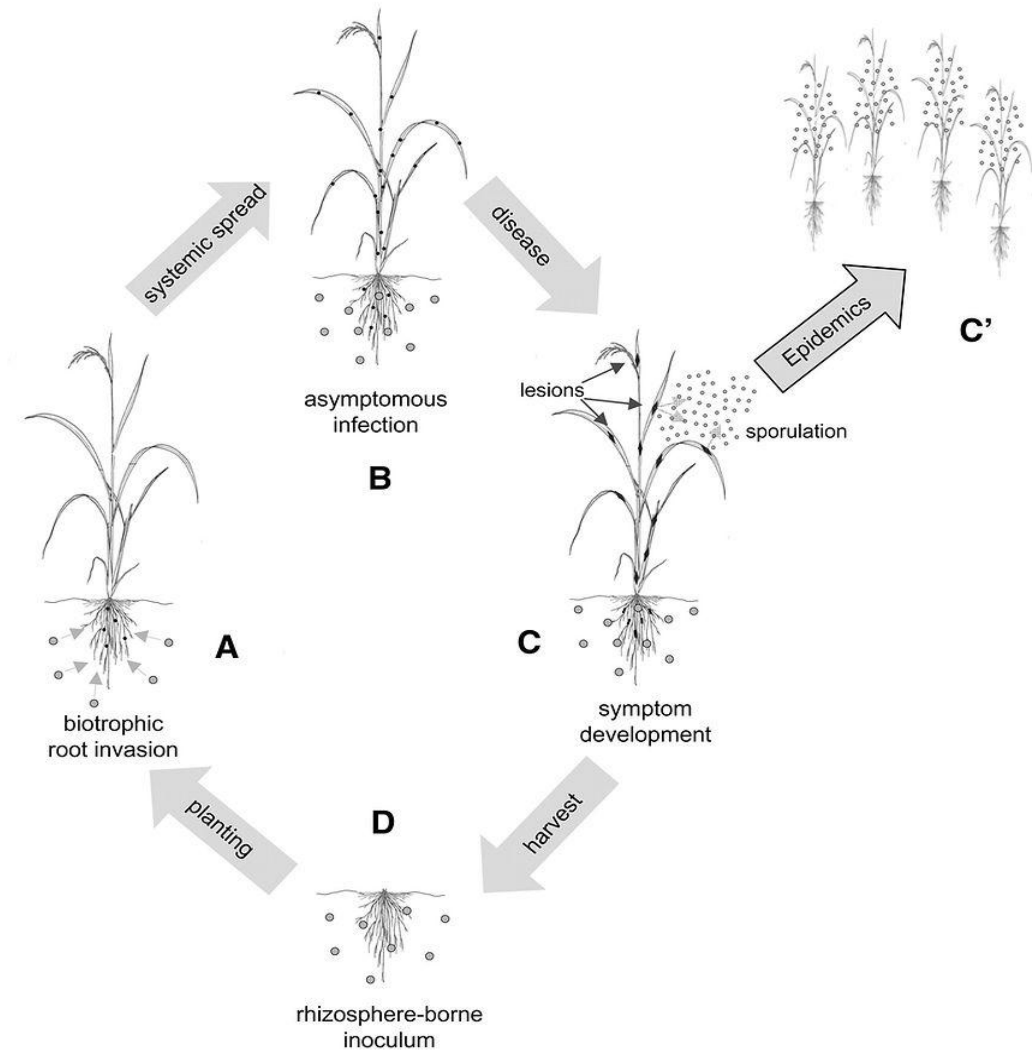

Fig -12.10. Disease Cycle

Control Measures

Crop rotation is one simple and effective technique that is highly recommended simply because it provides a mechanism that separates viable spores in crop residue from the newly emerging seedlings.

- Maintaining a proper flood level for the rice to grow.
- Using high quality and disease-free seed is always highly recommended because infested seeds left on the soil surface provide inoculum from which epidemics develop.
- The most economic method is the cultivation of resistant, high-yielding varieties like CO4, TKM-1, CO29, CO30, T-603, T-141, A- 67, A-90, A-200, A-249, IR-579 etc.
- Immersion of seeds in 0.2 percent solution of Kalimat B for 24 hours controlled the disease and promoted the growth of seedings. Hot water treatment for the seeds has also been

suggested.

