Department of Park Operations
Division of Natural Resources

Beech Leaf Disease Seasonal Symptom Progression

Cleveland Metroparks Technical Report 2019/NR-07

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Background

American beech (*Fagus grandifolia*) are being affected by an emerging disease known as beech leaf disease (BLD). Symptoms of the disease were first recognized at two sites in Lake County, OH in 2012 by John Pogacnik, biologist at Lake Metroparks. Since then, BLD has been identified in 40 counties from Ohio, Pennsylvania, New York, Connecticut, as well as the province of Ontario, Canada (Martin et al. 2019).

History, leaf symptom expression and distribution were broadly described by Ewing et al. (2018). They identify leaf symptoms as dark, interveinal bands, ranging from one to several bands covering up to two-thirds of leaf surface area. More severe symptoms apparently develop as the disease progresses, eventually covering more than two-thirds of the leaf and resulting in a smaller leaf size that is thickened and leathery in texture with curled leaf margins. Examples of both low severity and high severity leaf symptoms can be seen in Figure 1. Leaf symptoms are first evident in the seedling and sapling layer or along branches in the lower canopy of trees and are readily apparent when observed from below (see Figure 2). Eventually, symptom severity increases and includes aborted buds and twig and branch dieback resulting in reduced canopies. Occasional mortality in mature trees has been observed in areas affected by BLD, but elevated sapling mortality occurs where BLD has been present for several years.

Figure 1. BLD symptoms. Low severity symptomatic leaf (one band shown by arrow in A). Leaves with high severity symptoms displaying curled leaf margins and thick, leathery texture. (photo credit: C. E. Hausman and K. C. Lanzer).

Field observations have noted that all leaves produced from the same bud exhibit similar symptom expression to one another (Figure 2; personal observation, Hausman and Pogacnik). Additional field observations suggest that disease expression (asymptomatic, low severity, and high severity) is apparent at bud break in the spring and does not appear to progress over the growing season. However, individual leaf phenology and symptom progression has not been directly monitored over the full season.

This project seeks to formally identify leaf condition at the time of bud break and monitor changes in symptom expression on leaves during a single growing season. Based on field observations, we hypothesize that leaf damage is caused within buds prior to bud break. If leaf damage is caused while in the buds, we predict that BLD symptoms will be evident upon bud break. We further predict that no progression of symptoms (banding) will occur after leaf-out. Alternatively, if leaf damage is caused after bud break, we will observe symptom progression throughout the season from asymptomatic to symptomatic or low to high severity.

Figure 2. Similar symptomology produced by leaves originating from the same bud. Asymptomatic leaves produced from a single bud (left arrow) adjacent to leaves exhibiting symptoms of beech leaf disease (BLD) on the same branch. Symptomatic leaves with similar severity (right arrow) originated from a single bud. Location – Cuyahoga County, OH (BLD since 2014 – photo credit: C. E. Hausman).

Methods

Four trees with accessible branches were selected in April 2019 based on known BLD occurrence within Cleveland Metroparks. Cleveland Metroparks is situated in Cuyahoga County in northeast Ohio and has had BLD since at least 2014. While we attempted to choose trees with varying BLD symptom expression, true symptom expression and severity was unknown at the beginning of the project as each tree was still dormant. After tree selection, branches were marked with flagging tape prior to bud break to facilitate relocation of branch segments for repeat measures. Photographs were taken of one branch segment from each tree every two weeks from May to November. On average, each branch segment had 8 buds and 18 leaves that were monitored over the season. Because some branches contained many buds, picture scale was adjusted to fit all leaves into the picture frame once leaves emerged and reached full size. As a result, some branches required multiple pictures to capture all leaves. To provide maximum contrast for identifying BLD symptoms, a white background was placed behind branches while pictures were taken. Number of asymptomatic, low severity, and high severity leaves were tracked over the growing season to see if any changes in symptom expression occurred. For the purposes of this study, mild or low severity symptoms are defined as dark interveinal banding covering less than

approximately two-thirds of the total leaf area and heavy or high severity symptoms are defined as thickened and leathery in texture and having more than two-thirds of the leaf area covered with dark bands (Figure 2). Number of viable buds and aborted buds were also documented for each tree.

