Canker Problems in Apple Orchards

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Cankers in apple trees can be caused by more than a dozen different pathogens. In New York, however, the most common canker pathogens are *Erwinia amylovora*, the fire blight pathogen, *Botryosphaeria obtusa*, the cause of black rot canker, and *Botryosphaeria dothidea*, the cause of white rot canker. *E. amylovora* is unique among apple canker pathogens because it is a bacterium, whereas fungi cause most other cankers on apples. Also, *E. amylovora* can invade and kill healthy trees, whereas most of the fungi causing apple cankers are relatively weak pathogens that appear primarily in stressed trees. The rest of this article focuses on factors that contribute to development of fungal cankers in apple trees.

Fungal cankers usually appear in apple trees only after trees have been predisposed to infection by adverse weather conditions, wounding, inappropriate horticultural practices, or presence of other pathogens in the older wood in the tree. Studying canker diseases in apples is difficult because of the numerous interactions that contribute to canker development. As a result, the published literature contains few controlled studies that document the factors and time-sequences involved in appearance of apple tree cankers. Most of the information in this article is derived from my 30 years of personal observations in New York orchards and from published studies of canker development in other tree species.

Drought Activates White Rot Cankers

Botryosphaeria dothidea causes cankers on a wide range of woody crop plants including apples, almonds, peaches, grapes, and pistachios. In several of these cropping systems, researchers have shown that *B. dothidea* is favored by drought stress. In fact, apple trees that are not under drought stress may be relatively immune to damage from this pathogen.

In apple orchards, *B. dothidea* is commonly present in the outer bark of apple trees where it may cause superficial rounded depressions in the bark without causing any noticeable harm to the tree (Figure 1). So long as trees have an adequate water supply, *B. dothidea* remains innocuous. However, if trees are exposed to a lengthy period of drought stress, *B. dothidea* grows deeper into the bark and will ultimately produce a variety of canker symptoms. Initially, necrosis will extend further into the wood beneath what were previously superficial cankers. Under conditions of severe and continued drought, the cambium beneath the bark can be killed and the cankers may begin producing bubbles of darkened sap. Cankers with this symptom might be mistaken for fire blight cankers except that the stress-induced white rot cankers usually develop in late summer when fire blight is no longer active. On severely affected trees, entire scaffold limbs or sections of the central leader may be killed (Figure 2). More commonly, however, the white rot canker will be limited to one side or to a short section of a limb because the defense mechanisms within trees arrest canker development as soon as drought conditions are alleviated.

Fungal cankers usually appear in apple trees only after trees have been predisposed to infection by adverse weather conditions, wounding or inappropriate horticultural practices. If a tree is subjected to repeated stresses, the wood decay fungi will gradually colonize increasing proportions of the wood. Fungal cankers cannot be controlled with fungicide sprays. However, good horticultural practices that promote tree health will minimize stress conditions that can contribute to canker development.

Figure 1. Sunken areas in bark on tree trunks frequently harbor *Botryosphaeria dothidea*.

Figure 2. This large white rot canker resulted from drought stress when trees on M.9 rootstock were left unirrigated during a dry summer.

Figure 3. Scaly bark and "warts" caused by *Botryosphaeria obtusa* growing in superficial bark infections on scaffold limbs.

In trees exposed to drought stress, *B. dothidea* sometimes produces a superficial warty canker (Figure 3) that can persist for many years. The cambium layer beneath the affected tissue remains green, but the outer bark appears unhealthy. Why these "warts" develop is not understood, and no one knows if these cankers impact productivity of affected limbs.

Over the past five years, many growers in the Hudson Valley have complained about trunk cankers that appeared near the soil line of trees (Figure 4). Macoun trees were the most severely affected, and thousands of Macoun trees have been removed because of this canker problem. Similar cankers have been noted on many other cultivars, but tree losses have been significant only for Macoun. The cause of this basal trunk canker has not been identified with certainty, but the symptoms are typical of cankers caused by *B. dothidea*. It is possible that herbicide sprays hitting the base of the tree trunks may have caused localized water stress in the bark, thereby allowing *B. dothidea* to invade and kill the cambium in the cankered area. However, this hypothesis has not yet been proven.

