CHAPTER 10

Investigating the Extent, Severity, and Causes of Sugarberry Mortality in the Southeastern United States

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INTRODUCTION

Numerous instances of sugarberry (*Celtis laevigata*) mortality or dieback have been reported over the last 75 years in Europe and North America (Poole and others 2021). While most events were brief and thought to be caused by physical damage, environmental stress, or temporary eruptions of native pest species, more protracted episodes of mortality have also been reported. In Europe, European hackberry (*C. australis* L.) decline has been reported since 1949, and several pathogens (phytoplasma and fungi) as well as their interactions with insect damage and drought have been implicated in recent mortality events (Bertaccini and others 1996, Linaldeddu and others 2016). Louisiana was the location of an estimated 3 million acres affected by *Celtis* mortality between 1988 and 1990, which was the worst episode previously reported from North America. Similar symptoms were reported in Mississippi during the same period (Solomon and others 1997). A specific cause was not identified in that study, although a nonnative plant-feeding insect was suspected to play a role in the mortality.

The Southeastern United States is currently experiencing the worst episode of *Celtis* mortality ever reported in North America. Based on observations of dead and dying sugarberry from Columbia, SC, in 2009 (Andy Boone, personal communication[1]), this problem has been developing and expanding for more than 10 years. Sugarberry, one of six *Celtis* species native to North America, is common in riparian areas. It can grow as tall as 24–30 m and live an average of 150 years (Duncan and Duncan 2000, Tirmenstein 1990). To our knowledge, mortality is currently limited to sugarberry, and although sugarberry is not widely used for timber, there are multiple reasons to be concerned about widespread mortality (Poole and others 2021). This species produces berries that provide mast to wildlife species such as multiple bird species, small game, and deer. It is also a host plant used by several butterfly species. While sugarberry is a common riparian species, it is also now an urban species planted for shade in parks and yards, and is found as street trees and fencerows. Sugarberry also is considered of value for pulp production (Duncan and Duncan 2000, Tirmenstein 1990). Although mortality is most obvious among urban and residential trees, forest trees are also affected and even those growing in riparian zones are dying at alarming rates.

Here we summarize findings from ongoing research aimed at (1) describing patterns of sugarberry dieback and mortality at a single site in North Augusta, SC, (2) determining the spatial extent and spread of the mortality in the Southeastern United States, and (3) investigating what role, if any, insects are playing in the death of trees. These three study areas are described separately below.

[1] *Personal communication. 2021. A. Boone, President, DendroDiasnostics, Inc., 1901 Martin Rd., Chapin, SC 29036.*

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METHODS

Patterns of Sugarberry Dieback and Mortality

Beginning in October 2015, we established a long-term monitoring site at a single location in North Augusta, SC. We selected a total of 131 trees (11–69 cm in diameter) for long-term monitoring of dieback and mortality. All trees that could be relocated were used to assess mortality after 5 years. A subset of 72 trees was selected, and the trees were monitored monthly during the years 2016–2018. We monitored canopy conditions over time using a crown class rating system adapted from Solomon and others (1997) with the following rating categories (illustrations of the categories can be seen in fig. 2 in Poole and others [2021]):

1. No discernable crown loss
2. <10-percent crown loss
3. 11–33-percent crown loss
4. 34–66-percent crown loss
5. 67–99-percent crown loss
6. Dead

Spatial Extent and Spread of Sugarberry Mortality

Although it was not possible to systematically assess the health of sugarberry populations throughout the range of the species, we attempted to identify areas experiencing high sugarberry mortality in parts of South Carolina and Georgia. This included trips around Columbia, SC, Savannah, GA, and several locations along the Savannah River south of Augusta, GA. Because the crown conditions of sugarberry were highly variable, in part due to damage caused by the hackberry woolly aphid (*Shivaphis celti* Das) (see below), we were very conservative in classifying a site as affected.

Role of Insects

Our research on insects potentially contributing to sugarberry mortality has focused on two species that are common across the affected area. First, insect egg masses found on the bark of dying sugarberry trees were determined to be from a native species of buprestid beetle, *Agrilus macer* LeConte. Very little was known about the biology or distribution of this species, so we carried out several studies to better understand its biology and native range (Poole and others 2019). First, we felled five sugarberry trees to determine the number of egg masses per unit bark area. We used this data along with information on the number of eggs laid per egg mass (based on laboratory dissections) to determine the density of beetle larvae attacking declining trees in our area. We also obtained museum records to better understand the known distribution of the species.

