

A PRELIMINARY EXAMINATION OF BEECH BARK DISEASE AND THE INFLUENCE OF SOIL MOISTURE ON BARK THICKNESS AND DISEASE STATUS IN THE NORTHERN ADIRONDACK UPLANDS

Karla Van Leaven and Celia A. Evans¹

Paul Smith's College, Paul Smiths, NY

¹Corresponding author

Abstract

In a preliminary study of beech bark disease in the 'aftermath' forests of northern Adirondack watersheds, we collected data on disease status in relation to tree diameter and the relationship between soil moisture and bark thickness in 11 plots across 6 northern Adirondack watersheds. Sixty-two percent of trees sampled were ≤ 13 cm in diameter and no trees over 29.4 cm were recorded, even though at least two watersheds sampled are considered old growth. As predicted, larger trees were more diseased than smaller trees and the percent dead also increased dramatically with size class. We noted that some number of trees ≤ 10 cm had unexpectedly high disease ratings suggesting the need in future studies to collect data on smaller diameter trees so as to be able to predict how the disease will impact the large number of trees coming up in these size classes. Trees grown in plots that had medium soil moisture (as opposed to low) had significantly thicker bark, regardless of diameter, but this had no effect on disease status of trees.

Introduction

Beech Bark Disease (BBD) has been, and is currently, a major cause of *Fagus grandifolia* (American beech) mortality throughout the northeastern United States and Canada (Houston, 1979a). The disease is caused by the beech scale insect (*Cryptococcus fagisuga*) in combination with one or more fungi in the genus *Nectria* (Ehrlich, 1934). The scale insect possesses a 2 mm long stylet which it inserts into the bark of beech trees in order to feed intracellularly within the bark parenchyma. The damage to the bark from the feeding of the insect allows for the invasion of the bark killing fungus (Houston and O'Brien, 1998; Wainhouse and Gate, 1988). Although some resistant trees exist, the disease cycle typically culminates with the disfigurement and eventual death of the tree. In order to predict the future structure of northeastern forests we need a better understanding of how the infection proceeds in aftermath forests, and how

abiotic conditions (such as soil moisture) influence the status of the disease.

The growth/differentiation balance hypothesis (GDBH) states that when water is not readily available the fixation of carbon through photosynthesis and secondary metabolite production are both reduced. However, when water is not limiting, most of the fixed carbon is allocated to growth (Herms and Mattson, 1992). Yet, when water is available in moderation, photosynthesis is in excess of growth, and excess of carbon can be used in changes which lead to cell specialization or differentiation (Herms and Mattson, 1992) and secondary metabolite production (Ayers 1993; Lombardero, Ayers, Lorio, and Ruel 2000; Lorio 1985). One such secondary process may be the thickness of bark (Figure 1). The goal of this study was to gain a preliminary understanding of BBD and its current status in northern Adirondack uplands in a variety of watersheds, all long into the aftermath stage of the disease (Mize and Lea, 1979). The specific objectives of this study were to find out: 1) what size trees were infected with BBD and the extent to which they were infected, 2) if bark thickness was directly related to moisture availability (GDBH), and 3) if increased bark thickness increased trees defense toward BBD, therefore resulting in less evidence of the disease.

We hypothesized, based on GDBH that where water was not limiting growth (medium soil moisture availability), trees would have thicker bark which may increase their defense against BBD.

Bark Thickness vs. Water Availability

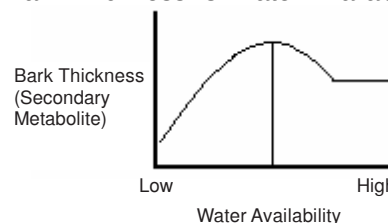


Figure 1.—Graph showing data that would support prediction of the growth/differentiation hypothesis. At periods of moderate water availability, there is an increase in bark thickness (a function of secondary metabolism).

Table 1.—Summary data for preliminary examination of *Fagus grandifolia* size structure and disease status in 6 northern Adirondack watersheds in 2003. Data are average values and standard deviations.

All trees				Live trees			
DBH range (cm)	n	% trees	% dead	Avg. scale index	Avg. fungal index	Avg. historical index	Avg. overall disease index
5 - 6.9	42	31	7	1.14±.64	0.29±1.08	0.10±0.37	1.52±1.73
7.0 - 13.0	42	31	9	1.88±1.31	1.14±2.07	0.52±0.92	3.55±3.33
13.1 - 19.8	28	20	20	2.39±1.50	2.61±2.47	1.43±1.55	6.43±4.10
20 - 39.1	24	17	33	2.54±1.28	3.95± 2.07	2.33±1.50	8.83±3.85

Methods

In the summer of 2003, data were collected in six northern Adirondack watersheds. Three of the watersheds were designated forest preserve (West North Ampersand, Dutton Brook, and Roaring Brook) and three were designated managed forest (Loon Lake North, East Branch of Cold Brook, and North Stephenson Brook) by the Adirondack Park Agency.

