Subdivition: Basidiomycotina, class: Teliomycetes (Uredinales, Ustilaginales) class: Hymenomycetes (Aphyllophorales)

General character of Basidiomycotina

Basidiomycotina fungi are highly evolved group. Mycelium is septate. Dolipore septum is present except rusts and smuts. Clamp connections present. Cell wall consists of chitin and glucans. Sexual spores are basidiospores. They are exogenously produced on basidium.

Key to the classes of Basidiomycotina

Basidiocarp lacking and replaced byTeliospores grouped in sori or scatteredwithin the host tissues **- Teliomycetes**

Basidiocarp usually well-developed,Basidia typically organized as a hymenium;Saprobes or rarely parasites **- Hymenomycetes and Gasteromycetes**

Class: Teliomycetes

This class includes many economically important plant pathogens commonly known as rusts and smuts. Mycelial hyphae septate and the septa are of simple type. Asexual reproduction is uncommon, through dikaryotic spores of conidial nature produced in rusts. In smut fungi, haploid sporidia may bud off into daughter cells. Basidiocarps absent. The class is characterized by thick walled, dikaryotic resting spores commonly called as teliospores in rusts and chlamydospores in smuts, Karyogamy takes place in this part and therefore, is actually a probasidium. The resting spores on germination produce promycelium (metabasidium) into which diploid nucleus moves and after meiosis four haploid nuclei are produced. These nuclei later, result in the formation of haploid basidiospores. The class is divided into 2 orders:

This class is divided into 2 orders:

Basidia arising from a thick-walled probasidium

1. Basidia becoming septate, bearing 2 to 4 (mostly 4) basidiospores, one at each septum and one nearly terminal - **Uredinales**
2. Basidia aseptate or septate, number of basidiospores indefinite **– Ustilaginales**

Characters	Smuts	Rusts
Perfect spore	Intercalary	Terminal
Number of basidiospores per promycelium	Many	Definite and four
Basidiospores	Globular	Sickle-shaped, elliptical or hypha like.
Basidiospores are borne on	Short sterigmata	Sessile spores
Basidiospores discharge	Discharged violently	Not discharged violently
Teleutospores	They are formed from terminal cells of binucleate mycelium	They are formed from intercalary cells of the binucleate mycelium.
Basidiocarps	Rare	Absent
Parasitic mycelium	Intercellular with haustoria	Intercellular with haustoria
Clamp connection	Present	Rare
Parasitism	Facultative saprobes	Biotrophs
Sex organs	Absent	Specialized
Heteroecism	Absent	Common
Polymorphism	Absent	Distinct

Order Uredinales (The rust fungi)

The members of this order are commonly called as 'rust fungi' due to the characteristic reddish brown colour of some of their spores. These are obligate parasites and cause great losses to many cultivated crops. The mycelium is septate without clamp connections. It grows intercellularly, frequently producing haustoria. In general, these fungi cause local infections in above ground parts of plants but sometimes these are systemic and may overwinter in roots or other parts. In recent years, rusts have been grown in tissues and axenic cultures e.g., Puccinia malvacearum, *M. lini*.

The rust in which life cycle is short and completed by only two types of spores (teleutospores and basidiospores) called microcyclic rust. The rust which has all the five spore stages (teleutospore, basidiospore, spermatia, pycniospore, aeciospore and uredospore) in its life cycle called macrocyclic rust. A macrocyclic rust in which uredospores are not formed has been named as demicyclic rust. The rust fungi that complete their life cycle in one host are termed as autoecious and those requiring two hosts for the completion of their life cycle are called as heteroecious. The rust fungi produce upto five types of spores in their life cycle, as given below:

Stage 0: Spermagonia with spermatia and receptive hyphae .

Stage I : Aecia with aeciospores

Stage II: Uredia with uredospores

Stage III: Telia with teleutospores

Stage IV: Basidia with basidiospores

(a) Pycniospores Stage(0)

These are the spores produced in a flask-shaped structure called as pycnium, containing a palisade of sporogenous cells which produce spores in nectar exuded from the ostiole. Periphyses and flexuous hyphae (receptive hyphae) are commonly present in pycnia. Pycnia are formed in the host after it is infected by the basidiospores. Pycniospores are single celled and behave as spermatia.

(b) Aeciospores Stage (I)

These are single celled dikaryotic spores produced in chains in cup-like structures known as aecia. The spores are yellow to orange in colour with a hyaline characteristically verrucose wall.

(c) Uredospores Stage (II)

These are single celled binucleate, pedicellate deciduous spores borne in naked or paraphysate sori breaking through the host epidermis, commonly called as uredia or uredinia. Uredospores are brown, echinulate having almost conspicuous germ pores. They behave as conidia and repeat several cycles in a season and are also called as summer spores.

