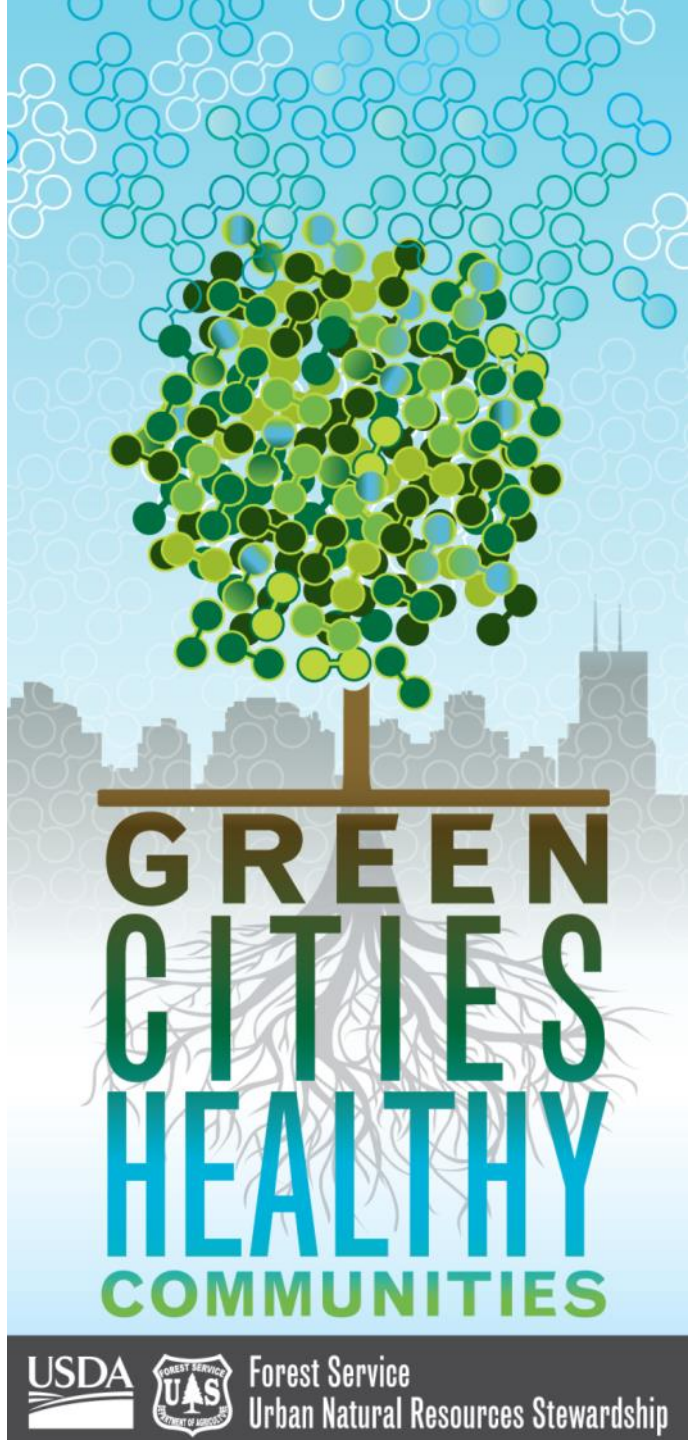

USDA Forest Service

URBAN FOREST CONNECTIONS

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Breeding and Restoring the Next Generation American Elm

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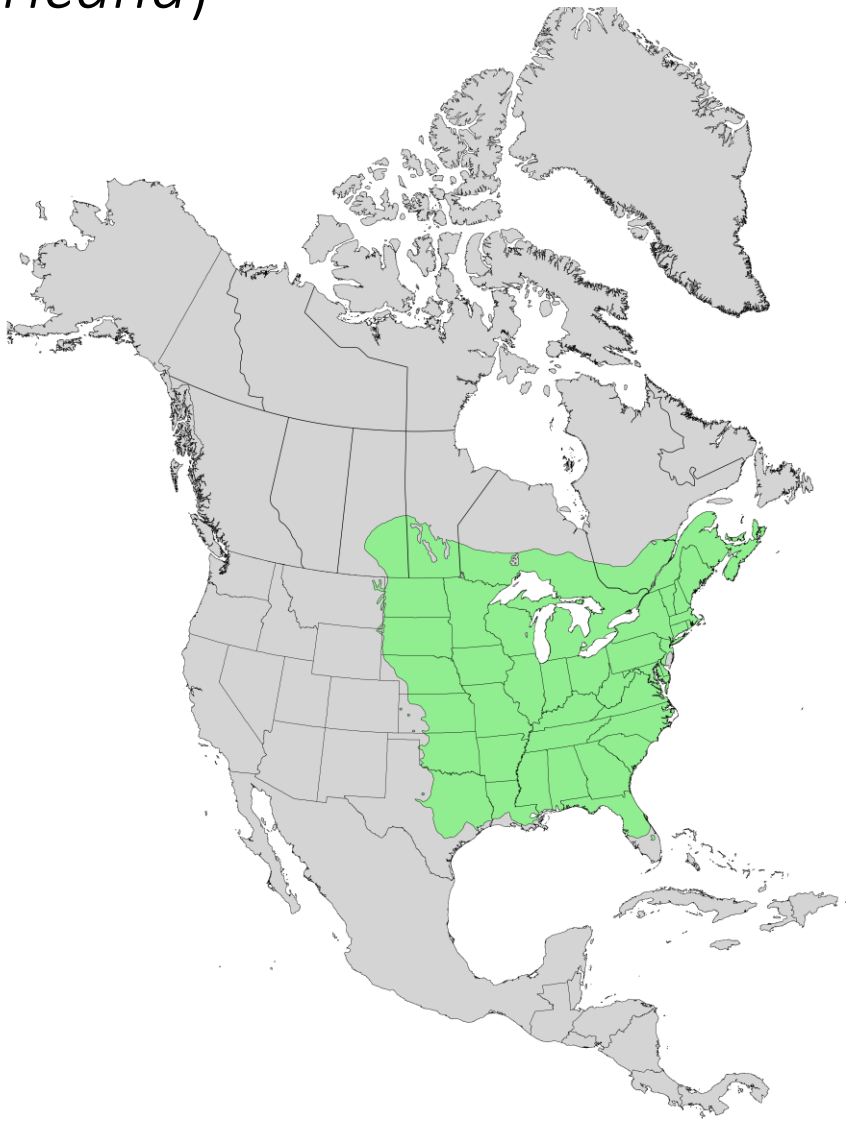
Breeding and restoring the next generation American Elm

Cornelia (Leila) Pinchot, Charles Flower, Kathleen Knight, James Slavicek

Outline

- Background:
  - American elm ecological and cultural value
  - Dutch elm disease and its impacts
  - Historical efforts to restore the species
- USFS NRS efforts to restore American elm
  - Develop DED-tolerant populations
  - Develop strategies for reintroducing elm to wildland and urban environments
    - Highlight two studies

American Elm (*Ulmus americana*)



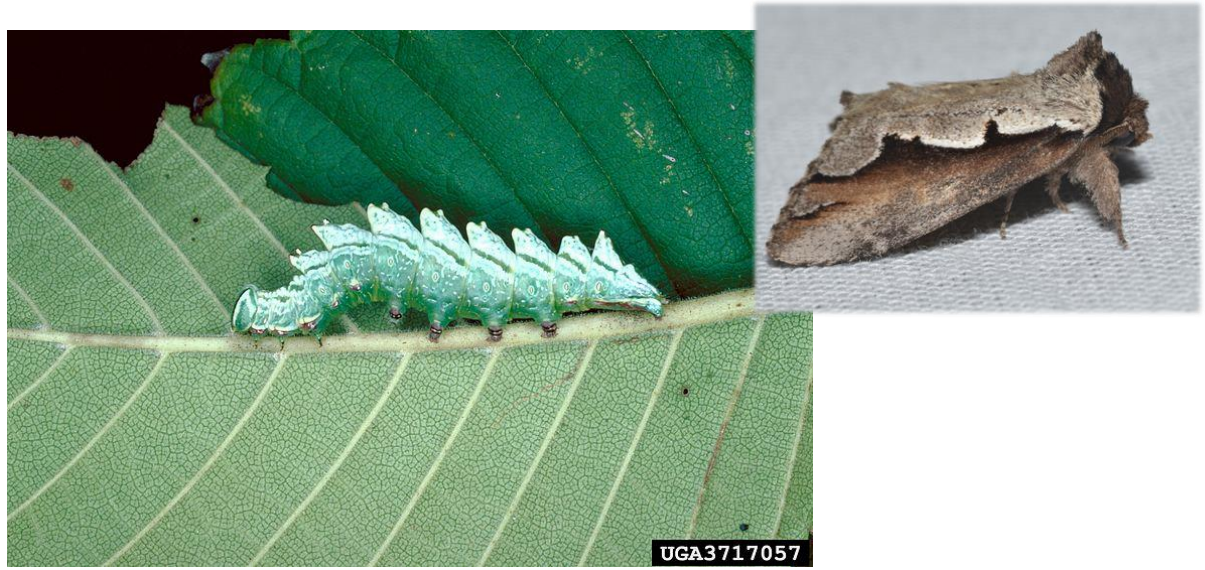
U.S. Geological Survey. 1999. Digital representation of E.L. Little 1971 "Atlas of United States Trees"

Table 1. Twenty most valuable plant genera ranked (from most to least) in terms of their ability to support Lepidoptera species in the mid-Atlantic (U.S.A.) region.

Rank	*Plant genus*	*Common name*	*Lepidoptera richness*
1	*Quercus*	oak	534
2	*Prunus*	cherry; plum	456
3	*Salix*	willow	455
4	*Betula*	birch	411
5	*Populus*	poplar; cottonwood	367
6	*Malus*	crabapple	308
7	*Vaccinium*	blueberry; cranberry	294
8	*Acer*	maple	297
9	*Alnus*	alder	255
10	*Carya*	hickory	235
11	*Ulmus*	elm	215
12	*Pinus*	pine	201
13	*Crataegus*	hawthorn	168
14	*Rubus*	blackberry; raspberry	163
15	*Picea*	spruce	150
16	*Fraxinus*	ash	149
17	*Tilia*	basswood	149
18	*Pyrus*	pear	138
19	*Rosa*	rose	135
20	*Corylus*	filbert	131

From Tallemy and Shropshire, 2009, Conservation Biology 23(4):941-947.

