Class: Oomycetes

Oomycetes contain 74 genera with 580 species. The members of the class Oomycetes are characterized by the oogamous type of sexual reproduction and the presence of biflagellate zoospores which lack cell wall. The gametes are non-flagellate. The members of the class are typically aquatic, either free-living (i.e., saprophytic) or parasitic on algae, acquatic fungi, small animals, and other forms of aquatic life. Some Oomycetes are terrestrial and many of them cause downy mildew diseases on higher plants.

The salient features of Oomycetes:

(i) Most of the members are aquatic but some grow on the soil and the others attack the shoots of terrestrial plants.

(ii) The primitive forms are unicellular, whereas the advanced forms have a well-developed branched, filamentous, and coenocytic mycelium.

(iii) The cell wall is mainly composed of cellulose-β-glucan and chitin is altogether absent.

(iv) Asexual reproduction takes place by means of pyriform or reniform biflagellate zoospores, which are devoid of cell wall. In pyriform zoospores, the flagella are attached anteriorly and in reniform laterally. One flagellum is of whiplash type and the other of tinsel type.

(v) In primitive aquatic form, zoosporangia are not well differentiated from somatic hyphae, whereas in advanced forms distinct zoosprangia are found.

(vi) Some forms also produce non-motile asexual spores, known as conidia.

(vii) Most of the Oomycetes are eucarpic, but the members of the order Lagenidiales are holocarpic.

(viii) The sexual reproduction is of oogamous type. The male and female sex organs are known as antheridia and oogonia, respectively. The sex organs are either terminal or intercalary.

(ix) Meiosis in Oomycetes takes place within the diploid nuclei of gametangia (antheridia and oogonia) hence is called gametangial-meiosis. That is, zygotic meiosis is absent. As a result, the vegetative thallus is diploid.

(x) The gametes are non-flagellate. The fusion of gametes results in the formation of thick-walled oospores.

(xi) Oomycets show interesting parallel changes in their biology and morphology, which are closely connected with their phylogeny. These changes are the following:

(a) Transition from aquatic to terrestrial existence.

(b) Replacement of sporangia producing zoospores by conidia, a change from water-dispersal to air-dispersal.

(c) Alteration is biological requirements from saprophytism to obligate parasitism.

(d) Refinement of parasitism increasing host specificity and even organ specificity.

Significance of Oomycetes:

(i) Many terrestrial Oomycetes cause serious plant diseases such as late blight of potato (*Phytophthora infestans*), downy mildew of grape-wine (*Plasmopara viticola*), white rust of crucifers (*Albugo candida*), damping off of seedlings (*Pythium sp*.) and others.

(ii) Late blight of potato (*Phytophthora infestans*) and downy mildew of grape-vine (*Plasmopara viticola*) are historically very important. The late blight of potato resulted in Irish Famine' in mid-19th century that caused death of millions of people and Europe. Downy mildew of grape-vine (*Plasmopara viticola*) helped Prof. Millardet to discover the first fungicide called 'Bordeaux mixture'.

(iii) Many members of this group help understand the evolutionary migration of fungi from aquatic to terrestrial environments.

Phytophthora

Phytophthora (Greek phyton = plant; phthora = destruction) is represented by 48 species (Water house, 1973) which are cosmopolitan in distribution. Most of the species attack higher plants, mostly angiosperms and cause diseases of economic significance. Some species are facultative parasites and others as facultative saprophytes. One of the most common and well known species of *Phytophthora* is *P. infestans*, causing the disease called late blight of potato or Potato blight.

Vegetative Structure:

The mycelium is coenocytic, aseptate, hyaline and profusely branched (monopodial branching). The septa are formed at the time of reproduction or at maturity. The cell wall consists of glucan. Chitin is, however absent. Cytoplasm contains many nuclei, mitochondria, endoplasmic reticulum, ribosomes, dictyosomes, vacuoles and many oil globules. The mycelium is intracellular, and directly kills the invaded cells

Life Cycle:

Reproduction

(i) Vegetative Reproduction:

Many species of *Phytophthora* (*P. colocasiae* and *P. parasitica*) reproduce by means by Chlamydospores. These vegetative reproductive bodies may be terminal or intercalary. They germinate by giving rise to 3-11 germ tubes which generally develop sporangia at their tips.

