Stem rust of wheat

DISEASE: **Stem rust (black rust)**

PATHOGEN: ***Puccinia graminis* f. sp. *tritici***

HOSTS: **Wheat and barley, common barberry (and some additional *Berberis*, *Mahoberberis*, and *Mahonia* spp.)**

Uredinia of *Puccinia graminis* f. sp. *tritici*

Stem rust was once the most feared disease of cereal crops. It is not as damaging now due to the development of resistant cultivars, but outbreaks may occur when new pathogen races arise against which the existing kinds of resistance are ineffective. Stem rust remains an important threat to wheat and barley and, thus, to the world food supply. Anton deBary first demonstrated the heteroecious life cycle of a rust fungus with *Puccinia graminis*, the causal agent of stem rust.

Symptoms and Signs:

On wheat and other grass hosts:

Plants do not usually show obvious disease symptoms until 7 to 15 days after infection when the oval pustules (uredinia) of powdery, brick-red urediniospores break through the epidermis (Figures 1, 2). Microscopically, these red spores are covered with fine spines (Figures 3, 4). The pustules may be abundant and produced on both leaf surfaces and stems of grass hosts. Later in the season, pustules (telia) of black teliospores begin to appear in infected grass species (Figure 5). Microscopically, teliospores are two celled and thick walled (Figure 6).

Figure 1

Figure 2

Figure 3

Figure 4

Figure 5

Figure 6

On barberry and other alternate hosts: Pycnia appear on barberry plants (Figure 7) in the spring, usually in the upper leaf surfaces. They are often in small clusters and exude pycniospores in a sticky honeydew (Figure 8). Five to 10 days later, cup-shaped structures filled with orange-yellow, powdery aeciospores break through the lower leaf surface (Figure 9). The aecial cups are yellow and sometimes elongate to extend up to 5 mm from the leaf surface (Figure 10). Microscopically, aeciospores have a slightly warty surface (Figure 11).