(d)Teliospores Stage(III)

These are binucleate; pedicellate or sessile; erumpent or embedded in host tissue. They may be single celled, bicelled or more than 2-celled, with dark brown walls, having one or more germ pores. They produce basidium and basidiospores upon germination.

(e) Basidiospores Stage(IV)

They are haploid, unicellular spores borne on sterigma. These arise from cylindrical to club-shaped 2 to 4 celled basidia. Depending on the reproductive stages present in the life cycle of rusts, rusts can be termed as 'macrocyclic'(all 5 stages present), 'demicyclic'(uredial stage absent) or 'microcyclic'(teliospore only as the binucleate spore). Rusts are either homothallic or heterothallic.

In the former case pycnia, are not necessary and frequently absent. Dikaryotic phase starts from two cell nuclei at some point in the life cycle. In the case of heterothallic macrocyclic rusts, basidium bears four basidiospores; two of +type or

two of -type. These basidiospores produce pycnia of + or-type respectively. The pycniospores behave as spermatia and fuse with the receptive hyphae of the opposite sex. The dikaryotic phase thus resulted, leads to the development of aecia.

Classification

There are four families in Uredinales

A. Teliospores sessile

1. Teliospores in single, palisade-like layers or solitary, germinating to produce a septate promycelium; mostly the spores are unicellular **- Melampsoraceae**
2. Teliospores in waxy crusts of one or two layers, becoming septate during germination without forming an external promycelium **- Coleosporiaceae**
3. Teliospores in chains **- Cronartianceae**

B. Teliospores pedicellate, germinating to form a promycelium, which become septate; spores uni -or multicellular, free **- Pucciniaceae**

Family: Pucciniaceae

This is one of the largest family of Uredinales and contains members , which attack a wide variety of angiosperms, often causing destructive diseases of cereals and legumes. The teliospores are pedicellate. Teliospores are never present in the form of layers of crusts. They may be simple (1-celled) or compound (2-or more celled). The uredinia may or may not have paraphyses. The aecia may be cupulate (cup-like) or hyphoid (naked). The peridium may be revolute (curved back). Spermagonia may be subcuticular and flattened or subepidermal and spherical with an ostiole. Both heteroecious and autoecious species are present. The family

contains more than 85 genera and about 3,000 species of which genera *Puccinia* and *Uromyces* account for 1800 and 600 species, respectively. Other genera in Pucciniaceae are *Gymnosporangium, Phragmidium, Hemileia* and *Ravenelia.*

Classification

Important genera in Pucciniaceae are

I. Teliospores single celled.

1. Telia non-gelatinous.

A. Teliospores walls colourless; uredospores reniform, basidia slender, symmetrical - ***Hemileia***

B. Teliospore walls coloured, thickened, ornamented or with visible pores. Telia subepidermal, each pedicel bearing single teliospore

a. Telial pedicel septate - *Trachyspora*

b. Telial pedicel aseptate; uredia and telia non-peridiate

i. Pycnia subepidermal, globose; teliospore wall thicker above than sides or coloured or smooth - ***Uromyces***

ii. Pycnia subcuticular, conical; teliospore usually ornamented, globose to ellipsoid.

On Anacardiacea **- *Pileolaria***

2. Telia gelatinous, telial pedicel aseptate; teliospore cells arranged serially, with pedicel attached to the lower one only. On Cupressaceae **- *Gymnosporangium***

II. Teliospores bicelled, subepidermal, non-gelatinous; uredia and telia non-peridiate; teliospore with one germ pore/cell.

1 .Teliospores in fascicles **- *Tranzschelia***

2. Teliospores not in fascicles. Pycnia globose, subepidermal; teliospores truly pedicellate, sometimes >2 celled **- *Puccinia***

III. Teliospores 3 or >3 celled.

A. Teliospore cells arranged as in phragmospores; teliospore wall coloured with 2 or more germ pores in each cell; pedicel usually long, teliospore without conspicuous outer hygroscopic layer **- *Phragmidium***

B. Teliospore cells arranged as inverted triangle; teliospore wall with 2 or >2 germ pore/cell **- *Nyssopsora***

C. Teliospore cells arranged in a radially discoid head; teliospore pedicels several per head, fused together, telial head with hygroscopic cysts **– *Ravenelia***

Genus 1

***Puccinia*:** In Puccinia the teliospores are brown and are with mostly 2 cells. They are borne on a simple pedicel. Telia are at first embedded in the host tissue but sooner or later the epidermis is ruptured and the spores become free. Spermagonia are subepidermal and spherical with ostiole. Aecia are cupulate with recurved peridium or maturity. Urediniospores (uredospores) are single and stalked, with long pedicel. They are often present in the same sori in which later the teliospores (teleutospores) are formed species are heteroecious.

