Division II: Eumycota Subdivision: Mastigomycotina, class: Chytridiomycetes (Chytridiales), Oomycetes (Peronosporales)

General characters

Members of the class Oomycetes are mostly aquatic but some are facultative or obligate parasites of vascular plants. Majority of them are with filamentous hyaline coenocytic mycelium. Cell wall contains cellulose. They produce asexual spores called zoospores. Oospore is the sexual spores.

Class: Oomycetes

Zoospores biflagellate (posterior flagellum whiplash-type; anterior tinsel-type); cell wall cellulosic.

1. Members of the class comycetes are mostly aquatic but some are facultative or obligate parasites of vascular plants.
2. They are distinguished by the presence of well-developed holocarpic or eucarpic mycelium or rhizomycelium and zoospores bearing two flagella, one whiplash type and the other tinsel type. In some members, Zoospores are not formed and the zoosporangia function as conidia. The cell wall does not contain chitin, small amounts of cellulose are detected but the principal components are glucans.
3. In sexual reproduction the union of antheridia and oogonia produces oospores.

Order: Peronosporales

This order includes highly economically important plant pathogens. The members cause downy mildew and white rust diseases. Hyphae are well developed and aseptate. Cell wall is composed of glucan-cellulose complex and hydroxyproline. Parasites produce haustoria, which may be knob-like, elongated or branched and are found within the host cells. Asexual reproduction is by well-defined sporangia. Sexual reproduction is by means of well-differentiated sex organs, antheridia (male) and oogonia (female). Oospores germinate directly or by producing a sporangium.

Families

Pythiacea*e*

Sporangiophores similar to the vegetative hyphae or if different then of indeterminate growth. Pythiaceae contains genera like *Pythium* and P*hytophthora*

Albuginaceae

Sporangiophores strikingly different from vegetative hyphae, slender or thick, variously club-shaped, arranged in a layer, and bear sporangia in chain at the tip. These are obligate parasites. It contains a single genus, Albugo.

Peronosporaceae

Sporangiophores strikingly different from vegetative hyphae, slender or thick, variously shaped, and with determine growth; sporangia produced singly or in cluster at the tip of sporangiophores or their branches; obligate parasites.

Classification of Peronosporaceae

A. Sporophores determinate, hyphae-like short, unbranched or obpyriform, not maturing synchronously, germinating by zoospores; antheridia always paragynous; oogonial wall thick and confluent with that of the oospores; oospore germinates by germ tube or a sporophore terminated by a sporangium. **-** ***Sclerophthora***

AA. Sporophores determinate, macronemous, stout, 10 or more microns broad, branched or unbranched, oogonial wall thick and rough or ornamented:

B. Sporophores unbranched, apex swollen and with short sterigmata bearing papillate sporangia germinating by zoospores; oospores aplerotic**.-** ***Basidiophora***

BB. Sporophores repeatedly branched in the upper portion, dichotomous; spores mature synchronously; oogonial wall thick; oospore plerotic; sporangia germinate by zoospores or germ tube; oospores germinate by a germ tube**.-** ***Sclerospora***

AAA. Sporophores determinate, narrow, not more than 15 microns broad, usually 8- 10 microns; oogonial wall unornamented except in *Bremiella:*

B. Spore wall uniformly thick (non-poroid), germination typically by germ tube. **-** ***Peronospora***

BB. Spore wall poroid, emerging through an apical pore with or without papilla:

C. Branching of sporophore at right angles, tips or branches blunt.**-** ***Plasmopara***

CC. Branching at acute angles:

D. Tips of branches acute **-** ***Pseudoperonospora***

DD. Tips much enlarged and bearing 3-4 peripheral sterigmata; oogonial wall and oospore wall thin and unornamented.. *Bremia* DDD. Tips of branches blunt and slightly enlarged; oogonial wall thick and ornamented.**-** ***Bremiella***.

Club root of cabbage, damping off and life cycles of *Plasmodiophora, Pythium* and *Phytophthora*

Club root of cabbage caused by *Plasmodiophora brassicae*

Enlarged roots appearing like spindles or clubs due to stimulation of root cells to abnormal enlargement (hypertrophy) and abnormal division (hyperplasia) is called **club root.**

Systematic position

Scientific categorization of the organisms in a hierarchal series of groups. Based on characteristics of the spores, spore bearing structures and mycelium. Many fungi were classified earlier based on the asexual spore and same were reclassified once they produced sexual spore.