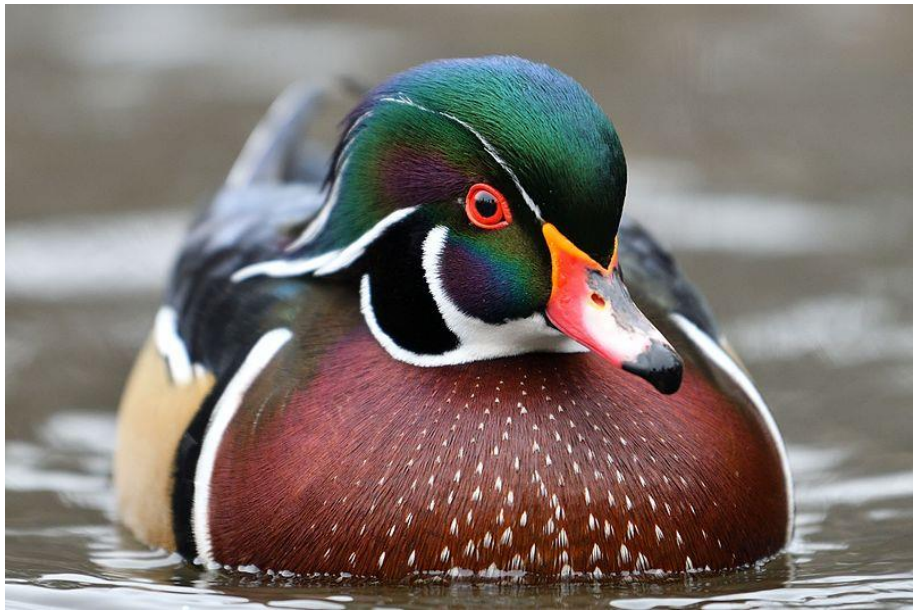
Elm sphinx moth, *Ceratomia amyntor*



Double-toothed prominent moth, *Nerice bidentata*

Wildlife that utilize American elm

North American porcupine



American wood duck

Yellow-rumped warbler

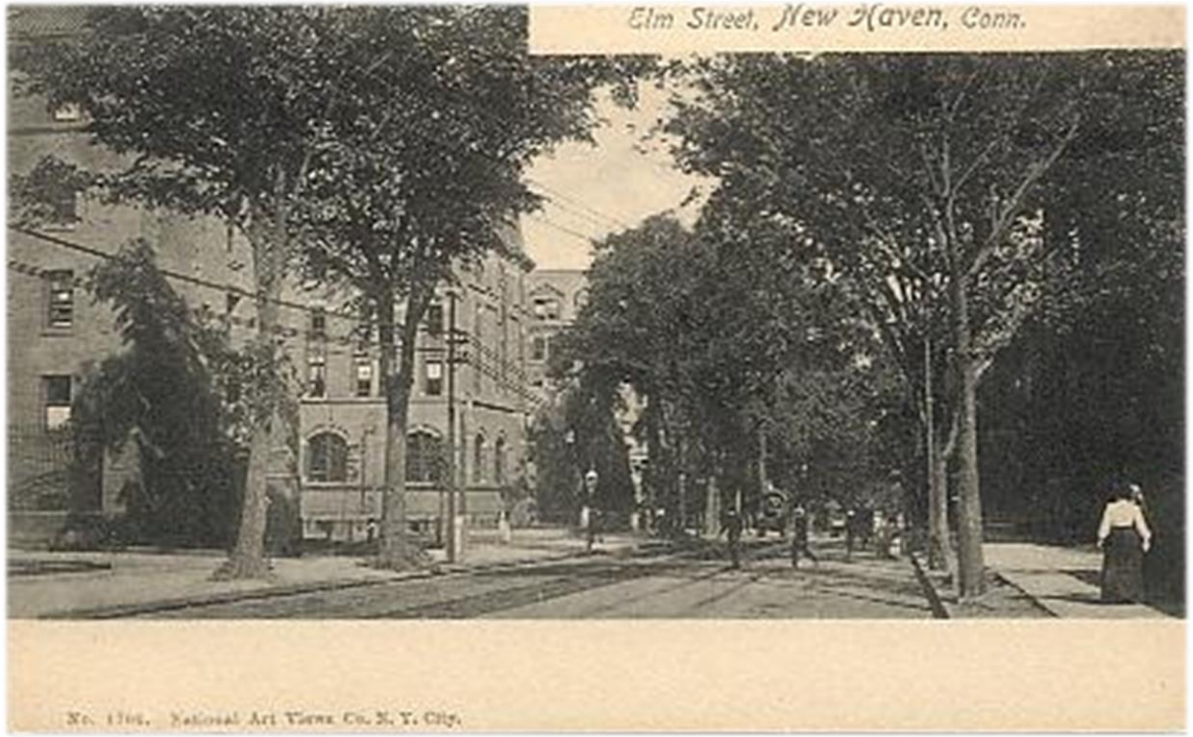
Purple finch

Ruffed grouse

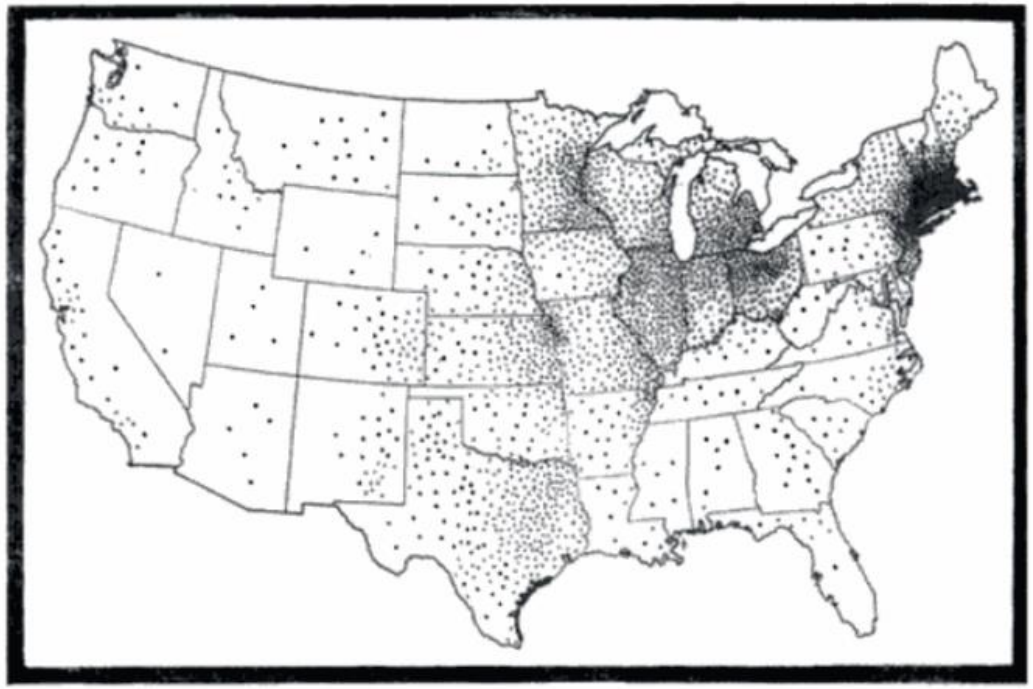
Northern bobwhite

Gray squirrel

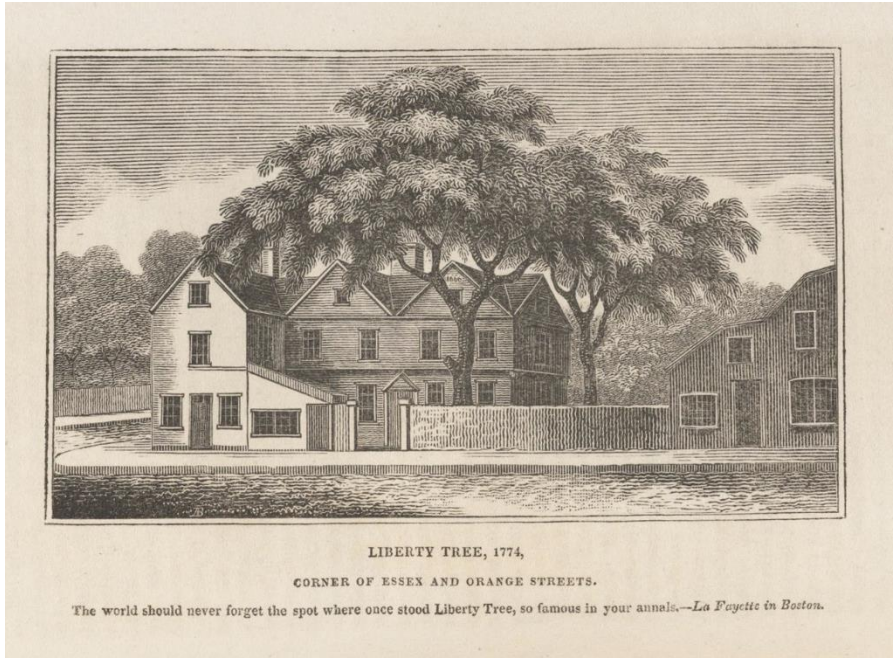
“Universal element of the American urban landscape”



“If the American dream had a home, it would be tucked beneath the sunshot canopy of elm street, USA.”
-Thomas Campanella, “Republic of Shade”



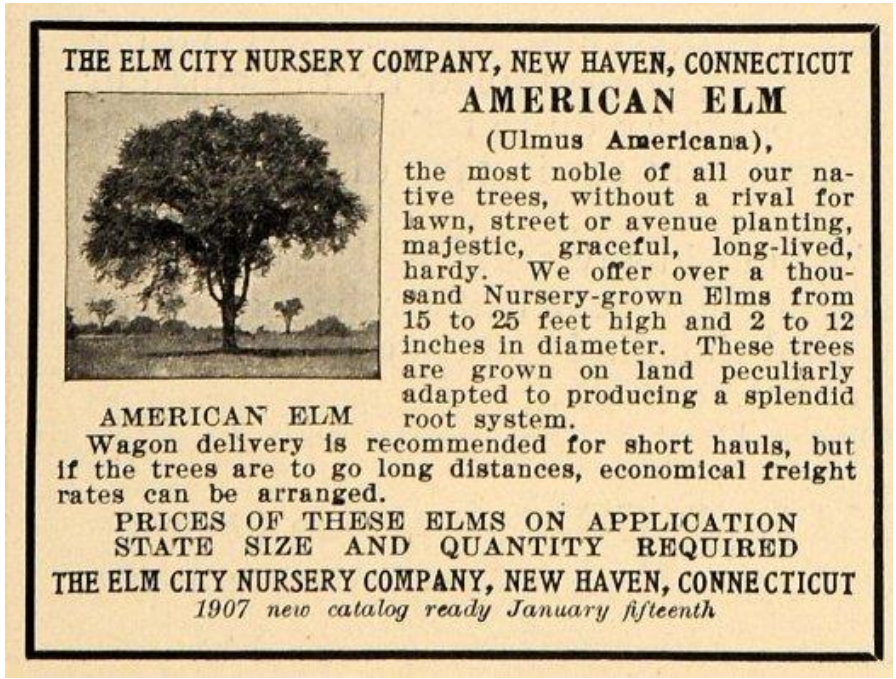
“America’s elms shade the nation.” Each dot represents ten thousand shade tree elms, showing clearly the concentration in New England, the wellspring of elm culture in America. (Joseph Edgar Chamberlain, “To Arms for the American Elm,” American Forests *40:5, May 1934)*



LIBERTY TREE, 1774,

CORNER OF ESSEX AND ORANGE STREETS.

