Recognizing and Managing Sapstreak Disease of Sugar Maple

David R. Houston
Abstract

Sapstreak disease is a potentially serious problem of sugarbushes and forest stands. It occurs when the causal fungus, *Ceratocystis virescens*, invades the sapwood of roots and bases of stems through wounds inflicted during logging, saphauling, or other activities. This bulletin describes how to recognize the disease, the factors that affect its occurrence and development, and management approaches to help reduce its effects.

The Author

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Introduction

Sapstreak of sugar maple (*Acer saccharum* Marsh) is a disease of the living sapwood incited by the fungus, *Ceratocystis virescens* (Davidson) C. Moreau (=*C. coerulescens* (Munch) Bakshi) (= *Endoconidiophora virescens* Davidson) (Hepting 1944). Sapstreak, first noticed in North Carolina in approximately 1935 (Hepting 1944), has since been reported in Michigan in 1959 (Kessler and Anderson 1960), Vermont in 1964 (Houston and Fisher 1964), Wisconsin in 1971 (Kessler 1972) and New York in 1978 (Beil and Kessler 1979, Houston and Schneider 1982). In each case, the disease occurred in stands where activities such as logging, road building, or sap hauling had inflicted root or lower stem wounds to the affected trees. These injuries allow *C. virescens* to invade and then kill the wood of lower portions of the stem and roots (Hepting 1944, Kessler 1978, Houston 1985). Because *C. virescens* is one of the most common fungi in northern hardwood forests (Shigo 1962), sapstreak disease has the potential to occur where the roots and lower stems of sugar maple trees are wounded during logging or other activities in these forests.

This paper presents information on (1) symptoms of the disease, (2) factors affecting disease occurrence and development and (3) management approaches to reduce disease effects. This information was obtained from published articles and a series of studies conducted from 1979 to 1991. Details of the studies are not presented in this paper.

Symptoms of the Disease

Usually, the first observed symptom of sapstreak is a distinctive “transparency” of the tree crown—a consequence of unusually small leaves, especially in upper branches but sometimes over the entire crown (Fig. 1). Often, these small leaves are normal in color, shape, and number the first year of the disease, but become off-colored and sparse in subsequent years. Branch dieback often occurs where small leaves had occurred the previous year, and this pattern of small leaves one year followed by death of supporting twigs and branches the next, can continue for several years until the tree dies (Fig. 2). Sometimes, however, symptom progression is arrested and results in trees whose upper crowns exhibit branch...
dieback or even major stagheading while lower branches are fully foliated with leaves of normal size and color. Some of these trees recover with no further disease progression while others, after several years of apparent remission, again exhibit symptoms.

Inside the tree the diseased wood of roots and lower stems exhibits a distinctive stain (Fig. 3). Freshly exposed, the stain is greenish yellow to yellow-tan with red flecks and appears watersoaked. Often, in cross-section, the stain columns appear to radiate outward and are bordered by a thin, intermittent, dark-green margin. Soon after exposure, the stain darkens dramatically, then later fades to a light brown.

External symptoms are related closely to development of internal stain. By the time crown symptoms appear, stain columns are well established (Fig. 4), especially in root tissues, and usually can be revealed by an ax cut into the buttress roots. In many trees, especially those in remission of crown symptoms, the outward extension of stain columns appears to be limited by newly-formed rings of healthy sapwood (Fig. 5).

When trees infected by sapstreak disease are cut into lumber, the stain columns often are very noticeable and distinctive (Houston 1986). Within a few minutes of cutting and exposure to air, stain columns become dark brown (Fig. 6). As drying progresses, the columns gradually change color, becoming lighter--while the clear wood, in contrast, darkens (Fig. 7). Surface planing of dried lumber reverses these patterns and again reveals the light brown stain of diseased wood in contrast to the clear, white, healthy wood.

Figure 3.--Sapstreak disease stain, when fresh, has a watersoaked, greenish-yellow-to-tan color with scattered red flecks, and is bordered by a narrow green margin. The stain often appears to radiate outward.

Figure 4.--Well developed stain columns at the root collar and occupying most of the sapwood. By the time the crown symptoms appear, the stain is well established.

Figure 5.--Internal stain column that is well compartmentalized by annual ring boundaries.
When *C. virescens* grows on board surfaces, where it sometimes sporulates, it usually occurs near the outer margins of the stain columns and often on clear wood immediately adjacent to stain columns (Fig. 7). The dark, smudgy appearance of the fungal growth is distinctive and develops within a few days of sawing. As drying continues, the surfaces of the sapstreak stained columns become heavily colonized by numerous common molds; clear wood remains free of such growths (Fig. 7).