The second insect species we are studying is the hackberry woolly aphid. This nonnative species was first detected in North America in the 1990s and often attacks sugarberry in great numbers. The density of aphids is often high enough to cause obvious stress to trees, including the formation of thick layers of sooty mold that grows as a result of copious honeydew production and premature leaf fall. Research is underway to determine cumulative effects on sugarberry health from repeated attacks by this species. More specifically, we are comparing the carbohydrate reserves in the roots and phenolic profiles of leaves of potted sugarberry trees that have been chemically protected (imidacloprid and Ecotrol® Plus, a broad spectrum botanical insecticide) from the aphids to those of control trees that are not protected from these insects.

RESULTS AND DISCUSSION

Patterns of Sugarberry Dieback and Mortality

The canopy conditions of trees at the beginning of our monitoring period ranged widely, with 4, 29, 21, 33, and 44 trees receiving initial ratings of 1, 2, 3, 4, and 5, respectively. To understand inter- and intra-annual variation in crown conditions, monthly evaluations were conducted by the same individual for 3 years thereafter (2016–2018). Final mortality was recorded for all tagged trees after 5 years in September 2020.

As shown in figure 2 in Poole and others (2021), symptomatic trees were characterized by thinning canopies, small and chlorotic leaves, and branch dieback. Of the original 131 trees monitored in North Augusta, SC, 36 trees had been cut down before mortality could be confirmed. Of the remaining 95 trees, 51.6 percent had died by the end of the 5 years.

After 5 years, 13 of the original 72 monitoring trees had been cut down. Of the 59 remaining trees, 30 (50.8 percent) had died. Figure 10.1A shows that trees died throughout the 5-year study with a steady decrease in tree survivorship. Average crown rating over time (fig. 10.1B) indicates some seasonality in crown conditions with fall ratings tending to be higher (greater deterioration of crown conditions) with observable improvement in crown conditions (lower crown rating) in the spring. This was observed even with considerable variability in ratings among dates of observation.

The tree death rate was highly variable after first receiving a crown rating of 3 or higher, which was the point at which a tree was considered symptomatic. A total of 25 trees that were monitored monthly became symptomatic after May 2016 and died by September 2020. Over half of these (52 percent) died within 1 year of appearing symptomatic, six (24 percent) of which died within 3 months of first appearing symptomatic. Another 32 percent died within 1 to 2 years, 12 percent died within 2 to 3 years, and 4 percent died within 3 to 4 years. By contrast, 28 trees were alive but symptomatic at the end of the 5-year monitoring period. These remaining trees were symptomatic for more than 2 years, and 28.6 percent were symptomatic for at least 4 years (Poole and others 2021).

Spatial Extent and Spread of Sugarberry Mortality

Mortality appears to be most noticeable along the Savannah River near Augusta, GA, and near Columbia, SC. More recently, high mortality has been observed in Savannah, GA, and in neighboring coastal regions (Poole and others 2021) (fig. 10.2). Although dead sugarberry trees

