Filamentous FOES and Mycological MALADIES

Don't let *Venturia inaequalis* put its footprint on your apples

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While the rest of us are hunting morels in abandoned apple orchards, apple growers and home orchardists are waging battle against several fungal pathogens – the most important one being *Venturia inaequalis*, the apple scab pathogen. The fungus also affects flowering crabapples (*Malus* spp.), hawthorn (*Crataegus* spp.), mountain ash (*Sorbus* spp.), firethorn (*Pyracantha* spp.), and loquat (*Eriobotrya japonica*). Pear (*Pyrus* spp.) is infected by a related fungus, *Venturia pirina*, which causes nearly identical symptoms.

The apple scab pathogen was first named *Spilocaea pomi* in 1819 by the Swedish botanist, Elias Fries; but it was G. Winter, in 1880, who first placed specimens of the sexual and asexual stages from apple leaves and labeled the fungus as a species of *Venturia*, although he did not demonstrate the relationship between the two stages. Aderhold, in 1897, was the first to do this, so the correct nomenclature for the fungus is *Venturia inaequalis* (Cooke) Winter amend. Aderhold (MacHardy, 1996). Barr (1968) provides the most thorough discussion of the Venturiaceae in North America.

Signs of the apple scab fungus are most noticeable on leaves and fruit although other plant parts can become infected. The first infections, often called lesions, are seen in the spring and are usually on the underside of the first-formed leaves because they develop with their undersides facing out, prior to unfolding. Once the leaves unfold, the upper surfaces also become vulnerable to infection. An infection first appears as an area that is a lighter shade of green than the surrounding leaf. The lesion is usually circular and as it increases in size it becomes olive-colored and velvety due to production of asexual spores (conidia) (Figs. 1 and 2). Lesions that form on young leaves are variable in size, some more than 1 cm in diameter. Infections that occur on older leaves are usually smaller because leaves become more resistant to infection as they age. Affected tissues eventually may become distorted and puckered, and the leaf lesions may become ripped or torn. Lesions on the fruit are generally more "scabby" in appearance, with a distinct margin (Fig. 3). The earliest noticeable symptoms on fruit are water-soaked areas which develop into velvety, green to olive-brown lesions.

Figure 1.

Infections of young fruit usually cause fruit distortions leading to unusual scabby shapes often accompanied by cracking (Fig. 4). Severely infected leaves or fruit will often drop from the tree prematurely. When significant defoliation for two or three years in a row occurs, the result can be weakened trees that are more susceptible to freeze damage, insect injury, and other diseases (Biggs, 1990).

Venturia inaequalis has long been a problem on apples; symptoms of the disease can be observed on fruit in paintings from the 15th and 16th centuries, with perhaps the earliest record (ca. 1600) seen in a painting by Michel Angelo Caravaggio *Christ and the two disciples at Emmaus* (National Gallery, London) (MacHardy, 1996). The frequent depictions of infected apples suggest that the disease was common and that the affected fruit was acceptable in earlier times. All the commonly grown apple varieties were susceptible to the disease, and there were no chemical treatments to prevent the disease until the late 1800s. At that time, copper- and sulfur-based fungicides provided protection if applied prior to infection, but the chemicals caused substantial damage to the apple foliage. Even today, in spite of the highly effective chemicals and the resistant apple varieties that are available, apple scab causes greater economic losses of apples in North and South America, Europe, and Asia than any other disease.

Venturia inaequalis is an ascomycete fungus within the class Loculoascomycetes, order Pleosporales, family Venturiaceae. Loculoascomycetes don't form a true perithecium, but instead form their asci inside locules that form by dissolving or crushing the internal tissues of the stroma, thus forming a pseudothecium (Fig. 5, courtesy American Phytopathological Society). Also, the walls of the asci are bitunicate in this class. The mycelium of *V. inaequalis* is septate, and the nuclei are haploid.

The brief diploid stage in the life cycle of *V. inaequalis* occurs within the pseudothecium in single hyphal cells, termed croziers, which give rise to the haploid ascospores following meiosis. The asci are elongated, sac-like structures, each of which contains eight ascospores in a linear arrangement. The ascospores are brown, two-celled, and have a characteristic "footprint" shape (see Fig. 5, ascospores are stained red). The unequal size of the cells of the ascospores inspired the Latin species epithet for the fungus, "inaequalis." They are 5 to 7 µm wide and 11 to 15 µm long. In the spring, when the over-wintered leaves become wet, the mature pseudothecia swell and protrude from the surface of the leaf. The ascospores are forcibly ejected and carried by rain and wind to the young blossoms and leaves of apple trees, where, under the appropriate set of conditions, they germinate and initiate infection. There is only one cycle of ascospore production per year.

