BEECH BARK DISEASE: THE OLDEST "NEW" THREAT TO AMERICAN BEECH IN THE UNITED STATES

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Background and History

Beech bark disease (BBD) has been killing American beech trees in eastern North America since the late 1890s (Ehrlich, 1934). The disease is initiated by feeding of the beech scale insect, *Cryptococcus fagisuga* (Fig. 1), which leads to the development of small fissures in the bark. Over time, as the population of scale insects builds on the bark, the small wounds provide entryway for fungal infection by one of the species of *Neonectria* (Fig. 1). As the fungus invades, it kills the inner bark tissue and, may completely girdle the tree, leading to death. Cankers may form as the tree attempts to stop the infection from spreading, resulting in wood defects (Fig. 2). Often trees are weakened to the point that they are susceptible to splitting during windy conditions (Papaik *et al*., 2005). Large numbers of severely deformed American beech persist in long-affected stands and their propensity for root-sprouting can result in the dense beech "thickets" that prevent other species from establishing, while offering little economic or ecological value. Consequently beech bark disease has the potential to alter the species composition of the forests it occupies (Twery & Patterson, 1984; Griffin *et al*., 2005).

Generally, three phases of beech bark disease have been recognized: 1) the "advancing front", which refers to stands where beech scale is present, but *Neonectria* infection has not occurred; 2) the "killing front" which represents areas where there are high levels of scale infestation and *Neonectria* infection is present (typically 3–5 years after scale appears, but can be 20 or more years) leading to heavy beech mortality; and 3) the "aftermath forest" which describes stands that have had heavy mortality in the past and still retain scale and *Neonectria* populations, but at a lower density (Shigo, 1972). Residual beech trees remain that are typically of smaller diameter, often of root-sprout origin, and mostly deformed and declining (Fig. 3).

Damage from this disease complex has been significant in areas throughout the eastern United States where American beech is an important component of mixed hardwood stands. As the disease moved through the New England states, typically 50 % of beech trees were killed and many more rendered highly defective from cankering (Miller-Weeks, 1983). The loss of beech can have a significant impact on wildlife as beech provides food and habitat for more than 40 species of birds and mammals. For example, studies have linked the success of black bear reproduction to good beechnut production years (Jakubus *et al*., 2005). In some northern hardwood forests where hickory and oak are rare, often beech is the only nut-producing species. In such areas, the loss of beech mast may have an even greater impact on wildlife.

The beech scale insect is believed to have been introduced from Europe on an ornamental European beech in the Halifax Public Gardens, Nova Scotia, Canada in the late 1890s (Erhlich, 1934). By the 1930s, beech bark disease was well established throughout Nova Scotia and had spread into the United States. In 1932, the disease was reported in Maine and by 1960 most of New England and part of New York were infected. The disease had invaded northeastern Pennsylvania by 1975 and slowly spread into New Jersey, Tennessee, and as far south as North Carolina. Outlying scale infestations were documented in West Virginia in 1981, Ohio in 1984 (Mielke *et al*., 1985), and Michigan in 2000 (O'Brien *et al*., 2001). The current status of the spread of beech scale and beech bark disease throughout the northeastern United States is illustrated in Figure 4.

The slow movement of this disease can be attributed to the brief phase in the insect's life cycle, immediately after hatching, when it has legs and is mobile. The newly hatched "crawlers" usually move to a different area on the same tree, but they also can be carried further by wind, birds, or animals. Most of the isolated scale outbreaks that have been reported were in scenic areas frequented by campers and tourists, suggesting that humans also play a role in moving the scale long distances. One way this may occur is through the movement of infested firewood between midsummer and early winter, when the mobile crawlers could easily infest new areas.

The recently documented infestations in Ohio and Michigan have renewed interest in the disease as previously unaffected forests are now experiencing high levels of mortality. In Ohio, the scale outbreak was first identified at the Holden Arboretum and low numbers of scale were reported in four additional surrounding counties (Mielke *et al*., 1985). However, the presence of *Neonectria* fungi was not confirmed until nineteen years later in 2003 (Mackenzie & Isra, 2005). In Michigan, the beech scale infestation and presence of two *Neonectria* species of fungi were documented simultaneously in 2000. By the time of this discovery, the scale infestation was already well established in seven counties in eastern and northern Michigan. The extent of the infestation and the presence of *Neonectria*, together with anectodotal evidence indicated that the scale insect had been in Michigan for at least ten years (Obrien *et al*., 2001). Beech bark disease, the "new" threat to the forests of Michigan and Ohio, was confirmed more than 100 years after it was first introduced into North America.