**Disease Development within Individual Trees**

**Infection and Importance of Wounds**

Infection occurs primarily through wounds to the roots, buttress roots, or the lower portion of stems near the ground during logging, saphauling, or other activities (Figs. 8, 9) (Hepting
Buttress roots and roots close to the soil surface typical of those damaged by traffic in the sugar bush; these roots are at risk to infection by the sapstreak fungus.

1944, Houston 1992, Meilke and Charette 1989). Stump wounds, created when sprout members are removed in thinning, can provide the fungus access to otherwise unwounded residual members (Fig. 10). A few cases have been observed where the fungus apparently entered the tree through roots injured by cattle trampling.

Injuries associated with sapstreak are nearly always close to the ground. Even though stem tissues can be infected, and invasion of upper portions of stems from infections originating in the roots or stem bases can occur, no definitive cases have been found where infection has occurred naturally through broken branches or other wounds of upper crowns or stems. No cases have been observed where, in practice, tapholes have become infected by sapstreak, and only rarely (2 of 142 times) did this occur when the fungus was placed experimentally into tapholes (Houston 1992). In each instance where infection did occur, its development around tapholes was sharply limited by the tree (Fig. 11).

Results from several studies suggest that wounds made in the late spring and early summer may be more readily infected by *C. virescens* than wounds made at other times. Other tree species are known to be most susceptible to vascular pathogens at this time. Meilke and Charette (1989) found no significant differences in the number of trees affected by sapstreak in Wisconsin stands logged during frozen versus nonfrozen conditions, although no records were available concerning the number of trees wounded or the actual conditions of the roadways when logging occurred.

A few cases have been observed where the fungus moved across functional root grafts from wounded, diseased trees to adjacent, nonwounded neighbors (Houston 1991).

**Disease Progression within Individual Trees (Patterns and rates)**

Within individual trees, the appearance of initial crown symptoms and the rate of their progression varies greatly.
Some trees exhibit severe crown dieback for many years before they die, while others become symptomatic and succumb rapidly, often within 2-3 years. Trees that die quickly and possess severe symptoms usually are extensively invaded by *C. virescens* (Fig. 12). In most such trees, vascular staining is present throughout the roots and much of the stems, and the fungus sometimes can be isolated from xylem tissues in the upper portions of stems, often up to 30-45 ft.

Sometimes disease progression, as revealed externally by crown symptoms, is arrested and recovery ensues, even in trees with more than 40 percent crown dieback. Some trees with root-stain patterns characteristic of sapstreak disease never developed severe foliar symptoms during the course of a 10-year study. In such trees, the columns of discoloration usually appear strongly restricted by the tree (Fig. 13).

Disease development within trees also can be monitored nondestructively. Sapstreak stained wood characteristically is very low in electrical resistance (ER) (50 K ohms and often as low as 5 to 10 K ohms) compared to healthy tissue (100-700 K ohms) (Houston and Schneider 1982). Tissues infected by sapstreak disease can be identified reliably by their ER measurements (Table 1).

Figure 12.--Bolts, 1 meter long, sequentially cut (from root collar up and placed in that order for photo) from a tree that died within 18 months after being infected with *C. virescens*. The dark fungus has grown out from the columns of stained xylem onto the cut ends of the bolts.

![Figure 12](image12.png)

Figure 13.--In this tree both developing columns of discoloration are limited strongly by compartmentalization.

![Figure 13](image13.png)

Table 1.--Comparison of electrical resistance (k-ohms) of buttress-root tissues of a healthy tree and a tree with sapstreak disease

<table>
<thead>
<tr>
<th>Depth (inches) into root wood</th>
<th>Root</th>
<th>.25</th>
<th>.50</th>
<th>.75</th>
<th>1.0</th>
<th>1.25</th>
<th>1.50</th>
<th>1.75</th>
<th>2.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Healthy tree</td>
<td>1</td>
<td>180</td>
<td>190</td>
<td>210</td>
<td>290</td>
<td>260</td>
<td>230</td>
<td>240</td>
<td>200</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>250</td>
<td>230</td>
<td>160</td>
<td>210</td>
<td>256</td>
<td>200</td>
<td>260</td>
<td>260</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>500</td>
<td>400</td>
<td>330</td>
<td>280</td>
<td>280</td>
<td>500</td>
<td>300</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>320</td>
<td>220</td>
<td>230</td>
<td>240</td>
<td>240</td>
<td>250</td>
<td>340</td>
<td>500</td>
</tr>
</tbody>
</table>