Results

In total, 74 leaves were tracked from 28 viable buds on four tree branches (Table 1). The timing of leaf emergence varied among trees, but generally occurred between the first and third weeks of May. We observed 45 asymptomatic leaves, 11 low severity leaves, and 18 high severity leaves. All leaf symptoms were apparent upon bud break, confirming our initial prediction. In addition, there was no change in leaf symptom severity throughout the season which confirms our second prediction. Leaves identified as asymptomatic at bud break remained asymptomatic through senescence.

Table 1. Number of viable buds, aborted buds, and leaves produced.

	Viable Buds	Aborted Buds	Leaves Produced	Average Leaves per Viable Bud
Tree 1	8	2	18	2.25
Tree 2	14	1	39	2.79
Tree 3	3	0	8	2.67
Tree 4	3	1	9	3.00
Total	28	4	74	2.64

Leaf loss occurred throughout the growing season but apparently varied based on symptom severity (Figure 3). Loss of leaves in late October or early November is most likely due to natural senescence, but early leaf drop (prior to October) is not likely due to natural senescence. No asymptomatic leaves and only 9% of low severity leaves experienced leaf drop before October, whereas 78% of high severity symptomatic leaves dropped earlier than expected.

Results for individual trees are described below, starting with the least symptomatic branch (Tree 1) and ending with the most symptomatic branch (Tree 4). Overall, Tree 3 and Tree 4 experienced the most presenescent leaf fall.

