SPATIAL AND TEMPORAL DEVELOPMENT OF BEECH BARK DISEASE IN THE NORTHEASTERN UNITED STATES

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Abstract

For most of a century, beech bark disease has been spreading south and west from its point of introduction in Nova Scotia. The objective of this paper is to illustrate the impact of disease progression on beech trees across the northeastern United States. Beech trees were observed at each of 22 plots during summer months between 1979 and 1992. The plots were located throughout 7 States in the northeastern U.S. They are drawn from regions where BBD has been present for varying lengths of time, including some that have been affected for 50 years or more, and some that were first affected during the study. In general, plots were visited annually. Some areas were characterized by sharp increases in mortality shortly after the initial invasion of the disease and a subsequent lower constant mortality (consistent with a typical killing front and aftermath zone). In other cases, the killing front mortality was delayed or extended for decades. A small number of trees never became infested with scale, indicating probable strong resistance. Moreover, as many as 20% showed only slight scale activity, indicating probable partial resistance. Immediately following initial *Nectria* infection, trees that died quickly showed higher levels of fruiting than those that survived at least 5 years.

Introduction

Beech bark disease (BBD), caused by the combined effects of the beech scale insect *Cryptococcus fagisuga* Lind. and bark-killing fungi in the genus *Nectria* (native *N. galligena* Bres., and introduced *N. coccinea* var. *faginata* Lohman and Watson), has continued to spread west and south from its point of introduction at Halifax, Nova Scotia, sometime before 1890. The spatial-temporal stages of the disease have been characterized as 1) the advancing front (where the scale insect occurs and whose populations are building), 2) the killing front (where high populations of both the scale and fungi occur and large numbers of big beech are being killed), and 3) the aftermath zone (where the killing front occurred sometime in the past, and where beech stands, previously dominated by large old trees, now support many young or small beech trees that with time become increasingly cankered and defective)(Shigo 1972).

As the disease agents spread west and south, they have encountered a mosaic of forests differing in composition and structure, use history, and climate regimes, all of which have the potential to either limit or enhance their populations and/or their disease-causing interactions (Houston et al. 1979). This paper describes the temporal patterns of development of beech scale and *Nectria* spp populations and the consequent mortality patterns on beech trees in forests of Northeastern United States affected for varying lengths of time.

Materials and Methods

Trees and Plots

Fifty to 266 beech trees were observed at each of 22 plots during summer months between 1979 and 1992 although not every plot was measured in every year. Plots, located in seven Northeastern States (Fig. 1), were selected to represent examples of beech-rich forests in different temporal stages of disease development—some had been affected for over 50 years, some were first affected during the study. Some plots were in locations where BBD monitoring plots (NY), or Continuous Forest Monitoring plots (MA) had been established earlier by State personnel. An attempt was made to include at least 200 trees > 4.0 dbh in each plot but this was not always possible. Plots, determined by distribution of trees, varied in size and shape.

Measurements

Annual measurements were taken of tree diameter at 4.5 ft (DBH), crown class (Avery and Burkhart 2002), and of the population levels of the disease agents.

Population levels of *C .fagisuga* and *Nectria* spp on the lower 2 meters were estimated annually. *C. fagisuga* populations were estimated on the basis of the amount of bole covered by wax and scored as: 0 (no colonies visible); 1 (trace = from one colony to very light scattered colonies, one or two larger colonies sometimes present); 2 (light = light to moderate scattered colonies, possible as few larger colonies); 3 (moderate = many colonies

