Resistance to EAB is real – here's what we can do to help restore ash in the future

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EAB Awareness Week 2026

Outline

1. The threat EAB poses across the US
2. Introduce resistance breeding and tree improvement
3. Steps to making resistance breeding work
4. Contrast green/white with blue and black ash
5. How you can participate
6. Acknowledgments

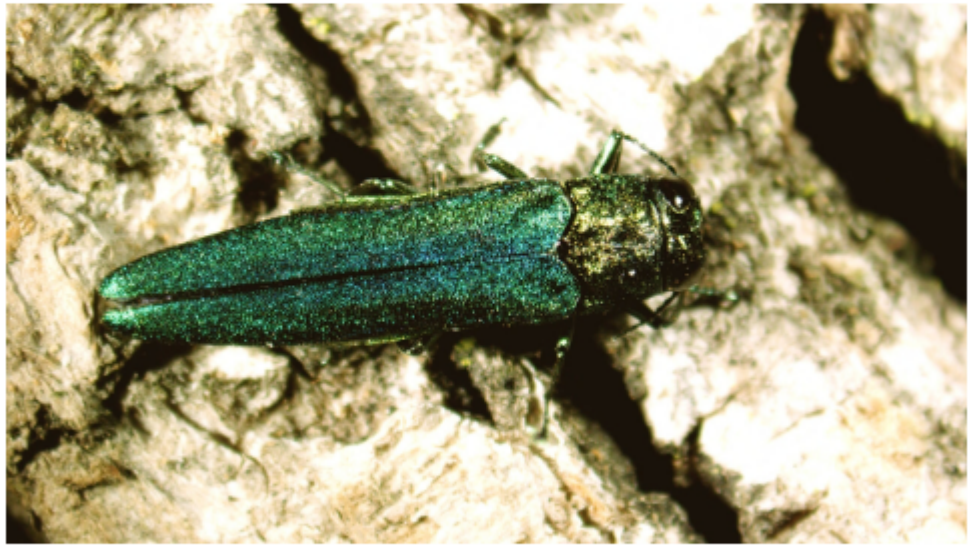
Emerald ash borer: *Agrilus planipennis*