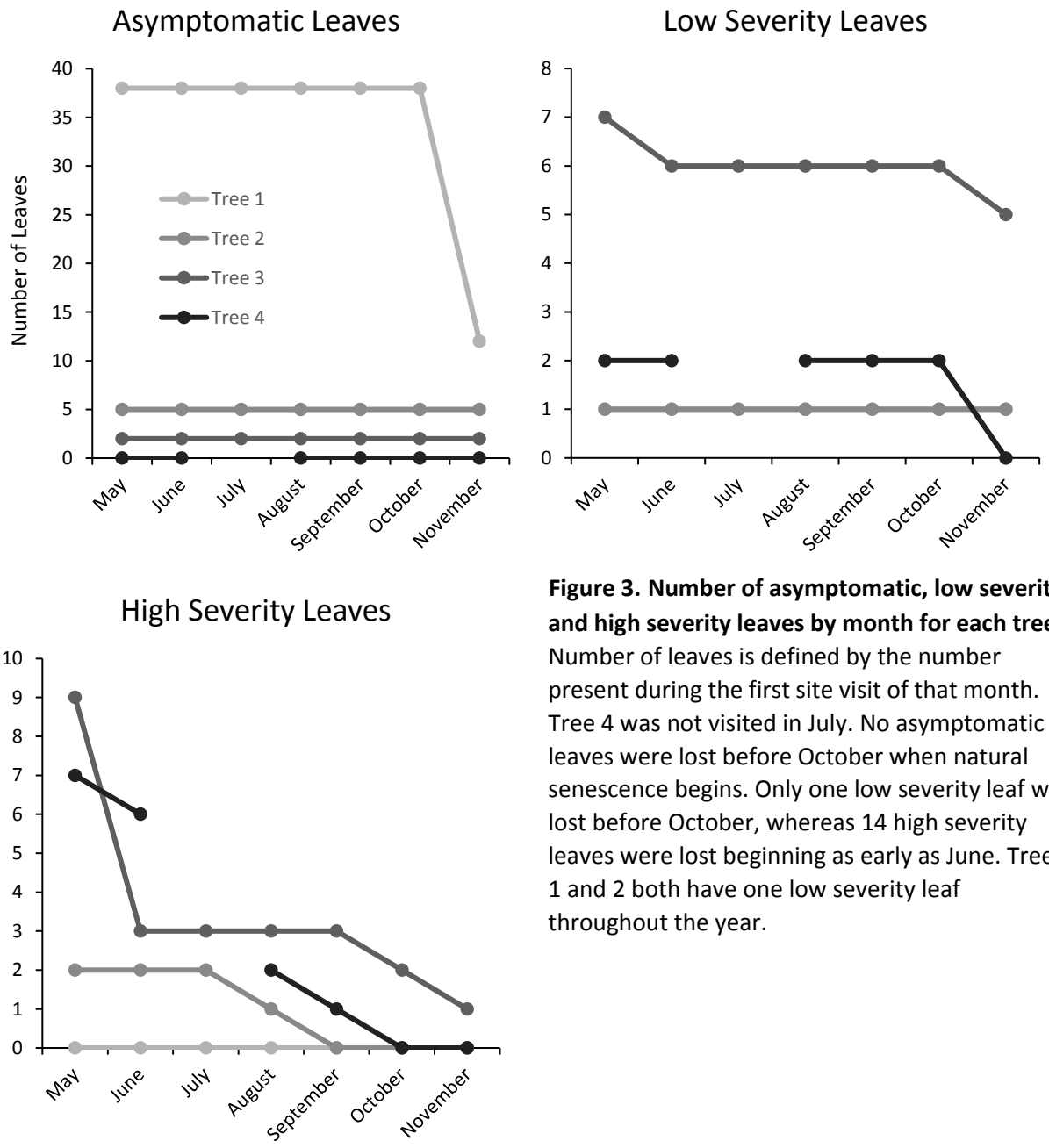

Figure 3. Number of asymptomatic, low severity, and high severity leaves by month for each tree. Number of leaves is defined by the number present during the first site visit of that month. Tree 4 was not visited in July. No asymptomatic leaves were lost before October when natural senescence begins. Only one low severity leaf was lost before October, whereas 14 high severity leaves were lost beginning as early as June. Tree 1 and 2 both have one low severity leaf throughout the year.

Tree 1

Tree 1 was an intermediate canopy tree in West Creek Reservation and had the lowest BLD incidence and severity of the four trees in this study. Few leaves on the tree exhibited BLD symptoms and canopy thinning was minimal. The branch contained 38 leaves from 15 buds, including one aborted bud, for an average of 2.79 leaves per viable bud (Table 1). Leaves began emerging the second week in May and were full size within two weeks. There were 38 asymptomatic leaves, one low severity leaf, and no high severity leaves. No asymptomatic leaves became symptomatic during the season and the only low

severity leaf had one small band near the tip which did not expand over the season (Figure 4). However, the band did become darker as the season progressed and the adjacent area became necrotic by August; additional close-up photos of this band can be found in Appendix A. Despite insect damage, all leaves persisted on the branch through October.

Figure 4. Subset of Tree 1 leaves in early (5/22/19) and late season (10/11/19). One dark band can be seen at the tip of a single mild symptomatic leaf (arrow). This single band does not change significantly over the season, but does develop necrotic tissue by 7/26/2019.

Tree 2

Tree 2 was a suppressed sapling in West Creek and was moderately affected by BLD. Much of the tree exhibited BLD symptoms and canopy loss was pronounced with many thinning or dead branches. Leaves from the selected branch began emerging the third week of May and were full size within one week. A total of eight leaves were produced from three buds, leading to an average of 2.67 leaves per bud with no aborted buds observed (Table 1). Five leaves were asymptomatic, one was low severity with a single band, and two were high severity (Figure 5). Asymptomatic leaves did not become symptomatic at any point during the season and the single low severity leaf did not change. However, both high severity leaves developed chlorotic and necrotic tissue, then fell off on 8/9/19 and 8/21/19. The remaining leaves persisted through October.

Figure 5. Tree 2 leaves in early (6/14/19; A), mid (8/9/19; B), and late season (10/11/19; C). One dark band is seen on the low severity leaf near the tip (upper arrow) and two high severity leaves are lost as the season progresses (lower arrows).

Tree 3

Tree 3 was a co-dominant canopy tree in West Creek Reservation which had an apparently high incidence and severity of BLD but overall canopy cover was not reduced. This branch contained 18

leaves from 10 buds, including two aborted buds (Table 1). Leaves began emerging the first week in May and were full size within two weeks. An average of 2.25 leaves were produced per viable bud. There were two asymptomatic, seven low severity, and nine high severity leaves. Figure 6 shows a subset of leaves from the beginning (5/13/19) and end of the season (10/11/19); additional photos can be found in Appendix B. Asymptomatic leaves did not become symptomatic at any point during the season and low severity leaves did not develop any additional bands or increase in leaf surface area covered by dark green bands. High severity leaves became necrotic, often starting at the margins then moving towards the center. Six high severity leaves fell off by June (Figure 3). Only one low severity leaf fell off early in the season.

