

Factors Associated with Rapid Mortality of Sugar Maple in Pennsylvania

Thomas J. Hall, James D. Unger, Thomas C. Bast, Norman C. Kauffman and Bradley S. Regester¹

Abstract

Mortality of sugar maple and red maple was observed throughout Pennsylvania in 1995 following an outbreak in 1994 by forest tent caterpillar and elm spanworm on sugar maple and red maple, respectively. Symptoms of leaf anthracnose caused by *Discula campestris* (Pass.) were observed during the refoliation period from July through September 1994; the refoliation of crowns of affected trees was extremely poor or almost non-existent. Subsequent mortality and tree condition were monitored in 15 sugar maple stands located in Bedford, Blair, Lycoming, Potter, Sullivan, Susquehanna, Tioga, and Wayne counties from 1995-1997. Initial mortality was 12.3% in 1995; by 1997 cumulative mortality was 19.9% (salvaged timber excluded). The role of multiple stress factors in relation to mortality is discussed.

Introduction

Unusual levels of sugar maple (*Acer saccharum* Marsh.) crown dieback and tree mortality have been observed across the northern-tier counties of Pennsylvania since the early to mid-1980s (Kolb and McCormick 1993, Quimby 1997). In some cases, tree decline has been characterized by slow crown deterioration and eventual mortality occurring over five or more years; in other cases the crown dieback and mortality process occurs relatively rapidly in only a year or two. Defoliation, drought, and other climatic events have been associated with decline and mortality of sugar maple elsewhere (Giese et al. 1964, Gross 1991, Bause and Allen 1991, Allen et al. 1992a and 1992b, Payette et al. 1996, Robitaille et al. 1995, Auclair et al. 1997). Recently, we had an opportunity to document a sequence of events which resulted in rapid mortality of sugar maple in Pennsylvania.

In May-June 1994, an outbreak of forest tent caterpillar (*Malacosoma disstria* Hbner) on sugar maple was responsible for extensive defoliation of northern hardwood stands throughout Pennsylvania. Affected areas included the northern-tier counties of Bradford, Columbia, Luzerne, Lycoming, McKean, Sullivan, Susquehanna, Tioga, and Wayne and the southcentral counties of Blair and Bedford. Based on estimates from aerial surveys conducted by the Pennsylvania Bureau of Forestry (Quimby 1995 and 1996), forest tent caterpillar defoliated approximately 283,000 hectares. An additional 93,280 hectares were defoliated in

areas infested by both forest tent caterpillar and elm spanworm (*Ennomos subsignaria* Hubner) on sugar maple and red maple, respectively. Subsequent refoliation of trees in affected stands was poor; trees exhibited extensive crown dieback, and foliage transparency in the range of 80 to 95+% was estimated.

In August 1994 visual inspection of foliage from affected sugar maple and red maple trees revealed symptoms of anthracnose presumably caused by the fungal pathogen *Discula campestris* (Pass.) (Hall 1995). Symptoms observed during the refoliation period were leaf blight, expansive necrotic leaf lesions characteristic of anthracnose, leaf cupping, extensive necrosis of succulent twig and bud tissue, lack of terminal bud formation, and extensive twig and branch dieback. In 1994 a study was initiated to evaluate the impact of the defoliation by forest tent caterpillar followed by anthracnose on sugar maple mortality in the years following the initial outbreak.

Methods

In November 1994, plots were established in 15 sugar maple stands for a multiyear monitoring study to record changes in tree crown condition and mortality following heavy (30-50%) to severe (50+%) defoliation by forest tent caterpillar and damage by *Discula campestris*, the sugar maple anthracnose fungus, during the subsequent refoliation period. Verification of damage by *Discula campestris* was based on the presence of bud and twig symptoms on samples taken from sugar maples within or near each study plot between September and late October 1994. Twig samples were collected and incubated in a moist chamber to induce fungal sporulation; subsequent cultures of *Discula campestris* were made from symptomatic twigs. Isolates of *Discula campestris* were tested for pathogenicity on sugar maple seedlings. After confirmation of anthracnose damage within a stand, a study plot, including 30 to 50 sugar maple trees that had been damaged by both forest tent caterpillar and *Discula campestris*, was established. Most of the sampled trees were of either dominant or codominant crown class. A total of 546 trees among the 15 plots was monitored. These plots were revisited in late May and early June 1995, 1996, and 1997 to collect data on tree mortality, percent crown dieback, percent live crown cover, foliage condition, foliage distribution and size, insect defoliation, and anthracnose activity.