Kingdom: Protista (Eukaryote)

Sub-kingdom: Mycota

Division: Myxomycota

Class: Plasmodiophoromycetes

Order: Plasmodiophorales

Family: Plasmodiophoraceae

Genus: *Plasmodiophora*

Species: *P. brassicae*

Symptoms

Enlargement of roots, club-shaped roots due to hyperplasia and hypertrophy, gradual and inconspicuous stunting, yellowing and wilting of plant.

Pathogen

The thallus is a plasmodium (a naked mass of nucleated cytoplasm with amoeboid movement) which gives to zoosporangia or resting spore, which on germination produce zoospores. Resting spores are spherical with spiny walls. Zoospores are anteriorly biflagellate, heterokont (unequal in length) and uninucleate, both the flagella are of whiplash type.

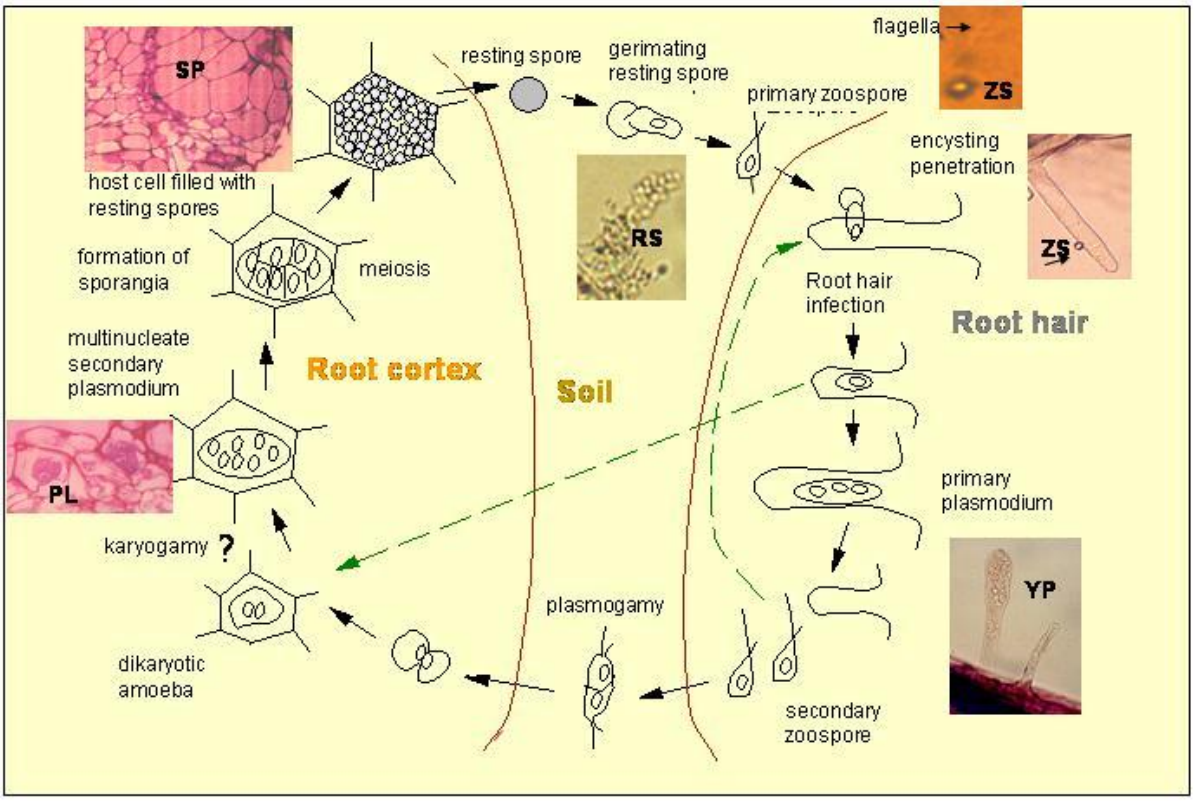
Disease cycle

Infection of the root hairs occurs during the seedling stage. Resting spores, which lie dormant in the soil upto several years, germinate and a circular pore is formed on its wall. An apically biflagellate zoospore comes out. Each resting spore produces single zoospore.