Figure 7

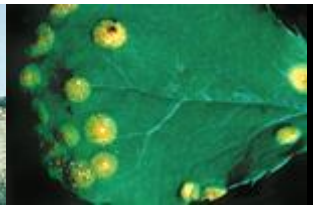


Figure 8

Figure 9

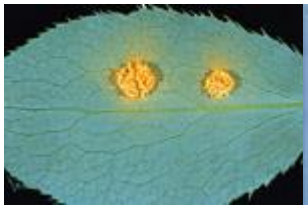


Figure 10

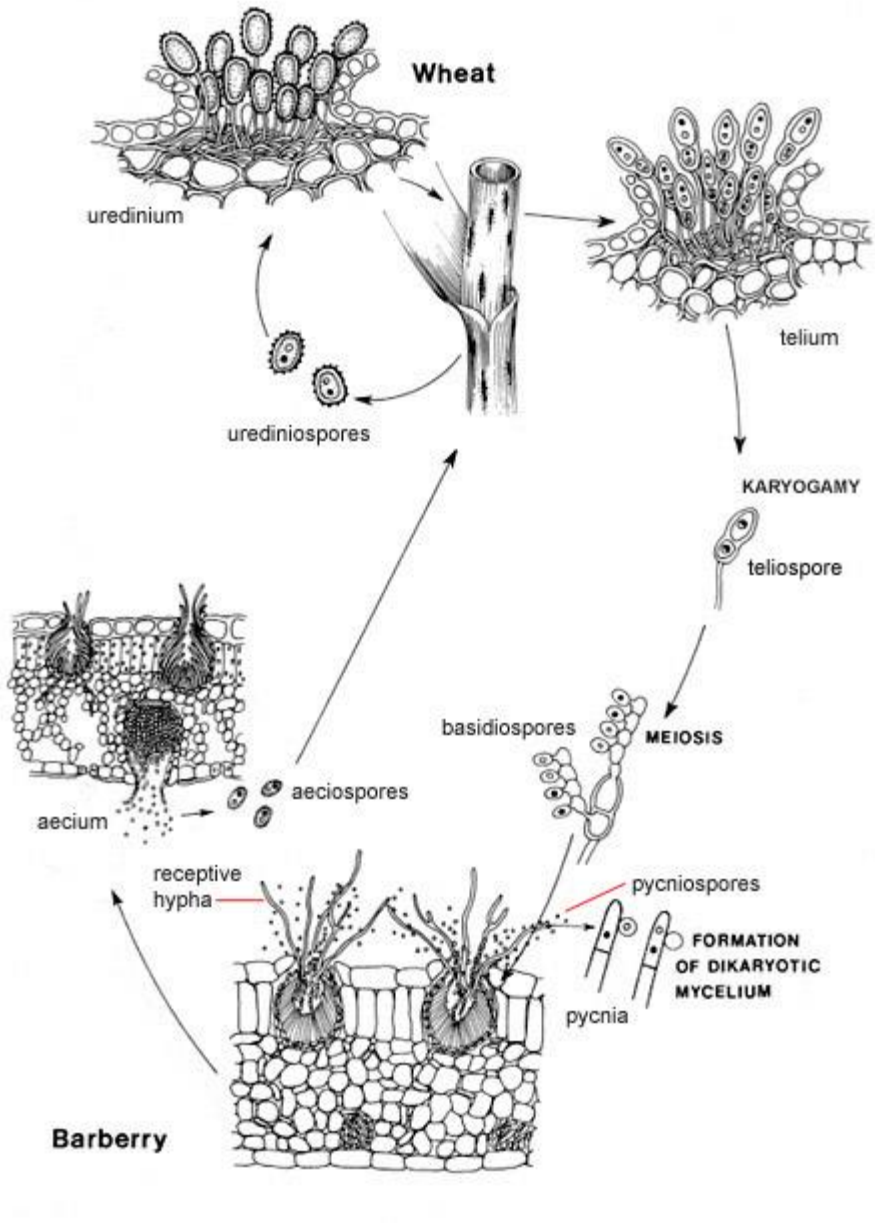
Figure 11

Pathogen Biology:

Rust fungi are obligate parasites. In nature, they require living host tissue for growth and reproduction; they cannot exist as saprophytes. In the absence of living host tissue, they survive as spores. In most rust fungi, only the teliospores are adapted to survive apart from a living host plant for more than a few months under field conditions.

Puccinia graminis is heteroecious. This word describes rust fungi that require two unrelated host plants, such as wheat and barberry, to complete their life cycle. *Puccinia graminis* is macrocyclic, producing all five spore stages: basidiospores, pycniospores (spermatia), aeciospores, urediniospores (uredospores), and teliospores. Anton deBary, in 1865, first recognized the nature of the heteroecious life cycle. Although stem rust is caused by a single species of fungus, *Puccinia graminis*, there is considerable genetic variation within the species

Disease Cycle and Epidemiology



The disease cycle of wheat stem rust starts with the exposure of each new wheat crop to spores of *Puccinia graminis* f. sp. *tritici*, which are the primary inoculum. The source of the first spores that infect the new wheat crop differs

depending on the region in which the wheat is grown. In warm climates, wheat is planted in late fall and harvested in early summer. The first spores to infect the young wheat plants in the fall are urediniospores. They generally come from infected volunteer wheat plants. Seed spilled in the field or on roadsides at harvest time often sprout and produce scattered volunteer plants. These plants can become infected from spores produced on late-maturing wheat plants still in the field. The infected volunteer wheat plants serve as a bridge that carries *P. graminis* f. sp. *tritici* through the summer to the next fall-sown crop of wheat.

Disease cycle, with barberry

Barberry is the most dangerous source of primary inoculum of stem rust in temperate regions. If barberry grows near wheat fields, it will be a consistent source of aeciospores for the earliest infections of wheat in the spring (Figure 13).

Figure 5 Figure 13

Puccinia graminis overwinters as black, thick-walled, diploid teliospores that are produced on wheat or other grass hosts toward the end of the growing season (Figure 5). Karyogamy (fusion of two haploid nuclei to form a diploid nucleus) and meiosis (reduction division to produce four haploid basidiospores) take place in the teliospore. Teliospores are produced in a telium.

In the spring, each teliospore germinates to produce thin-walled, colorless, haploid basidiospores (Figure 14). Basidiospores infect the alternate hosts such as common barberry.

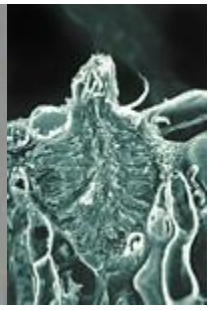



Figure 14 Figure 15

Basidiospores germinate and produce a haploid mycelium which colonizes the leaf tissue. From this mycelium, pycnia are formed inside the leaf but with the tops extending through the surface, usually in the upper surface, of barberry leaves. Pycnia produce receptive hyphae and pycniospores (Figure 15). No further development will occur until the receptive hyphae in the pycnium are fertilized by pycniospores from a pycnium of a different mating type. Pycnia and pycniospores are referred to as spermagonia and spermatia by some authors, but the former are the preferred terms of rust specialists.