Black Rot Cankers are External Evidence of Internal Problems

Black rot canker has traditionally been viewed as a "stand alone" disease problem. However, all black rot cankers that I have ever examined originated in trees that had been compromised by other wood-inhabiting pathogens.

Healthy apple trees never develop a true, dark-colored heartwood like an oak tree, so a trunk cross section of a completely healthy apple tree would show white sapwood extending all the way to the center of the trunk. Anyone who has pruned apple trees or cut apple trees for fire wood knows, however, that large limbs and trunks on apple trees have dark colored wood in their centers (Figure 5). The dark wood inside apple limbs develops when older xylem dies due to environmental conditions (cold injury) or invasion by pathogens. Eventually wood decay fungi colonize the discolored wood in most apple trees.

Most of the wood decay fungi are basidiomycetes that produce fruiting structures (bracts) on the surface of dead limbs or trunks (Figure 6). However, these fungi cannot produce bracts so long as they are encased inside living branches or trunks. These fungi remain hidden within the trees until some external factor further disables tree defenses or kills the tissues that separate the wood decay fungi from the outer bark.

Wood decay fungi gain access to the older xylem primarily through pruning cuts and other wounds. Trees that have suffered cold injury in the past are especially prone to invasion because cold-injury can limit the tree's ability to quickly seal and heal pruning cuts (Figure 7). A healthy tree produces lignin and other chemical compounds to rapidly seal off wounds. These compounds help the tree avoid moisture loss and make the wound less hospitable to microorganisms that would otherwise invade wounded tissue. If a tree's ability to seal off wounds has been compromised, then a succession of microorgansims will colonize the old xylem and the tree may ultimately develop black rot cankers.

In other tree species, scientists have shown that xylem tissue exposed by wounds are invaded by a succession of organisms that include bacteria, yeasts, and finally, wood decay fungi. These fungi can progress upward and downward through limbs and/or trunks until they are present throughout much of the tree. If the tree contains relatively little dead xylem, the tree may prevent the invaders from moving beyond the dead xylem and no damage will be evident on the outside of the tree. For the rest of its life, however, the tree will contain wood-decay fungi in the older xylem tissue. These fungi may eventually consume enough of the older wood to create a cavity or hollow trunk within the tree. Despite the presence of wood decay fungi in the older wood, affected trees can remain productive and often continue to produce healthy shoot growth.

Trees can remain productive despite the presence of internal wood decay fungi because the tree employs chemical warfare to limit growth of the wood-invading microorganisms and wood decay fungi. Trees restrict the growth of the invaders by producing inhibitory chemicals in the areas adjacent to infections. These defensive chemicals create barrier zones that cannot easily be penetrated by the invading microorganisms. In essence, trees attacked by wood-invading pathogens limit pathogen growth by creating a chemical box that surrounds the infection. When trees are cut, the chemical barrier zones in the wood are sometimes evident as a very dark brown or black line separating diseased and healthy wood.

Trees must actively maintain the chemical barrier zones because the en-

Figure 4. Basal trunk cankers on Macoun trees can cause tree death. (Figure 4a was provided by Mike Fargione.)

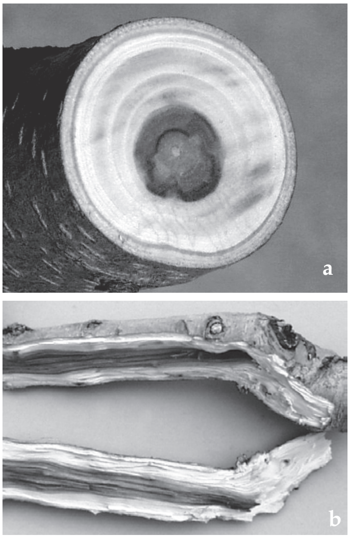

Figure 5. Discolored xylem shown in cross-section (A) and longitudinal section (B) is frequently colonized by wood-decay fungi.