They mostly parasitize and cause rust diseases in Gramineae and Cyperaceae. It is the largest genus with about 3000 to 4000 species parasitic on angiospermic plants. The important plant pathogenic species are as follows:

Uromyces

Uromyces is the second largest rust genus with about 600 species. It is characterized by the stalked, one celled teliospores on a simple pedicel with a papillum. Uredial, aecial and spermagonial characters are similar to *Puccinia*. The species may be heteroecious or autoecious. The members mostly cause rust disease in leguminous plants. The important species causing pant diseases are given below.

Fungus	**Disease**
P. arachidis	Groundnut rust
P.asparagi	Rust of Asparagus
P. chrysanthemi	Chrysanthemum rust
P. coronata	Crown rust of wheat
P. helianthi	Sunflower rust
P. hordei (P. anomala)	Barley rust
P. kuehnii & P. erianthi)	Sugarcane rust

P.substriata var. penicillariae *(P. penniseti)*	Pearlmillet rust
P. sorghi (P. zeae, P. maydis)	Sorghum rust
P. recondita (P. triticina)	Brown or leaf rust of wheat
P. striiformis (P. glumarum)	Yellow or stripe rust of wheat
P. graminis tritici	Wheat stem or black rust
P. graminis hordei	Barley rust
P. graminis avenae	Oat rust
P. graminis secalis	Rye rust
P. graminis phleipratensis	Timothy rust
P. graminis poae	*Poa pratensis* rust
P. graminis agrostidis	Rust on red top and other *Agrostis* spp.
P. antirrhini	Anirrhinum rust
P. sorghi & P. polyspora, *P . carthami*	Corn rust Safflower rust
P. cacabata P. allii Onion rust	Cotton rust
P. malvacearum	Holly hock rust
P. menthae	Mint (*Piper mentha*) rust
P. psidii	Guava rust

Fungus Diseases

Uromyces ciceris-arietini -Gram rust

U. *dianthi* -Carnation rust

U. *fabae* -Pea rust, *Vicia* rust, lentil rust

U. *phaseoli typica*=(*U. appendiculatus*) -Bean rust, blackgram rust, *Dolichos* and *Vigna* rust.

U. *pisi* -Pea rust

Family: Melampsoraceae

Melampsora lini – Linseed rust

M. ricini -Castor rust

Order: Ustilaginales

There are two families in this order.

Family: Ustilaginaceae

The general characters of the family are same as for the order. The family includes all the smut fungi in which the promycelium is transversely septate into several, usually four, cells with lateral and terminal sporidia, one or more from each cell. Sometimes there may be only one sporidium on the septate promycelium. Occasionally, the basidium (promycelium) develops directly into a mycelium without forming sporidia, as in *Ustilago nuda tritici*, or both conditions may be present (*Sphacelotheca sorghi*). Sometimes two ore more promycelia are produced by the same spore. Important genera are *Ustilago Sphacelotheca*, *Tolyposporium* and *Melanopsichium*.

Ustilago

Sori contain 1-celled teliospores, dusty at maturity and are covered by membrane of host origin. Germination is by means of septate promycelium, which may become infection hyphae or may produce sporidia laterally near the septa. The sporidia germinate easily in water by infection. Hyphae or may multiply by budding.

U*stilago nuda tritici* -Loose smut of wheat

U. zeae -Common smut of corn (syn. *U. maydis)*

U. hordei -Covered smut of barley

U. nuda -Loose smut of barley

U. kolleri -Covered smut of oats

U. avenae -Loose smut of oats

U. scitaminea -Whip smut of sugarcane

Family: Tilletiaceae

The general characters of this family also are same as for the order. However, the family includes only those smuts in which the promycelium is aseptate with terminal whorl of sporidia. The teliospores are single or combined into more or less permanent balls usually including sterile cells. Promycelium is simple, usually nonseptate up to the time of formation of sporidia. Sporidia are longer than in Ustilaginaceae, produced in clusters at the apex of the promycelium, fusing or not fusing in pairs, producing similar or dissimilar sporidia or germinating directly into infection threads. Important genera are *Tilletia, Neovossia, Urocystis, Entyloma* and *Turbicina*.

Class Hymenomycetes

This class is characterized by usually well-developed basidiocarp or fruiting bodies. Basidiocarps are typically gymnocarpic (primordium and mature sporocarp have exposed hymenium) or semiangiocarpic (partially closed till spores are matured). Basidiospores are ejected forcibly i.e. these are ballistospores.

Classification

a. Basidia aseptate -Sub-class Holobasidiomycetidae.

b. Basidia septate -Sub-class Phragmobasidiomycetidae

Holobasidiomycetidae

Holobasidiomycetidae is characterized by an undivided, cylindrical to clavate basidium (i.e. holobasidum), which usually extends into four sterigmata each bearing a basidiospores. The basidiospores produced in this group are non-repetitive. It contains mushrooms, pore fungi, tooth fungi, coral fungi, chantarelles, boletes and bracket fungi.