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Figure 1. The causal components of beech bark disease. Top. Beech scale insect covering the bark of a tree has a conspicuous white appearance due to a protective coating of the wax-like substance secreted by the insects. Bottom. Fruiting bodies of *Neonectria coccinea* that have developed in the bark fissures the result of feeding by the scale insect

Figure 2. Beech bark disease infested American beech tree. Vertical cracks in the bark resulting from insect feeding damage are apparent as are the red fruiting bodies of *Neonectria.* Attempts by the tree to wall off fungal infection by development of cankers also can be seen

Presumably beech bark disease will continue to spread throughout the natural range of American beech in the United States, which extends throughout the Appalachian Mountains and into the Mississippi River Valley. Current forest inventory data suggest that BBD has already invaded most of the area with relatively high densities of beech, but has yet to invade the bulk of the range of beech which including regions where beech occurs at lower densities (Morin *et al.*, 2007).

Pesticides are not Effective against BBD

Systemic insecticides such as imidacloprid (Merit®, Bayer CropScience), have demonstrated little success in controlling the beech scale insect (D. McCullough, personal communication). This may be because the insecticides are not transported to the tissues that the scale insect feeds on. Contact insecticides such as horticultural oils and insecticidal soap are not highly effective because the protective wax-like covering the adult insect secretes prevents direct contact with the oil. Minimal control using contact insecticide may be possible if applied during the few weeks that "crawlers" are out, since in some cases they emerge from underneath the protective wax covering. Such a treatment would have to be repeated at least annually. For high value landscape trees it is recommended that the scale insects be removed by physically scrubbing or using a high pressure wash. To remain effective, this approach also would need to be repeated on a yearly basis (McCullough *et al.*, 2001).

Figure 3. Highly defective, heavily cankered American beech tree typically seen in aftermath forests

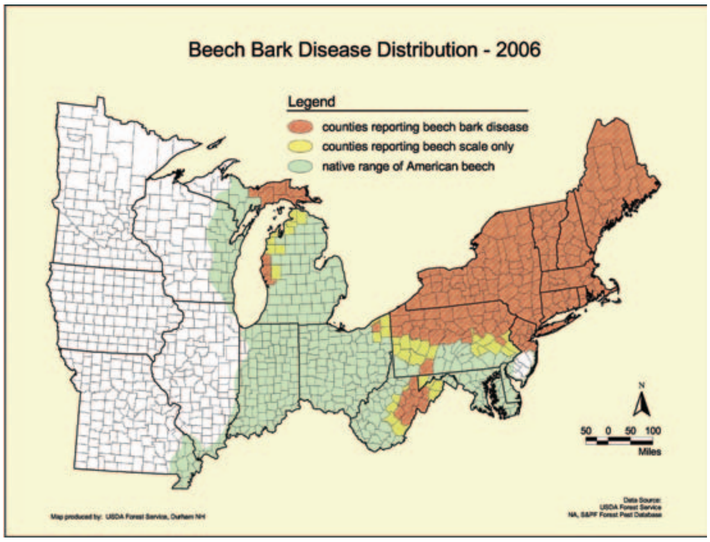

Figure 4. Distribution of beech bark disease in the United States. (Courtesy of Ann Steketee, US Forest Service cartographer)

Stand Management for Beech Bark Disease

Fortunately, there are beech trees that remain disease-free even in heavily infected areas. Testing has shown that this resistance is to the insect portion of the disease complex (Houston, 1983). Current management approaches are based on the objective of increasing the proportion of disease resistant beech by removing susceptible trees and retaining the disease-free trees, estimated to be between 1 and 5% of the total number of American beech. Recommendations for silvicultural management of beech bark disease have included guidelines such as reducing the amount of overstory beech (focusing on the removal of diseased or poor vigor beech trees with cankered or fissured bark) using a harvesting system that minimizes root injury which leads to root sprouting. At the same time, beech trees that appear to be disease-free with good healthy crowns and smooth, tight bark are retained. Other recommendations include the use of herbicides to control BBD susceptible beech regeneration following harvest or thinning operations and favoring the regeneration of other tree species (Heyd, 2005).

Research has provided evidence that silvicultural treatments can improve stand quality while maintaining a healthy beech component. Fifty years of single tree selection (removal of diseased beech) in the Bartlett Experimental Forest, New Hampshire, resulted in a basal area per acre of healthy, uninfested beech trees of 15%. In similarly aged, unmanaged stands the basal area per acre of healthy beech was 3.5% and in young, unmanaged stands the basal area per acre was only 1%. However, the success of this approach may be dependent on the density of resistant beech within the stand (Leak, 2006).