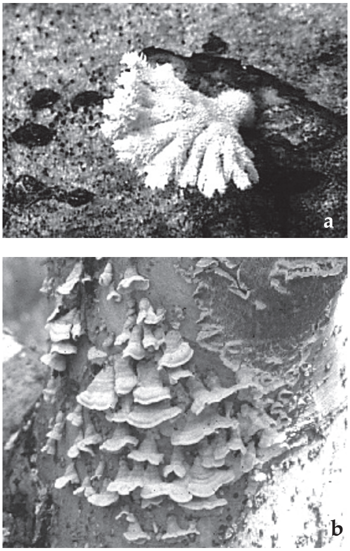

Figure 6. Fruiting structures (bracts) of two wood decay fungi commonly found on dead apple wood. *Schizophyllum commune* (A), produces small bracts that are usually less than one-half inch across, but it is one of the most common and most aggressive wood decay pathogens in New York apple orchards.

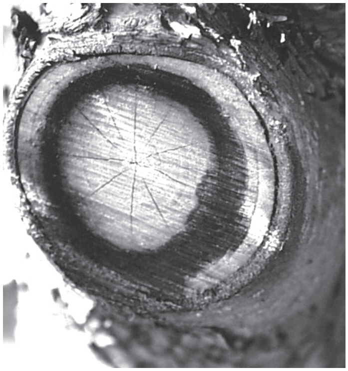

Figure 7. The dark ring of sap leaking from a pruning cut indicates that this winter-damaged tree cannot properly seal off pruning wounds.

closed pathogens continually attempt to break down and penetrate the barriers. Thus, trees must expend energy to maintain their defenses. Under good growing conditions, an apple tree can maintain these defensive barriers and still produce good crops. However, the tree's ability to fight the infection can be compromised if trees are subjected to drought, cold injury, or low oxygen stress (i.e., "wet feet"). When stress conditions leave trees unable to maintain their chemical defenses, wood-decay fungi can move through the chemical barriers and colonize additional portions of the older wood. When the stress conditions are alleviated, the tree again walls off the invaders by creating new barrier zones.

If a tree is subjected to repeated stresses, the wood decay fungi will gradually colonize increasing proportions of the wood as they grow outward toward the tree bark. As the thickness of healthy wood beneath the bark decreases, the remaining layer of healthy wood and bark becomes weakened until it can no longer defend itself via creation of barrier zones. At that point, trees become susceptible to canker fungi such as *B. otusa* that primarily attack the bark and outer woody tissues. Pruning cuts through limbs that have been largely colonized by wood-decay fungi will fail to heal and also provide ideal sites for establishment of black rot cankers.

The ecological succession of organisms that invade cold-injured trees often continues for several years before the full extent of the damage becomes evident. In the Champlain Valley, outbreaks of canker diseases often occur three to five years after severe cold injury because it takes that long for the wood-decay fungi to become established and weaken the tree enough to allow development of external cankers.

In the Hudson Valley, white rot cankers predominate following drought years because drought allows *B. dothidea* to become an active pathogen in trees that have not been compromised by wood-decay fungi. However, outbreaks of black rot canker have also been noted following drought years, probably because drought allowed internal wood-decay fungi to colonize more wood, which predisposed trees to black rot canker. Black rot is often cited as the problem in these orchards, whereas black rot is only the climax to a long progression of other events that reduced tree health.

Wood Decay Fungi Also Contribute to Other Canker Problems

Trees sometimes collapse suddenly in the spring or early summer as a result of large cankers that encompass scaffold limb crotches or due to cankers that appear on the southwest sides of trees (Fig-

Figure 8. The large trunk canker on this Rome Beauty tree is typical of cankers that result when wood-decay fungi rapidly colonize cold-injured tissue.

ure 8). These cankers appear because trees have been damaged by cold injury. Crotch cankers have been observed primarily in Rome Beauty and Empire growing on vigorous sites or in low spots where trees failed to harden adequately prior to the first deep freeze in early winter. Tree collapse from crotch cankers was especially prevalent where MM.106 rootstocks were used on poorly drained sites.