Phragmobasidiomycetidae

The metabasidium of these is completely or incompletely divided into 4 cells by transverse or longitudinal septa. The basidiocarp is usually gelatinous, waxy or dry. The probasidia may or may not be persistent. The basidiospores are often repetitive and sterigmata swollen.

Sub-class Holobasidiomycetidae

Order: Exobasidales

It is a small order consisting of the gall-forming plant parasites, especially of Ericaceae, Commelinaceae and Theaceae. The order is characterized by the 4-spored basidia, which form a layer (hymenium) on the leaf surface and lack the well-define basidiocarps. This order has a

single family, Exobasidiaceae with five genera. The genus, *Exobasidium* is important. *Exobasidium*: The characteristic feature of the genus is that the basidia, which arise between the epidermal cells of the host, form a more or less continuous hymenium at maturity. The dikaryotic mycelium is devoid of clamp connections, grows intercellularly and produces haustoria. This genus has about 50 species. They are parasitic on leaf, short stem and flowers of Dicotyledonous plants causing hypertrophy and deformation. *E. vexans* is responsible for blister blight of tea. *E. japonica* is responsible for galls of *Azalea.*

Order: Tulasnellales

Family: Ceratobasidiaceae

Ceratobasidium

Metabasidia much wider than pedicels, basidia abruptly narrowed at pedicels, hyphal cells binucleate; sclerotia present or absent.

Thanatephorus

Metabasidia little wider than the pedicels, spores ellipsoid with one side flattened, rarely obpyriform to obovate, hyphal cells multinucleate, sclerotial or sterile mycelia state (Rhizoctonia) present.

Order: Aphyllophorales/ Polyporales

Family: Corticiaceae: (Genera: *Chondrostereum, Peniophora, Athelia, Corticium*):

Family: Ganodermataceae (Genus: *Ganoderma*)

Genus: *Ganoderma*

The fruit bodies of this genus are either sessile or stipitate, the upper surface of the pileus being shiny as if varnished due to the presence of an amorphous waxy substance secreted by the hyphae. The basidiospores are coloured, elliptical, with a wall consisting of two layers, the apex at first rounded but later truncated.

Order: Agaricales

The order Agaricales is commonly called 'gill fungi', which include mushrooms, (edible), toadstools (poisonous) and boletes. Mushrooms are mainly terrestrial or lignicolous mostly growing saprophytically and some enter into mycorrhizal relationship with higher plants. The chracteristic macroscopic basidiocarp or fruit body is fleshy, generally having a stalk i.e. stipulate, and has a pileus bearing hymenium-covering lamellae on the underside. The young basidiocarp may be covered by a universal veil, which becomes broken down by the growth of

the stipe and pileus but part may remain as volva at the base of the stipe and as fragments on the upper surface of the mature pileus.

The developing hymenium may be covered by a partial veil, which later becomes a cortina or an annuals around the mature stipe. The hymenium may consist of cystidia of various kinds, setae, or hyphidia among the basidia the latter producing unicellular, hyaline or coloured ballistospores, typically in fours. Mycelium of Agaricales is typically basidiomycetous with primary, secondary and tertiary mycelia. In few of the Agaricales asexual reproduction takes place by oidia (*Coprinus* spp.) and chlamydospores (*Volvariella volvacea*). Majority of the members are heterothallic and show either unifactorial or bifactorial heterothallism. The compatible thalli are brought together either by hyphal fusion or by means of oidia. The dikaryotic mycelium thus formed ultimately leads to the formation of basidiocarps. The fusion of the dikaryotic nuclei takes place in the basidium (produced in the gills), which is followed by reduction division resulting in the formation of generally uninucleate but sometimes-binucleate basidiospores, which are haploid.

The order Agaricales contains 16 families (Smith, 1973). They are Boletaceae, Hygrophoraceae, Tricholomataceae, Entolomataceae, Amanitaceae, Pluteaceae, Lepiotaceae, Agaricaceae Bolbitiaceae, Strophariaceae, Coprinaceae, Cortinariaceae, Paxillaceae, Gomphidiaceae, Russulaceae and Cantharellaceae.

Family: Tricholomataceae *Armillariella, Pleurotus, Marasmius, Clitocybe, Tricholoma, Panus, Mycena* and *Omphalotus* are the important genera in this family.

***Pleurotus*:** Stripe is generally eccentric and pileus resupinate in some species. They have white or pigmented range fruiting bodies. They grow on wood, on dead or living hosts. This genus contains most valuable edible mushroom.