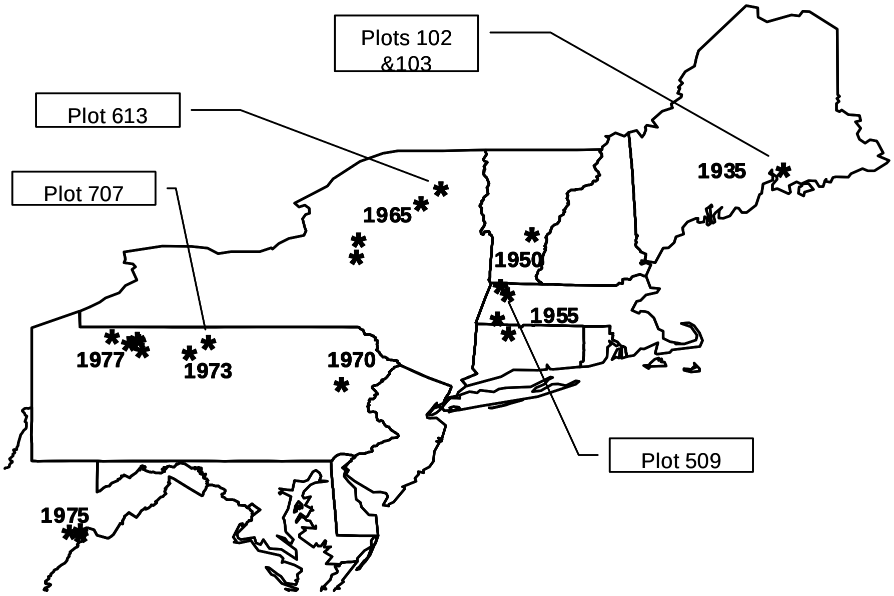
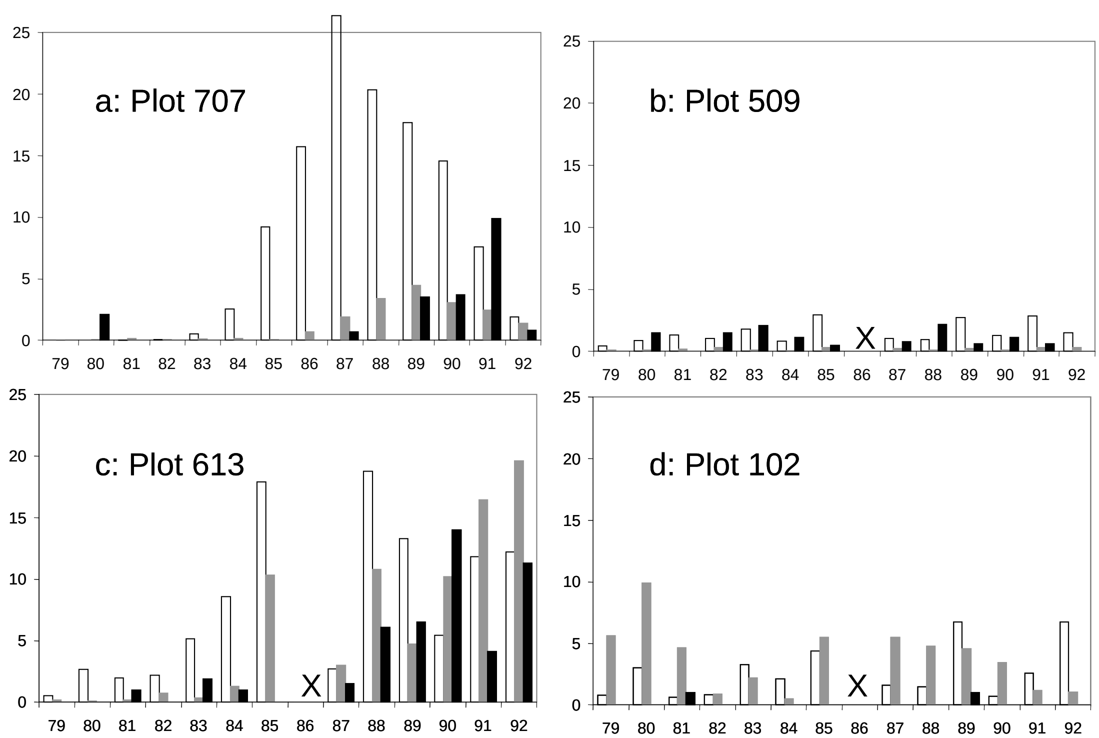


Figure 1.–Plot locations and approximate years of arrival of BBD. Plots referred to in Fig. 2 (below) are labeled.