| Diseased tree                | 1    | 21  | 34  | 18  | 27  | 22   | 46   | 21   |     |
|                              | 2    | 15  | 18  | 23  | 17  | 13   | 13   | 9    |     |
|                              | 3    | 80  | 80  | 70  | 80  | 70   | 50   | 60   |     |
|                              | 4    | 100 | 80  | 70  | 90  | 50   | 60   |      |     |

| aThe tree had severe crown symptoms in 1980 and was still alive in 1981. |
Development of the disease usually is more rapid and extensive in roots than stems. Often, extension of the stain columns into stems is sharply limited even when roots and root collar regions are severely colonized (Fig. 14). Repeated measurements on individual trees reveal the disease pattern in a sugar maple root system, July 1980 to July 1981 (Table 2).

Table 2.-- Electrical resistance in two successive years in buttress roots on different sides of a diseased tree reveal progression of the disease. Numbers below 50 indicate sapstreak disease.

<table>
<thead>
<tr>
<th>Date measured tree</th>
<th>Side of measured tree</th>
<th>.25</th>
<th>.50</th>
<th>.75</th>
<th>1.0</th>
<th>1.25</th>
<th>1.50</th>
<th>1.75</th>
<th>2.0</th>
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<tr>
<td>July 1980</td>
<td>N</td>
<td>24</td>
<td>45</td>
<td>35</td>
<td>110</td>
<td>80</td>
<td>1.50</td>
<td>1.75</td>
<td>2.0</td>
</tr>
<tr>
<td></td>
<td>W</td>
<td>500</td>
<td>500</td>
<td>450</td>
<td>380</td>
<td>300</td>
<td>500</td>
<td>500</td>
<td>-</td>
</tr>
<tr>
<td>Symptoms in extreme top</td>
<td>S</td>
<td>450</td>
<td>250</td>
<td>180</td>
<td>170</td>
<td>250</td>
<td>190</td>
<td>380</td>
<td>200</td>
</tr>
<tr>
<td></td>
<td>E</td>
<td>40</td>
<td>100</td>
<td>130</td>
<td>150</td>
<td>110</td>
<td>110</td>
<td>190</td>
<td>80</td>
</tr>
<tr>
<td>July 1981</td>
<td>N</td>
<td>55</td>
<td>60</td>
<td>70</td>
<td>60</td>
<td>55</td>
<td>65</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Symptoms same as 1980</td>
<td>W</td>
<td>100</td>
<td>175</td>
<td>45</td>
<td>40</td>
<td>40</td>
<td>38</td>
<td>40</td>
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<td></td>
<td>S</td>
<td>140</td>
<td>180</td>
<td>280</td>
<td>280</td>
<td>210</td>
<td>220</td>
<td>220</td>
<td>190</td>
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<tr>
<td></td>
<td>E</td>
<td>20</td>
<td>12</td>
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<td>8</td>
<td>7</td>
<td>6</td>
<td>5</td>
<td>4</td>
</tr>
</tbody>
</table>

Figure 14.-- Sometimes spread of the fungus upward into stem tissues is limited even though tree roots and root collars are severely colonized.

Speed and extent of column discoloration may relate to the severity and orientation of infection court and other wounds near expanding columns. In some trees, dramatically and greater discoloration occurs when fungus invades deep wounds across the tangential face of the tree stem or root, compared to wounds oriented toward the center. Deep tangential wounds disrupt more preestablished compartment barriers (Shigo 1977, 1979). In some trees, however, the fungus is limited regardless of the wound orientation, suggesting that trees vary in retarding the invasion process.

Finally, other organisms appear to influence the rate at which sapstreak diseased trees succumb. Trees dying of sapstreak disease almost always are colonized at their roots or root collars by Armillaria sp. (Fig. 15), Xylaria sp. (Pers.: Fr.) Grev. (Fig. 16), or, rarely, both (Hepting 1944, Houston 1985). These root fungi, ubiquitous inhabitants of long...
established maple stands, are maintained in root systems of stumps and dead trees. Root system "food bases" of large trees probably are more important for longer survival and vigor of root pathogens than are those of small trees whose roots are more quickly consumed. Although their actual role in sapstreak disease has not been demonstrated, it is likely that these fungi contribute significantly to the death of sapstreak affected trees.