P. sajor -caju Oyster mushroom

P. ostreatus - Oyster mushroom.

Family : *Amanitaceae*

The characteristic feature of the family is the presence of free gills with bilateral trama and the presence of both outer and inner veil. The basidiospores are white to creamish in colour. The members are found on the ground in woods, on termite nests or on wood. *Amanita, Limacella* and *Termitomyces* are the important general in this family. *Amanita:* The genus is characterized by free gills and the presence of the annulus and volva on the stripe. Remnant of

the volva may persist as volva scales on the cap. More than 5 species are known to be mycorrhizal in habit. Some are more attractive and used in decoration. Some are poisonous and produce toxins called phallotoxin and amatoxins.

A. virosa - called as 'Destroying angel'; or death angel. Decorative by its pure white basidiocarp; poisonous

A. caesarea - Called 'caesar's mushroom', yellow and orange capped and used in decoration

A. muscaria - Called 'fly agaric'; yellow or orange or brilliant red capped and used in decoration; poisonous to flies

A. phalloides - Called 'Depth cap fungus'and it is poisonous.

Family: Pluteaceae

It is characterized by the free gills having bilateral hymenophoral trama, which are convergent toward the center of the trama, and by the production of dull pink basidiospores. The genera *Volvariella, Pluteus* and *Chamaeota* are included in this family.

Volvariella

The genus *Volvariella* contains approximately 25 species reported from tropical, subtropical and temperate regions found growing in shady places on soil and on decaying organic matter. They appear during the rainy season and are recognized by pink spores, free gills forming a ring around the stipe or a stipe which bears no annulus but is enclosed at the base by a cup-shaped persistent 'volva'; The pileus is fleshy, white or pigmented and circular with a central stipe and is responsible for its name *Volvariella.* A few of the species such as *V. volvacea* and *V. diplasia* (commonly called the straw, or paddy straw or Chinese mushrooms) are edible.

Family: Agaricaceae

The family Agaricaceae is characterized by the blackish or brown colour of the basidiospores and the presence of pallid to pink or rosaceous coloured free gills on the pileus.

An annulus is typically present on the stipe. *Agaricus, Cystoagaricus* and *Melanophyllium* are important genera. *Agaricu*s: The characteristic features of the genus are the presence of deep purplishbrown free gills, and an annulus but no volva, and stalk that readily separates from the pileus. They are commonly found growing on ground in pastures. These mushrooms are edible for their delicacy.

A. campestris -Common or Field mushroom; or white button mushroom; edible

A. brunnescens - edible and cultivated mushroom *(=A. bisporus*)

A. placomyces – poisonous

A. silvaticus – poisonous

Edible mushrooms

Mushroom is a fleshy to tough, edible umberella like sporophores (basidiocarp)of certain basidiomycetes fungi. The mushroom consists of **stipe or stalk**, a membranous annular ring called **annulus**, cap or **pileus** arid **gills** or lamellae (plates). Each gill on cross section shows closely packed elongated fungal cells called trauma. On both sides of the trauma a **sub-hymenium** with spherical cells is formed. Over the sub-hymenial layer a fertile layer with palisade like cells called **hymenium** is found. It consists of club shaped **basidia**, sterigmata bearing single-celled basidiospores. In the hymenial layer stout sterile structure called **cystidia** are also found.

Morphology of Mushroom

Morphology of the edible and cultivated mushroom *Agaricus campestris* is given below: *Agaricus campestris* is a field mushroom growing on all organic matter in the fields. The mycelium is highly organized and the hyphae are often found to form rhizomorphs, which are thick strands or rope-like structures. Clamp connections are also formed by the hyphae and chlamydospores may be produced to resist the adverse conditions. The fruiting body or the basidiocarp commonly called as mushroom comes out of the soil and it consists of thick stalk called **stipe** on which an umbrellashaped **pileus**(cap) rest.

The stipe is cylindrical in shape, fleshy and usually swollen at the base. Just above the middle the stipe has a membranous ring known as **annulus**. This represents the remnants of the inner veil, which enclosed the lower surface of the pileus in the initial stages of development. The stipe is constituted by well packed hyphae at the basal portions being loosely placed towards the center permitting the formation of large air space. The pileus on the under surface exhibits numerous structures radiating from the stipe. They are called **lamellae** or **gills**, which are slender, pink when young becoming brown later. The lamellae are suspended from the pileus as thin strips of tissues converging towards the centre with their ends bend towards. The cross-section of a lamella or gills show the central loosely packed elongated fungal cells known as **trama**. On both sides of the trama are found **subhymenial** layers the cells of which will be spherical in shape. Over the sub-hymenial layer a layer of palisade-like cells known as **hymenial layer** is formed.

The hymenial layer consist of club shaped **basidia** which have two to four minute **sterigmata** at their tip. The sterigmata bear the haploid single celled, ink basidiospores. In the hymenial layer there are some stout sterile structures known as **cystidia** (sing. cystidium). The **basidiospores** are released forcibly and fall near the base of the stipe and form a pink mass.