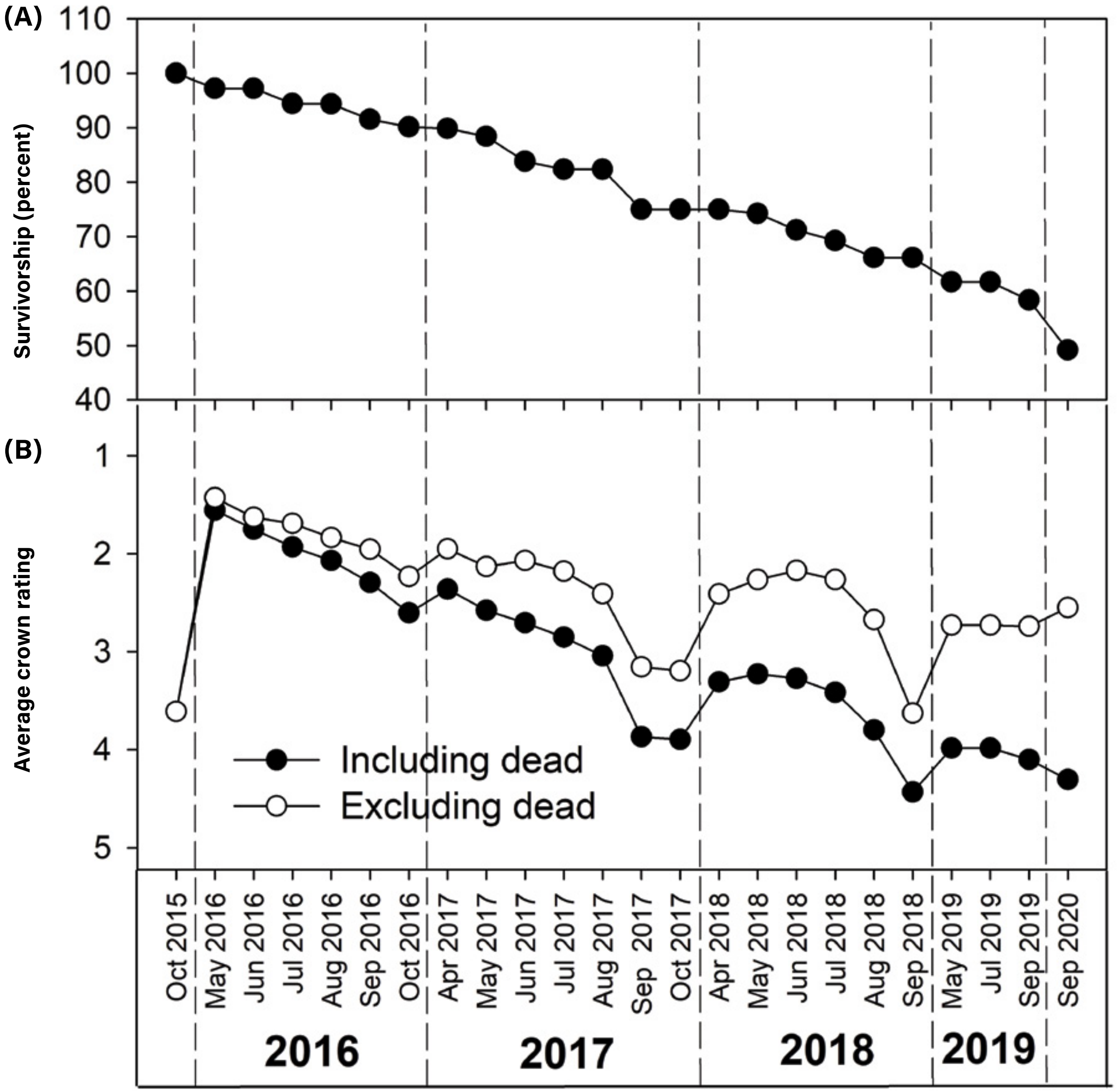

Figure 10.1—Long-term (2015–2020) monitoring data from North Augusta, SC. (A) Percentage of survivorship over time; (B) average crown rating of trees based on scores ranging from 1 (no discernable crown loss) to 6 (dead). Trees that were cut down before we could confirm mortality were not included in these calculations. Average ratings were calculated both including and excluding dead trees (black and white symbols, respectively). Vertical dashed lines separate calendar years. (From Poole and others 2021)