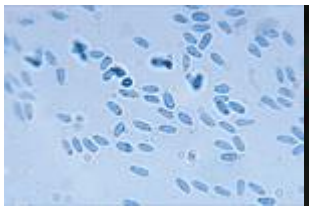
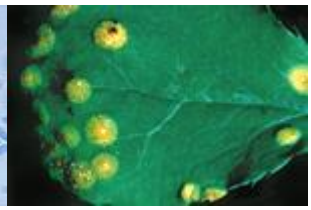



Figure 16 Figure 8

Pycniospores (Figure 16) are produced in a sticky honeydew that is attractive to insects and helps ensure that successful cross-fertilization occurs (figure 8). Insects carry pycniospores from one pycnium to another as they forage across the leaves feeding on the honeydew. Splashing raindrops also disperse pycniospores and aid in cross-fertilization. Fertilization of pycnia is critical in the rust fungus life cycle,

because it gives rise to the dikaryotic mycelium. After the nucleus of the pycniospore joins that of the receptive hypha, the paired, haploid nuclei divide in tandem in the mycelium throughout the remaining stages of the life cycle. All stem rust infections of wheat or other grasses involve dikaryotic spores and dikaryotic mycelium.

Over a period of days, the dikaryotic mycelium grows through the barberry leaf until a new structure, the aecium, breaks through the lower surface of the leaf to release the dikaryotic aeciospores (Figure 10). Aeciospores, although produced on barberry plants, can infect only wheat or other grass host of *P. graminis*. Aeciospores (Figure 11) differ from urediniospores, which also infect wheat, in their appearance - slightly warty rather than spiny - and in the way in which they are formed - in chains in an aecium rather than on individual stalks in a uredinium.

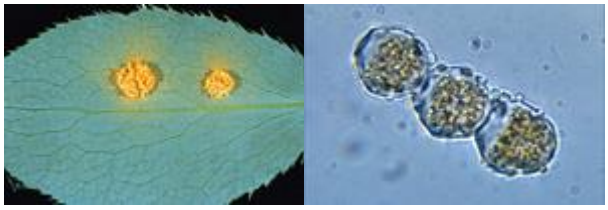


Figure 10 Figure 11

On wheat, aeciospores germinate, the germ tubes penetrate into the plants, and the fungus grows as dikaryotic mycelium. Within 1 to 2 weeks, the mycelium in each infection produces a uredinium filled with brick-red, spiny, dikaryotic urediniospores that break through the leaf or stem epidermis (Figure 1).

Figure 1

In heteroecious rusts, this important spore stage is called the "repeating stage," because urediniospores are the only rust spores that can infect the host plant on which they are produced. Under favorable environmental conditions, multiple, repeated infections of the same wheat plant and neighboring wheat plants can result in explosive epidemics.

Figure 5

Figure 6

Toward the end of the growing season, black overwintering teliospores are formed in telia (Figure 5), and the life cycle is completed. Because karyogamy and meiosis take place in the teliospore (Figure 6), this spore stage is an important source of genetic recombination in addition to its role as a survival spore.

Disease Management

1. Barberry eradication:

An expensive and extensive barberry survey and eradication program can eliminate stem rust, because the basidiospores would have no barberry hosts to infect. Barberry eradication has had significant positive effects on the control of stem rust epidemics. It removed a significant, early source of inoculum. A single barberry plant can produce as many as 64 billion aeciospores.

2. Cultural practices

It has long been known that moisture on leaves and excessive foliar nitrogen favor infections by rust fungi. This limits to develop the numbers of urediniospores that can contribute to epidemics.

3. Genetic resistance

Genetic resistance is the most commonly used and the most effective means to control stem rust. It is directly related to the reduced number of races present in the fungal population following the barberry eradication program.

4. Chemical control

In some areas where disease pressure is high, fungicides are applied to wheat to control rust diseases. Fungicides that inhibit the synthesis of sterols [i.e., sterol biosynthesis inhibitors (SBIs) or demethylation inhibitors (DMIs)] are particularly effective, but the cost of application is generally prohibitive for routine use in most wheat-growing areas.

5. Potential approaches to management

Urediniospores infect wheat only through stomata. It may be possible to breed wheat resistant that is resistant to urediniospore infection.