Agaricus* and *Pleurotus

Agaricus

Agaricus spp. are called **white button mushroom** or European mushroom or button mushroom. It has two important commercia1Jy cultivated species viz., temperate mushroom or white button mushroom, *Agaricus bisporus* and hot weather mushrooms, *A. bitorquis*

A .bisporus

It has stout, cylindrical, fleshy umberella-like pileus and possess annulus. Good crop of mushroom comes at low temperature of 15 to 25º C. Well decomposed wheat / paddy straw compost incorporated with nutrients is used as substrate. In a period of 85-100 days, 300-350 kg of mushroom can be harvested from one ton of compost. It ranks first in the world mushroom production.

Pleurotus

Pleurotus spp. are called oyster mushroom as it resembles shell of an oyster. The stipe is eccentric. In India it is called Dhingri. It is a tropical mushroom coming up well between 25-30°C. The colour may be white or grey or pink depending upon the species. Commonly cultivated species in India are *Pleurotus sajor-caju, P. eous, P.citrinopileatus, P.ostreatus, P.eryingii* etc., It is grown on paddy straw (substrate) in polybags. In a period of 30-45 days, it yield 1.0 to 1.4 kg per kg of paddy straw.

Symptoms of rust – Life cycle of *Puccinia*

Rust appears as brown or reddish brown pustules scattered on upper or lower or on both the surfaces of leaves sometimes on the stem also. The rust diseases are in the order Uredinales of the subdivision Basidiomycotina. The rust genera viz., *Puccinia, Uromyces, Hemileia, Phragmidium, Gymnosporangium* in the family *Pucciniaceae* and *Melampsora, Phakopsora, Coleosporium* and *Cronatium* in the family *Melampsoraceae* cause rust disease in crop plants.

There are three types of rusts based on the life cycle. They are,

1. Macrocyclic rust

a. Autoecious rust

b. Heteroecions rust

2. Demicyclic rust

3. Microcyclic rust.

1. Macrocyclic rust: Five spore stages are produced in their life cycle.

a. Autoecious rust: Five spore stages are formed on a single host. e.g., Sunflower rust - *Puccinia helianthi* , Pea rust - *Uromyces fabae* , Linseed rust - *Melampsora lini* and Castor rust – *M. ricini.*

b. Heteroecious rust: Two different hosts (viz., primary host and alternate hosts) are required for completion of its life cycle. **Primary host** is the plant where the teliospores are produced. Alternate host is a plant which is required to complete life cycle without which the pathogen cannot survive. Uredia and uredospores and telia and teliospores are formed on the primary host. Pycnia and pycniospores and aecia and aeciospores are formed on the alternate hosts. e.g., Wheat stem rust – *Puccinia graminis* var. *tritici.* For this rust wheat is the primary host and the barberry is the **alternate host.**

2. Demicyclic rust: Uredial stage absent and spermagonia may be present or absent. e.g., Cedar apple rust - *Gymnosporangium juniperi-virginianae*

3. Microcyclic rust: Teliospore is the only binucleate spore produced in this rust. It may be with or without spermagonia e.g., Holly-cock *rust-Puccinia malvacearum.*

i. Black or stem rust of wheat - *Puccinia graminis* var**. *tritici***

Systematic position

Sub-kingdom : Mycota

Division : Eumycota

Subdivision : Basidiomycotina

Class : Teliomycetes

Order : Uredinales

Family : Pucciniaceae

Genus : *Puccinia*

Species : *P.graminis*

Variety : *P.g. var.tritici*

Symptoms

Oblong, reddish brown pustules (raised blisters) are produced mostly on the stem and also on leaves in the initial stage. Later they become conspicuous, linear or oblong, dark brown to black and often merge with one another. Late in the season linear, black telia are formed in the same uredosori or on a separate place; severe infection causes drying of leaves.

Pathogen

It is a heteroecious rust. Primary host is wheat and the alternate host is barberry. The pathogen produces five kinds of spores viz., uredospore and teliospores on wheat, basidiospores from the teliospores found on the infected fallen leaves in the soil, pycniospores and aeciospores on barberry. The characters of different rust spores are described below.

Uredospores

(urediniospore, repeating spores or summer spores) are brown, binucleate, single celled, oval, thick walled with echinulations (thin short spines), borne singly on stalks and with four equatorial germ pores. **Teleutospores** (Teleutospore, resting spores or winter spores) are two celled, pedicellate, dark brown or cheshnut brown, thick and smooth walled. They are at the top rounded and somewhat pointed and thickened apex each cell has a germ pore.

Basidiospores

(Sporidia) are hyaline, haploid; thin walled, single celled and oval. Pycniospores (spermatia) are hyaline, thin walled, small and spherical. Teliospore has a constricted at the septum. Aeciospores are yellow, unicellular, thin walled, hexagonal and produced in chains.