In each watershed, two 10 m radius plots were established. Data for a total of 11 plots were analyzed due to the loss of data from one plot in North Stephenson Brook. All of the plots had a minimum of six *Fagus grandifolia* trees. Percent slope, aspect (degree), and elevation (m) were recorded for each plot. The DBH of all living and dead trees ≤ 5.0 cm were measured and recorded. The condition of each living tree was recorded. Indices were used to assess the condition of the lower 2 m of the bole of each tree: Scale Index, Fungal Index (D. R. Houston, personal communication), and Historical Evidence of BBD Index. The indices developed by Houston provided a standardized estimate of the presence of scale and fungal fruiting bodies. The Historical Evidence of BBD Index was a composite of two new indices developed for this study: Fissure Index and Canker Index. Since fissures on beech bark can be induced by heavy scale infestation, and cankers are an indication of previous *Nectria* presence, these indices were used to estimate past evidence of BBD even if scale or *Nectria* fruiting bodies were absent at the time of sampling. The sum of the scale, fungal and historical indices was considered an overall rating of the influence of disease (Overall Disease Index).

Bark samples were taken from the least infected area of the bottom 2 meters of each tree, typically close to DBH

if possible, by pounding a circular leather punch into the bark with a rubber mallet until it hit the vascular cambium. The thickness of the plugs was measured to the nearest mm and as a comparison, plugs were oven dried and weighed. As expected, there was a strong positive relationship between the two variables ($r^2 = 0.80$).

We measured soil moisture in each tree plot gravimetrically. A volume of soil (approximately 1000 cm³) was collected on August 16th and 17th from three locations within each tree plot (5m out from the center of the plot at 100, 200 and 300 degrees). There was no precipitation on either of the two sampling dates. In the lab, 15 g of the well-mixed soil was used to determine % water weight. The three replicates were averaged. Regression analyses were used to examine relationships between disease indices, between DBH and disease indices, and between bark thickness and disease indices. Regression lines for the relationship between DBH and bark thickness for trees growing in low, medium, and high soil moisture regimes (as determined by our one time sampling) per plot were compared to determine if slopes were significantly different. A total of 136 live beech trees were sampled.

Results

Disease Status

More than half (62%) of trees we sampled were ≤ 13.0 cm DBH. Only 17% of trees were 20 cm or larger. The largest living tree has a diameter of 29.4 cm. The percent of dead trees sampled was substantially greater in trees with a diameter >13 cm than in smaller trees. Thirty-three percent of beech trees with a diameter between 20 and 39.1 cm were dead (Table 1). This represents a > 4 fold increase in dead trees in the largest size class over the

smallest. All indices used to estimate disease status of the trees showed an increase from the smallest diameter class to the largest (Table 1), however, the strongest positive correlation was between tree diameter and the overall disease index ($r = 0.6558$, $P = < 0.001$) rather than any single measure (Figure 2).

Bark Thickness, Soil Moisture, and Disease Index

Bark thickness ranged from 1 mm to 4.4 mm with a mean of 2.11 mm. Larger trees had thicker bark ($r = 0.8482$, $P = < 0.001$). Figure 3 shows the relationship between DBH and bark thickness for trees grown in low, medium and high soil moisture plots. Because of its strong correlation to DBH, bark thickness was also positively correlated to the total index ($r = 0.5980$, $P = < 0.001$).

The minimum average percent soil moisture in plots we sampled was 23.22, the maximum was 89.9. Plots were divided into those that had low, medium, and high average percent gravimetric soil moisture, in order to determine if soil moisture influenced bark thickness as predicted by the GDBH. Four plots had average soil moisture ranging from 23.2 to 33.7% (low), 6 plots had average soil moistures ranging from 51.1 to 58.6% (medium), and only one plot had an average soil moisture of 89.9% (high). Due to the small number of trees represented in the high moisture plot those data were not included in the analyses. A statistical comparison of slopes (Zar, 1984) showed that beech trees grown in medium moisture had significantly thicker bark at a given DBH than those grown in low moisture ($P = 0.011$, Figure 3). There was, however, no difference in the relationship between bark thickness and disease severity at any moisture regime (Figure 4).