The world should never forget the spot where once stood Liberty Tree, so famous in your annals.—*La Fayette in Boston.*



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AMERICAN ELM

(Ulmus Americana),

the most noble of all our native trees, without a rival for lawn, street or avenue planting, majestic, graceful, long-lived, hardy. We offer over a thousand Nursery-grown Elms from 15 to 25 feet high and 2 to 12 inches in diameter. These trees are grown on land peculiarly adapted to producing a splendid root system.

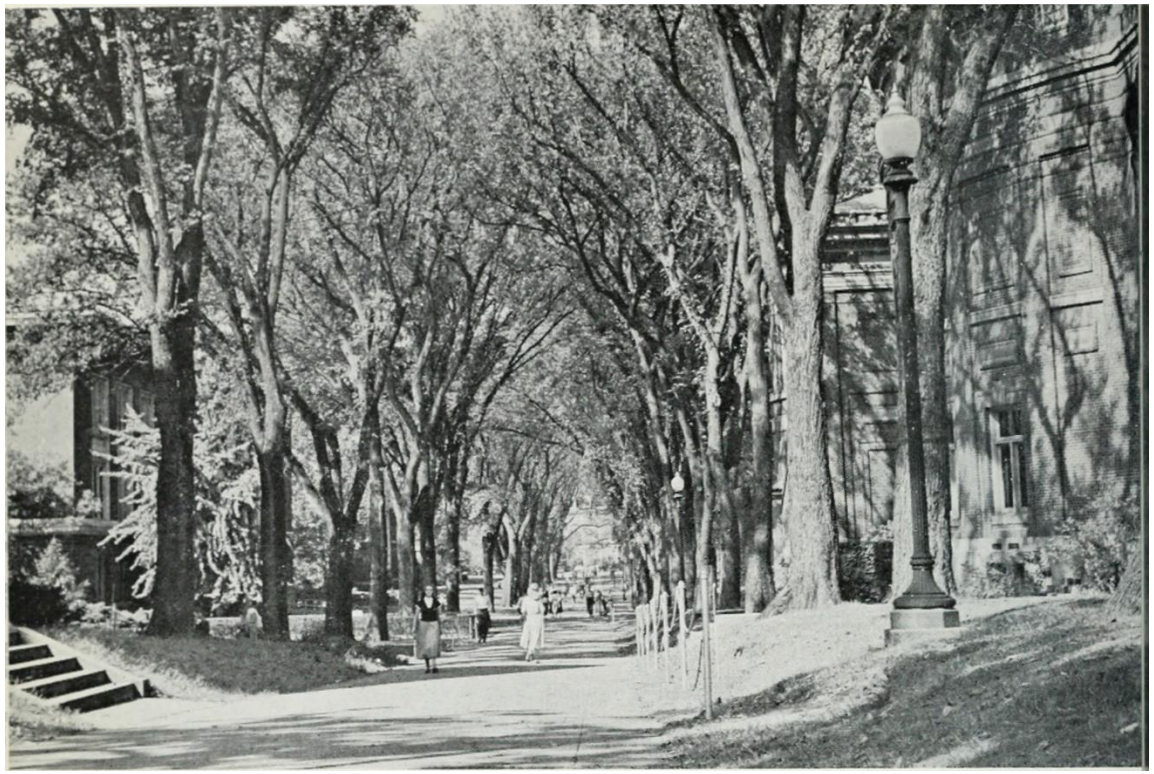
AMERICAN ELM

Wagon delivery is recommended for short hauls, but if the trees are to go long distances, economical freight rates can be arranged.

PRICES OF THESE ELMS ON APPLICATION
STATE SIZE AND QUANTITY REQUIRED

THE ELM CITY NURSERY COMPANY, NEW HAVEN, CONNECTICUT

1907 new catalog ready January fifteenth



Elms at the University of Illinois, from “Dutch elm disease in Illinois”, by J.C. Carter

OUR AMERICAN ELM.

By George Bancroft Griffith.

The hangbird weaves his pensile nest beneath its flowing spray,—
This noble elm,—a landmark still beside the broad highway;
From its vast dome of lovely green for many and many a year
The songs of late and early birds have cheered the list'ning ear.

And almost sacred unto me this native giant seems,
For oft when wand'ring far away 'tis pictured in my dreams.
My father's sire the little slip with his own hand set here—
Now youth and beauty seek its shade,—the dear old tree revere!

The May-queen 'neath its tasseled roof was crowned in days of yore
When the sweet, early flowers of spring the greensward daisied o'er;
And many a weary traveler beneath its wide spread boughs,
By heat and length of way o'ercome, in thankfulness could drowse.

The woodsman's axe shall never lay our homestead's fav'rite low,
Its hoary head, a century old, shall pristine glory show
Till storm and stress and Time's sharp tooth combine to end its reign,
And hurl it down, a monarch still, though prostrate on the plain!

Its sturdiness and grace I love, its winter grandeur, too,
When laden full of icy gems, all flashing bright and new!
Ne'er may it droop as if with grief o'er a deserted home,—
Though some who 'neath it played have died, none now as aliens roam.

Once more balm-breathing June is here, the grand old elm, how fair!
The lilac's scent is all abroad, and shines the golden air;
I bare my head beneath the boughs in splendor arched above,
And lo! they fold me in again with singing summer love.

Field elms in the Connecticut Valley – Albert Bierstadt, 1862

Elm in the New York Times

TO BEAUTIFY WASHINGTON

Secretary of Art League Explains the Plan.

A Mall from the Capitol to the Washington Monument Flanked by an Avenue of Elms—A Forest-Bordered Canal.

Glenn Brown of Washington, Secretary of the American Institute of Architects of that city, and also Secretary of the National Art League, lectured last night at the National Arts Club, 37 West Thirty-fourth Street, on the proposed improvements in Washington between the Capitol and the Potomac.

Mr. Brown's lecture was a comprehensive exposition of the scheme, which all branches of the National Government approve, for an artistic grouping of all the public buildings and parks in Washington in a series of vistas, which will centralize the most striking points of interest in the capital. He illustrated his lecture with stereopticon views.

NYT Feb 13, 1902

HOOVER PLANTS ELM TODAY

It Will Be One of 10,000,000 Trees to Be Set In Washington's Honor.

WASHINGTON, April 20 (AP).—President Hoover will plant tomorrow one of the 10,000,000 trees the American Forestry Association hopes to have planted as a part of the celebration of the 200th anniversary of George Washington's birth. The President will plant an American elm on the north grounds of the White House.

Boy Scouts, Girl Scouts, the Parent-Teachers Association and many other organizations have signified their intention of planting during 1931 and 1932 various types of trees as a memorial to the first President.

Although Washington's 200th birthday anniversary is not until next Feb. 22, President Hoover inaugurated the tree planting campaign early so it would be well under way by that time.

NYT April 21, 1931

TREES FOR THE CITY

It is good news to learn that the Park Department has embarked on its large-scale program of tree planting, involving this Spring some 30,000 trees and 500,000 shrubs and vines. Results of this program, carried on for several years with the cooperation of the various borough governments and WPA, already are apparent. The parks themselves, from Central Park down to the smallest triangle, are more lovely than they have ever been since brick and stone replaced green countryside. New highways, and many an older one, give promise through their young trees of the dignity and beauty they will acquire with the passing years. Playgrounds, athletic fields and public building sites have been enriched with well-chosen plantings. But it is perhaps in the busy avenues and side streets themselves that one appreciates most the refreshing green of the new trees.

Time was when only such adaptable varieties as the plane tree were thought suitable for the rigors of sidewalk planting. That the plane still is among the most desirable for urban use is shown by rehabilitated Bryant Park. But the Park Department has made use successfully of many other splendid trees. Pin oaks, lindens, tulips, the gum trees and the American elm are among varieties that give grace and shade along our streets. Where the setting makes it possible a wide variety of native flowering minor trees and shrubs also have been planted. The program has proved that oases of peace and charm can be created where they are most welcome and most needed.

