Using Dutch Elm Disease-Tolerant Elm to Restore Floodplains Impacted by Emerald Ash Borer

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Abstract

American elm (*Ulmus Americana* L.) was a dominant species in floodplains and swamps of the Midwest before Dutch elm disease (DED) (*Ophiostoma ulmi* and *O.novo-ulmi*) reduced its populations. In many areas, ash (*Fraxinus* spp.) became dominant in these ecosystems. Emerald ash borer (EAB) (*Agrilus planipennis*), an introduced insect, is now spreading through the Midwest and killing up to 99 percent of ash trees in infested areas. In spring 2011, we began a restoration experiment to study reforestation of ash-dominated floodplains impacted by EAB through plantings of native tree species, including DED-tolerant American elm, sycamore (*Platanus occidentalis* L.), and pin oak (*Quercus palustris* Münchh.). We are testing the effect of planting trees before, during, or after ash mortality by planting in sites across a gradient of EAB infestation duration. Initial causes of seedling damage differed among sites. At sites that experienced flooding, many seedlings had wilted leaves. However, at the site that did not experience flooding, most seedlings had insect herbivory. Initial seedling mortality was low and differed among sites and species. American elm seedlings tolerant to DED performed as well as or better than the pin oak and sycamore seedlings planted in this experiment. Future results of this experiment will provide recommendations to managers for methods to restore EAB-impacted floodplain forests with DED-tolerant American elm and other tree species.

Key words: American elm, Dutch elm disease, emerald ash borer, floodplain restoration

Introduction

Dutch elm disease (DED) is caused by two nonnative fungal pathogens (*Ophiostoma ulmi* and *O. novo-ulmi*) of elm trees (*Ulmus* spp.) (Brasier 1991), which are spread by elm bark beetle species (primarily *Scolytus multistriatus* and *Hylurgopinus rufipes*) in North America (Schreiber and Peacock 1979). The first epidemic of *O. ulmi* was noticed in North America in the 1930s (Schreiber and Peacock 1979), and the second, more aggressive epidemic of *O. novo-ulmi* probably spread during the 1940s. The two epidemics decimated populations of American elm (*Ulmus americana*) (Gibbs 1978). While it was a popular street tree, American elm also was an important tree species in many riparian areas and swamps (Barnes 1976). The disease killed almost all of the large American elm trees, restricting elm populations to small diameter trees, while ash (*Fraxinus* spp.) and a few other tree species replaced American elm as dominant canopy species in these habitats (Barnes 1976).

Emerald ash borer (EAB) (*Agrilus planipennis*), an introduced insect pest, has killed millions of ash trees in the midwestern United States and adjacent Canada and is spreading rapidly (Cappaert et al. 2005). The impact of EAB is greatest in riparian areas and swamps where ash is the most abundant tree genus, sometimes making up 50 percent or more of the basal area of these stands (Knight, unpublished data). As the ash trees are killed, large canopy gaps provide an opportunity for both native plants and invasive plants to respond to the increased light in the understory (Knight et al. 2010). In turn, these changes reverberate through the ecosystem, affecting other organisms and ecosystem processes. In some areas, there is very little regeneration of native tree species. Invasive plants such as reed canary grass (*Phalaris arundinacea* L.) and common buckthorn (*Rhamnus*

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cathartica L.), which inhabit these ash-dominated areas (Knight, unpublished data), may inhibit future tree establishment.

Restoration strategies for ash-dominated riparian and swamp habitats are needed. Ongoing work to develop DED-tolerant American elm trees has generated several genotypes of DED-tolerant American elm trees from large-scale screening operations (Smalley and Guries 1993; Townsend and Douglas 2001; Townsend et al. 1995, 2005). Ash mortality provides an opportunity to introduce DED-tolerant American elm into these areas, re-establishing a canopy tree species that had been lost from these forests. This is also an important opportunity to diversify these forests by planting other native forest tree species, with a long-term restoration goal of creating resilient, functional floodplain forests.