Disease cycle

The fungus overwinters as teliospores on infected wheat debris. They germinate and produce basidia and basidiospores. The basidiospores are ejected forcibly into the air. They are spread through wind and fall on the upper surface barberry leaf, where they germinate and penetrate the epidermal cells. It grows intercellularly and in 3-4 days, the mycelium develops into spermagonia (pycnia), which ruptures the epidermis. The opening of the spermagonia emerges on the upper surface of the leaf. The spermatia are exuded through the opening called **ostiole** and are found embedded in a honey like sticky liquid. Long, flexuous and branched structures called receptive hyphae from the spermagonium extend beyond the opening. Visiting insects spread the spermatia to the receptive hypha of other spermagonia. Rain water or dew running on the plant surface also helps in spreading the spermatia. Spermatization between a

spermagonium of a (+) type when comes in contact with receptive hypha of a (-) type (compatible) or *vice-versa.* It leads to aecial primordial (dikaryote) and formation of aecia on the lower side of the leaf.

The aecia are formed in groups or clusters and called cluster cups and protrude beyond the surface of the barberry leaf. The aecisopores are produced in chains inside the aecium and are released. They are carried by wind to wheat plant on which they germinate and infect stem or leaf sheath or leaf through stomata. The mycelium grows intercellularly and collects below the epidermis as a mat of mycelium. Many short sporophores and uredospores are produced and they exert pressure on the epidermis and pushed out as uredosori. Later, the epidermis breaks irregularly and release 100 thousands of rust coloured uredospores giving a powdery appearance. Uredospores are carried by wind to several kilometres from the point of their origin and infect the wheat plant in the presence of dew or film of water.

They germinate and produce germ tubes, enters through stomata, forms mycelium and leads to formation of uredia in 8-10 days. The uredospores infect wheat plant and produce uredospores till the plant reaches maturity. When the wheat plant approaches maturity telia develop on the wheat leaves or stems separately or from the ured33ia. Teliospores from the telia do not germinate immediately, they overwinter for sometime and do not infect wheat again. In the teliospores fusion of two nuclei takes place. Teliospore germinate and produce promycelium and basidiospores and infects only barberry, the alternate host and not wheat.

ii. Rust of pearlmillet - *Puccinia substriata* var**. *penicillariae***

Systematic position

Sub-kingdom : Mycota

Division : Eumycota

Sub-division : Basidiomycotina

Class : Teliomycetes

Order : Uredinales

Family : Pucciniaceae

Genus : *Puccinia*

Species : *P.substriata*

Variety : *P.s. penicillariae*

Symptoms

The uredosori are round, reddish brown and occur in groups on both the surfaces of leaves. The teliosori are black and elliptical. Finally the leaves dry.

Pathogen

It is also heteroecious rust. Primary host is pearlmillet and the alternate post is **brinjal**. Uredospores are oval, yellowish brown, single celled, sparsely echinulated with four equatorial germ pores and pedicellate. Teleutospores are pedicellate thick walled, two celled cylindrical or club-shaped, broad at top and taper towards the base, with single germ pore. Basidiospores are single celled. Pycniospores are hyaline and elliptical. Aeciospores are yellowish orange coloured, polygonal, thin walled, smooth and are formed in chains. Other examples are, rust of groundnut caused by *Puccinia arachidis,* rust of sunflower caused by *P. helianthi,* rust of sorghum caused by *P.purpurea,* rust of maize caused by *P. sorghi*

Rust of black gram / greengram / cowpea / beans /horsegram – *Uromyces* *phaseoli-typica* (syn. *U. appendiculatus).*

Symptoms

It is an autoecious and macrocylic (long cycle) rust. The uredosori are small, roundish, open, powdery, brown coloured and are formed in groups. Each sorus is surround by a yellow halo. Several sori on a leaf cause premature defoliation. The teliosori are fewer in number, dark brown and linear.

Pathogen

Uredospores are globose, **single celled**, echinulated, Pedicellate, golden brown with two equatorial germ pores. Teliospores are single celled, smooth walled, globose, chestnut brown, pedicellate and with hyaline papilla at the top. Other examples are chickpea rust caused by *U. ciceris-arietini,* Pea rust caused by *U. fabae* and U. *pisi,* coffee rust caused by *Hemileia vastatrix* and cotton tropical rust caused by *Phakopsora gossypii.*

Symptoms of smuts and life cycle of *Ustilago* and *Neovassia* Smut

Smut is a disease caused by the fungi in Ustilaginales of the subdivision Basidiomycotina that is characterized by the transformation of ovary into black dusty or powdery dark spore mass. Smut spores are called teleutospores, chlamydospores or ustilospores. Smut fungi are more dangerous than rust fungi. They are facultative saprophytes. Smut fungi belong to the order Ustilaginales in the subdivision Basidiomycotina.