Like most other ascomycetes, *V. inaequalis* reproduces asexually by producing spores called conidia. The conidial stage of the *V. inaequalis* has its own name, *Spilocaea pomi*. The conidia are single-celled, uninucleate, brown or olive in mass and are narrower at one end. They are 6 to 12 µm wide and 12 to 22 µm long. Conidia are produced by specialized short hyphae called conidiophores. The conidiophores are formed on a dense mat of mycelium that pushes up through the leaf cuticle and ruptures it. It is the mass of conidia and conidiophores that causes the

Figure 2.

Figure 3.

Figure 4.

velvety appearance of the young lesions. Conidia are produced within the lesions from nine to thirty days after initial infection of the leaf, depending on the temperature. Conidia are disseminated by wind and by wind-blown and splashing rain. Once a conidium lands on an apple leaf, blossom or fruit, it adheres to the surface and germinates in the presence of free moisture. The germination hypha penetrates the cuticle and establishes a new infection. There can be many cycles of conidial production and infection within a single growing season, often leading to severe disease outbreaks termed epiphytotics.

Spores: ascospores brown, two-celled, with a characteristic "footprint" shape, 5 to 7 µm wide and 11 to 15 µm long; conidia single-celled, uninucleate, brown or olive in mass, narrower at one end, 6 to 12 µm wide and 12 to 22 µm long.

Diagnostic macroscopic feature: olive-green lesion with feathery margin on apple leaves; scabby lesions on fruits.

Diagnostic microscopic feature: ascospores have distinctive "footprint" shape.

Nutritional mode: obligate parasite during pathogenesis and saprotroph during sexual reproduction.

Substrate: lesions with conidia on leaves, petioles, blossoms, sepals, fruits, and pedicels; ascospores in pseudothecia on over-wintering leaves.

Habitat: worldwide wherever apples are grown, particularly in cooler climate regions.

Fruiting season: spring, summer, fall.

Prevention: sanitation is the best method of prevention, although it is difficult to implement on a large scale; removing all fallen leaves and fruit prior to the new growing season will disrupt the disease cycle; there are good cultivars with complete genetic resistance and these are recommended for home gardeners and organic growers; sanitation and timely applications of fungicides based on weather forecasts, plant development, and pathogen presence are the basis for commercial apple production.

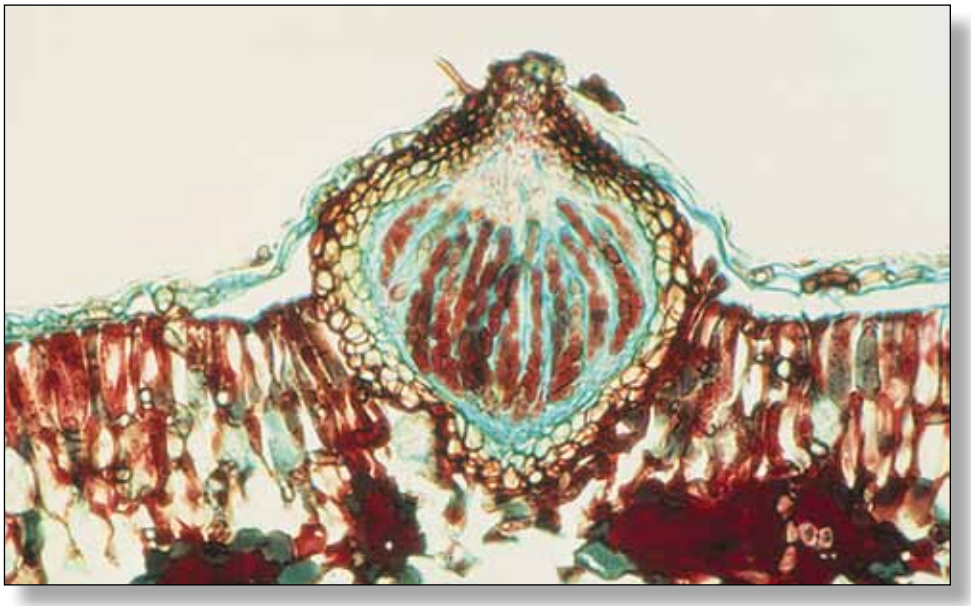

Figure 5.

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