We are conducting a restoration experiment to understand tree seedling growth and survival in floodplains, to study the performance of planted DED-tolerant elms, and to determine optimal restoration techniques for these ecosystems. Our long-term research is focused on two main questions:

- What factors affect the growth and survival of planted tree seedlings in Ohio floodplains impacted by EAB?
- What factors affect DED incidence and survival of planted elms?

These questions will be answered over several years. However, for the initial spring planting, we have examined the following questions:

- What are the major causes of initial damage or mortality for the planted tree seedlings?
- Does damage or mortality differ among species, sites, and sizes of planted tree seedlings?

Methods

Three riparian sites in Ohio were selected for this study (fig. 1). The Swan Creek floodplain in Oak Openings Preserve Metropark in northwest Ohio has been infested by EAB for the longest time period. The first EAB exit holes were observed in 2005 and 97 percent of the mature ash trees were dead by 2009. Green ash (*F. pennsylvanica* Marsh.) was the most abundant tree species in the floodplain, followed by American elm, boxelder (*Acer negundo* L.), and silver maple (*A. saccharinum* L.). The Tuscawaras River floodplain in the Clinton Conservation Area in northeast Ohio is currently uninfested by EAB (no exit holes have been observed), and the majority of the ash trees are healthy. Green ash is the most abundant tree species in this floodplain, followed by silver maple, red maple (*A. rubrum* L.), and boxelder. The Spring Creek floodplain in Sharon Woods Metro Park in central Ohio has been recently infested by EAB. The first EAB exit holes were observed in 2009 and 33 percent ash mortality in the floodplain was recorded in 2011. White ash (*F. americana* L.) is the most abundant species in the floodplain, followed by American elm, sugar maple (*A. saccharum* L.), and blue ash (*F. quadrangulata* Michx.).

Figure 1—Restoration planting sites in Ohio, USA.

Pin oak (*Quercus palustris* Münchh.) and sycamore (*Platanus occidentalis* L.) seedlings grown from seeds collected in Ohio were purchased from Riverside Native Trees (Delaware, Ohio). American elm seedlings were produced by the USDA Forest Service from crosses between Valley

Forge and R18-2, two cultivars with known tolerance to DED. Valley Forge is a selection from a chemical test that showed high levels of DED tolerance that was identified by Alden Townsend and Lawrence Schreiber. R18-2 is one of 17 survivors out of 21,000 seedlings screened for DED tolerance by Cornell University and the Boyce Thompson Institute. The geographic origin of these trees is unknown. Crosses between these disease-tolerant cultivars have been shown to have high levels of tolerance to DED (Slavicek and Knight, Generation of American elm trees with tolerance to Dutch elm disease through controlled crosses and selection, these proceedings).

At each site, plots were located in ash-dominated areas that were easily accessible. Three "large tree plots" were planted at each site with containerized seedlings 0.5 to 2.5 m tall on a 6 x 7 m grid (fig. 2). Two sites—Oak Openings Preserve Metropark and Clinton Conservation Area—also had three "small tree plots" planted with containerized seedlings 0.3 to 1 m tall on a 2.5 x 2.5 m grid. American elm, pin oak, and sycamore containerized tree seedlings were planted in random order on a grid pattern at each plot with half of the trees planted in spring 2011 (late May and early June) and the other half in fall 2011 (September) (fig. 2). Half of the large trees received cages to prevent deer browsing and rubbing. The DED-tolerant cultivars Valley Forge (VF), Princeton (PRN), and New Harmony (NH) were obtained from JLPN Inc. (Salem, OR) as bare-root stock, grown for 3 weeks in containers, and then planted in rows outside of each plot (fig. 2). These known DED-tolerant cultivars were planted to compare their survival to those elms from the USDA Forest Service crosses.