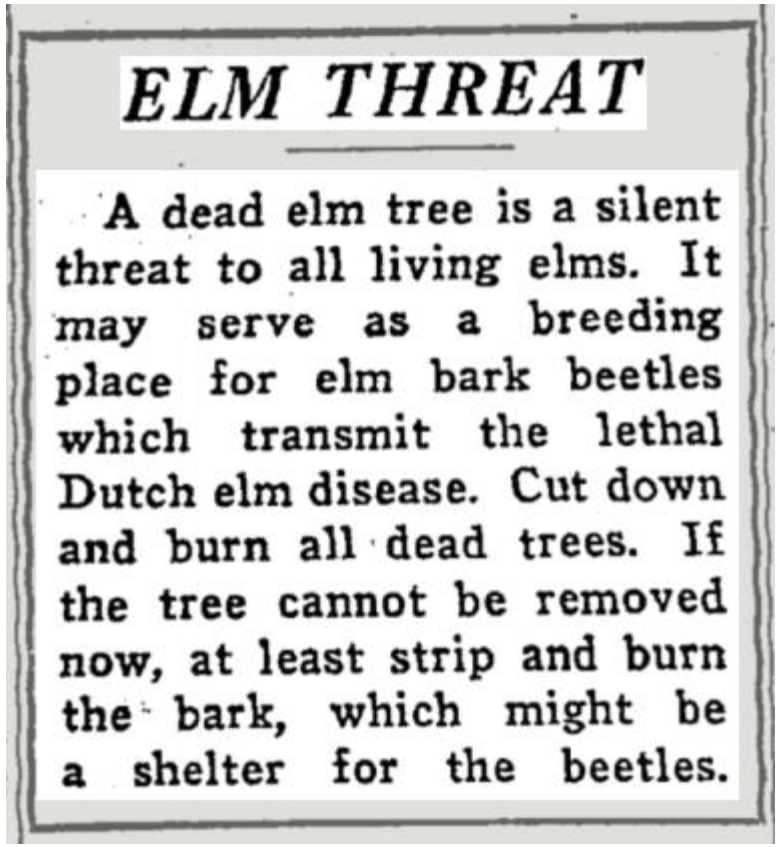
NYT May 20, 1941

BIG ELM Brewing
SHEFFIELD, MA

ELM
SHAKESPEARE
COMPANY

Dutch elm disease (DED)

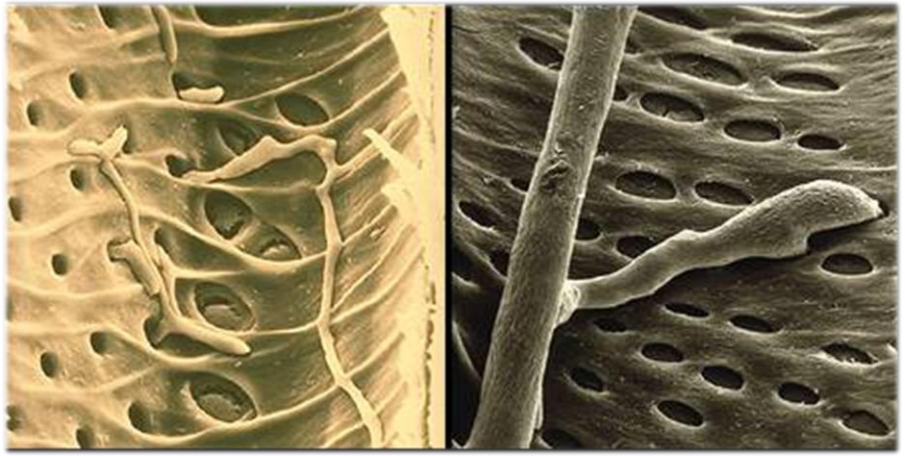
Caused by *Ophiostoma ulmi* and *Ophiostoma novo-ulmi*



ELM THREAT

A dead elm tree is a silent threat to all living elms. It may serve as a breeding place for elm bark beetles which transmit the lethal Dutch elm disease. Cut down and burn all dead trees. If the tree cannot be removed now, at least strip and burn the bark, which might be a shelter for the beetles.

NYT Sept 30, 1956

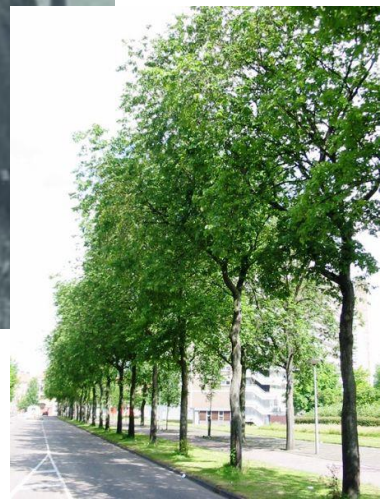


Scanning electron micrographs of mycelial growth of *O. ulmi* in elm xylem vessels. www.dutchelmdisease.org

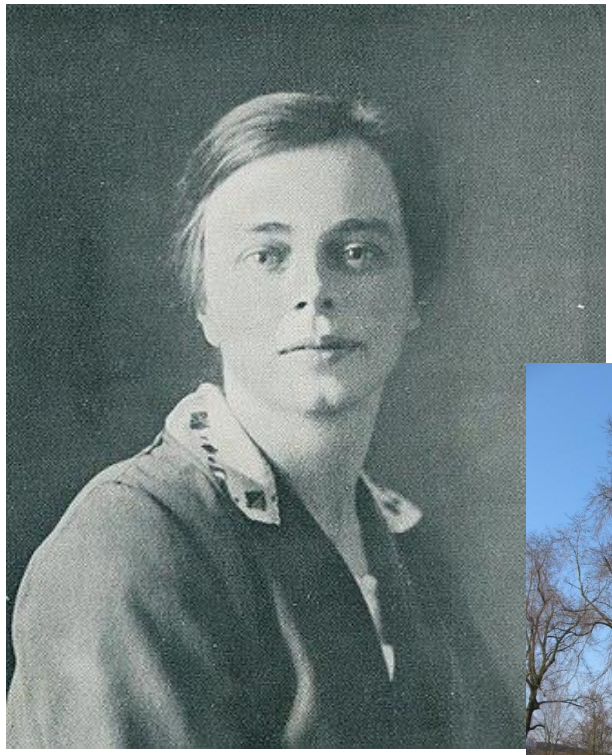
Xylem discoloration caused by DED

DED pioneers

Dr. Marie Beatrice Schol-Schwarz
and Dr. Johanna Westerdijk

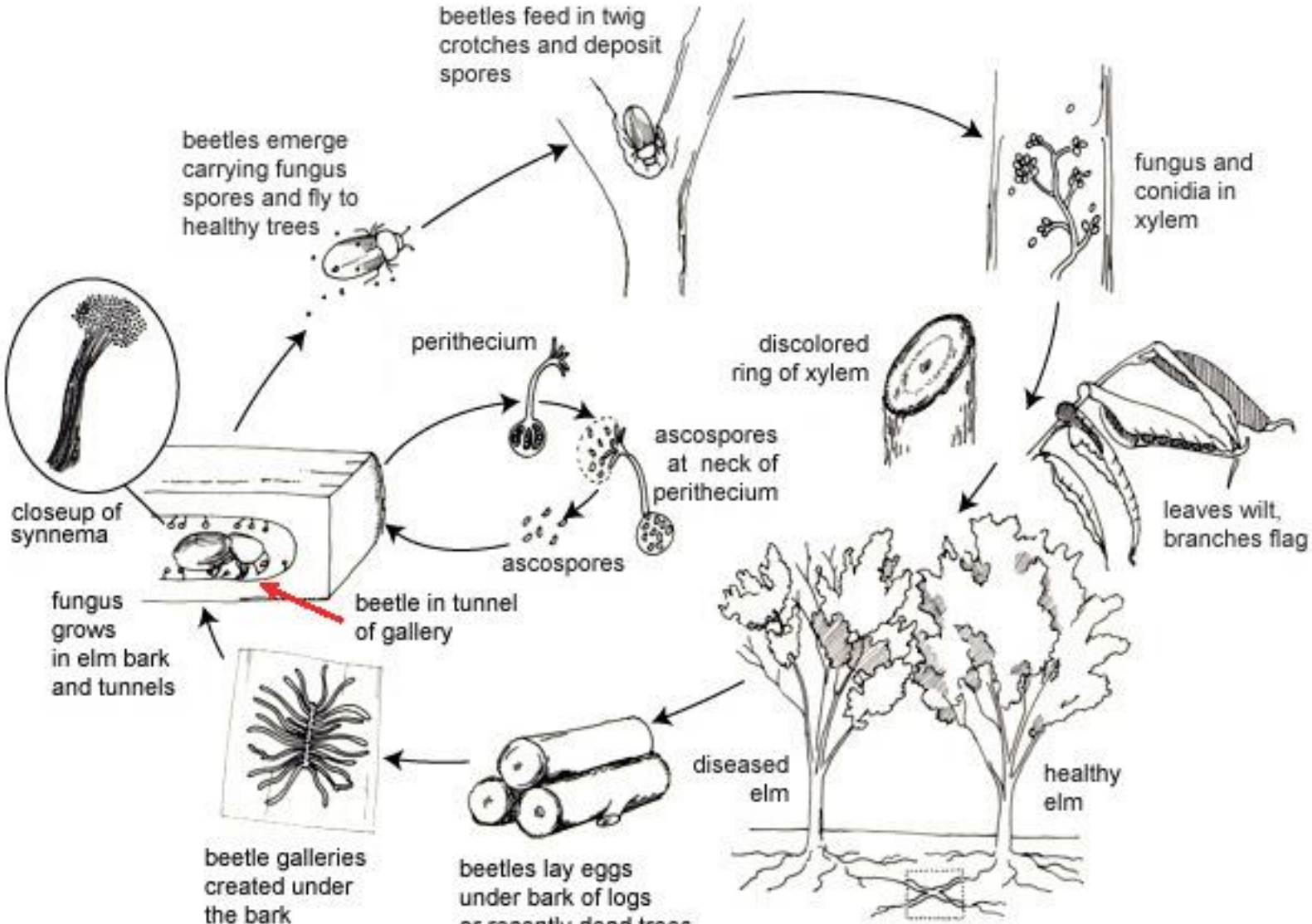


Ulmus x hollandica
'Bea Schwarz'