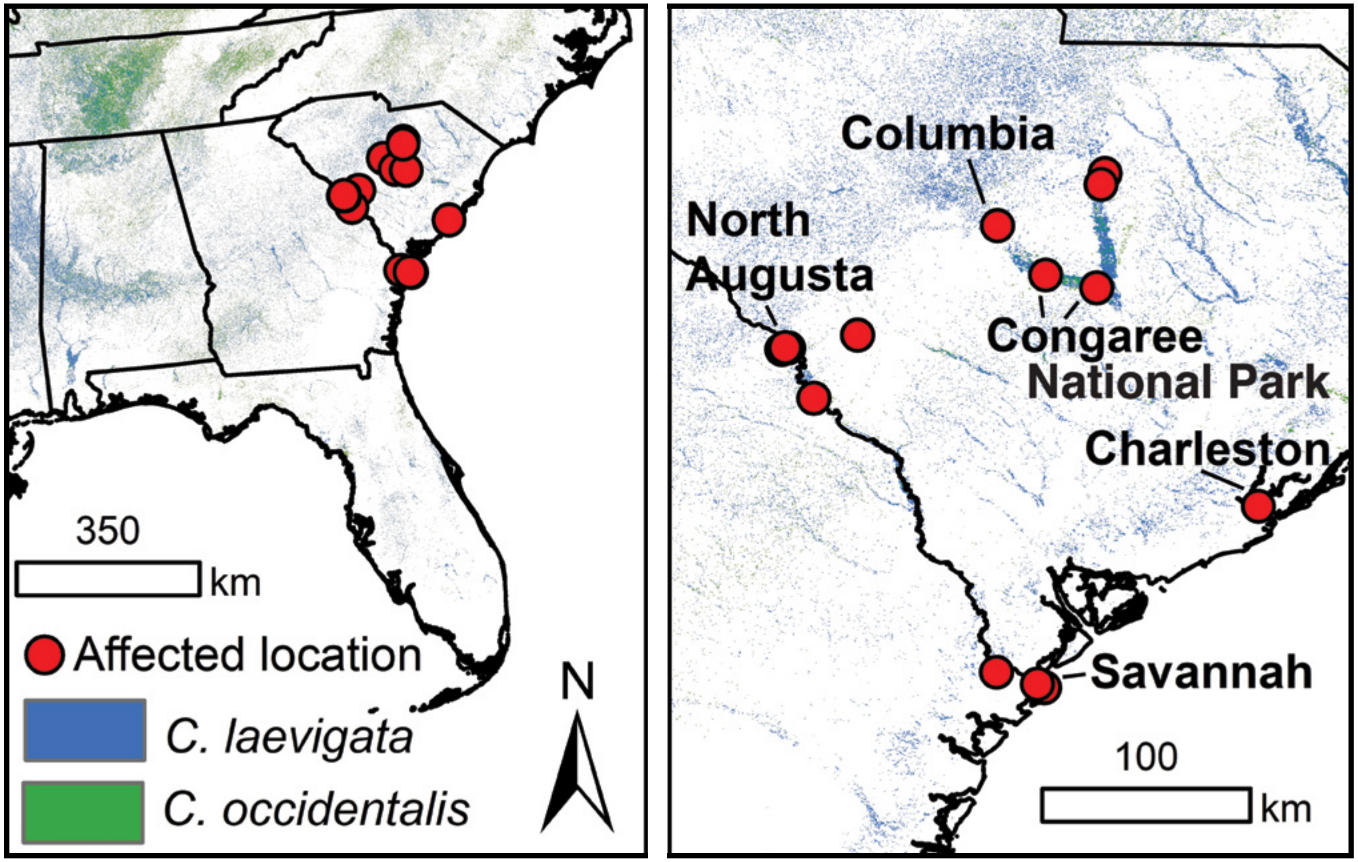

*Figure 10.2—Locations in South Carolina and Georgia known to be experiencing high levels of sugarberry mortality. Areas shaded in blue and green reflect the distributions of sugarberry (*Celtis laevigata*) and hackberry (*Celtis occidentalis*), respectively. (From Poole and others 2021)*

are more easily observed in urban areas, mortality is not limited to such areas. Indeed, trips to heavily forested places like Congaree National Park confirm that this is a serious issue facing forests as well. Because the mortality cause is still unknown, the beginning and rate of spread of the problem in the Southeast cannot currently be determined. We do know, however, that unusual sugarberry mortality was first observed in Columbia, SC, and Savannah, GA, in 2009 (Andrew Boone, personal communication [see footnote 1]) and 2019 (Bates and others 2020), respectively. With about 200 km separating these two cities, this suggests the problem is either expanding rapidly or is caused by widespread factors. Based on our observations, we suspect the problem has reached far beyond the areas depicted in figure 10.2. Because sugarberry is found throughout the Southeastern United States, this problem has the potential to spread throughout other States, which could already be occurring unnoticed. Furthermore, if other species of *Celtis* are also susceptible, this problem with mortality could become a forest health challenge throughout much of North America.

Role of Insects

We found the buprestid beetle, *A. macer*, was attacking some trees at incredible densities, with some trees having hundreds of thousands of eggs (Poole and others 2019). We made dissections of logs to observe the different larval stages of the beetle and made observations of females preparing egg masses. We also collected data on the seasonality of the adult beetles using flight-intercept traps. A survey of museum records found that this beetle has formerly been captured throughout the Southern United States, including the Southeast and is thus not new to this area (Poole and others 2019). Our observations indicate that it only attacks weakened or dying trees and that relatively healthy trees are able to overcome attacks from this species. Taken together, our results indicate that *A. macer* is only a secondary pest on sugarberry and this species has experienced a large population increase in response to the high availability of suitable host material within the affected area. As our latest research on how the aphid *S. celti* affects potted sugarberry health is ongoing and unpublished, we do not yet have data to share from this work.

CONCLUSIONS

The mortality reported here from the Southeastern United States represents the most severe, protracted, and extensive episode of *Celtis* mortality ever reported from North America. Mortality has been observed for at least 10 years, and large parts of Georgia and South Carolina are being affected. The mortality data reported in this summary are from one site, North Augusta, SC. The patterns of mortality, however, appear to be consistent with the rest of the affected area. It is concerning that 51.6 percent of our monitoring trees died after 5 years. Moreover, the crown conditions of the remaining trees continue to deteriorate. If the trees that were cut before we could determine mortality had died, or would have died, the mortality would have been nearly 65 percent over this period of time. It is important to note that based on the canopy class ratings we recorded, trees showed high variability in how quickly they died after first symptoms were observed. Some died in a few months while others continued to live for several years. A question requiring continued monitoring is whether affected trees can recover, specifically when competition may be reduced if neighboring trees die (Zhang and others 2017).

This problem has the potential to impact much of the Southeast, since sugarberry occurs throughout the region and its loss will cause many negative ecological and economic impacts. For example, loss of sugarberry trees has the potential to exacerbate the spread and dominance of invasive shrubs such as Chinese privet (*Ligustrum sinense* [Lour.]) in the forest understory.

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