- The spraying of Bordeaux mixture is quite effective against neck and node infection.
- The spraying of other copper fungicide, such as perenox, coppesan and cupravit are also effective against blast disease of rice.
- the plant debris should be collected and destroyed.
- Excessive use of nitrogenous fertilizers should be avoided as it predisposes the plant to infection.
- Use of balanced manuring by the application of potassic and phosphatic manures.

SAQ5

(a) Rice blast disease is caused by …………………………..

(b) Rice blast is favoured by ……………………… and ……………………..

(c) Use of high quality and disease free seeds helps in ……………………..

12.7Late Blight of Potato

Pathogen: *Phytophthora infestans*

Systematic Position of Pathogen:

Class – Oomycetes

Order – Peronosporales

Family – Pythiaceae

Occurrence: The likely home of late blight of potato is Mexico, where it is endemic on wild native species. The disease appeared in epidemic form in Europe in 1845 and led to the cause of famous famine of Ireland. Now it is a world wide distributed serious fungal disease. In India, the disease was first observed in the Nilgiri Hills, thereafter it was observed in the other parts of the country. Now the disease is of common occurrence in the plains of northern India.

Symptoms: The disease usually appears in the month of January on the above ground parts of the plant. First of all, a small dead brownish to purplish black lesion appears on the tip and margin of the leaflets, rachis, petiole and stem. In low temperature and moist weather the spot

spread and cover the whole plant. As a result the host plant decay and produce a foul smell. The infection also spreads in the potato tuber which get depressed and wrinkled. The skin of the tuber becomes brown and black and decay before the harvesting of crop.

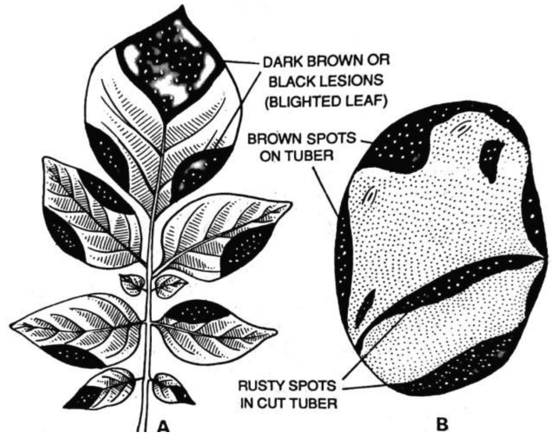

Fig. 12.11. Affected leaf showing characteristic symptoms of disease; B. Affected tuber

Host-Pathogen relationship: The pathogen is facultative saprophyte and facultative parasite. The mycelium of the fungus is branched, hyaline, aseptate. It grows into the intercellular spaces of the host tissue and produces intracellular globular or branched haustoria which absorbs nutrients.

Environmental Relationship: Disease develops in wet conditions under high relative humidity, cloudiness, moderate rainfall and temperature between 22-23^{0}C.

Disease Cycle: The primary infection take place either through the infected tubers used as a seed or by oospore present as plant debris in the soil. Thus disease is seed borne as well as soil borne. In India the infected tubers are main source of primary infection as climatic conditions of India do not favor survival of pathogen in soil. The pathogen survives as dormant mycelium in the tuber. When such tubers are used as a seed the mycelium becomes activated. It grows in the vegetative part of the growing plant and establish themselves in the intercellular spaces.

In case of soil borne disease the oospore germinates in the soil and produces sporangium. Biflagellated zoospores are produced in the sporangium get liberated in the soil. The zoospores withdraw their flagella becomes round off and encysted. Then it germinates on host surface and produce intercellular mycelium which has intracellular haustoria.

On the host surface pathogen reproduce asexually and produces sporangia on sporangiophore which comes out through stomatal openings. These sporangia act as secondary inoculum. The sporangia are disseminated by wind and falling on healthy potato plant. It germinates and produces a number of biflagellated zoospores. These zoospores germinate on the host surface, penetrate and causes secondary spread of disease. The process is repeated as a result disease spreads during the growing season over large tracts under potato cultivation. As a result of sexual reproduction oospores are produce in the soil.

The severity of late blight disease is governed by following environmental conditions.

- Night temperature below dew point for 4 or more hours.
- Minimum temperature 10^{0}C or slightly above
- Mean cloudiness not below 0.8^{0}C on the next day
- Rainfall during next 24 hours at least 0.1mm.