Home > Plants > Plant Health > Plant Pests and Diseases > Emerald Ash Borer

Emerald Ash Borer

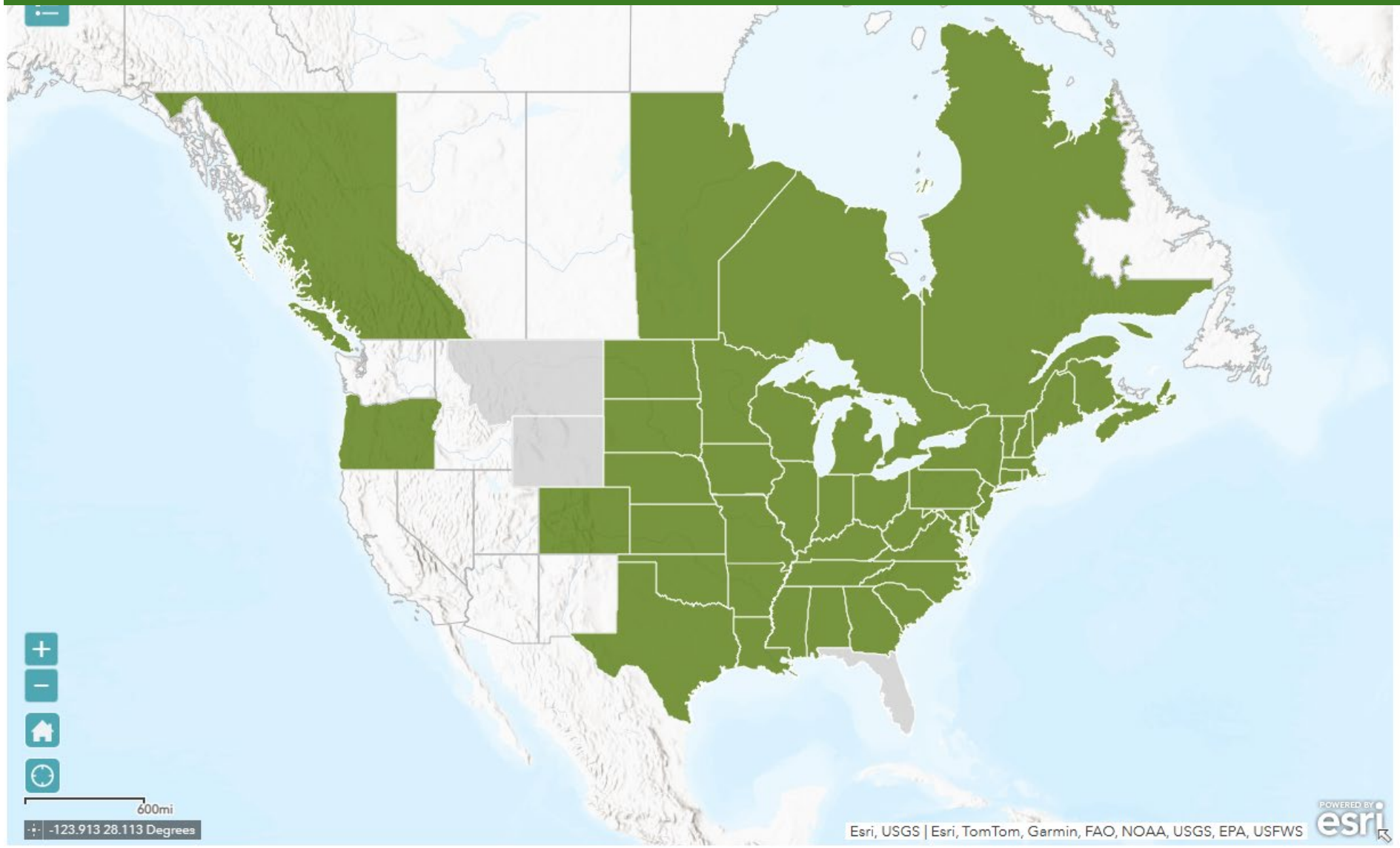
Last Modified: April 03, 2026

The emerald ash borer (EAB), an invasive wood-boring beetle from Asia, is responsible for the death and decline of tens of millions of ash trees in North America. EAB lays its eggs in the bark crevices of ash trees. The eggs hatch and the larvae burrow into the tree where they feed. This feeding is what damages the trees. We have detected EAB infestations in 37 States and the District of Columbia.



https://www.aphis.usda.gov/plant-pests-diseases/eab

Current distribution of EAB in North America



Over 8 billion ash trees in North America may be impacted!

https://www.emeraldashborer.info/


EAB is devastating...

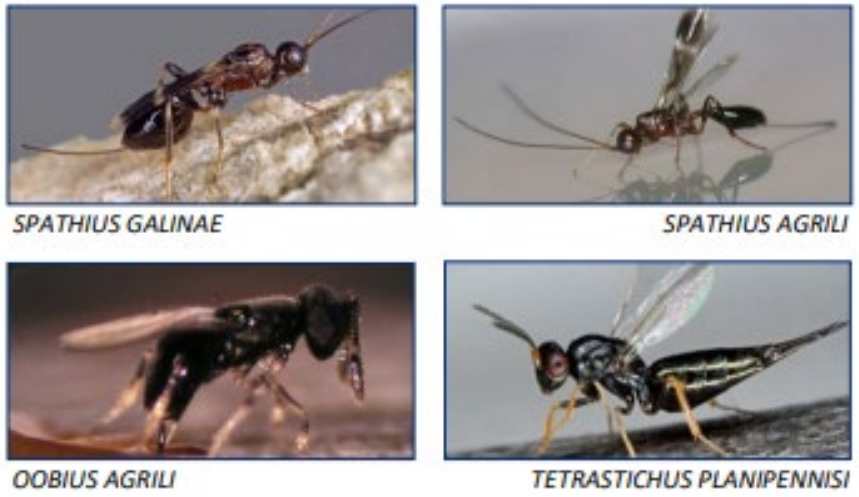
…but there is that 1% that survives!

This is the silver lining.

Response options

Prevention:

- "slow-the-spread"
- Chemical treatments insecticides
- Biological controls



https://www.aphis.usda.gov/sites/default/files/faq_eab_biocontrol.pdf

DONTMOVEFIREWOOD.org

Table 1. Insecticides for EAB management.