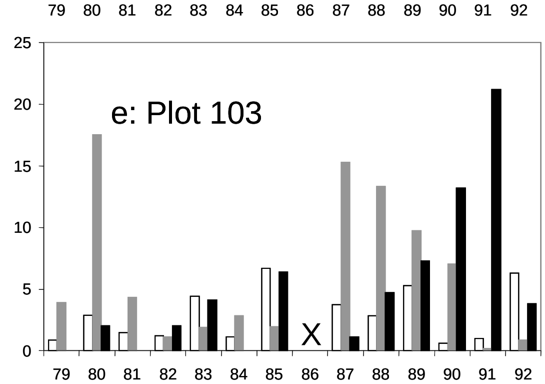


Figure 2.–Scale index (x 0.5: white bars), infection index (x 2: gray bars), and annual mortality (%: black bars) by year for selected plots discussed in the text. Years when plots were not measured are marked with “X”.

present, substantial number of larger colonies sometimes present); 4 (heavy = many large colonies present, some coalescing), or 5 (very heavy = much of the bark conspicuously white with wax).

Nectria populations were scored based on the presence of clearly visible red or brownish perithecia as: 0 (absent); 1 (sparse = a few localized perithecia or perithecia in a few scattered circular infections); 2 (light = scattered moderate fruiting; 3 (moderate = many isolated circular infections with abundant perithecia); and 4 (heavy = large areas of bark with heavy fruiting—parts of the tree's bark conspicuously red or brownish). The recent infection by *Nectria* was also assessed indirectly by the presence of tarry spots, i.e., recently-formed dark, weeping bark exudates reflecting localized invasion and killing of bark. The number of tarry spots was scored as: 0; 1 (1-5); 2 (6-10); or 3 (> 10).

Data Summarization and Analysis

Data for each plot were summarized to provide yearly estimates of tree condition and mortality. Weighted mean scale infestation and *Nectria* infection indices were calculated where wax scores of 1 to 5 were cubed and equated to 1, 6, 27, 48, and 125 respectively, and where *Nectria* scores were similarly cubed and added to the tarry spot scores (score numbers cubed).

To demonstrate the possible patterns of scale infestation, *Nectria* infection, and beech mortality, indices were developed to describe the annual average wax and infection levels and the annual percent mortality for all locations.

To evaluate the frequency of different levels of wax occurring on surviving trees, a maximum wax index was calculated for each tree. The maximum index is equal to the largest wax index value assigned to the tree during any year in which it was measured. Maximum wax indices for all trees which survived the study were plotted by diameter class.

Lastly, in order to predict the eventual fate of trees which become infected by *Nectria*, trees were selected from the dataset which showed no signs of *Nectria* during the first year measured and developed *Nectria* during the study. This subset of trees was divided into two groups: trees which survived the study and those that did not. For survivors, only observations at least 5 years before the last observation were used in order to eliminate trees "in the process of dying". The cumulative *Nectria* infection indices of selected trees were calculated starting from year of first infection (i.e., cumulative infection index for the second year since infection = infection index from the first year + infection index from the second year, etc.).

Results and Discussion

The temporal records at each location illustrate potential patterns of the spread and development of BBD (Fig. 2). At many locations, spread patterns follow the generally accepted concepts of an advancing front, killing front and aftermath zone. Plot 707 in Pennsylvania (Fig. 2a) is an example of the typical disease progression as the advancing and killing front move quickly through an area. Beech scale arrived in the general area during the 1970's but was not common at the sampling location until the 1980's. Scale populations built up quickly from the early 1980's and peaked in 1987. By 1989, high levels of *Nectria* fruiting were observed and, by 1991 beech mo mortality was high. Plot 509 in Connecticut (Fig.2b) is more representative of an aftermath forest. Beech bark disease had been present in this area for approximately 25 years before the present study began. Low levels of beech scale, *Nectria* fruiting, and beech mortality occurred throughout the study.

In other locations, disease progression is less typical. For example, BBD had been present for almost 20 years at Plot 613 in New York (Fig. 2c), before our study began. Nevertheless, there had never been a severe outbreak of the disease typical of the killing front. Approximately 5 years into our study, scale populations finally began to increase. This scale outbreak was soon followed by increases in *Nectria* fruiting and beech mortality.

Our results also indicate that site conditions can influence the impact of BBD dramatically. Figs. 2d and 2e show the patterns of scale accumulation, *Nectria* fruiting, and beech mortality for Plots 102 and 103 in Maine. These two locations are approximately 2 miles apart, yet Plot 103 experienced greater levels of scale and *Nectria* accumulation and dramatically more mortality than Plot 102.