The zoospore penetrates the root hair and develops into uninucleate primary plasmodium. The plasmodium cleaves into multinucleate portions. Each portion develops into a zoosporangium containing 4-8 zoospores. The zoospores are discharged outside the host through pores dissolved in the host cell wall. The zoospores fuse in pairs to produce zygotes.

These zygotes with four flagella cause new infection and produce new plasmodium. This plasmodium penetrates the young root tissues directly or the older roots and underground stems through wounds. Thus the plasmodium spreads to cortical cells in cambium by direct penetration. When the plasmodia establishes in the host cells, they are stimulated to enlarge (hypertrophy) and divide abnormality (hyperplasia). The cells become larger (5 or more times). The plasmodium develops into large number of resting spores inside the. Plant tissues, which are released into soil by disintegration of, clubbed roots.

The Life Cycle of *Plasmodiophora brassicae*



Damping off of vegetables (tomato, brinjal, chillies, etc.) and tobacco – *Pythium aphanidermatum*

Damping off is a special name given to denote wilting of young seedlings in nursery. The rapid death and collapse of very young seedlings in the seedbed is called **damping off**.

Systematic position

Sub-kingdom: Mycota

Division: Eumycota

Sub-division: Mastigomycotira

Class: Oomycetes

Family: Pythiaceae

Genus: *Pythium*

Species: *P. aphanidermatum*

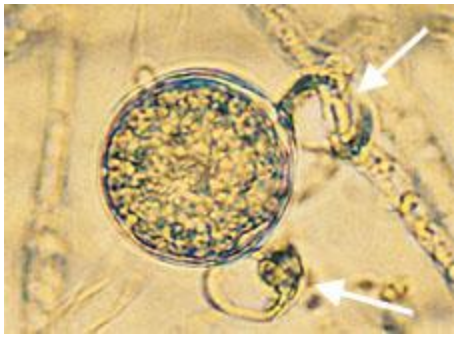
Symptoms

It is generally observed two weeks after sowing. Water-soaked lesions appear on the collar region of seedlings; browning and shriveling of stem tissues at soil level in the collar region; toppling down of seedlings in the nursery; ultimate death of sick seedling.

Pathogen

It is a facultative parasite and homothallic (both male and female gametes are produced in the same mycelium. Mycelium is hyaline, coenocytic (von-septate), branched, inter and intra cellular giving the appearance of a white fluffy cellular mass, does not have haustoria. Cell wall of this fungus contains cellulose. Sporangium is lobed or irregular; it forms vesicle. Sporangiophores are undifferentiated and similar to somatic hyphae.

Zoospores are produced in spherical vesicle and liberated after bursting of vesicle. They are reniform and biflagellate with flagella attached to lateral side, one pointing upward is tinsel type and the other pointing downward is whiplash type. Antheridium (male gametangium) is paragynous, club shaped, terminal or intercalary and it is applied to the side of the oogonium; the hyphal branch bearing antheridium may arise either from oogonial stalk (monoclinous) or from a separate -hypha (diclinous). Oogonium (female gametangium) is globose, generally develops at the tip of hyphal branch and consists of central denser zone called ooplasm or oosphere and peripheral lighter zone called periplasm. Oospores are the sexual spore, which helps to tide over adverse conditions (resting spore). They are spherical, thick walled with yellowish brown wall and does not fill oogonial cavity called aplerotic oospore.