Insecticide Class	Active Ingredients (Trade Name)	Method of Application	Recommended Timing and Use	Relative Efficacy and Frequency of Application
Pyrethroids (3A) (Contact insecticides)	Bifenthrin (OnyxPro®) Cyfluthrin (Tempo® SC ULTRA) Permethrin (Astro®)	Preventive trunk, branch, and foliage cover sprays.	Late spring to early summer. Two applications a month apart.	Moderate: can protect trees for 1 year.
Neonicotinoids (4A) (Systemic insecticides)	Imidacloprid (Merit® 75 WP, Merit® 75 WSP, Merit® 2F, Xytect® 2F)	Soil injection or drench.	Early to middle spring or middle fall.	Good: can protect trees for 1 year.
	Imidacloprid (Imicide™)	Trunk injection.	Middle to late spring after trees have leafed out.	Very good: can protect trees for 1 to 2 years.
	Dinotefuran (Safari® 20 SG, Transtect™, Zylam® Liquid Systemic Insecticide)	Soil injection, soil drench, or trunk spray.	Middle to late spring for soil application, or middle to late spring after trees have leafed out.	Very good as trunk spray: can protect trees for 1 year. Good as soil application: can protect trees for 1 year.
Avermectins (6) (Systemic insecticides)	Emamectin benzoate (ArborMectin®, TREE-äge G4, TREE-äge R10)	Trunk injection.	Middle to late spring after trees have leafed out.	Excellent: can protect trees for 1 to 3 years.
Azadirachtin (UN) (Systemic insecticides)	Azadirachtin (AzaSol™, Lalguard AZA, TreeAzin™ Systemic Insecticide)	Trunk injection.	Middle to late spring after trees have leafed out.	Very good: can protect trees for 1 to 2 years. Annual application is required with higher densities of EABs.

There may be other insecticides with the same active ingredients to use for EAB.