(ii) Asexual Reproduction:

The asexual reproduction takes place by means of sporangia which are borne on aerial sporangiphores. Low Temperature (12-20°C) and high relative humidity (91-100%) favours the growth of sporangia. The sporangiophores arise directly from the internal mycelium and emerge out of the host singly or in clusters through stomata or by piercing through the epidermal wall (Fig. 9 A).

Each branch of sporangiophore bears, sporangium at its tip. With the growth of the hypha below, the sporangium is shifted to lateral position and another sporangium is formed at the tip. The process may be repeated several times. Thus, the sporangiophore in Phytophthora is sympqdially branched.

The sporangia may vary in shape (i.e. lemoni form, ovoid or elliptical). It is hyaline to light yellow in colour, terminally papillate and has a basal plug. The sporangia are deciduous (fall off) and are disseminated by water or are blown by the wind. At the place of detachment of sporangia, the sporangiophores bear nodular swellings which are typical for this fungus (fig. 9 C).

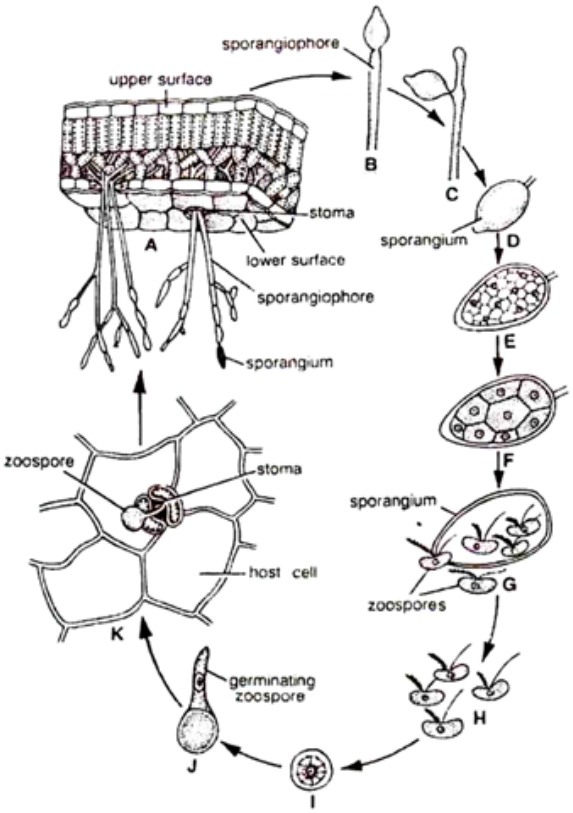

Fig. 9 (A–K). *Phytophthora* : Asexual reproduction

On falling upon a suitable host, the sporangia germinate. The germination of sporangium is governed by two main factors i.e., moisture and temperature. At high temperature (20-30°C), the sporangium germinates directly by a germ tube.

However, lower temperature (12°C) and presence of moisture favours indirect germination i.e., by zoospore formation. The sporangia are also susceptible to dessication. They loose their viability above 20°C temperature in 1-3 hours in dry air and 5-15 hours in moist air.

Direct Germination:

In the absence of moisture and high temperature (25 °C), sporangia germinate directly by germ tube and behave as conidia. The germ tube enters through a stomata and infects the leaf.

Indirect Germination:

In the presence of moisture and lower temperature (12°C) it behaves as zoosporangium and produces zoospores. The protoplasm of the sporangium is cut off into many uninucleate polyhedral pieces (Fig. 9 F, 10 in P. infestans and about 20 in *P. colocasiae*). Each polyhedral piece later rounds up and metamorphoses into zoospore (Fig. 9 G).

Zoospores are kidney shaped, biflagellate and possess flagella on lateral side. Of the two flagella one is of whiplash type and the other of tinsel type. The zoospores are liberated by the bursting of the sporangial wall. After swimming for some time they come to rest, encyst (Fig. 9 I) and germinate by a tube (Fig. 9 J).

The germ tube adheres on the epidermis of the host and produces a flattened pressing organ i.e., appresorium, at its tip. From the appresorium a fine tubular, peg like outgrowth arises. It is the infection hypha. It peneterates the host tissue through stomata or epidermal cells (Fig. 9 K).