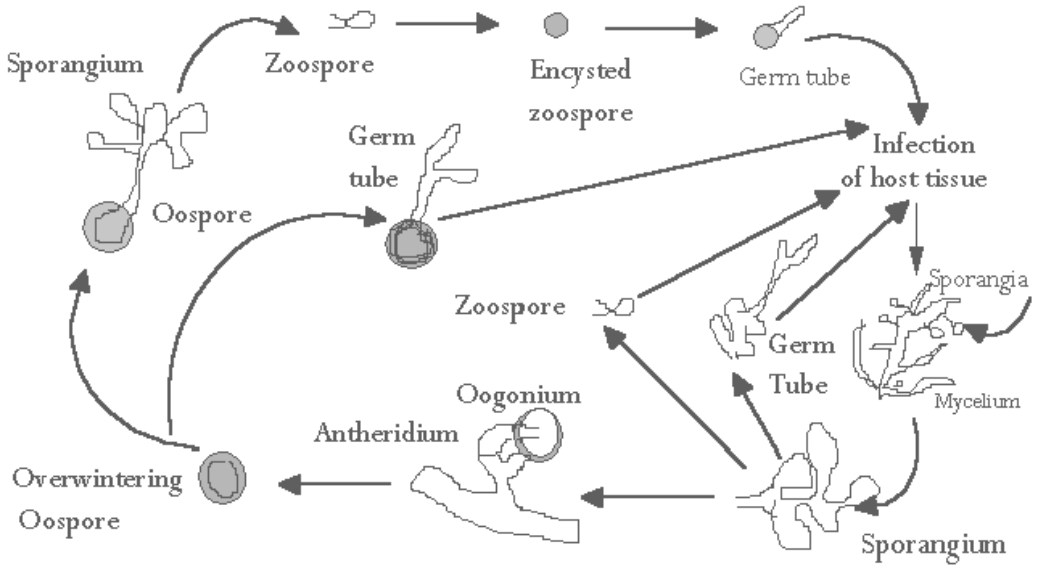


Paragynous arrangement of oogonium and antheridia in *Pythium*. (Courtesy P.B. Hamm) (arrows indicate antheridia)

Disease cycle

In the asexual stage, sporangia are borne terminally on sporangiophore. At the time of zoospore formation, a bubble-like protoplast moves into the vesicle and the zoospores are formed in this vesicle. When the crowded zoospores start rocking motion and bounce on the wall, the delicate vesicle bursts like a soap bubble. In the sexual reproduction oogonia and antheridia are produced. Antheridia get attached to the side of oogonium. On gametangial contact the walls between the sex organs are dissolved and a short tubular projections called fertilization tube is produced by the antheridium.

The fertilization tube passes through periplasm and penetrates oosphere. The contents of the antheridium moves through fertilization tube and evacuated into the oogonial cavity. The protoplasmic content of oogonium and antheridium mixes (plasmogamy). Plasmogamy is soon followed by nuclear fusion (karyogamy). The osphere after fertilization develops a thick mass and it is called oospore.



Life cycle of *Pythium aphanidermatum*

Disease cycle

Oospore or encysted zoospore germinates and produce germ tubes or saprophytic mycelium which come in contact with seed or seedling tissues of host plant and enter by direct penetration. Pectinolytic enzymes of the fungus dissolve the pectins (holding cells together) resulting in maceration of tissues. The mycelium grows between and through the cells. Proteolytic and or cellulolytic enzymes causing complete collapse and disintegration of cell walls break down the protoplasts of invaded cells. As a result, the infected seeds / young seedlings are killed and turned into a rotten mass.

Late blight of potato and tomato caused by *Phytophthora infestans*

Systematic position

Sub-kingdom : Mycota

Division : Eumycota

Sub-division : Mastigomycotina

Class : Oomycetes

Order : Peronosporales

Family : Pythiaceae

Genus : *Phytophthora*

Species : *P. infestans*

Symptoms

Brown to purplish black water-soaked lesions; enlarge rapidly; lower surface shows whitish mildew growth, severe defoliation; potato tubers show purplish, slightly sunken lesions leading to dry rot.