Results

Only tree mortality and crown dieback are presented. Table 1 lists annual and cumulative mortality for 1995-97. In 1995, sugar maple mortality among all plots was 12.3% (67 of 546 trees), though initial tree mortality was high in four stands located in Lycoming, Sullivan, and Wayne Counties. Most residual tree crowns were damaged, and many were in fair to poor condition in most stands. Two plots located in

¹Thomas J. Hall, Plant Pathologist, James D. Unger, Forest Entomologist, Thomas C. Bast, Forest Entomologist, Norman C. Kauffman, Forest Entomologist, and Bradley S. Regester, Entomologist, Division of Forest Pest Management, Bureau of Forestry, Department of Conservation and Natural Resources, 208 Airport Drive, Middletown, PA 17057, respectively.

Table 1.—Percentage of sugar maple mortality associated with 1994 defoliation by *Malacosoma disstria* and anthracnose caused by *Discula campestris* for 15 stands located in eight* Pennsylvania counties.

Mortality category	Year		
	1995	1996	1997
Annual	12.3 (67/546)**	8.1 (39/479)	0.7 (3/427)
Cumulative	12.3 (67/546)	19.4 (106/546)	19.9 (109/546)
Salvage healthy	-	-	2.7 (15/546)
Salvage unhealthy	-	-	15.2 (83/546)
Total salvage	-	-	17.9 (98/546)

*Bedford, Blair, Lycoming, Potter, Sullivan, Susquehanna, Tioga, and Wayne.

**Actual mortality figures presented for each category with the numerator representing dead trees and the denominator representing the study population.

Table 2.—Percentage of crown dieback in sugar maple due to the 1994 outbreak of forest tent caterpillar and anthracnose caused by *Discula campestris* on 15 study plots in Pennsylvania.

Dieback class*	Percent crown dieback by year		
	1995	1996	1997
0-15%	48.9**	57.7	79.9
20-30%	9.9	14.9	13.1
35+%	41.2	27.4	7.2

*Dieback class based on Sugar Maple Management Highlights for the Region from the North American Maple Project (Anonymous 1997).

**Percentage based on the number of standing live trees at the time of data collection; salvaged trees are not included.

Table 3.—Percentage of crown dieback in sugar maple stands* due to the 1994 outbreak of forest tent caterpillar and anthracnose where cumulative tree mortality was below 2%.

Dieback class**	Percent of crown dieback		
	1995	1996	1997
0-15%	74.2*** (242/326)	74.5 (240/322)	78.7 (251/319)
20-30%	11.3 (37/326)	11.8 (38/322)	9.7 (31/319)
35+%	13.2 (43/326)	9.9 (32/322)	9.7 (31/319)

*Data reflects nine stands which remain under study beyond 1997.

**Dieback class based on Sugar Maple Management Highlights for the Region from the North American Maple Project (Anonymous 1997).

***Percentage based on the number of standing live trees at the time of data collection.

Sullivan County on the Wyoming State Forest (Dry Run and Slab Run) each with 50 trees had 13 and 36 dead trees, respectively. Of the remaining live trees, 18 and 11 trees, respectively, had crown dieback of 80% or more. Only three additional trees died in these stands in 1996, but crown dieback was 80% or more in 22 and 8 trees, respectively. By 1996, 52 trees were dead, 30 trees had crown dieback >80%, and only 8 trees were healthy with dieback <25%. These stands were subsequently marked for salvage and removed from the current study after 1996. One plot in Wayne County on Pennsylvania State Game Lands #159 was the location where forest tent caterpillar and anthracnose were first observed and confirmed in 1994. Of the 30 trees in this plot, 4 died in 1995 and 7 in 1996. Crown dieback was >80% on 22 of 30 trees in 1995 and 14 of 19 living trees in 1996. The latter plot was marked for salvage in 1996 and removed from this study.

In 1995 two plots with 30 trees each, one in private ownership at Franklin Forks, Pennsylvania, in Susquehanna County and the other owned by the Rockport Gun Club in Wayne County, had only 1 dead tree among the 60; crown dieback of >80% was observed on 7 and 4 trees, respectively. In 1996 salvage at the Franklin Forks stand resulted in removal of 4 healthy trees and 12 trees in poor health; salvage at the Rockport Gun Club resulted in removal of 8 healthy trees, though some showed symptoms of crown dieback. These plots also were removed from the study in 1996.

Table 1 lists mortality data for the study to date. Total cumulative mortality due to natural causes for the 15 plots was 109 trees out of 546 sampled trees (19.9%). Salvage operations in 1996 and 1997 removed 98 of 546 trees (17.9%) of which 15 (2.7%) were healthy and 83 (15.2%) were in poor health. Natural mortality and salvage of trees with extensive dieback resulted in the removal of 35.1% (192/546) of the study population within three years of the forest tent caterpillar and anthracnose outbreak.