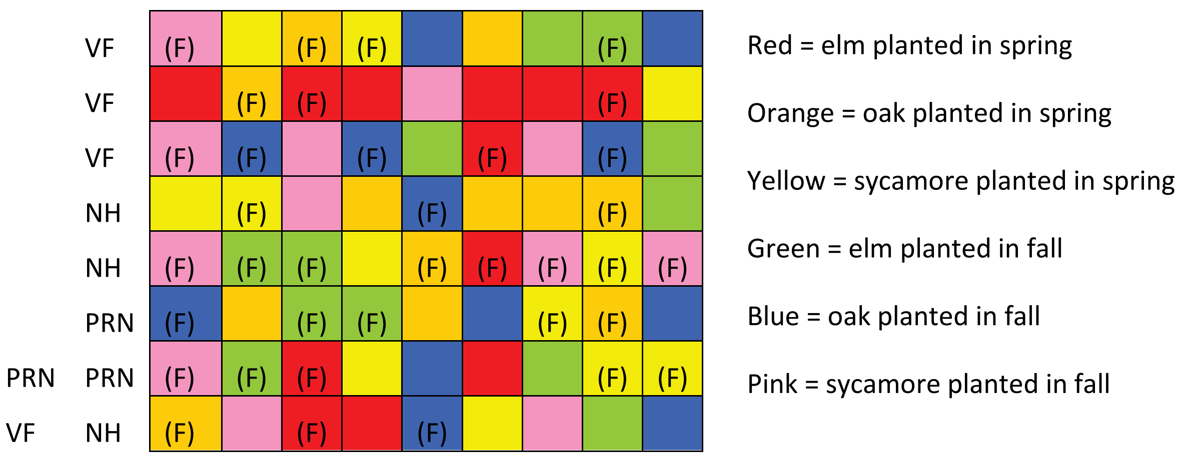

Figure 2—Planting design for one of the large tree plots, with trees planted on a 6 x 7 m grid. Valley Forge (VF), Princeton (PRN), and New Harmony (NH) are the Dutch elm disease-tolerant cultivars planted outside the plot. (F) represents cages randomly assigned to half of the trees.

One to 2 days after spring planting, Oak Openings Preserve Metropark and Clinton Conservation Area experienced heavy flooding. Trees were submerged for 1 to 4 days. The duration and depth of flooding was not measured, but appeared to be greater at Clinton Conservation Area. Approximately 2 weeks to 1 month after spring planting, we measured the following variables for each planted seedling: initial damage, survival, diameter of the stem at 2.5 cm height, seedling stem height to highest live leaf or bud, and canopy openness using a concave spherical densiometer.

A general linear multivariate mixed model using a binomial logit distribution was used to analyze mortality and the incidence of wilting, deer browsing, and insect herbivory. The main effects of site, tree size class (small seedlings or large seedlings), and species (elm, oak, sycamore) were tested. Analyses comparing tree size classes included both small tree and large tree plots at Oak Openings Preserve Metropark and Clinton Conservation Area. Sharon Woods Metropark data was analyzed in separate analyses using only large trees for all three sites, because only large trees were planted at Sharon Woods. These results were similar to the results of the first analyses and are not reported here. Post-hoc Tukey tests were used to determine differences among class variables.

Results

Damage

Leaves that were submerged during flooding wilted and died, then the seedlings sprouted new leaves (fig. 3) or died. Tall seedlings often exhibited wilted lower leaves and healthy upper leaves, probably because the upper leaves were not submerged long enough to kill them. Wilting differed among sites ($p<0.0001$) and species ($p<0.0001$). Wilting was most common at Clinton Conservation Area, with >50 percent of the trees of all species exhibiting wilting (fig. 4). Wilting was also observed at Oak Openings Preserve Metropark, but was uncommon at Sharon Woods Metropark. The incidence of wilting was similar for small and large trees ($p>0.05$). Differences among species were inconsistent between sites and size classes, but in general, sycamore seedlings exhibited more wilting than oak seedlings.