The order ustilaginales is divided into two families *viz.*, Ustilaginaceae and Tilletiaceae, on the basis of the mode of teliospore germination. The family Ustilaginaceae produces a septate promycelium bearing terminal and lateral basidiospores. *Ustilago, Sporisorium, melanopsichium, Sphacelotheca and Tolyposporium.* In Tilletiaceae, the promycelium is a hollow tube, which bears only terminal basidiospores, are, included in this family *Tilletia, Neovossia, Urocystis and Entyloma are included in Tilletiaceae.*

Covered / kernel / short / grain smut of sorghum- *Sporisorium sorghi.*

(Syn. Sphacelotheca sorghi)

Systematic position

Sub-kingdom : Mycota

Division : Eumycota

Sub-division : Basidiomycotina

Class : Teliomycetes

Order : Ustilaginales

Family : Ustilaginaceae

Genus : *Sporisorium*

Species : S *sorghi*

Symptoms

The smut sori are oval, long and dully-grey in colour. Most of the grains of an infected earhead are replaced by the smut sori.

Pathogen

The sorus has a tough wall and a long, hard, central tissue called **columellum**. The columellum is made up of host tissues, including, parenchyma and vascular elements. A dense mass of black to dark-brown, smooth, thick walled, single-celled spores and fills the space between the columellum and sorus wall.

Disease cycle

The smut spores germinate in water by producing four celled promycelium and a single sporidium from each cell. They infect the seedling by penetrating through the radicle or mesocotyl to establish systemic infection that develops along the meristematic tissues. At the

time of flowering the fungal hyphae get converted into spores, replacing the ovary with the soil. If the diseased earheads are harvested with the healthy ones threshed together, the healthy grains become contaminated with the smut spores released from bursted sori. The spores remain dormant on the seed until next season. It is externally seed-borne.

Loose smut of sorghum - *Sporisorium cruentum* (syn. ***Sphacelotheca cruenta)***

Symptoms

The infected plants are shorter than the healthy plants, produce thinner stalks, more tillers and earlier flowering (2 weeks earlier) than the healthy plants. All the spikelets of an infected earhead are malformed and hypertrophied. The sorus replaces the pistil and stamens and is borne on glumes and pedicel. The infected earhead become loose and appears like a leafy or leathery structure.

Pathogen

The smut spores are in the form of masses of spores enclosed by thin sorus membrane. Columellum is longer, bigger and more curved than the columellum of grain smut. The smut spores are spherical to elliptical, dark brown with a minutely pitted spore wall. It is primarily spread by infected seeds (externally seed-borne). Disease cycle is as in grain smut.

Long smut of sorghum -*Tolyposporium ehrenbergii*

Symptoms

Only a few grains are converted into smut sori and are scattered. The sorus is covered by a whitish membrane and is cylindrical and much longer than those of the other two smuts.

Pathogen

The spores are firmly united into **spore balls**, which is characteristic of this genus. They are globose, or angular, brownish green.

Head smut of sorghum -*Sporisorium reilianum* (syn**. *Sphacelotheca reiliana)***

Symptoms

In the place of a normal inflorescence, a sorus fully covered with a greyish-white membrane emerges from the boot leaf when it has fully emerged. The fungal wall ruptures, exposing large mass of black, powdery smut spores. The spores are blown away exposing dark filaments or fibres. Complete destruction of the earhead is common unlike in other smuts.

Pathogen

The smut spores or chlamydospores are angular to spherical, brown. It is both soil-borne and seed-borne.

Smut of pearl millet smut- *Tolyposporium penicillariae*

Symptoms

Florets are transformed into larger green smut sorus. Later sori become dark brown, break and release black smut spore balls. Only few florets in an earhead in affected.

Pathogen

Smut spores are in compact mass of spore balls. The spores are round and light brown.

Loose smut of wheat - *Ustilago nuda tritici*

Symptoms

Infected plants are shorter than the healthy plants. Usually infected ears emerge from the boot leaf, a few days earlier than healthy. All spikelets of an earhead are transfonned into a mass of black powdery spores. Before emergence the smutted spikelet in covered by a thin silvery membrane, which breaks while the ear. Emerges

Pathogen

The smut spores or chlamydospores are pale olive-brown, spherical or oval and are with minute echinulations. It is **internally seed-borne** and viable in stored seeds for more than 15 years.

Whip smut of sugarcane - *Ustilago scitaminea*

Symptoms

Production of a long (up to several feet) whip-like structure (modified inflorescences / stem) from the apex of the infected stalk. In early stage, a thin silvery white membrane covers the whip and it ruptures exposing dense black dust of smut spores.

Pathogen

The smut spores are light brown, spherical and echinulated.