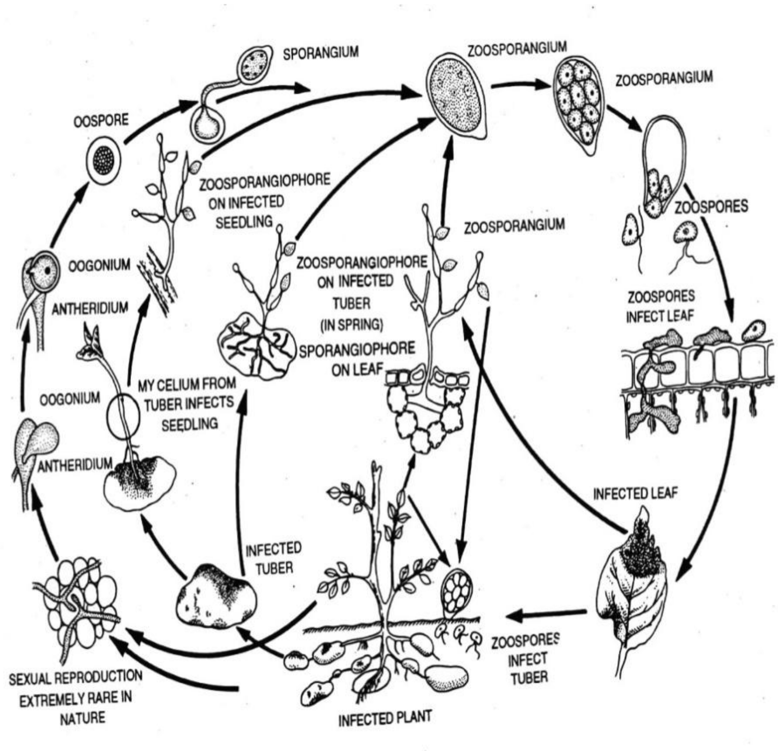

Fig. 12.12. Disease cycle of Late blight of potato

Control Measures:

1. The tubers used as a seed should be disease free.
2. Use of resistant varieties such as: Kufri Naveen, Kufri Jeevan, Kufri Badshah, Kufri moti, Kufri Alankar etc.
3. Timely and repeated foliage spray of fungicides like Dithane Z-78, Dithane M-22, Bordeaux mixture, Blitox-50, Fytolan.
4. Dusting the foliage with copper lime dust is an effective control measure.
5. Destruction or proper disposal of infected potato tuber also helps in reducing incidence of disease.
6. Before storage the tubers should be dipped in 1:1000 mercuric chloride solution for 90 minutes and should be washed before use.

SAQ6

(a)The disease usually appears in the month of …………..on the above ground parts of plant.

(b) Late blight of potato is caused by ………………

(c) Late blight is a …………….. borne and ……………borne.

12.8Summary

- Millions of people over the world depends on the plant products for their existence.
- Early blight of potato is a soil borne diseases caused by *Alternaria solani.*
- Wilt of Arhar is also a soil borne disease caused by *Fusarium oxysporum.*

- Late blight of potato is soil borne as well as seed borne disease caused by *phytophthora infestans*. The disease appeared in epidemic form in Europe in 1845 and led to the cause of famous famine of Ireland.
- Early blight of potato is a soil borne disease caused by *Alternaria solani.*
- Stem gall of coriander is to a seed borne disease caused by *Protomyces macrosporus.*
- Symptoms of the stem gall disease appears as gall/ tumor on the stems. Peduncles and inflorescence.
- Downy mildew of cucurbits is a soil borne disease. It is world wide in distribution and caused by *Pseudopernospora.*
- Blast of Rice is caused by *Pyricularia oryza.*
- The symptoms of Rice Blast include lesions that can be found on all parts of the plant, including leaves, leaf collars, necks, panicles, pedicels, and seeds.

12.9 Terminal Questions

7. Describe the life cycle of stem gall of corianders diseases.

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8. Describe the life cycle of late blight of potato giving emphasis on the symptoms, mode of infection and methods of control.

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9. Give a brief account of bast of rice disease.

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10. Give an account of downy mil of cucurbits.

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11. Write short notes on:

    (c) Wilt of Arhar.

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(d) Early blight of potato.

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(e) Downy mil of cucurbits.

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12.10 Answers

SAQ-1

(a) *Alternaria solani.* (b) world wide (c) early stage

SAQ-2

(a) *Protomyces macrosporus* (b) gall/tumor (c) seed.