After penetration it develops into a profusely branched mycelium. The mycelium is intercellular and develops haustoria in the host cells. Under favourable conditions numerous sporangiophores

emerge from the stomata and give rise to large number of sporangia. They are again disseminated by the wind and infect new plants. Thus, under favourable conditions the pathogen can reproduce several times by asexual method in one growing season.

(iii) Sexual Reproduction:

Clinton (1911) reported for the first time the sexual stages (oospore) in *P. infestans*. The sexual reproduction in *Phytophthora* is highly oogamous. The fungus is heterothallic i.e., requires two opposite strains, + and – for sexual reproduction. The male and female reproductive organs are called antheridia and oogonia, respectively.

Antheridium:

The antheridium is of following two types:

(a) Amphigynous:

Attached to oogonium as a collar e.g., *P. infestans*

(b) Paragynous:

Attached laterally to the oogonium e.g. *P. cactorum*. The antheridium arises earlier than the oogonium showing a protandrous condition. It develops as a terminal, more or less club shaped structure on a short lateral hypha of one strain. In young stages, it is thin walled with non-vacuolar cytoplasm and possessing only one or two nuclei.

The mature antheridium is funnel shaped and forms a collar like structure at the base of the mature oogonium (Fig. 10 A-E). The two nuclei divide mitotically and forms 12 nuclei. All nuclei disintegrate except one in mature antheridium.

Oogonium:

It is initiated laterally or below the antheridium on a hypha from other strain (Fig. 10 B). The young oogonium pierces the developing antheridium from below and swells above it into a pear shaped or spherical structure (Fig. 10 C). When young, it is multinucleate (up to 40 nuclei) contains dense cytoplasm. On maturity it becomes vacuolated and differentiated into an outer multinucleate periplasm and a central uninucleate ooplasm. (Fig. 10 D). The nucleus of the ooplasm divides mitotically and out of the two one survives and it functions as an egg or oosphere nucleus (Fig. 10 E, F).

Fertilization:

The oogonial wall bulges out at one point inside the antheridium and forms the receptive papilla. Later on the wall at the receptive spot dissolves and the antheridium pushes a short fertilization tube towards the oogonium. It penetrates the periplasm and passes into the ooplasm. Its tip opens and liberates a male nucleus and some of the cytoplasm.

However, in *P. himalayensis* 2 to 3 papilla like outgrowths develops from the antheridium. One of these grows upwards and establishes a connection with the oogonium. The male nucleus passes into the oogonium through papilla and brings about fertilization (Fig 10 G). The oospore may also develop parthenogenetically in some cases.

Oospore:

During fertilization, first of all the plasmogamy takes place. The fertilized oospore secretes a wall and undergoes rest. Fusion of the two nuclei is very late and occurs even until after the oospore walls are laid down (Fig. 10 H). A mature oospore consists of an outer thick wall called exospore and an inner thin wall endospore. Exospore is made up of pectic substances and endospore is composed of cellulose and proteins.

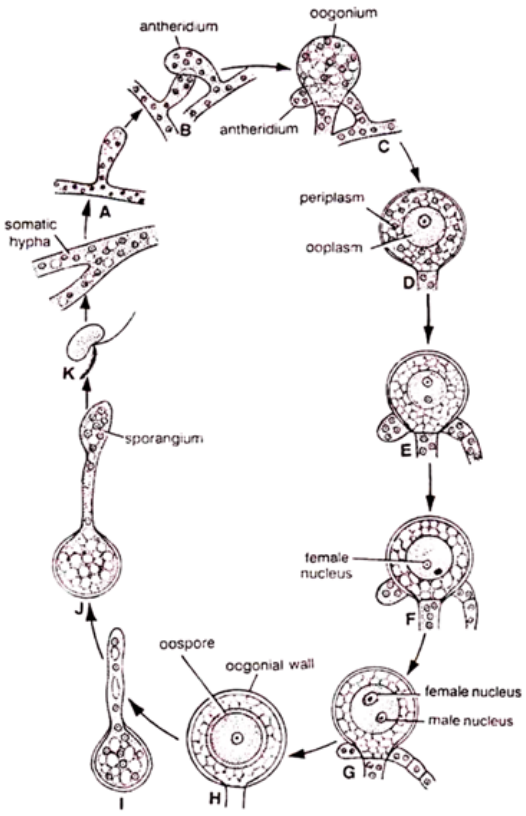

Fig. 10. (A–K). *Phytophthora* : Sexual reproduction

Germination of Oospore:

It is of rare occurrence and observed in a few species like *P. cactorum*, *P. palmivora* etc. The fusion nucleus divides meiotically and later on successive divisions result in the formation of few or many nuclei in the oospore.