The ability of Armillaria spp. to invade and kill trees weakened by stress factors, especially insect defoliation, is well known (Wargo and Shaw 1985). Presence of these pathogens and perhaps others, such as Hypoxylon deustum (Hoffm.: Fr.) Grev. and Ganoderma applanatum (Pers.) Pat., on dying trees and their apparent absence from severely affected, but recovering trees, suggests that their attacks may determine which sapstreaked trees die or recover.

Severely affected trees often are attacked by Ambrosia beetles. Initial concentrations usually are near the buttress roots and lower bole with columns of sapstreak discoloration near the cambium (Fig. 17). The role of these insects or their fungal associates in the disease is not known; their great abundance in later stages of disease suggests they hasten the demise of diseased trees.

Figure 17.--Long streaks (between vertical split and arrow) of sapwood discolored by sapstreak disease sometimes occur near the cambium. The cambium touched by these streaks dies, and cankers (not yet obvious in this recently infected sampling) may form. Often, Ambrosia beetles penetrate these areas into the underlying sapwood (arrow).

Disease Development in Sugarbushes

In sugarbushes, sapstreak disease rarely results in large numbers of trees dying at one time. Rather, it appears to affect a few trees, now and again. The following description is based on observations in many different bushes, in particular, those made annually over 11 years in two typical sugarbushes in northern New York.

In sugarbushes, sapstreak disease is not related directly to the tapping process but to associated activities that result in wounds to roots and lower stems. Vehicles or equipment that bruise or cut shallow or buttress roots to expose sapwood appears the most important factor. The close association of sapstreak diseased trees to roads used for sap hauling in a New York sugarbush is shown in Figure 18.

Figure 18.--Locations of sapstreak diseased trees (boxed outlines) and the years when symptoms were first observed in a New York sugarbush. Main access and sap hauling roads (dash lines) lead to the sugarhouse near plot 6.
In other sugarbushes, sapstreak disease has occurred in trees with roots injured by cattle and by log skidding. In one instance, a tree, located adjacent to a field, developed sapstreak symptoms a few years after its roots had been injured when the field was plowed and disked. Whether the injuries that led to sapstreak disease were made during sap hauling or at some other time is not known. The fact that very few cases of sapstreak have been observed in sugarbushes employing tubing collection systems could be due either to reduced sap hauling traffic or to less traffic at other times. Regardless of the sap collection system used, the disease often is most severe near the sugarhouse where traffic and other activities are concentrated (Fig. 19). Other factors, including a possible buildup of the pathogen on wood from diseased trees stacked near the sugar house, also may contribute to infection of nearby wounded trees. The fungus often is found colonizing (Fig. 12) recently cut surfaces of stumps and logs (Ohman and Kessler 1963, Shigo 1962).

**Disease Development in Forest Stands**

In forest stands as in sugarbushes, sapstreak diseased trees usually have severely injured roots or lower stems. The patterns of occurrence in forest stands, however, usually differ from those in sugarbushes in ways that reflect the less frequent, but more severe, wound-inflicting disturbance associated with harvesting operations. In the area within a harvested stand in northern New York that was near the log landing, 27 trees were found with sapstreak disease in 1985 (Fig. 20). All of these trees were immediately adjacent to skid

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**Figure 19.**.—Plot 6 in a New York sugarbush. Numbered trees (large solid circles) became diseased during the decade of observation (1980-1990).

**Figure 20.**.—Locations of sapstreak diseased trees in a forest area in northern New York, a portion of which was logged in 1981.
Figure 21.—Locations of sapstreak diseased trees in a 30-acre portion of a forest stand in northern New York. The stand was thinned in 1980. Trees not dead by 1990 are in remission and appear to have recovered trails created when the stand was logged in early summer of 1981. This “flush” pattern, in which a large number of diseased trees occurs at one time (from infection of wounds during heavy skidding activity), is in contrast to the occasional infection of trees in some sugarbushes, in which annual, but less damaging, intrusions into the stand may result in new or repeated wounding of additional trees.

In forest stands, sapstreak diseased trees usually exhibit initial symptoms from 3 to 6 years after the injury-causing event. While the period over which diseased trees dies frequently is more protracted, the trees that are going to die will have done so within 6 to 8 years after they became infected.