Insect herbivory differed among sites ($p=0.006$) and was most common at Sharon Woods Metropark, where almost 100 percent of the trees exhibited some herbivory (fig. 5). Herbivory was more common on large trees than small trees ($p=0.0003$) and was less common on elms than other species ($p<0.0001$). Browsing by deer was uncommon at all sites during the spring when the data was collected (fig. 6), but differed significantly among sites ($p<0.0001$) and species ($p=0.0004$). However, browsing was more common in the fall (data not shown), and may have a greater impact than the initial results suggest. Raccoons or groundhogs dug up or destroyed some of the small seedlings planted at Oak Openings Metropark and Clinton Conservation Area; seedlings that survived this disturbance were replanted.

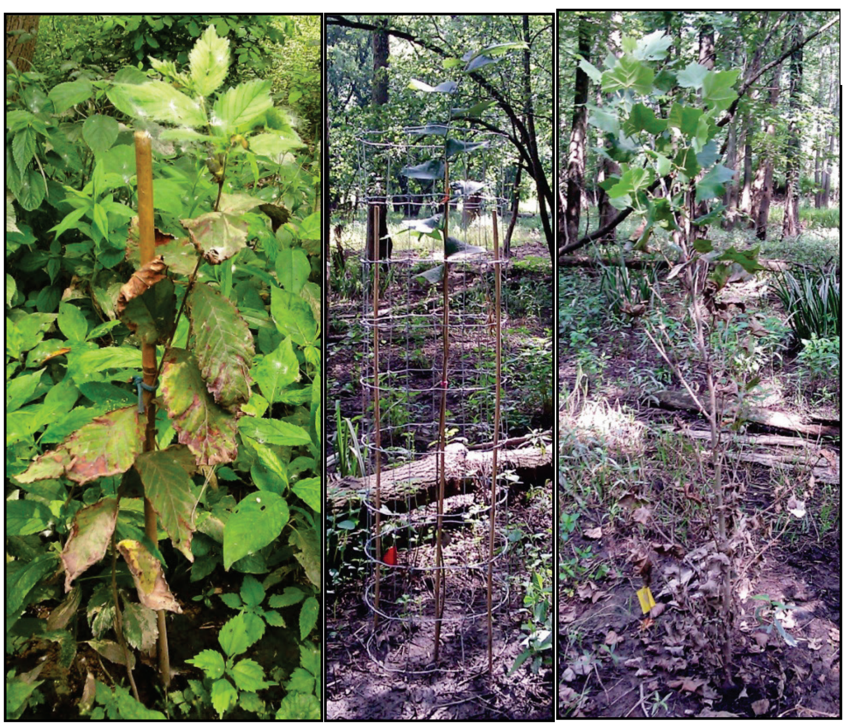

Figure 3—Elm with wilted lower leaves; re-sprouting new upper leaves (left). Elm with dead lower leaves that fell off, surviving upper leaves (center). Sycamore with dead lower leaves and surviving upper leaves (right).

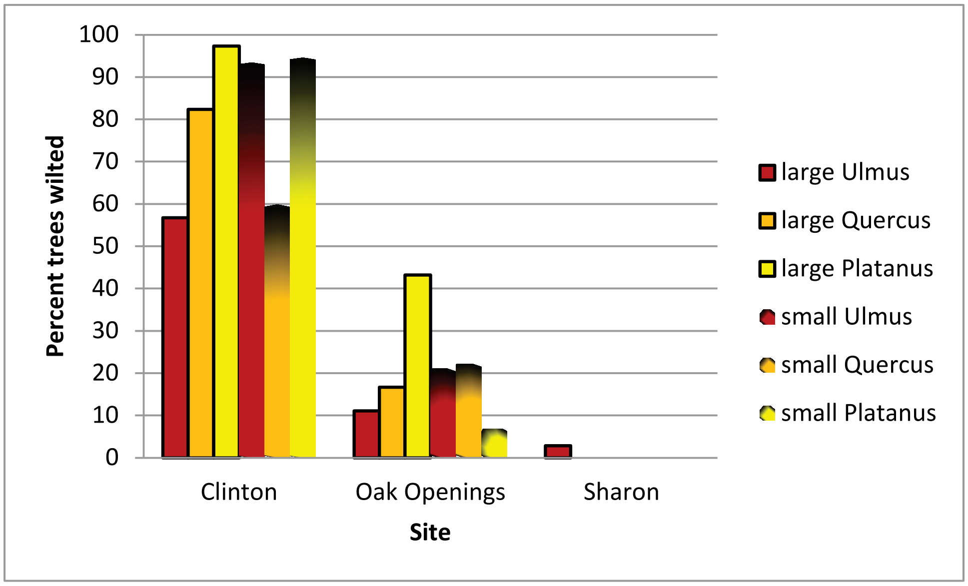

Figure 4—Wilting differed among sites and species.