Resistance to beech scale is an important element in the BBD dynamics; trees completely free of infestation occur

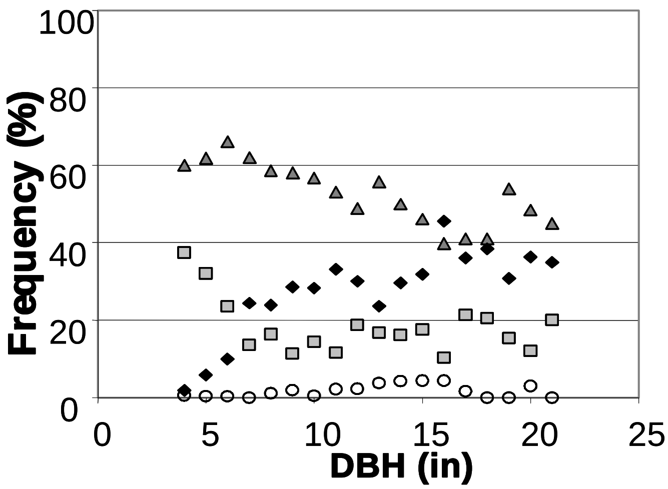


Figure 3.–Frequency of different levels of maximum wax index on trees that survived: 1 = circles; 2 = squares; 3 = triangles; 4 or 5 = diamonds.

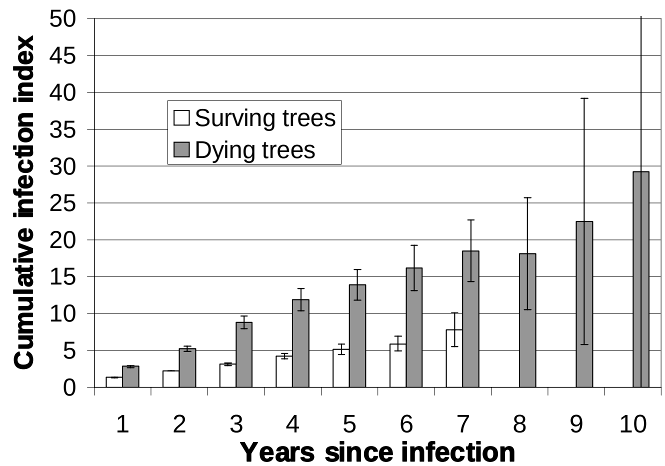


Figure 4.–Cumulative infection index (*Nectria* fruiting + tarry spots) on trees that survived (white bars) or died (gray bars) during the study. Error bars show ±1 standard error.

in low numbers (Houston 1983, Houston and Houston 1987). In our study, a small percentage of trees (< 5%) never became infested despite the fact that scale was present at all locations. Similarly, approximately 20% of trees > 5 in dbh, from all locations combined, experienced trace levels of scale infestation at some time during the study, but the infestation never progressed to moderate or high levels (Fig. 3). Severe levels of infestation (scale indices of 4 or 5) were more common on large trees than small trees (Fig. 3).

For trees that were infected with *Nectria* during the study (i.e., trees that had an infection index of 0 during their first measurement year but subsequently showed signs of active fruiting) the average cumulative infection index increased at a relatively constant rate every year post infection. The rate of increase was significantly higher for trees that eventually died during the study than for those that survived (Fig. 4). These results suggest that it may be possible to develop a method of predicting the eventual fate of infected trees using an index similar to the cumulative infection index used in this study.

Summary and Conclusions

At many locations, the spread pattern described as an advancing front, killing front, and aftermath zone was clearly observable. However at some locations the pattern was altered or delayed, possibly due to site or climate conditions. The apparent complete resistance to beech scale of a low percentage of trees is consistent with the results of earlier studies with American beech elsewhere. However, of special interest is the finding that for a significant proportion of the trees (ca. 20%) in all size classes, scale infestation levels remained very low throughout the study. Such trees may possess a partial resistance to the insect, perhaps similar to that noted for European beech. During the first 7 years after infection the spread of *Nectria* on trees which die was significantly faster then on trees which survive.

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Contains invited papers, short contributions, abstracts, and working group summaries from the Beech Bark Disease Symposium in Saranac Lake, NY, June 16-18, 2004.

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