Dr. Christine Buisman

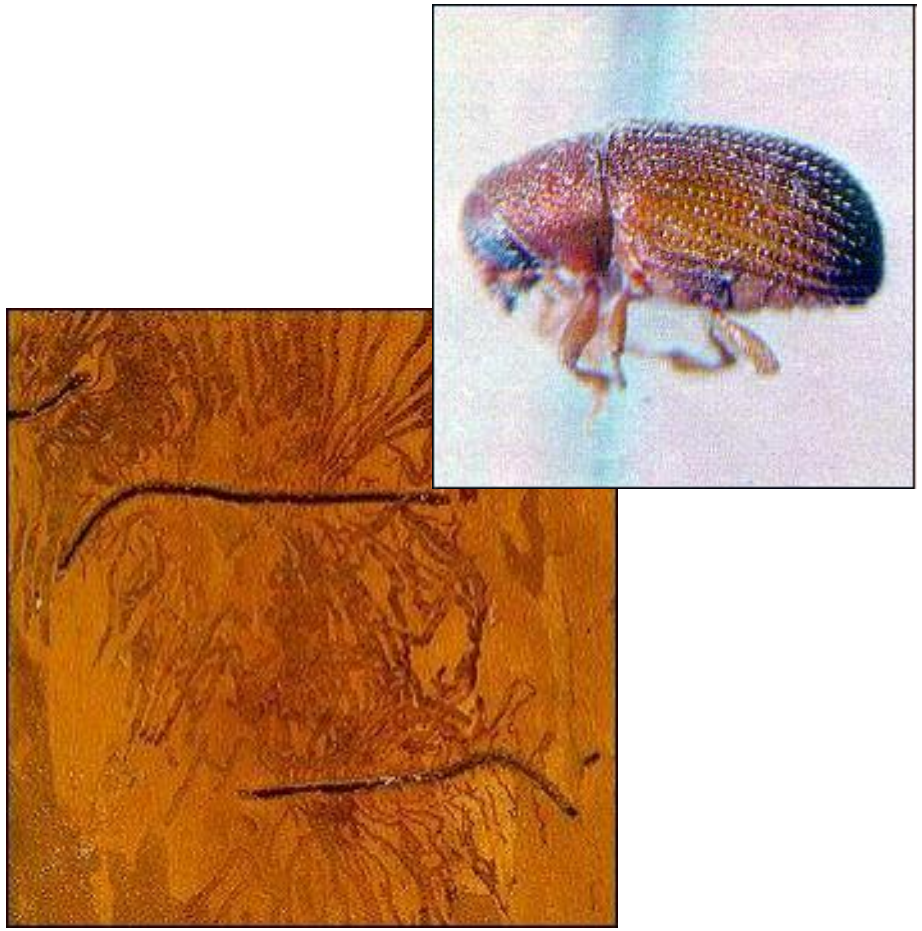
Ulmus minor
'Christine Buisman'



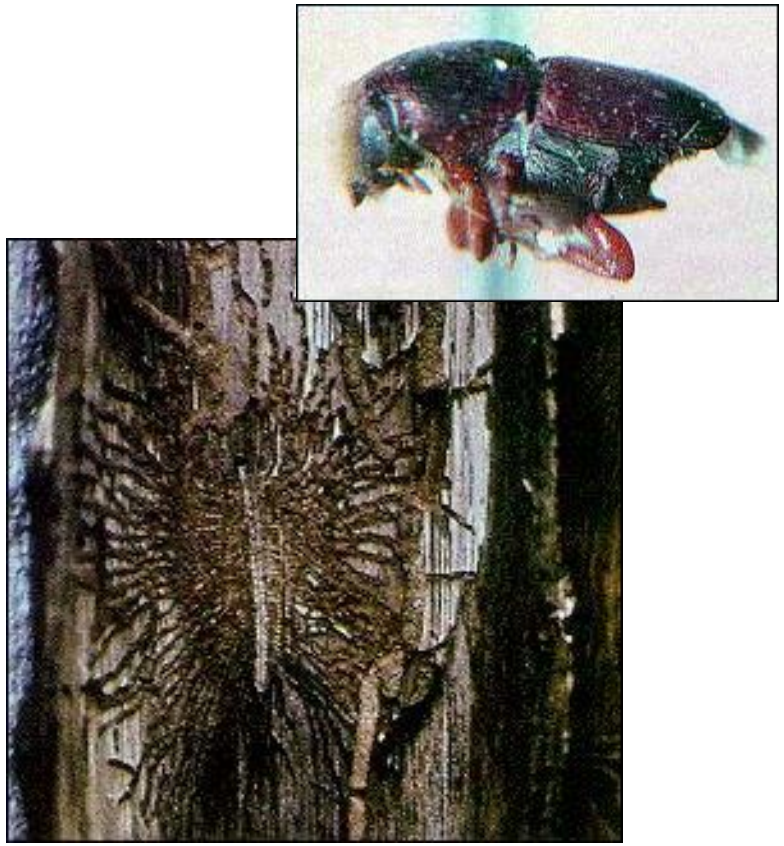
Drawing courtesy Vickie Brewster

Vectors of Dutch Elm Disease

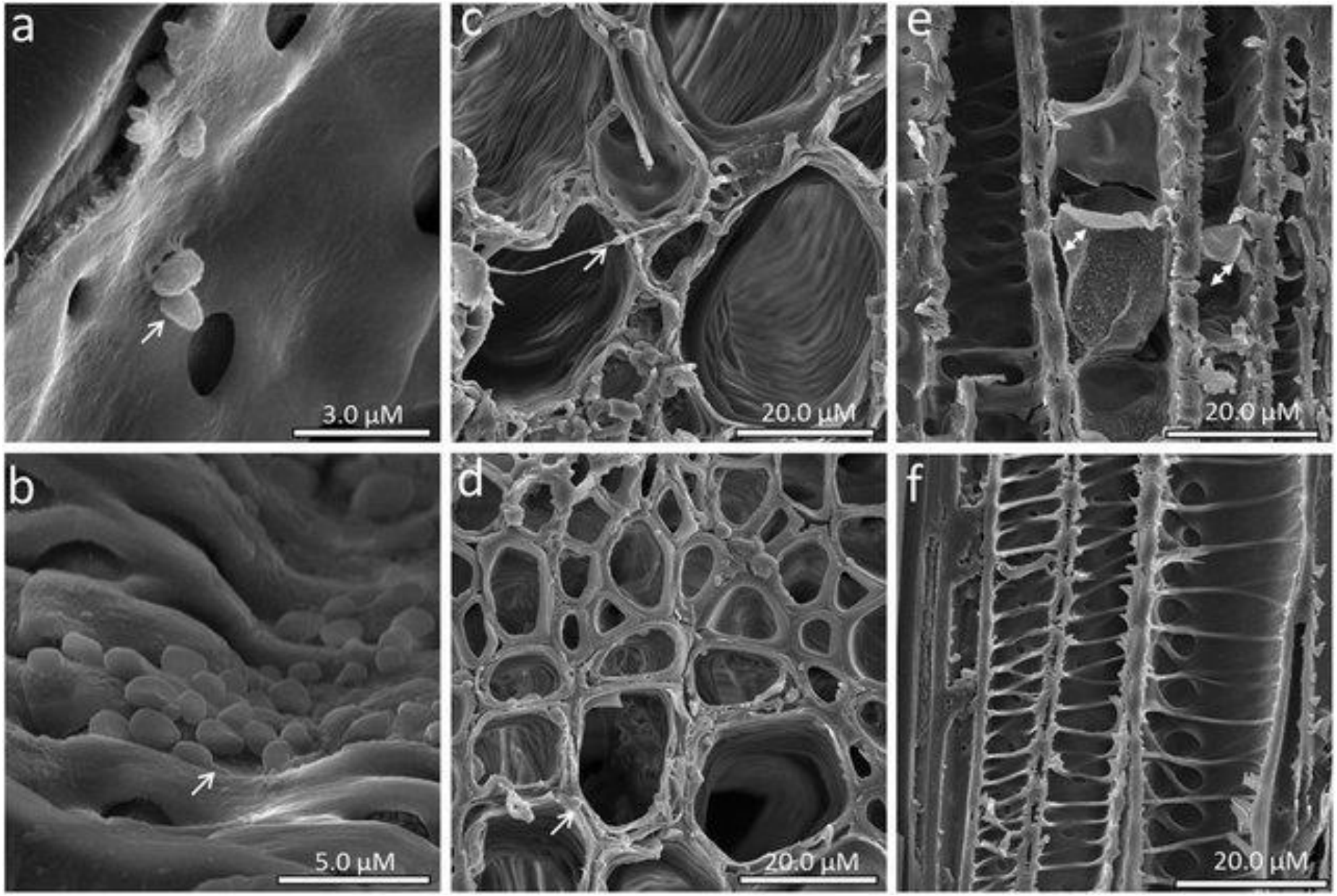
Native elm bark beetle



Smaller European elm bark beetle



P. Svihra, apsnet.org



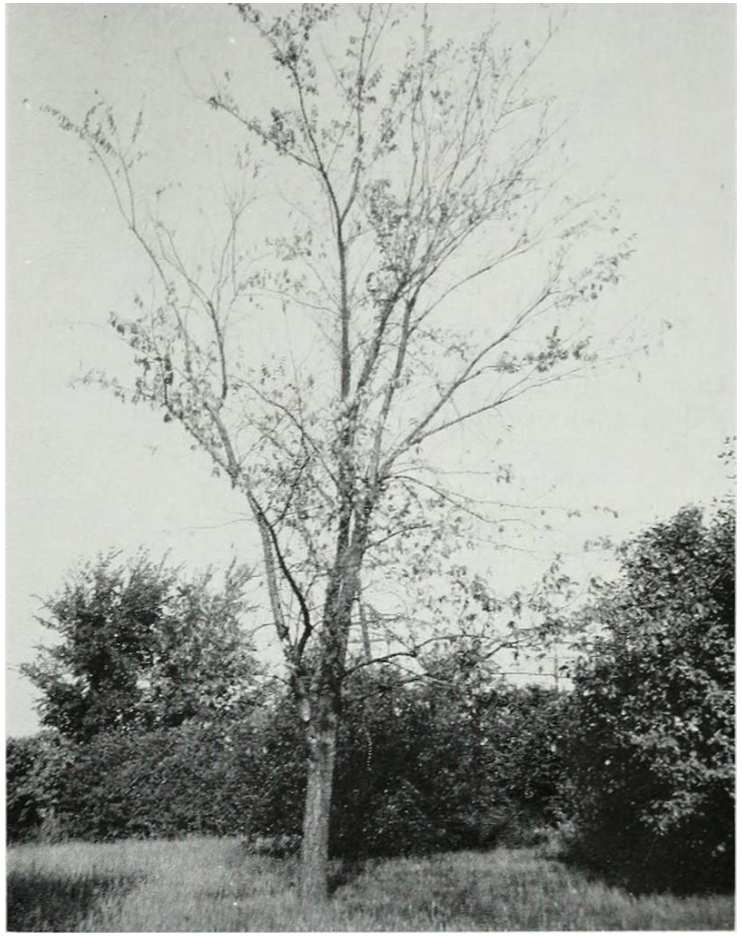
Sherif SM, Shukla MR, Murch SJ, Bernier L, Saxena PK. Simultaneous induction of jasmonic acid and disease-responsive genes signifies tolerance of American elm to Dutch elm disease. Scientific reports. 2016 Feb 23;6:21934.