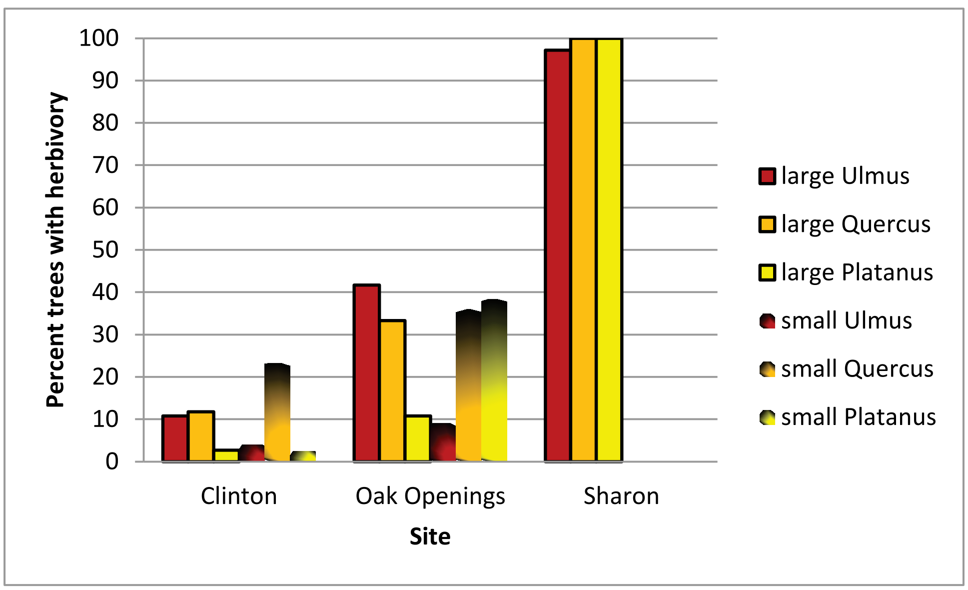

Figure 5—Insect herbivory differed among sites and species.

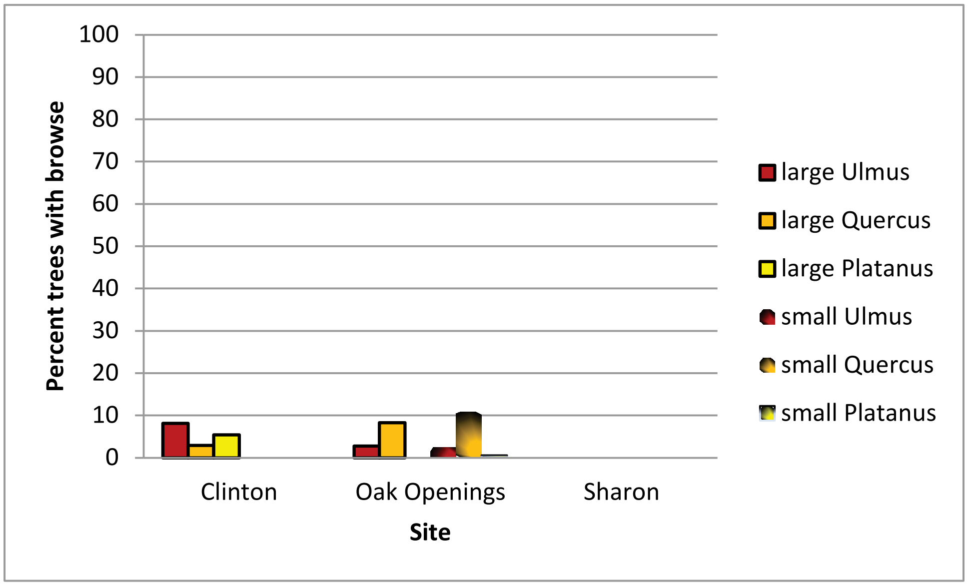

Figure 6—Browsing by deer was uncommon.