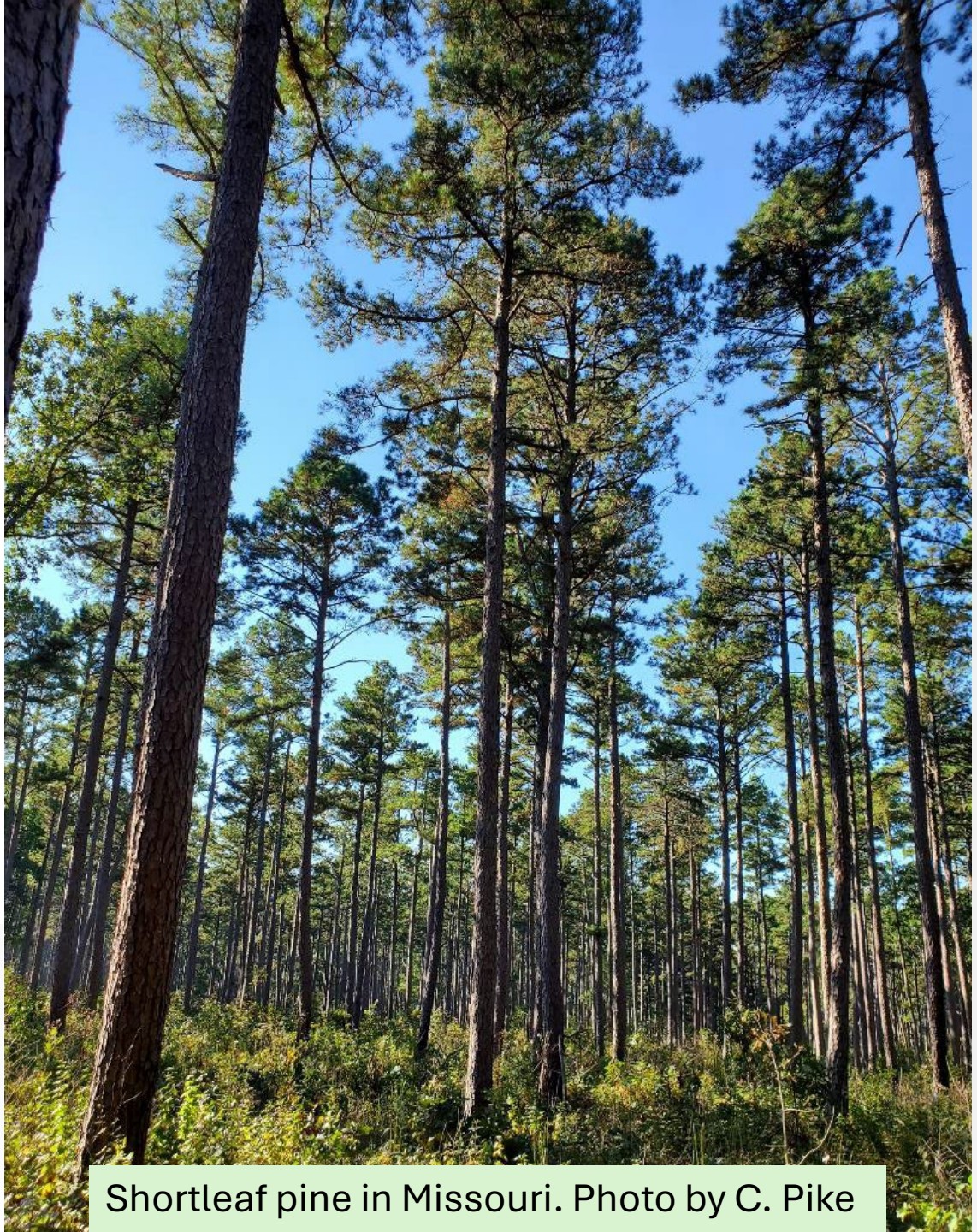
Post-EAB: reforestation

PLANT NON-EAB HOSTS

PLANT ASH WITH INCREASED RESISTANCE

Tree improvement: a time-tested paradigm for developing seed sources for reforestation

In the case of emerald ash borer we are trying to improve resistance instead of timber growth or form. The trait is different but the process is similar.



Shortleaf pine in Missouri. Photo by C. Pike

Trees are exceptionally good at “migration” through pollen and seed!

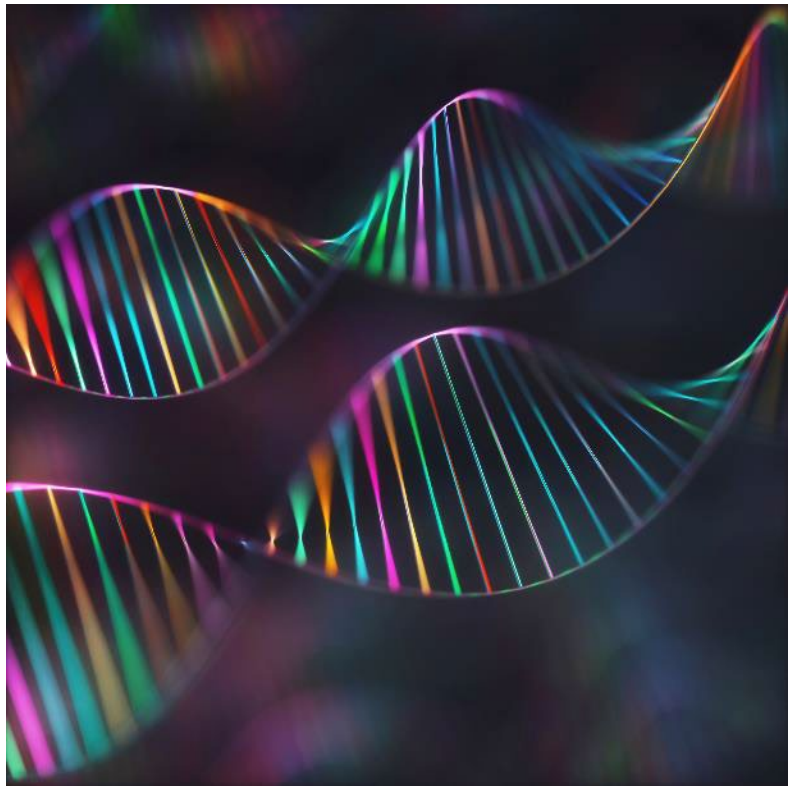
Genetic diversity tends to be VERY high: lots of variation on the chromosomes, large genomes, and some species have 4- or 6- sets of chromosomes

Genetic variation is the key to resistance (and may other things too)

- ✓ Huge ranges, big numbers
- ✓ Wind pollination & outcrossing
- ✓ Population structure
- ✓ Local adaptation to many environments
- ✓ Genetic processes …founder effect, etc. maintain MANY and RARE genes

With high levels of genetic variation, we don't usually know what genes code for which traits

In agriculture we have been breeding plants successfully for thousands of generations without ever knowing what genes were associated with traits of interest!



Genomics-based tools are now used to accelerate breeding in crops and trees.

100% immunity to a pest or disease is not the goal of resistance breeding! We are seeking partial resistance that can be amplified through breeding.

The goal of resistance breeding is to develop an improved seed source with latent amounts of genetic variation.

Cultivar

Genotype selected because of some desirable trait: flower color, leaf morphology, etc.