Late blight of potato on tuber **Late blight of tomato**

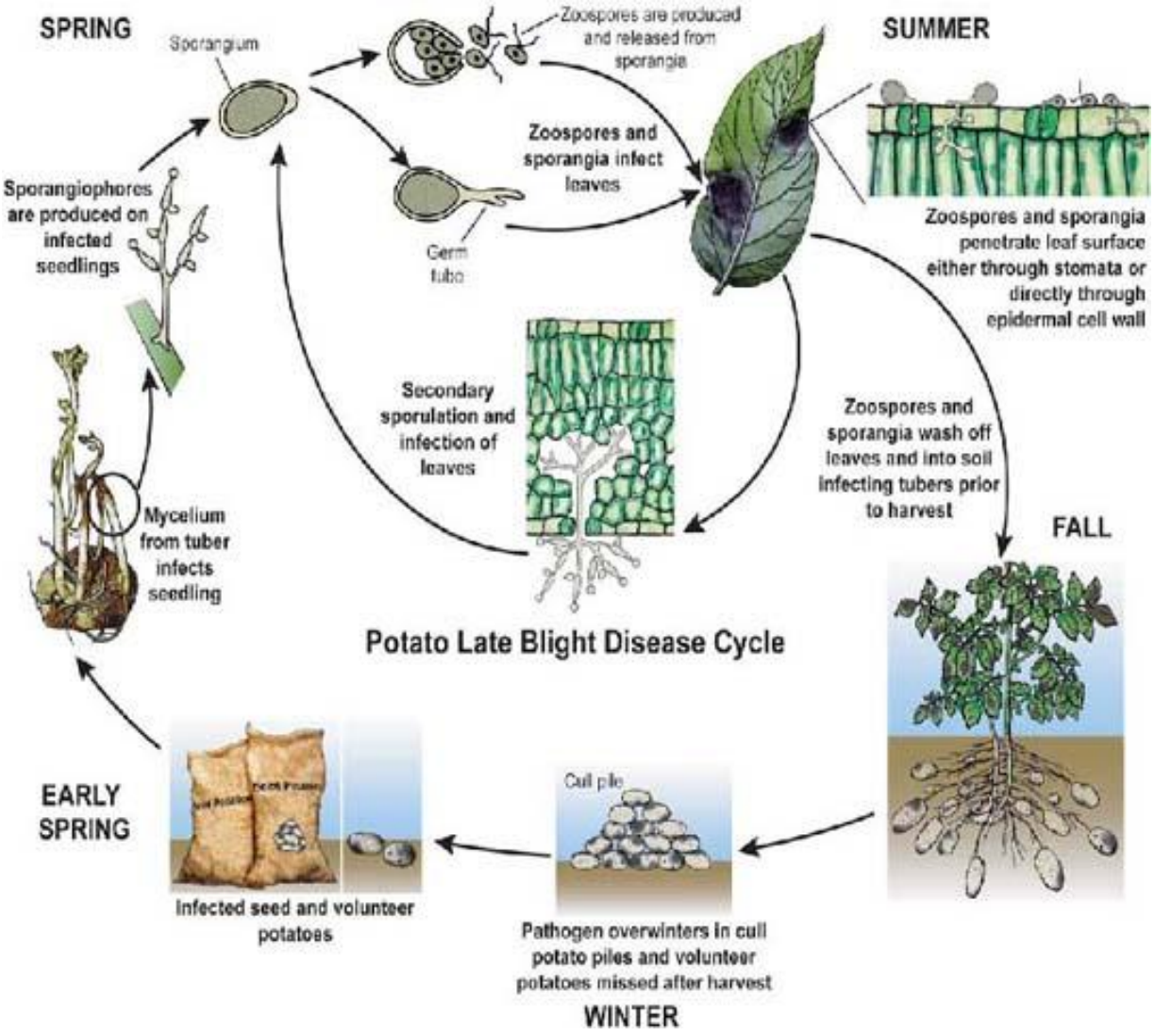
Late blight of potato on leaf

Pathogen

Mycelium is endophytic, coenocytic, hyaline, branched, and inter-cellular. Haustoria club shaped. Sporangiophores are hyaline, branched, indeterminate, thickwalled, arise through stomata on leaves or lenticels on tubers. Sporangia are multinucleate, thin-walled, hyaline, and oval or per shaped with a definite papilla at the apex. Zoospores are reniform, biflagellate (anterior tinsel and posterior whiplash). Oospores are thick-walled and smooth.

Life cycle

Primary infection is through use of infected tubers. Mycelium spreads into shoots produced from infected tubers and reaches the aerial parts of the plant. Sporangiophore emerges through stomata on stem and leaves and produce sporangia, which are spread by rain to wet potato, leaves or stem and cause disease. Large number of asexual generation in a growing season kills the foliage rapidly. The zoospores found in the soil germinate, penetrate through lentils or wounds into the tubers and send intercellular mycelium and haustoria into the cells and cause infection.