Figure 6. Subset of Tree 3 leaves in early (5/13/2019) and late season (10/11/2019). All leaves that fell from this part of the branch were classified as high severity. Arrows point to unchanged bands on the only fully intact leaf remaining. Insect damage was present on several of the leaves from this branch.

Tree 4

Tree 4 was a suppressed sapling in Brecksville Reservation and was the most severely affected tree of all trees in the study. The tree had few healthy leaves and a reduced canopy. The surrounding area also had many stems that showed substantial canopy loss and a high incidence and severity of BLD. Bud break began the first week in May and leaves were fully developed within two weeks. A total of nine leaves were produced from three viable buds, leading to an average of three leaves per viable bud (Table 1). All nine leaves were symptomatic upon bud break with two low and seven high severity leaves (Figure 7). The low severity leaves did not show any expansion in banding pattern over the season, although one band on each leaf did begin to yellow in August. High severity leaves developed necrotic tissue in May and continued to form over the season. One high severity leaf had fallen by June and the remaining six high severity leaves fell prior to October (Figure 3). In contrast, the two low severity leaves persisted into October until normal senescence. Some bands began to develop chlorotic tissue in August while others did not. There did not appear to be any pattern to chlorotic tissue appearance within leaves.

Figure 7. Subset of Tree 4 leaves in early (5/16/2019) and late season (10/11/2019). Two low severity leaves and seven high severity leaves were present at bud break with one aborted bud (arrow). Only low severity leaves remain in October.

Summary

This project validated field observations that BLD symptoms are apparent at bud break and do not progress through the growing season. We hypothesized that leaf damage is caused in buds prior to bud break. Our two predictions were confirmed by tracking leaf symptoms from individual buds prior to bud break through the growing season. First, any leaf symptoms observed were apparent upon bud break. Our second prediction was partially confirmed; asymptomatic and low severity leaf symptoms did not expand over the season, although we did see chlorotic and necrotic tissue develop. These results support the conclusion that the critical time period for leaf damage occurs some time prior to bud break.

Our results that leaf damage is caused in buds is consistent with the findings of diagnostic efforts from another research group. In the fall of 2017, David McCann from Ohio Department of Agriculture, first detected a foliar nematode in large numbers on symptomatic leaves collected in northeast Ohio. This nematode was later identified by Carta et al. (in review) as a subspecies, *Litylenchus crenatae mccannii*, to a recently described foliar nematode, *L. crenatae*, first collected from Japanese beech (*F. crenatae*) exhibiting similar symptoms to BLD in Japan (Kanzaki et al. 2018). Recent data indicates this nematode may be the causal agent of BLD. Carta et al. inoculated wounded buds of previously asymptomatic, potted beech trees with a nematode solution prior to bud break. Leaves that developed from inoculated buds exhibited symptoms of BLD. Inoculated leaves did not produce any symptoms and inoculated undamaged buds only occasionally produced symptoms.

Interestingly, we did not expect early leaf drop on symptomatic trees. High severity leaves often developed extensive necrosis and occasionally chlorotic tissue before falling as early as June. Only four out of eighteen (22%) high severity leaves persisted on all trees into October. In contrast, only one low severity leaf fell off prior to October and no asymptomatic leaves exhibited early leaf fall. Early senescence has implications for BLD survey timing. Data presented here indicates that surveys for BLD can begin as soon as leaves emerge, generally mid to late May in northeast Ohio, because banding symptoms are present at bud break. The later in the season surveys are conducted, the higher the likelihood that high severity leaves have already fallen. The timing of surveys could misrepresent the severity of BLD by underreporting the percentage of leaves exhibiting high severity symptoms.