In less heavily trafficked areas within forest stands, or in stands where fewer trees are being harvested, for example, in improvement cuts or light thinnings, fewer trees are apt to become injured and diseased (Fig. 21). In general, diseased trees often are concentrated in wet areas where roots are more severely damaged. Residual members of thinned sprout clumps occasionally are infected by the sapstreak fungus, apparently through the stump wounds created by the thinning (Figs. 10, 21).

The following relationships, gleaned from our observations and studies and from earlier work by others, are pivotal to the development of management guidelines to prevent or reduce losses from sapstreak disease in sugarbushes and forest stands.

- There is an almost universal association of wounds and the occurrence of sapstreak disease. The disease rarely occurs in nonwounded trees (see Forest Stands).

**Location**

Wounds of great importance are those near the ground—roots, buttress roots, and lower stems.

Wounds of little or no importance are those of branches and upper stems—branch stubs, pruning wounds, and tapholes.

**Causes**

Activities that result in wounds (in order of importance) include skidding logs, hauling sap and wood, building and maintaining roads, thinning sprout clumps, and trampling by cattle.

**Timing**

Wounds made during spring and early summer may be more important than those made at other times.

Wounded trees, on rare occasion, become diseased when the sapstreak pathogen invades their roots through functional root grafts with closely adjacent diseased trees.

Trees that die of sapstreak disease also almost always are invaded by root pathogens, especially *Armillaria* sp. and *Xylaria* sp.

These relationships are reflected in the following management options and guidelines for reducing losses from sapstreak disease in sugarbushes and forest stands.

**Management Options and Guidelines to Reduce Losses from Sapstreak Disease**

**Sugarbushes**

**Reduce infection courts**

- Avoid wounding of roots, buttress roots, and lower portions of the stem.
- Employ tubing collection systems when feasible.
- Use permanent access and haul roads.
- Avoid travel with heavy equipment during spring-early summer mud season and wet periods.

**Avoid creating other infection courts**

- When conducting thinnings or stand improvement operations either leave or take all members of sugar maple sprout clumps.

**Avoid susceptible period**

- Conduct thinnings, stand improvement operations, wood hauling, and other activities that may result in injuring trees, in late summer, fall, and winter when trees seem to be less susceptible to infection.
Avoid build-up of sapstreak disease inoculum

- Monitor sugarbush to detect diseased trees.
- Concentrate surveys to trees along roadways and near sugarhouse.
- Remove diseased trees promptly (see above for best periods).
- Avoid stacking infected wood near the sugarhouse. If possible, dry diseased wood in large open areas away from areas where trees are apt to be injured.

Reduce threat from mortality-associated root pathogens

- Ideally, establish sugarbush at early age to reduce the need to remove large trees in later thinnings and consequently reduce large stump food bases for root decay organisms.
- Monitor sugarbush to track populations of defoliating insects. When necessary, arrange to control outbreaks of insects whose effects will predispose trees to invasion by root pathogens.

Reduce inoculum and losses

- Revisit stands 4 to 5 years after logging operations to monitor the occurrence of sapstreak.
- Focus surveys on trees adjacent to skid trails or landings, and especially on those trees with basal skidding injuries.
- If feasible, remove diseased trees taking care not to create additional new injuries. (See infection courts above).

Forest Stands

Reduce infection courts

- Avoid wounding roots, buttress roots, and lower portions of stems.

- Establish permanent skid trails and haul roads. If possible, use trees other than sugar maple as bumper trees.
- Schedule forest operations to avoid mud season or periods when soil is saturated and soft.
- For stands rich in sugar maple, schedule operations to avoid the late spring-early summer period when trees appear to be most susceptible.
- Don't thin sugar maple sprout clumps that are pole-sized or larger--leave them all or remove them all.

Reduce effects of associated root pathogens

- Monitor climatic factors such as open, cold winters; drought; late spring frosts; and biotic factors such as insect defoliator outbreaks known to predispose trees to root pathogens.
- When possible, schedule forestry operations to avoid conducting them during, or soon after, stress events.

Literature Cited


Sapstreak disease, a potentially serious problem of sugarbushes and forest stands, occurs when the causal fungus, Ceratocystis virescens, invades the sapwood of roots and bases of stems through wounds inflicted during logging, saphauling, or other activities. Describes how to recognize the disease, the factors that affect its occurrence and development, and management approaches to help reduce its effects.

Keywords: Ceratocystis virescens, root and buttress-root wounds, vascular disease, sugarbush, forest management.
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