Beech Bark Disease Tolerance: An Emerging Concept in American Beech Management

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INTRODUCTION

Beech bark disease (BBD) affects the health and quality of American beech (*Fagus grandifolia*). This disease complex, which spread from Nova Scotia in the late 1800s to the Great Lakes region by the early 2000s, is caused by the nonnative beech scale insect *Cryptococcus fagisuga* and *Neonectria* fungi. The scale insect feeds on living bark, altering the tissue, and allowing the fungus to enter, establish, and spread. This kills the cambium, resulting in cankers and ultimately causing mortality of many trees.

The spread of BBD is classified into three stages or zones (Shigo 1972). In the advance front, the scale insect arrives and proliferates. In the killing front, high levels of the scale insect and fungus result in high levels of beech mortality, especially of larger trees. In the aftermath zone, endemic populations of the causal complex result in stands of mostly small, defective beech with some larger trees. In these areas, forest management recommendations often advise removing all beech except the very small percentage (<1 percent) with smooth bark due to resistance to scale infestation. Yet this has the potential to reduce ecological contributions of beech such as wildlife habitat provision (Cale and McNulty 2018).

An emerging concept relevant to beech management—tolerance to BBD— suggests that some trees infested by the scale insect (and therefore not resistant) may have the ability to wall off bark tissue infected by the fungi before they reach the cambium. Increases in the underlying periderm layers result in raised bark lesions (delimited cankers) that may indicate BBD tolerance (Ostrofsky and Blanchard 1983). These raised lesions differ in appearance from sunken cankers that form where fungal infection killed the cambium. The objective of this study was to evaluate beech in the aftermath zone to determine whether raised bark lesions are associated with other measures of BBD tolerance such as relatively better crown condition and growth. We hypothesized that trees with more raised bark lesions are more tolerant of BBD and thus exhibit less crown dieback and more growth.

METHODS

This research was conducted on the Penobscot Experimental Forest (PEF) in Maine, in two <1.0-acre plots established by the USDA Forest Service in the 1970s for a BBD study (Houston et al. 2005). Within those plots, measurements were made annually on numbered beech trees ≥3.5 inches in diameter (i.e., d.b.h., measured at 4.5 ft) starting in 1979. Measurements continued until 1992 and included tree attributes (e.g., d.b.h. and crown condition) and evidence of BBD (e.g., amount of wax from scale insect infestation, tarry spots from fungal infection, and fungal fruiting) on three bole sections (i.e., 0–6.5, 6.5–13, and >13 ft).

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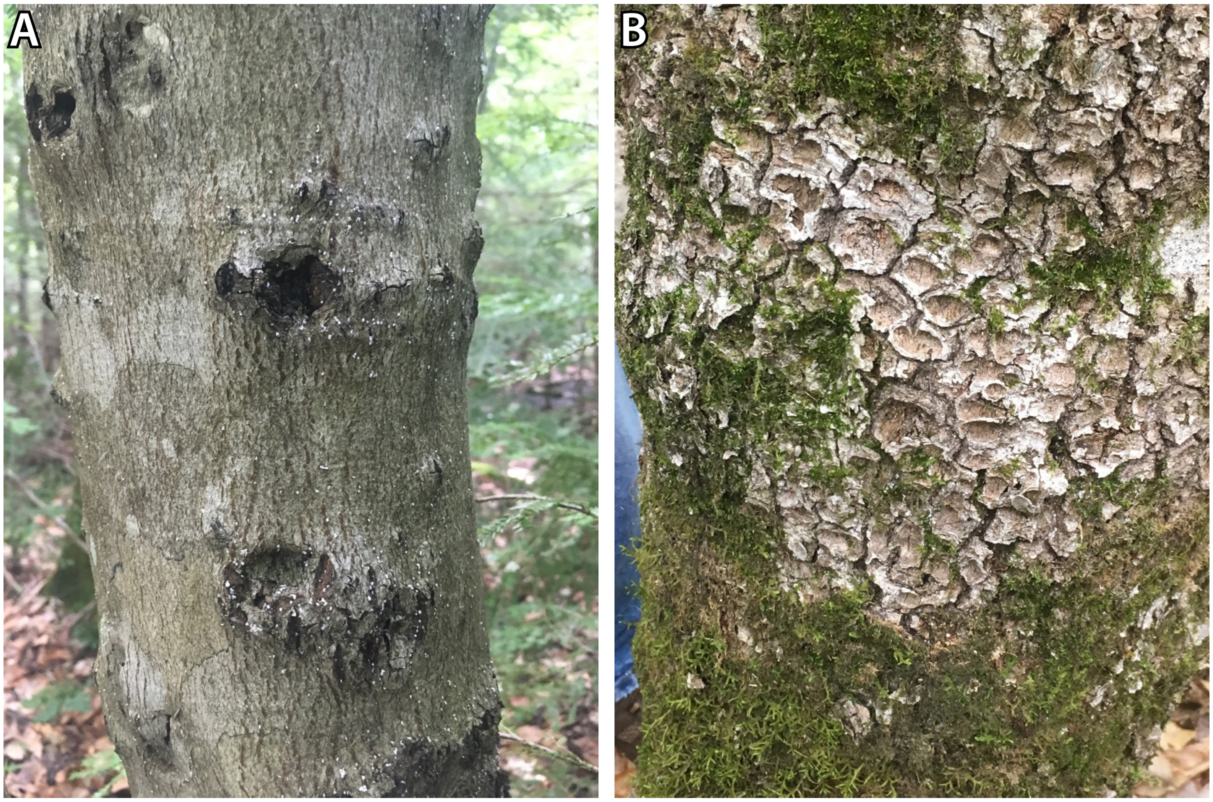