Mortality

Initial mortality was greater for small seedlings than large seedlings (p<0.0001), and differed among species and sites (p<0.0001) (fig. 7). Small sycamore seedlings exhibited the greatest mortality. Initial mortality was greatest at Oak Openings Preserve Metropark, and there was no initial mortality at Sharon Woods Metropark. It was difficult to determine the cause of mortality among seedlings. Some seedlings may have died from submergence under water at the flooded sites. During the fall planting, additional mortality, especially of small sycamore seedlings at Clinton Conservation Area, was recorded (data not shown). A second flood in July at Clinton Conservation Area may have caused the additional mortality.

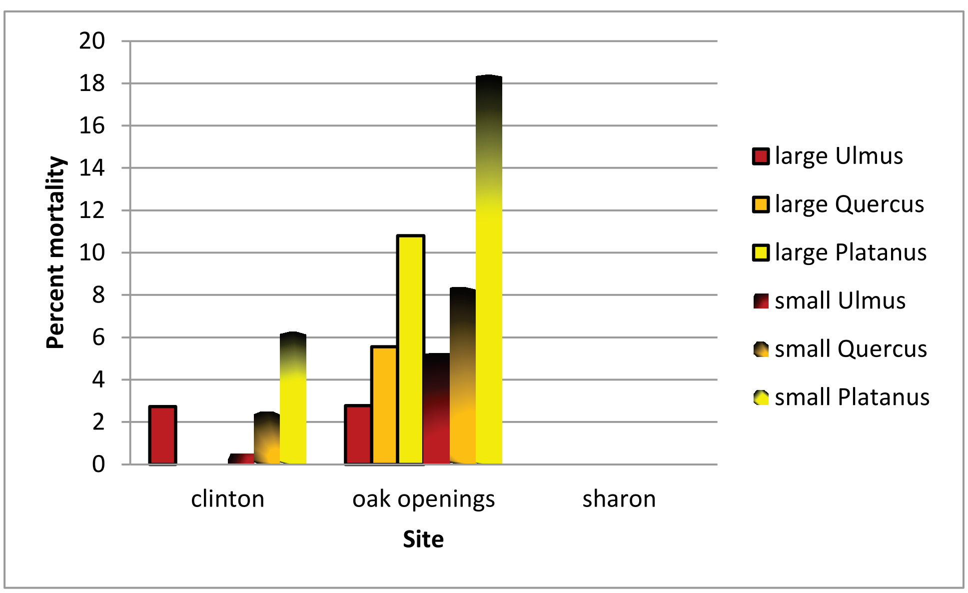

Figure 7—Mortality differed among sites, species, and size classes.

Discussion

Mixed plantings of DED-tolerant American elm, sycamore, and pin oak showed good initial survival. Damage for all three species was mostly due to wilting from flooded conditions or herbivory at the site that was not flooded. The incidence of wilting seems to reflect the severity of flooding with >50 percent of the seedlings wilted at the site with the greatest depth and duration of flood waters. However, many of the wilted seedlings resprouted. At the site that did not experience flooding, herbivory by insects was common. It is possible that insect populations are greater at that site or that herbivory was inhibited by flooding. DED-tolerant elm seedlings (VF x R18-2) performed as well as or better than the other two floodplain tree species, which is a promising result for the use of DED-tolerant elm in restoration. We will continue to monitor the survival and growth of the planted seedlings. The future results of this study will allow us to make recommendations to managers for restoration of EAB-impacted floodplains using DED-tolerant American elm and other tree species.

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