SAQ-3

(a) *Pseudopernospora.*(b) soil (c) sporangia

SAQ-4

(a) *Fusarium oxysporum.*(b) soil (c) Rotation of crop

SAQ-5

(a) *Pyricularia oryza.*(b) moderate temperature and high moisture.(c) Soil, seed

SAQ-6

(a) January (b) Phytophthora infestans (c) disease control.

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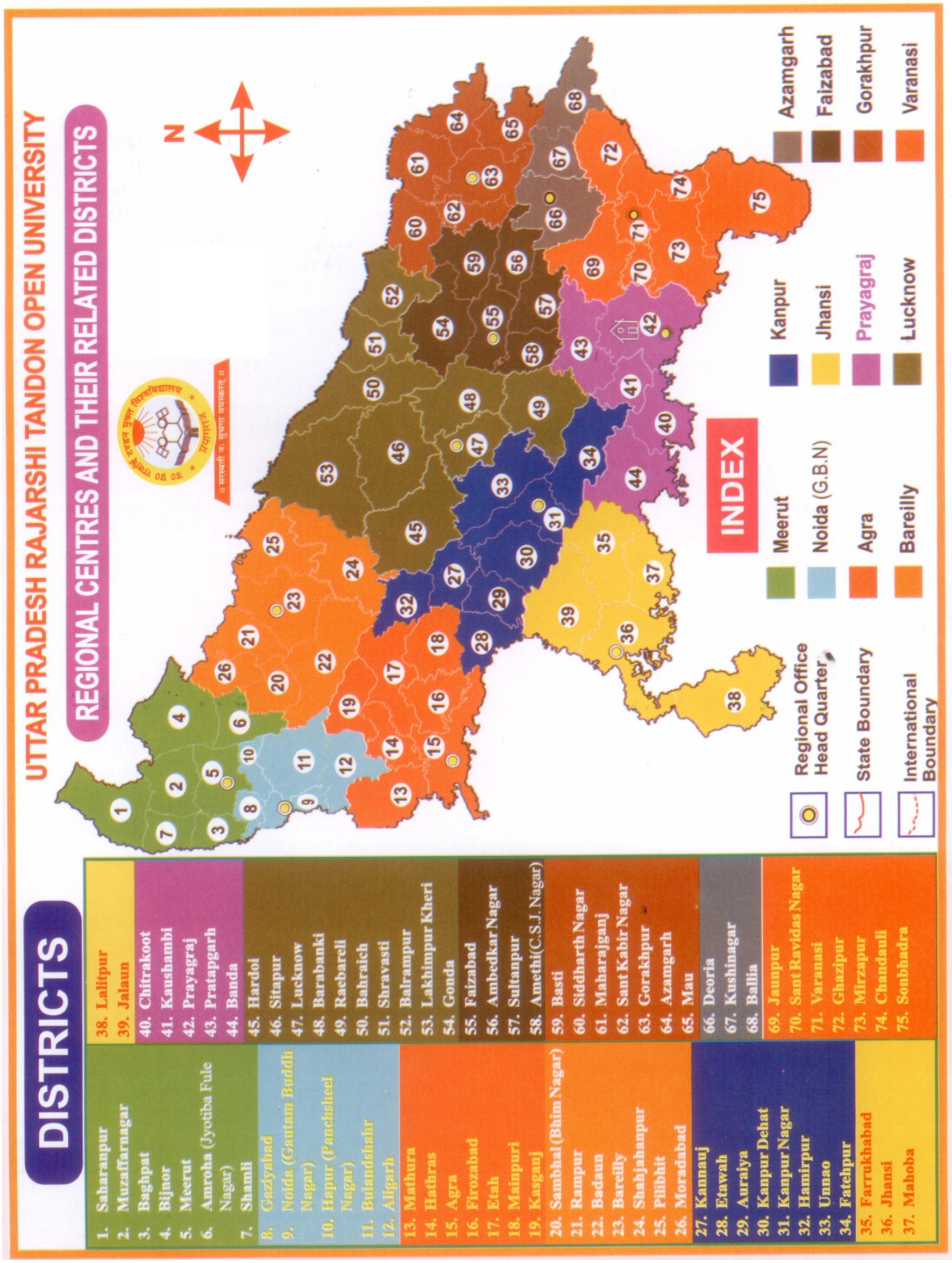

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