Figure 1.—Trees with BBD with (A) sunken cankers where fungal infection reached the cambium and (B) raised lesions (i.e., delimited cankers) where fungal infection was walled off by the periderm. Sunken cankers are places where the wood is decayed. Raised lesions—which resemble corn flakes or tiny moon craters—are delimited cankers that can be detached with a pocketknife, revealing sound wood. Bark of trees with many raised lesions may thicken and crack over time. Photo A: Courtesy photo by Lauren Keefe, used with permission. Photo B: USDA Forest Service photo by Laura Kenefic.

In 2018, the PEF plots were re-established, and tree measurements resumed for the lower two bole sections using original protocols on one historical and one new plot (i.e., n = 141 and 186 trees on plots 102 and 102A, respectively, including ingrowth). Additional measurements since 2018 include proportion of each bole section covered with sunken cankers (i.e., areas where the fungal infection breached the cambium, causing decay) and raised lesions (i.e., areas where the fungal infection was walled off by the periderm; Fig. 1). We used analysis of variance to test for significant differences in historical diameter growth (i.e., change in d.b.h. between 1979 and 2019, plot 102) and current crown dieback (i.e., <10 percent dead branches, 10–50 percent dead branches, and >50 percent dead branches in 2019, plots 102 and 102A) among sunken canker and raised lesion percent-cover categories (1–5, 5–50, 50–75, and >75 percent) on the lower (0–6.5 ft) bole in 2019. Plot was included as a random effect in the crown-dieback model and Tukey's multiple-range test was used for pairwise comparisons; differences were interpreted using a significance level of 0.10.

RESULTS

Crown dieback was greater (i.e., $p < 0.01$) and diameter growth was lower (i.e., $p = 0.03$) on trees with more than 5 percent sunken canker cover on the lower bole relative to trees with less-sunken canker cover (Figs. 2 and 3). Raised-lesion cover, however, was less clearly related to crown dieback and growth. Though we did find significantly more crown dieback on trees with 5–50 percent percent raised-lesion cover than on those with >75 percent percent raised-lesion cover (i.e., $p = 0.10$), dieback did not differ among other categories (i.e., $p > 0.10$; Fig. 2). Trees with >75 percent lesion cover also exhibited greater growth than those with 5 to 50 percent lesion cover (i.e., $p = 0.08$; Fig. 3).