Early DED control efforts

The Gazette

(Photograph by Walter Dahlberg)

Impacts of Dutch Elm Disease on the American Elm



From “Dutch elm disease in Illinois”, by J.C. Carter

Photo credit: University of Wisconsin Extension

By 1960, over 40 million American elm trees had died

American elm breeding efforts

- Research on American elm has focused primarily on the identification of selections that can withstand the DED pathogen.

- More than 100,000 American elm trees have been tested for resistance to DED, with very few exhibiting adequate levels of tolerance:

    - Cornell University and Boyce Thompson Institute
        - 16 of 21,000 inoculated seedlings demonstrated decent tolerance
    - The University of Wisconsin began a research and breeding program 1950s
        - Extensive research resulted in 6 select trees known as “American Liberty Multiclone”
    - The National Arboretum of the Agricultural Research Service
        - New Harmony and Valley Forge
    - The University of Guelph: Elm Recovery Project
    - The Morton Arboretum
        - Bred other *Ulmus* species for replacement

Denny Townsend, ARS

Commercially available American elm with increased DED-tolerance

Princeton

New Harmony

Jefferson

Not enough genetic diversity for ecological restoration plantings

No/little tolerance to elm yellows

Growth form not ideal for urban plantings

Valley Forge

Colonial Spirit

Prairie Expedition

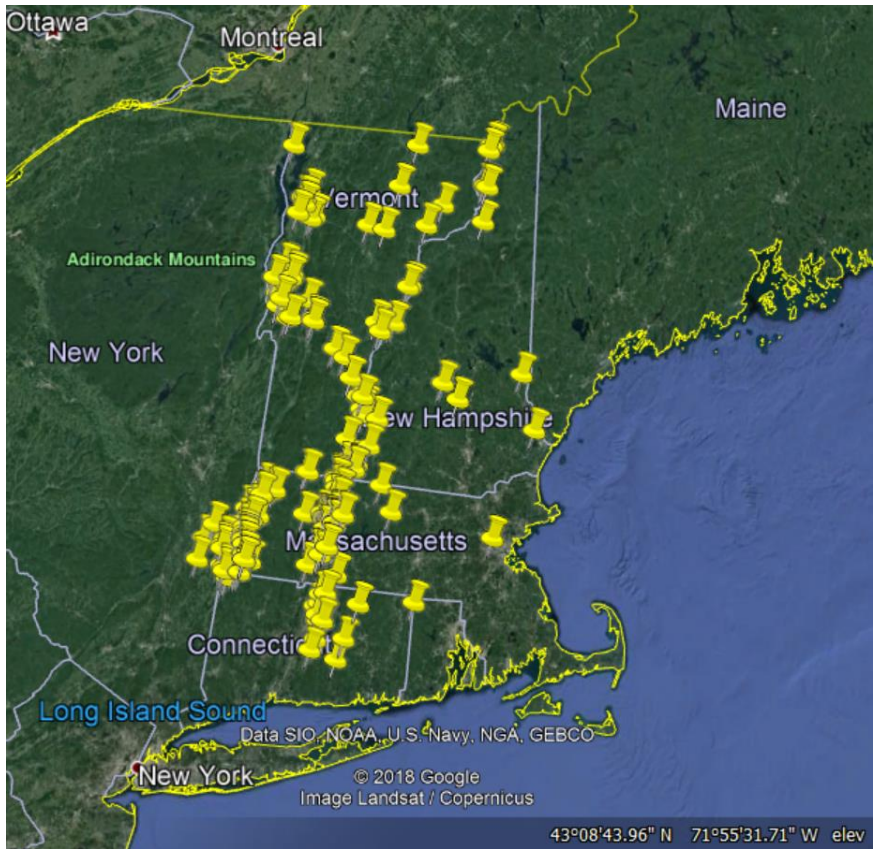
St. Croix

American Elm Restoration Research

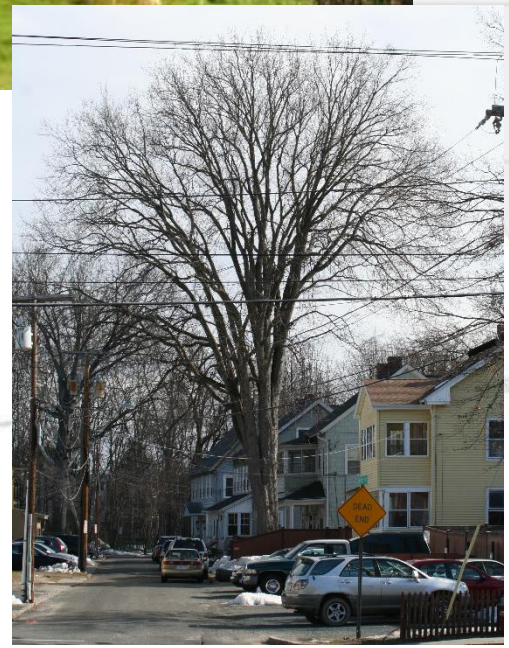
Primary Goal: Produce genetically diverse, DED-tolerant American elm for reintroduction in forests and urban areas

1. **Identify additional DED-tolerant American elms for horticultural selections**
2. **Identify additional DED-tolerant American elms for seed orchards for restoration plantings**
3. Test resistance of DED-tolerant elms to different strains of the DED fungus
4. **Develop guidelines for reintroducing elm to rural and urban areas**
5. Identify genes responsible for DED tolerance
6. And more!

Identify Additional DED-tolerant American elms: Survivor elms from partners and website



Large survivor elms in the North Eastern US identified by C. Marks



824 Submitted elms

Propagate clones of survivor trees

- We have a residual bank of elm material and have recently sourced 41 survivor elms from New England, Michigan, and Ohio which were propagated from 2016-2017.

"West Springfield #4" elm in Massachusetts

Elm Propagation Techniques

Scion is grafted onto existing rootstock

Cuttings are taken from grafted material and new clones are generated

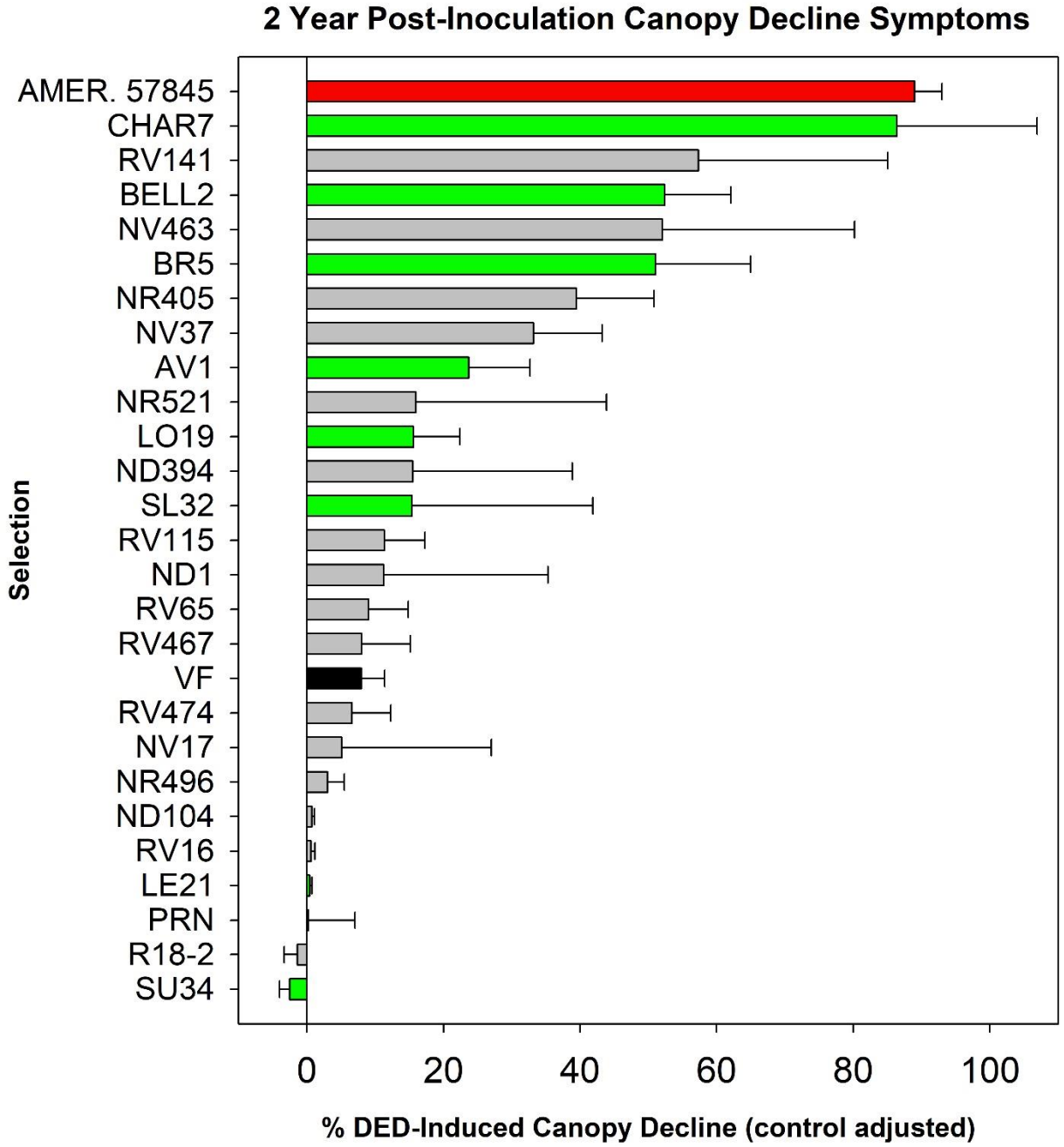
Controlled pollinations

After 5-7 years of growth, trees are inoculated with DED to test tolerance

Lower Midwest survivor elms

Dale Lesser, farmer

- Clones of 22 survivor American elms were planted in complete replicate blocks in Delaware, OH and inoculated with DED ~ 10 years after planting