Recent genetic studies provided support for the success of such silvicultural treatments. In these studies, families of beech seedlings were tested for resistance to the scale insect by artificially applying insect eggs to their stems (Koch & Carey, 2005) (Fig. 5). A known number of scale eggs were placed on foam pads, and the pads were affixed to the bark of the seedlings (Fig. 6). A year later, the pads were removed and the number of established healthy egg-laying adult scale insects was counted (Fig. 6). Highly resistant trees had no successfully established adults or only a few adults, but without any signs of reproduction (eggs and crawlers). The families that were tested came from seed collected from the following: an open-pollinated resistant parent; an open-pollinated susceptible parent; a susceptible parent cross-pollinated with a resistant

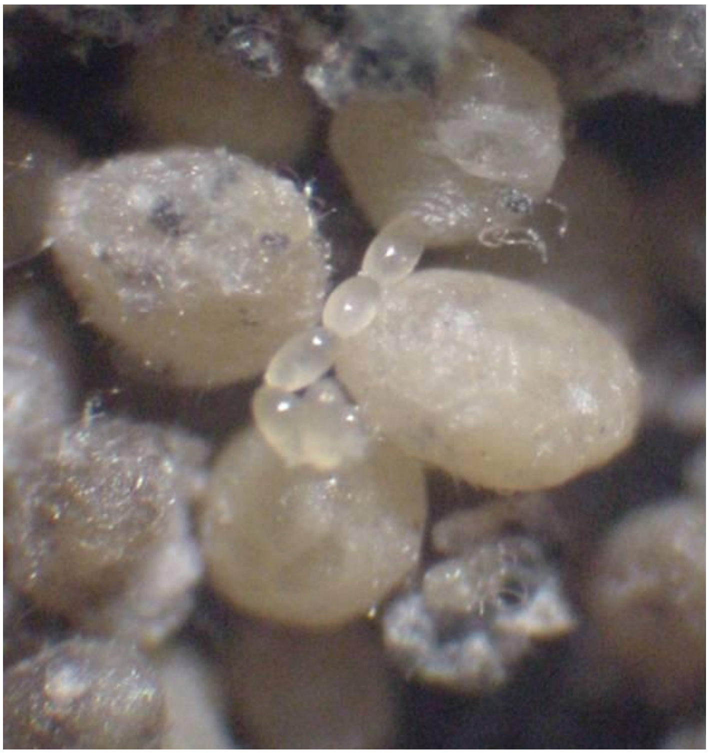

Figure 5. Adult scale insects in the process of laying their eggs

Figure 6. Screening for beech scale resistance: artificial infestation technique. **Left.** Scale eggs place on foam and affixed to bark of one-year-old seedling. **Right.** One year later the foam pad is removed to reveal a heavy scale population that has developed on this susceptible seedling

parent; and from pairs of resistant parents cross-pollinated with other resistant parents (Table 1). One family that was tested came from a resistant tree, ME(R), located in a stand in Sebois County, Maine that had been managed for beech bark disease through the removal of all diseased American beech trees in 1991 (Houston 2001; Farrar & Ostrofsky 2006). The only possible paternal parents (i.e., pollen donors) were the remaining resistant trees, so this family can be considered as having two resistant parents. The families that had the highest proportion of resistant seedlings were those with two resistant parents, including the open-pollinated family from the resistant tree in Sebois County, Maine, providing evidence that management directed at the removal of diseased trees can lead to stand improvement. Comparisons between the different families in this study demonstrated that resistance to the beech scale insect is a trait that is controlled genetically (versus environmentally) and genetic improvement of stands can be realized either through traditional tree improvement programs (seedling development and planting) or through silvicultural methods designed to manipulate stand genetic composition by that favoring resistant trees, or a combination of both (Koch *et al*., in press).

Table 1. Comparison of the proportion of resistant progeny obtained from open-pollinated (OP) and controlled cross-pollinated families. An enriched proportion of resistant progeny was observed only when breeding two resistant parents (R) and not when one of the parents is susceptible (S)

Maternal Parent	Pollen Parent	Percent Resistant Progeny
1510(S)	OP	0
1506(S)	OP	1
1504(R)	OP	0
1506(S)	1504(R)	6
ME(R)	OP	52
1505(R)	1504(R)	26
1211(R)	1228(R)	52
1228(R)	1211(R)	58

Researchers at the Northern Research Station of the U.S. Forest Service have recently developed methods to graft mature American beech trees efficiently (Koch *et al*., 2007). Beech bark disease-resistant American beech are currently being identified, grafted, and propagated as part of a cooperative effort among several of the National Forests including the Allegheny (PA), the Hiawatha (MI), the Chequamegon-Nicolet (WI) and the Monongahela (WV) as well as the Michigan Department of Natural Resources, the Michigan Tree Improvement Cooperative, the Pennsylvania Department of Conservation and Natural Resources, and the Holden Arboretum (Kirtland, OH). The long-term goal is to use resistant trees to establish seed orchards that will supply an enriched source of regionally adapted disease-resistant beechnuts for use in restoration plantings. By utilizing the knowledge gained about the genetics of resistance to beech bark disease, this old "new" threat may be manageable, allowing healthy American beech to remain a valuable component of North American forests.

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