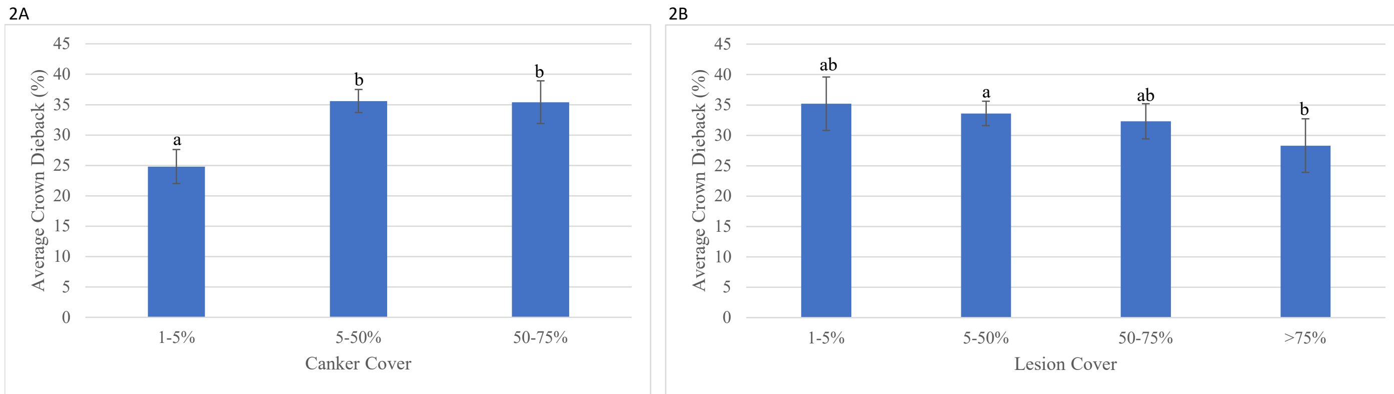

Figure 2.—Relationships between average-crown dieback (percent) and percent of the lower bole of American beech trees in the PEF plots covered with (A) sunken cankers and (B) raised lesions in 2019. Means with different letters are significantly different (i.e., p ≤0.10).

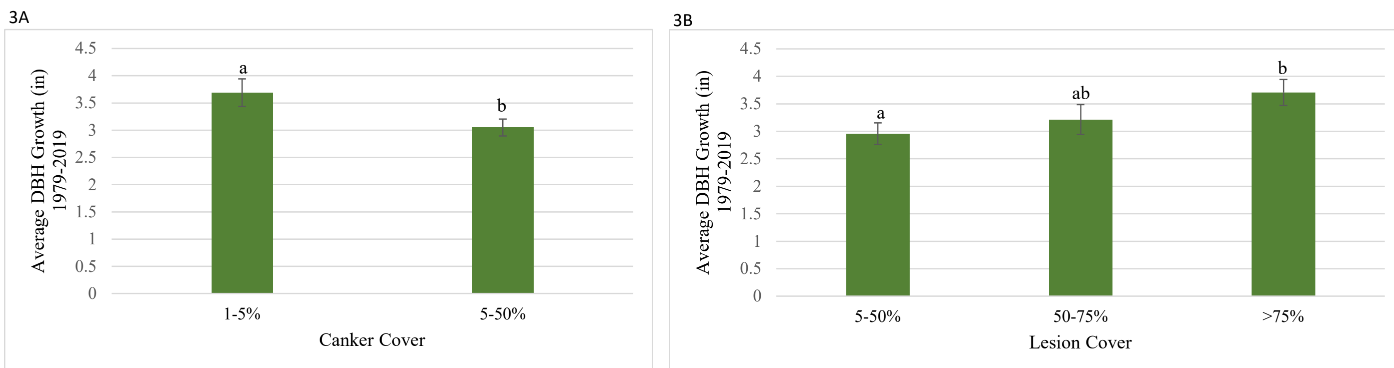

Figure 3.—Relationships between past-diameter growth (i.e., change in d.b.h. between 1979 and 2019 for surviving trees) and percentage of the lower bole of American beech trees in PEF plot 102 covered with (A) sunken cankers and (B) raised lesions in 2019. Means with different letters are significantly different (i.e., p ≤0.10).

DISCUSSION

Preliminary findings suggest that BBD tolerance is not an all-or-nothing condition, but a gradient on which trees exhibit varying proportions of bole area where fungi have either reached or been excluded from the cambium, resulting in sunken cankers or raised lesions. Our hypothesis that proportions of these features indicate degree of BBD tolerance as represented by other measures of tree health was partially supported. Trees with more sunken canker cover (>5 percent) on the lower bole in 2019 grew less over the past 40 years and had poorer crowns. Those with more raised-lesion cover (>75 percent) generally grew more and had better crowns, but those relationships were less distinct. Further investigation is warranted. Most trees in our sample had both sunken cankers and raised lesions; those with more raised-lesion cover likely also had lower sunken-canker cover. Ratios of sunken canker to raised lesion cover on individual trees might better reflect tolerance than either alone; this will be explored in future work.

Monitoring change over time will be critical to determining the potential of using bark condition as an indicator of tolerance, as even tolerant trees likely succumb to the disease eventually. The reasons for differences in raised lesion formation among trees and on a given tree over time merit further study; these might be related to timing of infection relative to the growth period, tree vigor, bark thickness, or other factors (e.g., genetic). Finally, articulating ecological or commodity values (e.g., mast production or wood soundness) of trees with varying degrees of tolerance will help management decision-making.

CONCLUSION

Our preliminary results support the observations of original study PI Houston and others (Ostrofsky and Blanchard 1983) that beech trees exhibit different degrees of tolerance to BBD, and that this tolerance can be observed, in part, as raised lesions on trees infested with the scale insect. Though further work is needed, our findings are an encouraging development for natural resource managers interested in maintaining beech in the aftermath zone (McNulty 2020). Continued work on the idea of "gardening the beech" (Nyland and McNulty 2021) will be strengthened by knowing how to better identify not only resistant but tolerant trees, allowing such trees to be retained if desired.

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