Upper Midwest survivor elms

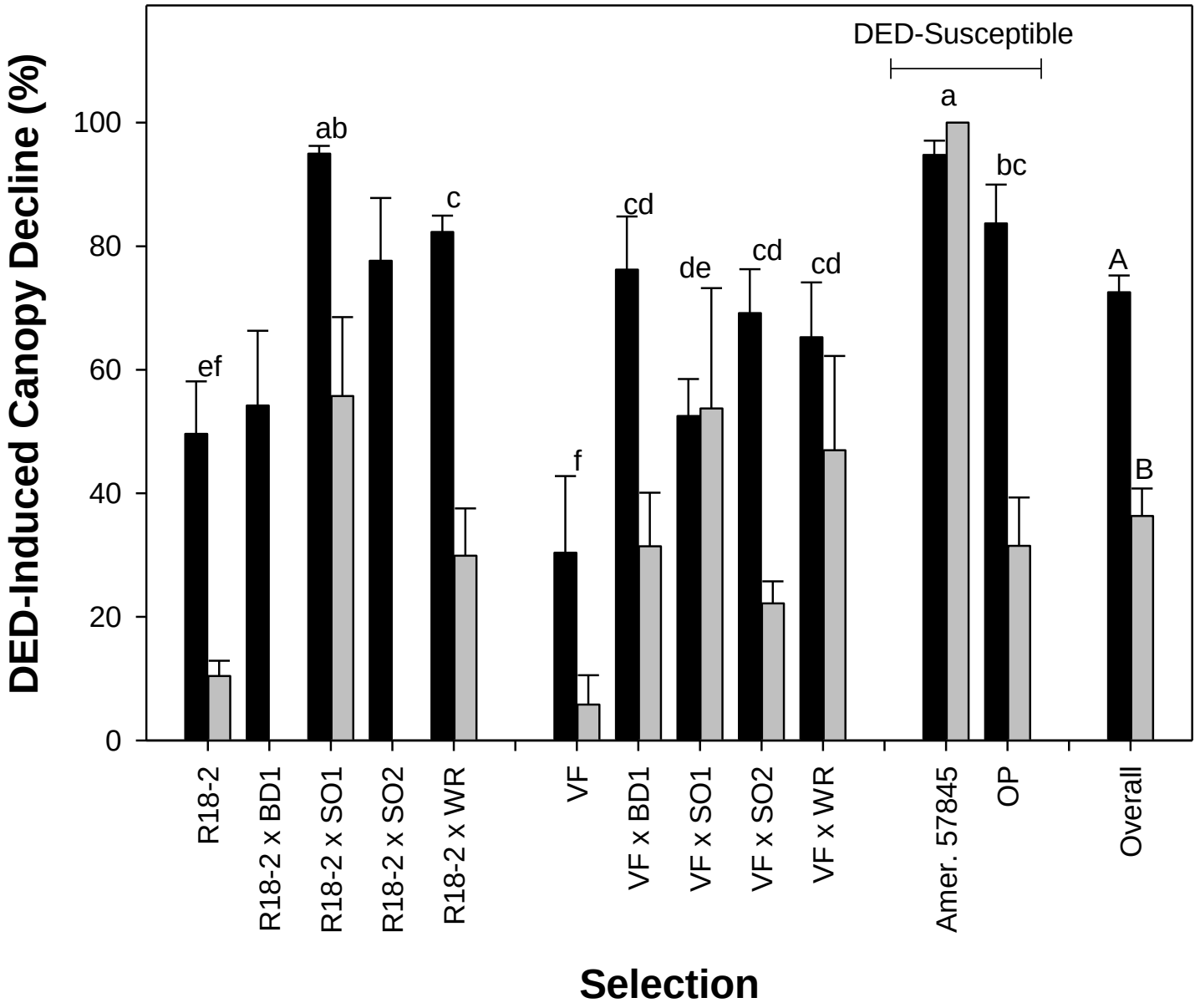
Chippewa National Forest

- 2007-2009 Crosses between 4 survivor American elms and 4 DED-tolerant elms were made and planted in completely randomized block design replicated in 3 sites in MN and 1 in OH

In collaboration with Gary Swanson, Region 9, Chippewa NF

Upper Midwest survivor elms

Chippewa National Forest



American elm reintroduction across the rural to urban gradient

“If ecosystems are viewed as open and dynamic, re-creation of some historic condition becomes an exercise in nostalgia.”

- Richardson, David et al. 2007 "Riparian vegetation: degradation, alien plant invasions, and restoration prospects." *Diversity and distributions* 13(1): 126-139.

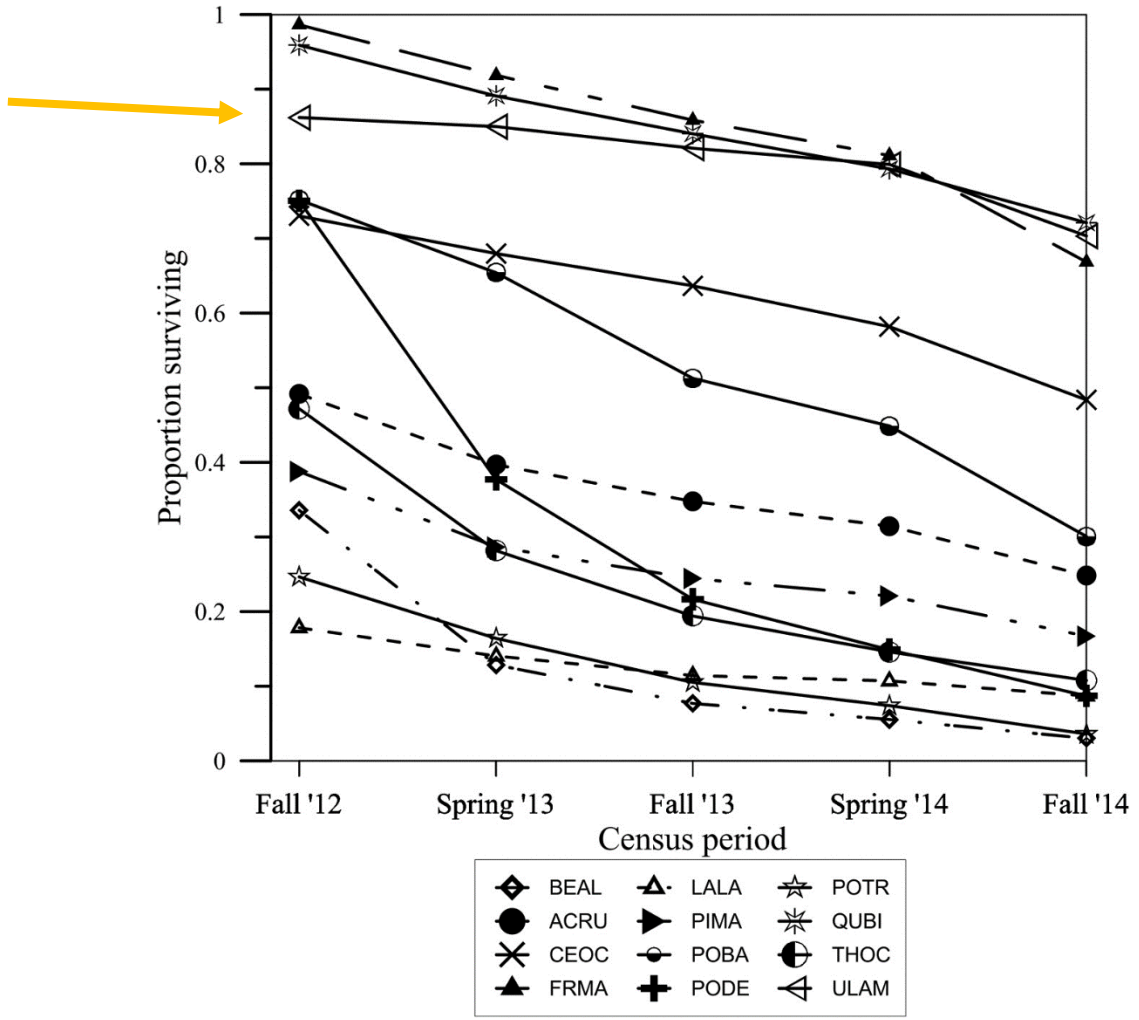
Reintroduction of elm to rural ecosystems

- American elm as a component of restoration strategies:
  - Emerald ash borer impacted floodplains
  - Formerly grazed riparian corridors
  - Reclaimed minelands

Grazed riparian corridors

EAB impacted floodplain

Modern ecological relevance of American elm



Looney CE, D'Amato AW, Palik BJ, Slesak RA. Overstory treatment and planting season affect survival of replacement tree species in emerald ash borer threatened *Fraxinus nigra* forests in Minnesota, USA. Canadian Journal of Forest Research. 2015 Aug 19;45(12):1728-38.

Ecosystems (2016) 19: 248–270
DOI: 10.1007/s10021-015-9929-y

ECOSYSTEMS

Potential Species Replacements for Black Ash (*Fraxinus nigra*) at the Confluence of Two Threats: Emerald Ash Borer and a Changing Climate

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Abstract

The emerald ash borer (*Agrilus planipennis;* EAB) is causing widespread mortality of ash (*Fraxinus* spp.) and climate change is altering habitats of tree species throughout large portions of North America. Black ash (*F. nigra*), a moist-soil species common in the Northwoods of Minnesota, Wisconsin, and Michigan, USA, is under a double threat of losing habitat from climate change and near annihilation from EAB. Because black ash often occurs in nearly pure stands, planting non-ash species is a management strategy already underway or being planned for thousands of acres. Tools are needed to assist managers in prioritizing sites for early treatment and to select potential species to replace black ash. This study explores the implications of threats to black ash ecosystems using analyses of field data and models to assess both the threats to, and potential replacement species for, black ash in Minnesota. For our analysis we (1) assessed the status of ashes and co-occurring species in forest inventory plots throughout Minnesota; (2) modeled the risk of EAB attack for multiple years in Minnesota; (3) modeled potential impacts of climate change on tree species with current or potential future habitat in Minnesota; (4) evaluated species co-occurring with black ash in plots in Ohio and Michigan, southeast of Minnesota; and (5) synthesized these results to provide a classification for candidate replacement species, both from within Minnesota and from points farther south. Though this process is demonstrated for black ash in Minnesota, the elements to be considered and modeled would be similar for any other location with a pest or pathogen threat for a species which simultaneously faces a changing climate.