Beech leaf disease is an emerging disease with little research done to understand its impacts. Diagnostic efforts are ongoing and experimental chemical treatments are being tested. However, if preventing the spread of BLD is not possible, mitigation for the loss of beech may need to be considered. Additional basic research is needed to fully comprehend the gravity of BLD presence.

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Literature Cited

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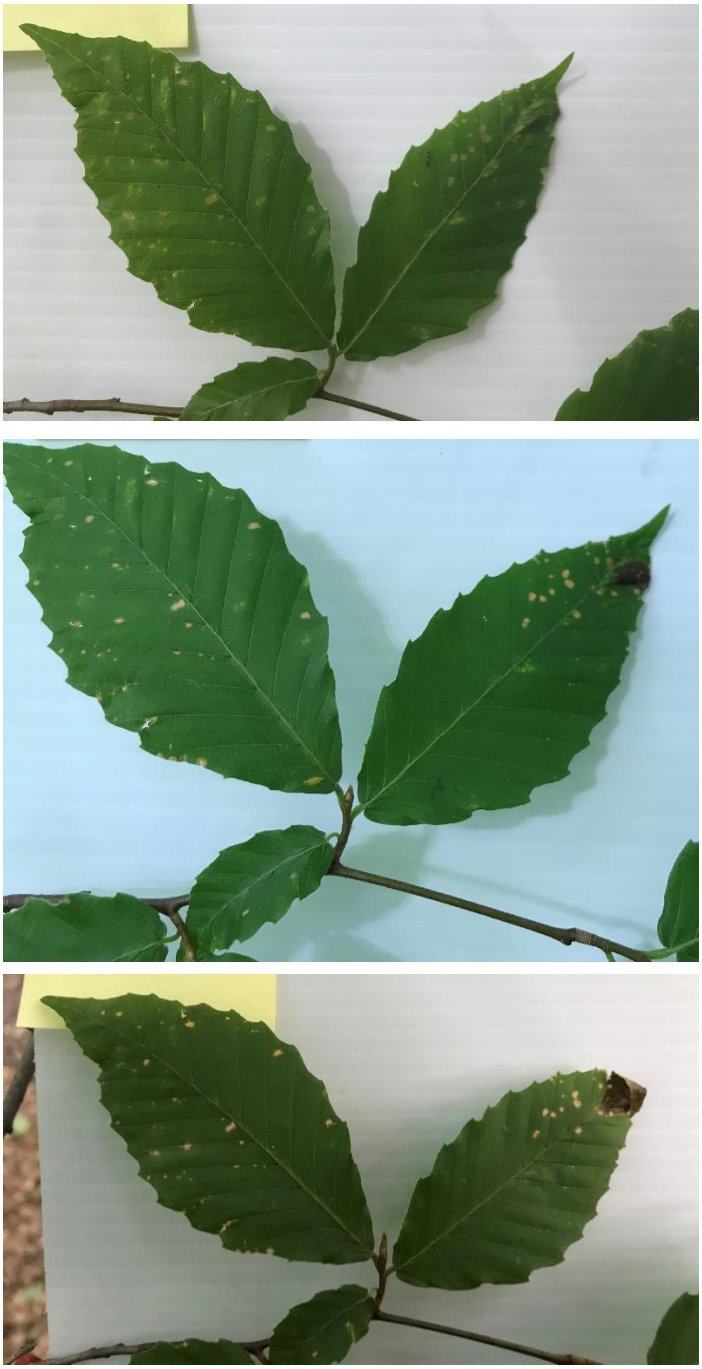
Appendix A – Tree 1 Photos