To illustrate the impact of insect defoliation and anthracnose on crown dieback, we used information developed through the North American Maple Project (NAMP) to categorize tree health among easily determined dieback classes (Anonymous 1997). Table 2 shows the tree distribution

among three crown dieback classes. Trees in the 0-15% dieback class represent those with the greatest probability of long-term survival, while those with >35% dieback have a lower probability of survival. From 1995 to 1997, the proportion of trees in the 0-15% dieback class increased, while those in the >35% dieback class decreased.

Table 3 illustrates crown dieback distribution for 1995-97 among the nine stands which remained under study after 1997. Tree mortality in these stands was low. In 1995, only 4 dead trees were observed among the remaining study population of 326 trees; 3 additional trees died in 1996 and 3 more in 1997. Cumulative mortality for 1995-97 was 3%, and incidence of trees with severe dieback (>80%) for the 1995-97 period was 4.9%. Over the three years of data collection, tree crowns had less dieback and appeared to be recovering. Since 1994 there has been little or no additional insect defoliation or anthracnose damage. However, a severe drought from late June through September 1995 may have contributed to tree mortality and crown damage expression in 1996.

Discussion

High mortality and extensive crown dieback were evident within ten months of the initial defoliation. Subsequent crown recovery in residual trees was apparent by 1996 and has since improved throughout the remaining 9 stands under study. Many factors may interact to account for apparently high mortality rates following defoliation (Houston 1981). These include site factors such as soils that are excessively or poorly drained, high stand density, prior defoliation (Houston 1981, Bause and Allen 1991), and defoliation followed by anthracnose outbreaks (Heichel et al. 1972). Unfortunately, these factors along with predefoliation crown condition could not be determined in this study. Adverse environmental factors such as drought or frost also may contribute to tree mortality following defoliation (Houston 1981). While defoliations occurred in May and June, previous research has shown that June defoliations were the most severe, resulting in the fastest and greatest amount of crown damage (Wargo 1981). In the current study, defoliation was followed by precipitation patterns that ensured moist conditions over an extended period, providing a favorable environment for anthracnose infestations (Heichel et al. 1972, Neely and Himelick 1963). During subsequent refoliation attempts, emergent leaves and subtending twigs were attacked by the anthracnose fungus which prevented any significant canopy refoliation until seasonal leaf drop in early November 1994. Therefore, affected trees with insufficient photosynthetic leaf area might not produce sufficient carbohydrate reserves to survive the winter and produce new foliage in the next growing season (Wargo 1981). Alternatively, trees with sufficient carbohydrate reserves that were not consumed during initial foliation and refoliation might survive, but would be expected to exhibit damage to residual crowns.

Other maple decline studies have noted mortality or increased crown dieback associated with secondary organisms such as the root and collar rotting fungus *Armillaria mellea* (Vahl:Fr.) P. Kumm. or the twig and branch fungus *Steganosporium ovatum* Corda. Both of these organisms may hasten the death or increase the amount of crown dieback of already stressed trees (Wargo 1981, Houston et al. 1990). There are no previous reports of the interaction between forest tent caterpillar and *Discula campestris* with the fungus acting to accelerate mortality. However, Heichel et al. (1972) describes a field experiment where red oak and red maple saplings were manually defoliated to simulate gypsy moth or elm spanworm defoliation; during the subsequent refoliation period, emergent leaves and twigs exhibited anthracnose symptoms followed by severe twig dieback in both species. The observations of Heichel et al. (1972) suggest that insect defoliation and anthracnose can occur simultaneously to cause severe damage to tree crowns and could be a contributing factor when assessing tree decline. Given the difficulty of examining and sampling the crowns of mature trees, the role of anthracnose diseases may have been previously overlooked or attributed to other factors, including insect defoliation.

While there are many reports of long-term sugar maple mortality, only a few studies have monitored mortality rates during decline events. In the Allegheny National Forest, 340 stands surveyed in 1994, approximately ten years after initiation of sugar maple decline, revealed 28% of the sugar maple basal area (trees >2.5 cm dbh) were dead (McWilliams et al. 1996). Precise mortality rates cannot be calculated because no pre-decline data was available from these plots. Averaged across seven states and four provinces, the six-year average annual mortality rate for sugar maple in all crown classes was 0.9% for 165 plots located in sugarbushes and nonsugarbushes monitored in the North American Maple Project (Allen et al. 1995). In New England, annual mortality rates (over ten years) for sugar maple in northern hardwood stands ranged from 0.14% to 2.75% or 0.0009 to 0.0204 m²yr⁻¹ of basal area (Solomon 1977). In our study, mortality was greatest (12.3%) the year following the defoliation and anthracnose infestations; average annual mortality was 6.6% from 1995 to 1997. By 1997, annual mortality was only 0.7%, suggesting that the 1995 and 1996 mortality was episodic and by 1997 rates had returned to those found by Allen et al. (1995) and Solomon (1977). Periodic occurrences of high levels of annual mortality will influence forest composition, age structure, and stand density with irregular patterns in time and space across the landscape. Long-term annual monitoring of tree health may help to understand the influence of specific stressor events on mortality patterns.