The exospore cracks and the endospore comes out in the form of a germ tube which develops a sporangium at the tip (Fig. 10 I, J). The contents of sporangium may divide to form zoospores (Fig. 10 K) or sometimes may directly develop into a mycelium (*P. cactorum*). Thus, it completes its life cycle only within its host tissue. It has no saprophytic existence. It lives as dormant mycelium in the dead host remains lying in the soil.

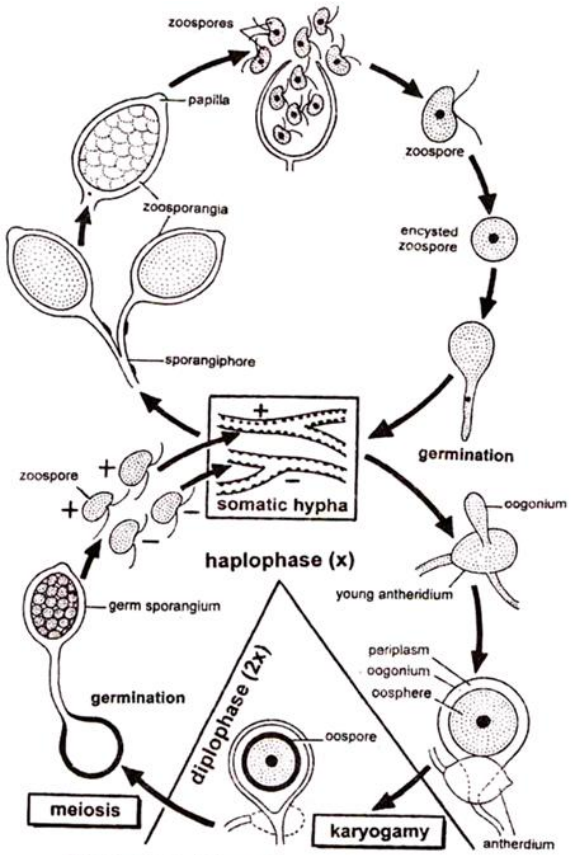

Fig. 11. *Phytophthora* : Diagrammatic life cycle

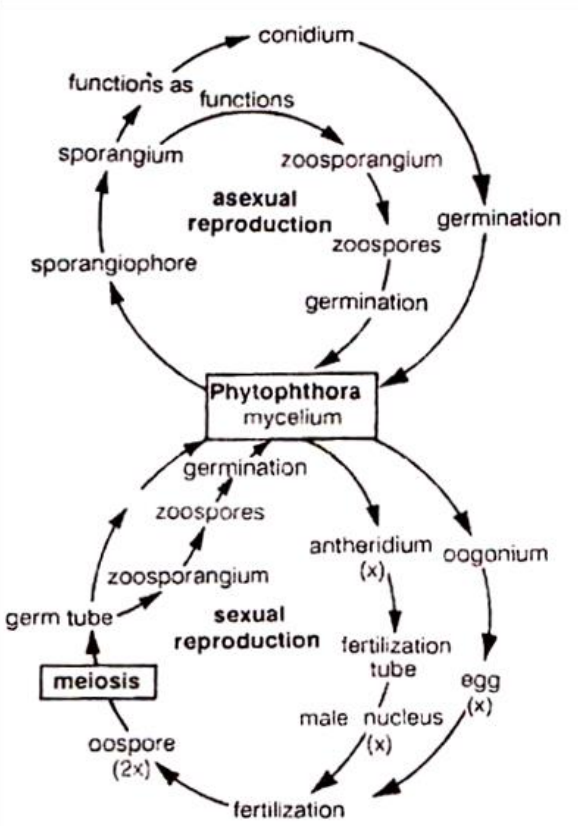

Fig. 12. *Phytophthora* : Graphic life cycle