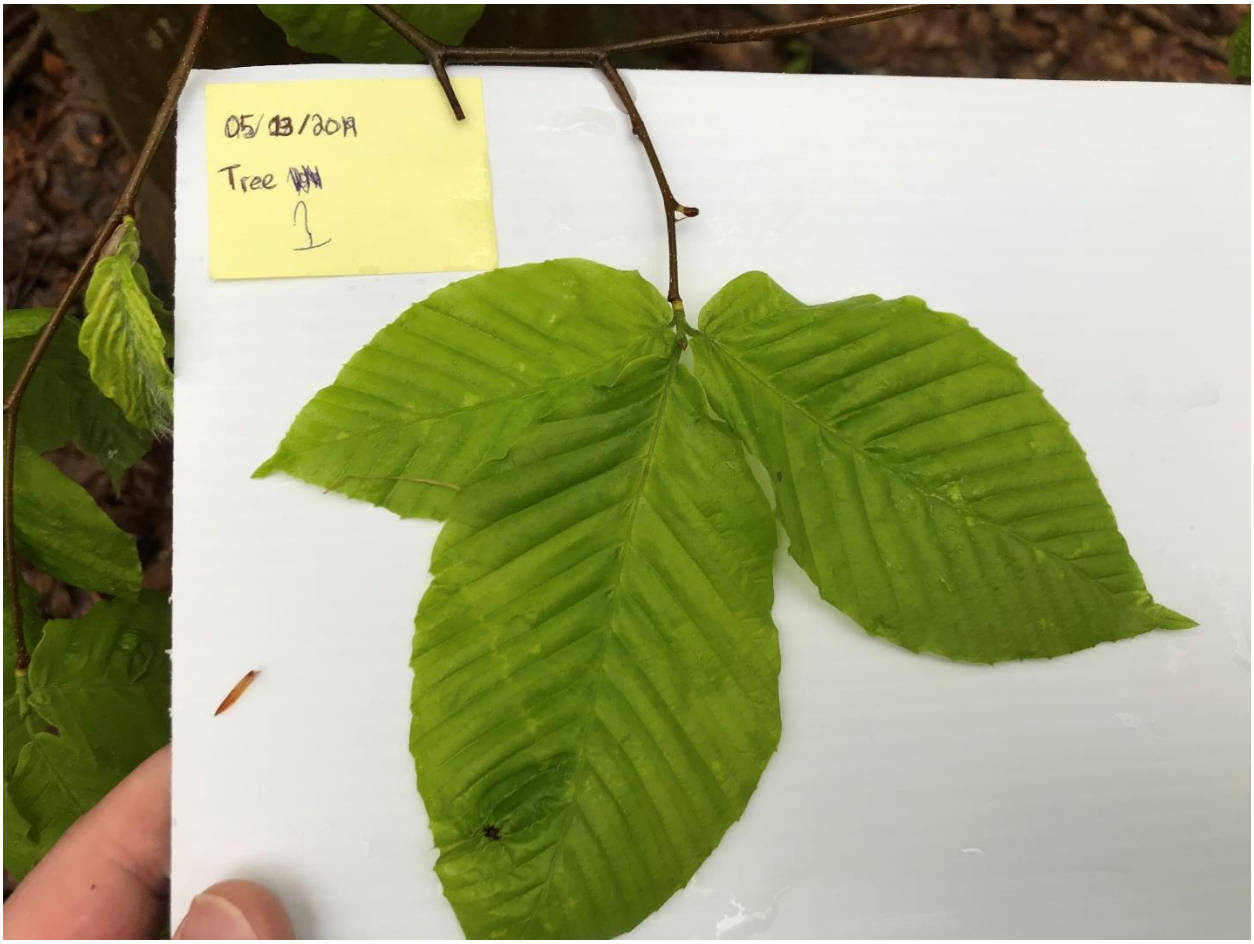
Zoomed in version of Figure 4. Image dates from top to bottom are 6/14/19, 7/12/19, 8/21/19. Band becomes dark and necrotic throughout the season.

6/7/2019. Separate twig from Tree 2 branch. All leaves are asymptomatic. Some insect damage occurred.

10/11/2019. Separate twig from Tree 2 branch. More insect damage later in the season. Asymptomatic leaves are still asymptomatic.