Life cycles of *Sclerospora* and *Albugo*

Downy mildew

Appearance of white downy growth in patches on the lower surface of the leaves and yellow discolouration correspondingly on the upper surface. Downy mildew fungi are obligate parasites belonging to the family peronosporaceae of the sub division Mastigomycotina cause downy mildew disease. They produce sporangia during asexual reproduction and oospores during sexual reproduction. Sporangiophore branching characters of genera, which cause downy mildew diseases are given below.

i. Sporangiophore is club-shaped with a swollen head, over which the sporangia are borne on minute sterigmata. e.g., *Basidiophora.*

ii. Sporangiophore is short, stout with many upright branches near the end, bearing the sporangia at tips. e.g., *Sclerospora.*

iii. Sporangiophore is branched at right angles and are irregularly spaced. e.g., *Plasmopara.*

iv. Sporangiophore is dichotomously branched at acute angles and taper to gracefully curved pointed tips on which sporangia are borne. e.g., *Peronospora* and *Pseudoperonospora.*

v. Sporangiophore is dichotomously branched at acute angles and the tips of the branches are expanded into cup-shaped apophyses with four sterigmata. e.g., *Bremia.*

Downy mildew of pearlmillet caused by *Sclerospora graminicola*

Systematic position

Sub-kingdom : Mycota

Division : Eumycota

Sub-division : Mastigomycotina

Class . Oomycetes

Order : Peronosporales

Family : Peronosporaceae

Genus : *Sclerospora*

Species : S. *graminicola*

Symptoms

Pale yellow discolouration of leaves; whitish fungal growth on the lower surface of leaves; twisting and crinkling of leaves; drying of leaves; infected seedlings when planted die within 30 days; green ear symptom i.e., transformation of floral parts into green leaf-like structures.

Symptoms often vary as a result of systemic infection. Leaf symptoms begin as chlorosis at the base and successively higher leaves show progressively greater chlorosis. Infected chlorotic leaf areas can support abundant white asexual sporulation on the lower leaf surface. Severely infected plants are generally stunted and do not produce panicles. Green ear symptoms result from transformation of floral parts into leafy structures

Pathogen

It is an obligate parasite. Mycelium is hyaline, coenocytic, intercellular and become systemic. Haustoria are finger- or button - like. Sporangiophores emerge through stomata, short, stout, non-septate with upright branches, crowded with sporangia bearing stalks (sterigmata) with pointed ends at the apex. Sporangia are hyaline, broadly elliptical, thin, smooth walled and papillate. Each sporangium contains 3 to 23 zoospores, which are irregularly reniform and biflagellate. Oospores are spherical, thick walled and yellowish brown.

Disease cycle

Soil borne oospores germinate by put forth germ tube and infect the root hairs / coleoptile of the host seedlings. Inside host tissue, fungus becomes systemic and produces hyaline, coenocytic, highly branched, strictly intercellular mycelium with **finger shaper haustoria**. During dewly nights, hyphae emerge through the stomata and form sporangiophores either singly or in groups. During such period, downy growth is noticed on the diseased area. A single sporangium is formed at the tip of the sterigma. The sporangia are deciduous and are carried by wind. The sporangia germinate by releasing zoospores. Zoospores swim for sometimes, come to rest, encyst and then germinate by germ tube to form new mycelium. Infected plant parts produces sporangia over a considerable period of time under humid condition and then necrosis begins.

In the sexual stage, the sex organs (antheridia and oogonia) develop in the intercellular spaces of the host tissues (leaves and malformed floral organs). It is typically oogamous. The fertilization tube formed by the antheridium carries the male nucleus into the oosphere where the two nuclei fuse to form a diploid zygote nucleus. The oosphere develops a warty wall and becomes the oospore. Oospores have a long period of rest lie in the soil (soil - borne) or on the seed surface. Oospores are liberated by the disintegration of the host tissue .They germinate and infect roots of young seedlings, from where the mycelium spreads systemically in the entire plant.