Discussion

Griffin et al (2003) reported that 53% of beech stems they sampled in the Catskill Mountains of NY were between 10 and 20 cm in diameter. Similarly, we found that 51% of beech stems were in the 7 to 20 cm diameter class in our Adirondack watersheds. In contrast to Griffin et al. (2003) who reported 19% of their trees had diameters > 30 cm, we sampled no live trees larger than 29.4 cm, even though two of the watersheds are known to be old growth (Ampersand and

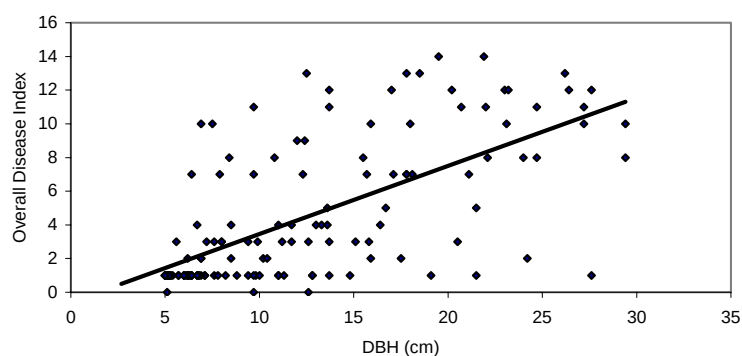


Figure 2.—Correlation between the Overall Disease Index (a composite index) and diameter for *Fagus grandifolia* in 11, 10 m radius plots in 6 northern Adirondack watersheds during the 2003 growing season ($n = 136$ trees)

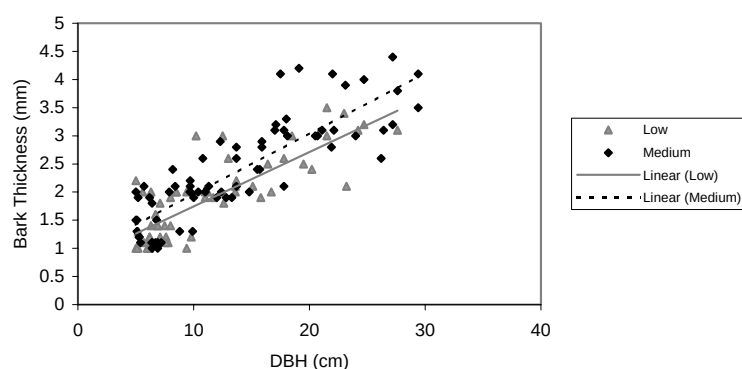


Figure 3.—Diameter vs Bark thickness for beech trees grown in low and medium soil moisture. Trees growing in medium soil moisture plots had thicker bark than those growing in plots in low soil moisture plots.

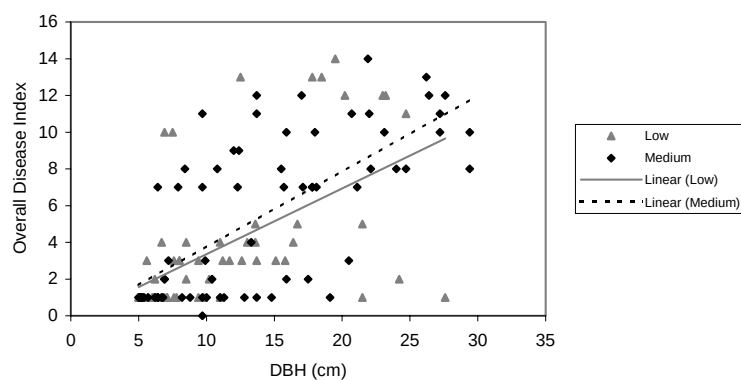


Figure 4.—Diameter vs. Total Disease Index at low and medium average percent soil moisture per plot. Regression lines were not significantly different for trees growing in low versus medium soil moisture.

Dutton Brook). Forrester and Runkle (2000) sampled beech in an old growth beech/maple forest in 1985 (minimally impacted by the disease) and reported that

stems were equally distributed between 10 - 24 cm, 25 - 49 cm, and 50+ cm. It is likely that our small sample size (n=136 trees) precluded us from sampling some larger trees, however, it is reasonable to conclude that the complete absence of large beech, even in plots in old growth forests, is in large part due to mortality of those trees. Based on visual observations of evidence of disease, mortality of all standing dead beech we did measure was apparently due to BBD. An evaluation of coarse woody debris in these forests would provide valuable information, at least with respect to recent history of beech mortality.

Disease severity increased as diameter increased. This trend is corroborated by many other studies that suggest that larger trees are more susceptible to BBD than smaller ones (Gavin and Peart, 1993; Griffin et al., 2003; Forrester et al. 2003). We sampled trees as small as 5 cm in diameter because we were interested in whether smaller trees, in the absence of large trees, may be becoming proportionately more infected by the scale and associated fungi. While there are few published data to compare the disease status of trees smaller than 10 cm diameter, it is worth noting that trees within the 7 - 13 cm diameter class had an overall disease rating of 3.55 ± 3.33 (SD) and seven trees within that size class had much higher overall disease ratings of between 7 and 11. As we develop models to predict the future structure and composition of beech in aftermath forests, it is critical to make reasonable assumptions about the way the disease will affect the growth and reproduction of the 'new' beech understory that often results from the death of large beech.