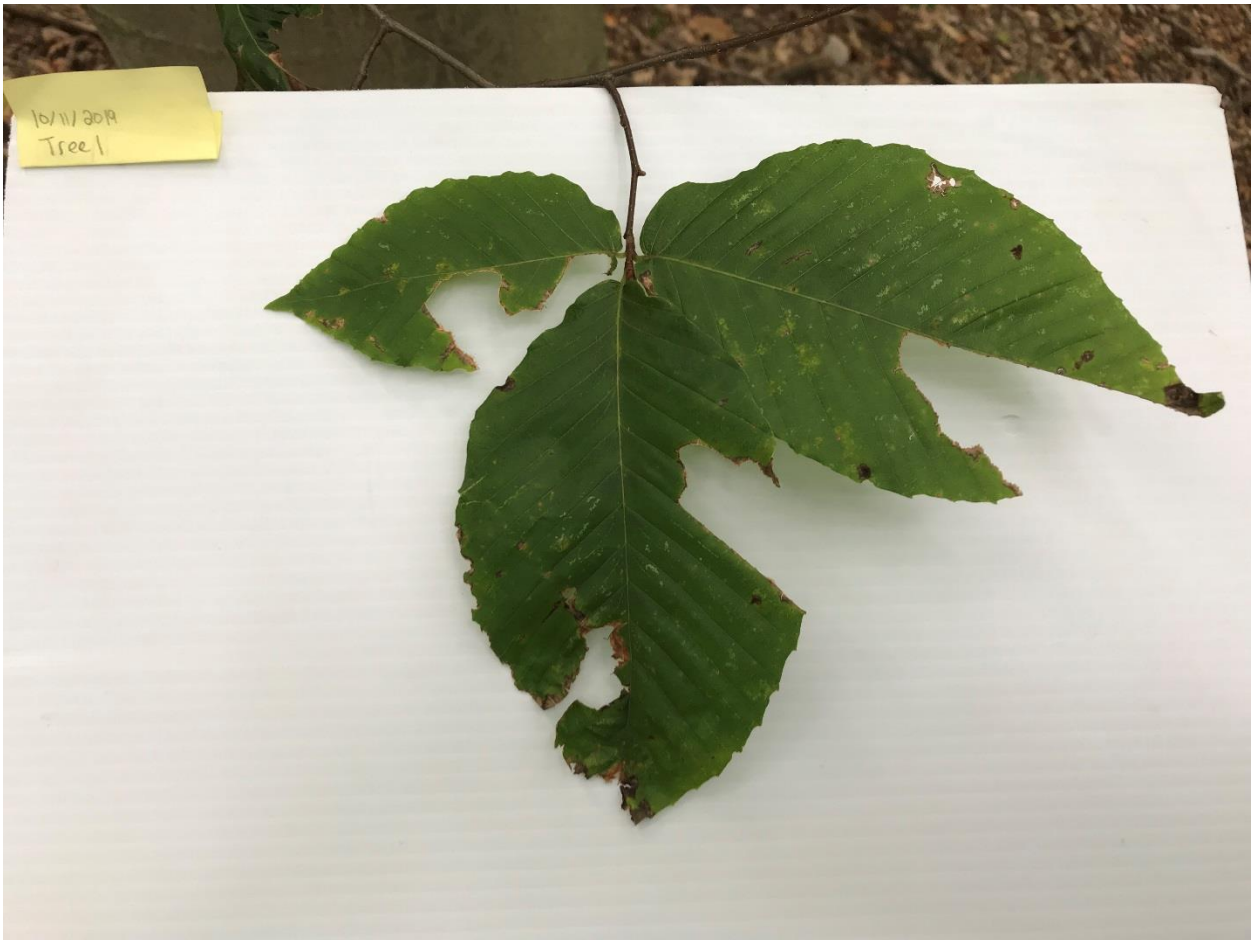
Appendix B – Tree 3 Photos

5/31/2019. Additional photo from Figure 6. Necrotic tissue appeared just before the five leaves on the left fell.



5/13/2019. A separate cluster of leaves from Tree 3 with only one band on the mild symptomatic leaf at the bottom. The other two leaves are asymptomatic.

6/14/2019. Tree 3 with some necrotic tissue beginning to form in June around the band.



10/11/2019. Tree 3 with insect damage mid-season. No changes in leaf symptoms occurred on this leaf cluster.

Appendix C – Tree 4 Photos

5/30/2019. Additional photo from Tree 4, Figure 7. Significant necrotic tissue has formed. One leaf has already fallen off.

8/8/2019. Additional photo from Tree 4, Figure 7. Five leaves have fallen off by August. Necrotic tissue continues to form. Slight yellowing appears on two bands from the mild symptomatic leaves.