Literature Cited

- Allen, D. C., Barnett, C. J., Millers, I., and Lachance, D. 1992a. **Temporal change (1988-1990) in sugar maple health, and factors associated with crown condition.** Can. J. For. Res. 22: 1776-1784.
- Allen, D. C., Bauce, E., and Barnett, C. J. 1992b. **Sugar maple declines—causes, effects, and recommendations.** In: Forest decline concepts (P. D. Manion and D. Lachance, Eds.), pp. 123-136. APS Press, New York.
- Allen, D. C., Molloy, A. W., Cooke, R. R., Lachance, D., and Barnett, C. 1995. **North American Maple Project Seven Year Report.** USDA For. Serv., Northeastern Area State Priv. For. and Can. For. Serv. 57 p.
- Anonymous. 1997. **Sugar maple management highlights for the region.** Vermont Dep. For. Parks Rec., Waterbury, VT.
- Auclair, A. N. D., Eglinton, P. D., and Minnemeyer, S. L. 1997. **Principal forest dieback episodes in northern hardwoods: development of numeric indices of areal extent and severity.** Water, Air, Soil Poll. 93: 175-198.
- Bauce, E., and Allen, D. 1991. **Etiology of a sugar maple decline.** Can. J. For. Res. 21: 686-693.
- Giese, R. L., Houston, D. R., Benjamin, D. M., Kuntz, J. E., Kapler, J. E., and Skilling, D. D. 1964. **Studies of maple blight.** University of Wisconsin Res. Bull. 250.
- Gross, H. L. 1991. **Dieback and growth loss of sugar maple associated with defoliation by the forest tent caterpillar.** For. Chron. 67: 33-42.
- Hall, T. J. 1995. **Effect of forest tent caterpillar and *Discula campestris* on sugar maple in Pennsylvania.** Phytopath. 85: 1129 (Abstr.).
- Heichel, G. H., Turner, N. C., and Walton, G. S. 1972. **Anthracoze causes dieback of regrowth on defoliated oak and maple.** Plant Dis. Rep. 56(12): 1046-1047.
- Houston, D. R. 1981. **Mortality and factors affecting disease development.** In: The Gypsy Moth: Research Towards Integrated Pest Management (C. C. Doane and M. L. McManus, Eds.), pp. 281-293. U. S. For. Serv. Tech. Bull. 1584.
- Houston, D. R., Allen, D. C., and Lachance, D. 1990. **Sugarbush management: a guide to maintaining tree health.** USDA For. Serv. Gen. Tech. Rep. NE-129. 55 p.
- Kolb, T. E., and McCormick, L. H. 1993. **Etiology of sugar maple decline in four Pennsylvania stands.** Can. J. For. Res. 23: 2395-2402.
- McWilliams, W. H., White, R., Arner, S. L., Nowak, C. A., and Stout, S. L. 1996. **Characteristics of declining forest stands on the Allegheny National Forest.** USDA For. Serv., Northeastern For. Expt. Sta. Res. Note NE-360. 9 p.
- Neely, D., and Himelick, E. B. 1963. **Temperature and sycamore anthracnose severity.** Plant Dis. Rep. 47(3): 171-175.
- Payette, S., Fortin, M.-J., and Moreau, C. 1996. **The recent sugar maple decline in southern Quebec: probable causes deduced from tree rings.** Can. J. For. Res. 26: 1069-1078.
- Quimby, J. W. (Ed.). 1995. **Pennsylvania—1994 forest conditions report.** Pennsylvania Dep. Environ. Res., Bur. For. 46 p.
- Quimby, J. W. (Ed.). 1996. **Forest conditions in Pennsylvania—1995.** Pennsylvania Dep. Conserv. Nat. Resour., Bur. For. 19 p.
- Quimby, J. W. (Ed.). 1997. **1996 Pennsylvania damage appraisal.** Pennsylvania Dep. Conserv. Nat. Res., Bur. For. 5 p.
- Robitaille, G., Boutin, R., and Lachance, D. 1995. **Effects of soil freezing stress on sap flow and sugar content of mature sugar maples (*Acer saccharum*).** Can. J. For. Res. 25: 577-587.
- Solomon, D. S. 1977. **The influence of stand density on structure and growth of northern hardwoods in New England.** USDA For. Serv., Res. Pap. NE-362. 13 p.
- Wargo, P. M. 1981. **Defoliation and tree growth.** In: The Gypsy Moth: Research Towards Integrated Pest Management (C. C. Doane and M. L. McManus, Eds.), pp. 225-240. U. S. For. Serv. Tech. Bull. 1584.