The fact that large trees had thicker bark as well as higher disease incidence and mortality makes clear that thick bark affords no major protection from disease agents. This is not necessarily surprising since characteristics of bark on older trees such as cracks, fissures, and general roughness are thought by field experts to be at least partially responsible for the increased susceptibility of larger trees to scales and fungi (D. R. Houston, Pers. comm.). We had hypothesized, based on the GDBH, that medium soil moisture would increase bark thickness (at any diameter) and that this difference may afford some protection from BBD. Soil moisture did significantly increase bark thickness, supporting the GDBH. This increase, however, had no influence on the relationship between diameter and disease status.

Acknowledgments

This work was supported by the National Science Foundation under Grant No. DEB 022165. The authors would like to thank the entire Adirondack Watershed RUI research team for their help with field data collection. We would specifically like to acknowledge the contributions of Corey Laxson and Dr. Tom Woodcock for logistical help and manuscript suggestions. The authors would also like to thank Dr. David Houston for his guidance and input to the project.

Literature Cited

- Ayres, M.P. (1993). **Global change, plant defense, and herbivory**. Sunderland, MA: Sinauer Associates, pp. 75-94.
- Ehrlich, J. (1934). **The beech bark disease. A *Nectria* disease of *Fagus*, following *Cryptococcus fagi* (Baer.)**. Can. J. Res. 10: 593-692.
- Forrester, J.A., G.G. McGee, and M.J. Mitchell. (2003). **Effects of beech bark disease on aboveground biomass and species composition in a mature northern hardwood forest 1985 to 2000**. Journal of the Torrey Botanical Society 130: 70-78.
- Forrester, J.A., and J.R. Runkle. (2000). **Mortality and replacement patterns of an old-growth *Acer-Fagus* woods in the Holden Arboretum, Northeastern Ohio**. The American Midland Naturalist 144: 227-242.
- Gavin, D.G., and D.R. Peart. (1993). **Effects of beech bark disease on the growth of American Beech (*Fagus grandifolia*)**. Canadian Journal of Forest Research, 23: 1566-1575.
- Griffin, J.M., G.M. Lovett, M.A. Arthur, and K.C. Weathers. (2003). **The distribution and severity of beech bark disease in the Catskill Mountains, NY**. Can. J. For. Res. 33: 1754 -1760.
- Hermes, D.A., and W.J. Mattson. (1992). **The Dilemma of Plants: To Grow or Defend**. *The Quarterly Review of Biology*, 67 (3): 283.
- Houston, D.R., and J.T. O'Brien. (1998). **Forest Insect & Disease Leaflet 75: Beech Bark Disease**. FIDL.

Retrieved February 26, 2003, from <http://www.na.fs.fed.us/spfo/pubs/fidls/beechnbark/fidl-beech.htm>.

- Houston, D.R., E.J. Parker, and D. Lonsdale. (1979a). **Beech bark disease: Patterns of spread and development of the initiating agent *Cryptococcus fagisuga***. Can. J. For. Res. 9: 336-344
- Jones, R.H., and D.J. Raynal. (1987). **Root sprouting in American beech: production, survival, and the effect of parent tree vigor**. Can. J. For. Res. 17: 539-544.
- Lombardero, M.J., M.P. Ayres, P.L. Lorio, and J.J. Ruel, (2000). **Environmental effects on constitutive and inducible resin defenses of *Pinus taeda***. *Ecology Letters*, 3, 329.
- Lorio, P.L. (1985). **Growth-differentiation balance: a basis for understanding southern pine beetle-tree interactions**. *Forest Ecology and Management*, 14: 259.
- Mize, C.W., and R.V. Lea. (1979). **The effect of the beech bark disease on the growth and survival of beech in northern hardwoods**. Eur. J. For. Pathol. 9: 242-248.
- Runkle, J.R. (1990). **Eight years of change in an old *Tsuga canadensis* wood affected by beech bark disease**. Bull. Torr. Bot. Club. 117 (4): 409-419.
- Wainhouse, D. and I.M. Gate. (1988). **The Beech Scale. in Dynamics of forest insect populations**. A.A. Berryman, ed. Plenum Press, pp. 67-85.

Evans, Celia A., Lucas, Jennifer A. and Twery, Mark J. 2005. **Beech Bark Disease: Proceedings of the Beech Bark Disease Symposium.** Gen. Tech. Rep. NE-331. Newtown Square PA, US. Department of Agriculture Forest Service, Northern Research Station. 149 p.

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

Key Words: Beech Bark Disease, forest structure, wildlife, silviculture and management, genetics, Northeastern forests, research agenda, *Cryptococcus fagisuga*, *Nectria coccinea* var. *faginata*, *Fagus grandifolia*