The crotches between the lower scaffolds and the trunk are the last areas of the tree to become winter-hardy, and they therefore sustain the greatest damage if cold injury occurs in late fall or early winter. After the crotch areas are damaged and can no longer sustain their internal defenses, wood-decay fungi already present inside the trees rapidly invade the damaged wood and bark. Cankers erupt over large areas of the trunks and scaffold limbs in late-May and June of the year following the injury, but the fungi causing those cankers usually invaded the bark from the inside of the tree rather than from the outside as most observers might assume.

There Are No Simple Solutions for Managing Canker Problems

Apple tree cankers cannot be controlled with fungicide sprays. However, good horticultural practices that promote tree health will minimize stress conditions that can contribute to canker development:

- Trickle irrigation on drought-prone sites will help prevent water stress, thereby enabling trees to maintain their natural defense systems. Overhead irrigation may be necessary in very dry years in blocks where trickle irrigation is not available.
- Trees on poorly drained sites will benefit if they are planted on broad raised beds or berms that allow for better root growth and less exposure to low-oxygen stress during wet periods.
- Applying white paint to trunks can help prevent southwest injury. Paint is likely to be most beneficial on cultivars like Rome and Empire that frequently develop canker problems, and on trees four to 12 years old. Younger trees are too small to have much wood directly facing the sun. Older trees develop roughened and thickened bark that is difficult to paint and is more naturally resistant to southwest injury.
- Cankers and weak or dying limbs should be removed during pruning. Active cankers may contain sporulating fungi that add inoculum to the orchard. Energy that a tree might use to maintain a weak limb is better spent in healing the pruning cut where the limb was removed.
- Making clean, smooth pruning cuts and leaving no pruning stubs can minimize probabilities that pruning cuts will become infected. Stubs eventually die, providing an entry site for wood decay fungi. Cutting limbs too close to their point of attachment is also damaging, however. The collar of wrinkled bark at the base of branches and limbs should be left intact on the tree because the collar is essential for rapid closure of pruning wounds.
- Paints and coatings for pruning cuts have generally proved useless for protecting pruning cuts. The paints develop microscopic cracks that allow the fungi to enter the wood anyway. Sometimes paints actually trap moisture in dead wood that would otherwise become too dry for fungal invasion.
- Large limbs removed during pruning should be removed from orchards before bract fungi begin sporulating on them (usually six to 12 months after they are cut). Similarly, dead stumps should be removed from orchards to eliminate these large sources of inoculum.
- In blocks with existing canker problems or in trees recovering from winter damage, all pruning should be completed during cold winter weather. Unlike the case with fire blight bacteria, canker fungi will NOT spread on pruning tools. However, several studies have shown that aged and dried out wounds are less susceptible to infection than fresh wounds. Because wood-decay and canker-causing fungi cannot grow at sub-freezing temperatures, pruning cuts made during winter will be less prone to infection than cuts made after trees begin to grow in spring. (Note that this is the exact reverse of the recommendations for avoiding Cytospora canker on peaches: different pathogens, different host, different defense mechanisms!)

Understanding the underlying factors that contribute to canker problems may allow corrective measures (e.g., irrigation during drought) to be applied before orchards sustain irreversible damage. However, in many cases, canker problems develop as a result of unusual weather patterns or other unpredictable circumstances and little can be done to reverse the damage. The only alternatives in these orchards is to either remove diseased limbs and/or dead trees as they appear or to remove the entire block if canker problems make the block unprofitable.

Where blocks are removed because of severe canker problems, it may be unwise to replant the site unless the factors that compromised tree health in the original planting can be addressed. For example, Empire trees seem especially susceptible to canker diseases, so it makes little sense to plant Empire in poorly drained sites or in low spots that are subject to winter damage. Sites that are subject to drought stress should not be replanted using M.9 or other rootstocks that cannot tolerate drought unless the new planting can be irrigated.

Ultimately, canker problems must be managed by employing an integrated program of good horticultural practices. Trees have defense mechanisms that limit their susceptibility to most canker diseases, and good horticultural practices allow trees to maintain those natural de fenses.

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