Key words: assisted range expansion; invasive insect spread model; climate change; emerald ash borer; multiple forest threats; restoration; species distribution models.

Received 30 December 2014; accepted 23 August 2015;
published online 2 November 2015
Author contributions LI designed study. All authors performed research. JA, SM, MP, AP, KK, LI analyzed data. LI KK wrote the paper.
*Corresponding author; e-mail: liverson@fs.fed.us

Introduction

Two of the most significant issues facing natural resource managers are invasive species and climate change. The globalization of trade and transport accelerates risk of invasions (Lodge and others

"The models showed that many species currently dominating the Northwoods, quaking aspen, balsam fir, balsam poplar and paper birch, may lose substantial habitat due to warming and varied hydrological conditions, and thus are less suitable as long-term replacement species. **Species including American elm,** American basswood, red maple, bur oak, and boxelder **may be able to colonize areas vacated by the loss of black ash."**

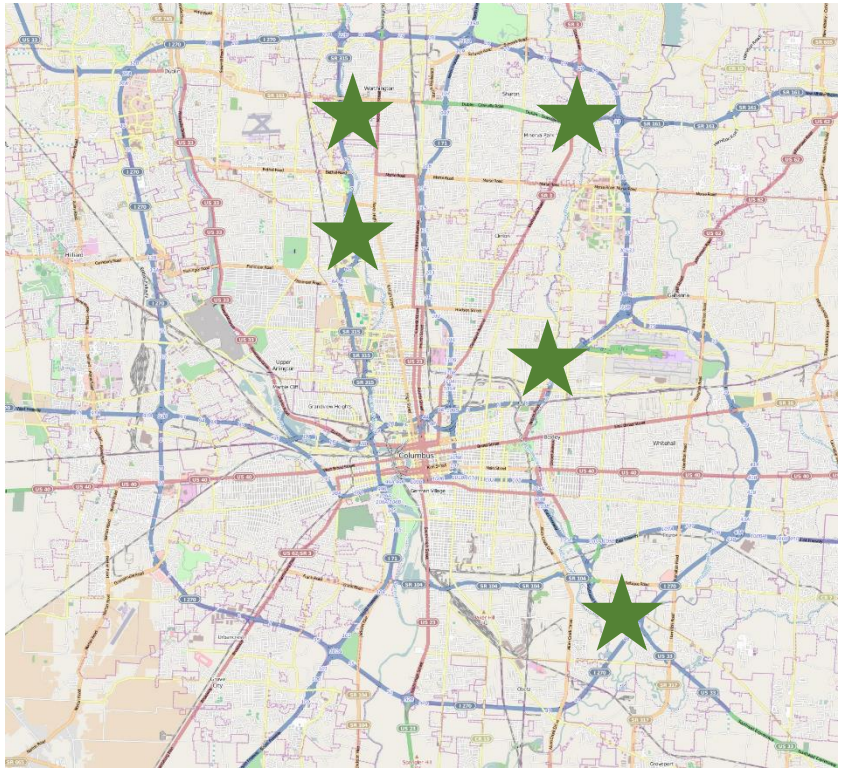
Reintroduction of elm to urban/suburban ecosystems

- Unique challenges:
  - Harsh conditions
    - Compaction
    - Contaminated soil
    - Heat island effect
    - Construction
    - Vandalism
    - Competition from invasive species
  - Aesthetic and structural requirements
  - Require higher levels of disease tolerance
  - Require higher levels of success

Photo by Christian Marks, TNC

Using elms to enhance urban riparian forests across Columbus, OH

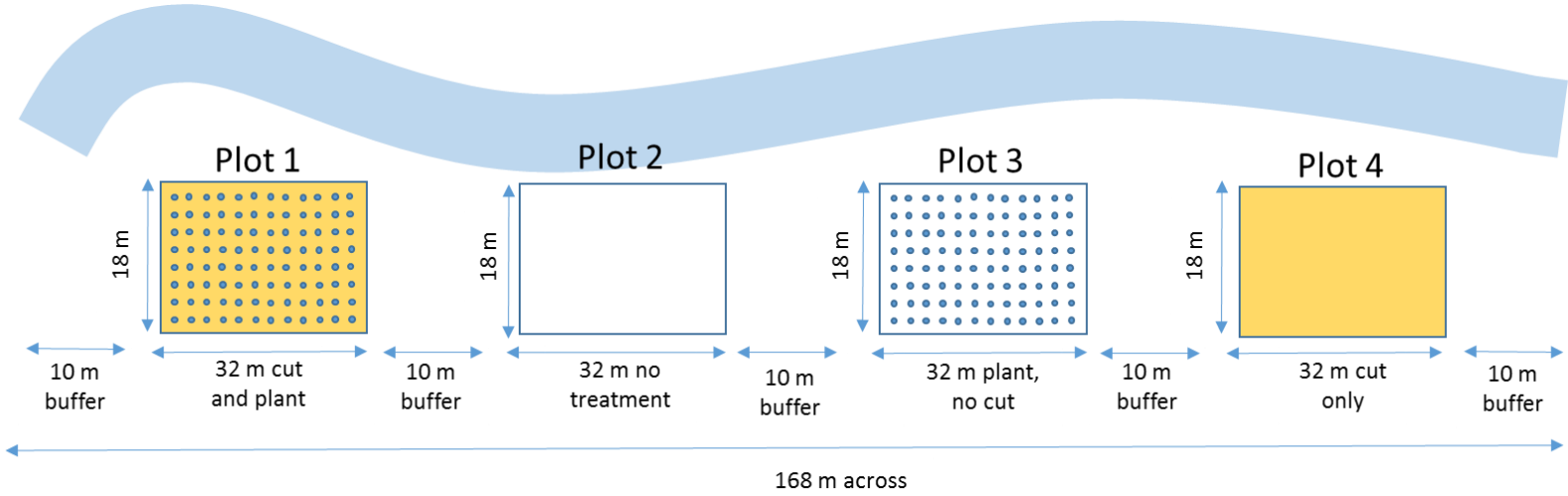
Urban riparian corridor heavily invested with Amur honeysuckle



Columbus, Ohio

Using elms to enhance urban riparian forests across Columbus, OH

- Overarching research goal to control invasive shrubs, enhance biodiversity and habitat quality.
  - Enhance ecosystem function via removal of the invasive understory.
  - Investigate the relationships between vegetation structural complexity and avian abundance/behavior.
  - Reintroduce native woody plant material (elm, bur oak, pawpaw, musclewood, coralberry, nannyberry).
  - Determine strategies and guidelines for riparian restoration.



In collaboration with S. Matthews, A. Fotis, City of Columbus, Columbus Recreation and Parks Dept.

Using elms to enhance urban riparian forests across Columbus, OH

Honeysuckle removal (followed by chemical treatment)

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Honeysuckle removal and seedling planting

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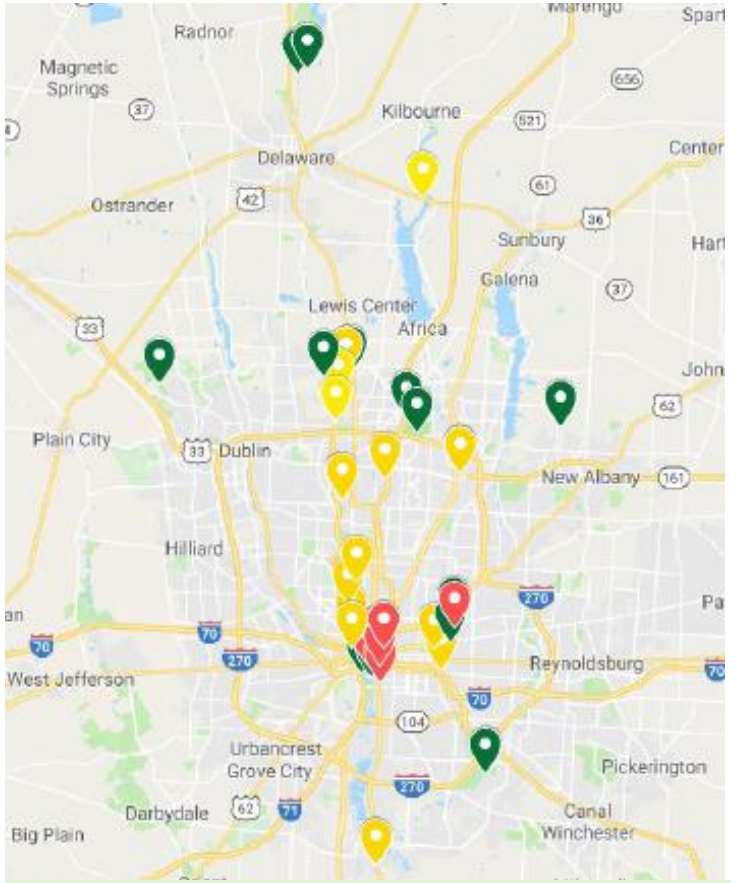
- Evaluating:
  - Survival and growth among planted seedlings (elm, bur oak, paw paw, spicebush, nannyberry, and musclewood)
  - Vegetation dynamics across treatments and over time
  - Changes in structural complexity using handheld LIDAR among treatments and over time
  - Wildlife use and impact across treatments

Test newly developed DED-tolerant elms across an urbanization gradient

- Many of the newly developed DED-tolerant American elms have not been tested for tolerance to urban stressors.

- We are working with municipalities across 3 cities to investigate the tolerance of these elms.
  - Columbus, OH
  - Philadelphia, PA
  - Newark, DE

- We will investigate how urbanization metrics and a variety of other factors drive elm tree establishment and growth.



Potential planting sites in Columbus, OH

In collaboration with V. D'Amico, T. Trammel, L. Roman, K. Nislow, City of Columbus, Columbus Recreation and Parks Dept.

Future Directions

- Continue to identify and test potentially DED-tolerant material.
- Investigate differential virulence/pathogenicity of DED from around the US.
- Understand gene flow associated with our DED-tolerant restoration plantings.
- Continue investigations into DED-resistance genes.

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