White rusts or white blisters

White rusts or white blisters are the characteristic pustules fructifications of *Albugo* in Albuginaceae on plant surfaces, especially on leaves.e.g.,white rust of Amaranthus caused by *Albugo bliti*, white rust of crucifers caused by *A. candida* and white rust of sweetpotato caused by *A. ipomeae panduranae.*

White rust of crucifers - *A. candida*

Systematic position

Sub-kingdom : Mycota

Division : Eumycota

Subdivision : Mastigomycotina

Class : Oomycetes

Order : Peronosporales

Family : Albuginaceae

Genus : *Albugo*

Species : *A. candida*

Symptoms

The fungus attacks cabbage, cauliflower, mustard, radish and turnip. The disease name is a misnomer. The pustules formed by white rust resembles the aecial stage of true rust belonging to the subdivision Basidiomycotina and hence the name. All aerial plant parts viz., leaf, stem and inflorescence are affected. On the lower surface of leaves it causes white or creamy yellow pustules of various sizes and shape. They are shiny and 1 to 2 mm in dia. Rarely the infection is seen on the upper leaf surface. Very often several of them coalesce to form patches.

They are formed below the epidermis and are unbroken. But with the pressure of sporangia from below, they rupture the epidermis and appear as powdery masses on the surface of leaves. The leaves are not distorted. In severe cases, the infection spreads to the stem, which is uniformly swollen for a length of several centimetres. Lateral buds, which are normally latent, may proliferate resulting in a bushy growth. Flowers and peduncles are also attacked. Peduncles become enormously swol1en. Affected flowers show various discolouration and malformation. The petals become green and stamens turned into leaf-like structures.Some times they may be changed into thickened club-shaped sterile bodies.

The pistil is hypertrophied into a large conical, thick walled sac or transformed into a sterile carpillary leaf. The fungal parasite stimulates cell activity leading to an abnormal increase in cell size (hypertrophy) and abnormal increase in cell division (hyperplasia) and formation of chlorophyll and starch at place where none is usually seen. Sepals become enlarged to several times than the normal sepals. Normally seed development is arrested. Pustules may occur on hypertrophied organ also.

White rust on leaf

White rust stag head symptom

Pathogen

It is an obligate parasite. The thallus is eucarpic and mycelial. Mycelium is well developed, strictly intercellular, hyaline, non-septate (coenocytic) and branched. Haustoria are knob-like or globular. Sporangiophore is club-shaped, short, erect, non-septate, closely arranged, unbranched and thick walled. Sporangia are globose or hexagonal (flattened at the sides), hyaline, smooth, thin walled and produced in basipetal chains (oldest at the top and youngest at bottom) with isthmus.Sporangia are formed at the tip of the sporangiophores. Antheridia are clavate or club shaped, multinucleate and paragynous. Oogonia are globose, terminal or

intercalary. Oospores are reticulate and round. Zoospores are biflagellate and reniform and 4 to 8 per sporangium.

Disease cycle

In the asexual stage, hyphae aggregate at several places under the epidermis. Sporangiospores are formed as a palisade-like layer. These cut multinucleate sporangia, which remain, attached to form a chain at the apex. The oldest sporangia lie at the top and youngest at the base of the chain (called basipetal). The sporangia are separated from each other by a gelatinuous disc-like structure called disjunctor or isthmus. The disjunctors are dissolved by water and the sporangia are set free. The numerous sporangia that are produced at the apical end of sporangiophores push against the epidermis, which bulges out and ultimately breaks.

The areas with broken epidermis and creamy mass of sporangia appear as pustules or blisters on the leaves. Sporangia germinate by means of germ tube (direct germination) or by formation of zoospores (indirect germination). Direct germination is not common. Sexual reproduction occurs when the crop season comes to an end and it is typically oogamous.

The antheridia and oogonia borne terminally on somatic hyphae. Plasmogamy takes place by gametangial contact, where the male nucleus from antheridium is transferred to oogonium through the fertilization tube. Karyogamy occurs and a thin membrane develops around the diploid zygote and a thick warty, tuberculate or roughened epispore. After a resting period, the oospore germinates and forms a vesicle, which contains 40-60 zoospores. The rupture of the vesicle wall releases the zoospores. The zoospore germinates by forming a germ tube, which infects the host plant.