Usually clonally propagated through grafting or tissue culture

Example: Valley Forge American elm

Improved seed source

A population selected because of a desirable trait: growth rate, disease resistance

Propagated via seed, usually collected from a seed orchard with many genotypes represented.

Example: Loblolly pine in the southeastern US

Breeding has public support

Planting trees is an easy sell the public especially when the trees are not genetically modified.

Breeding is part of Integrated Pest Management

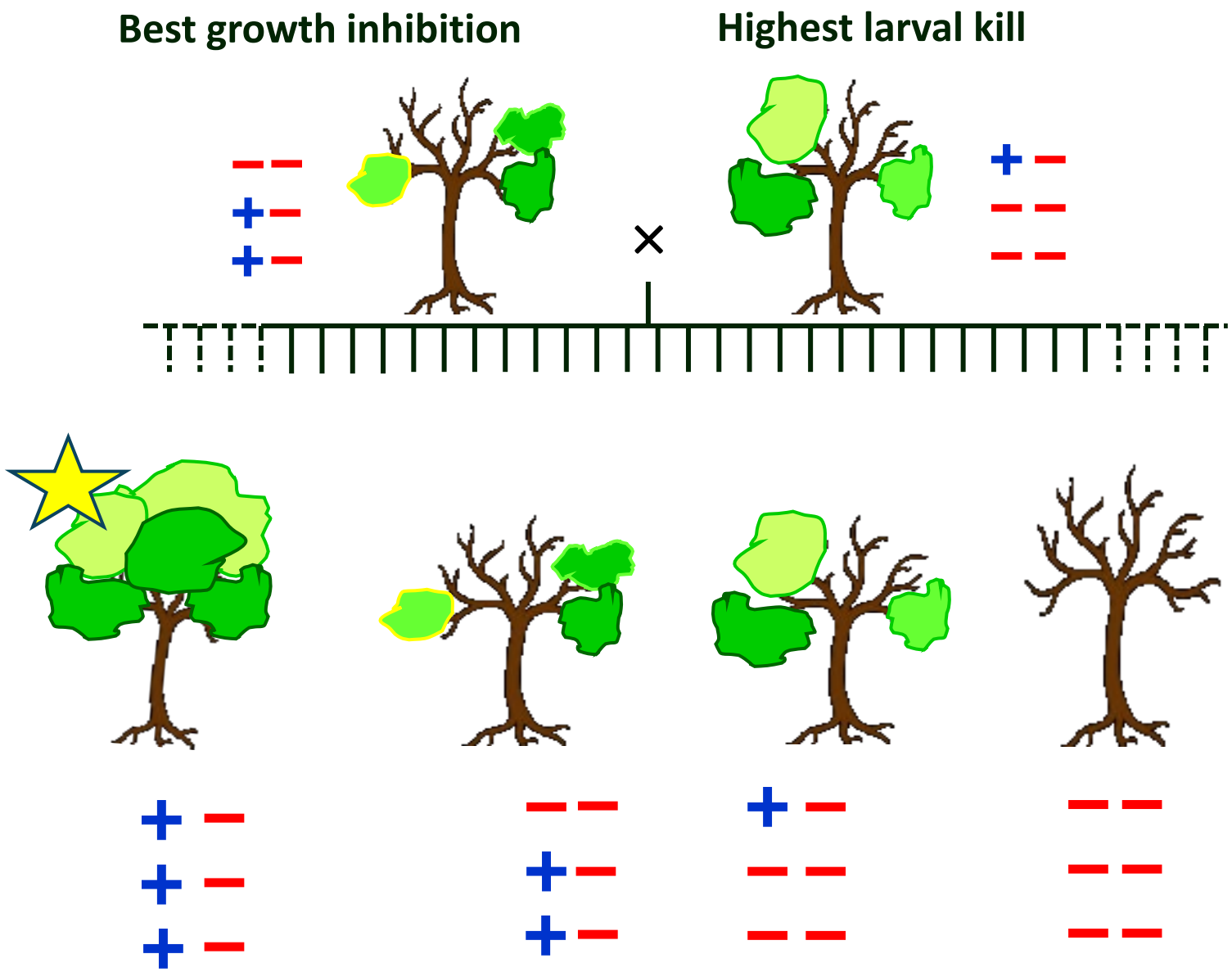
↑ **Host-Resistance + Insect Population** ↓

(selection & breeding) = (biocontrol)

Sustainable ash resources in North America in the future

Slide: J. Koch

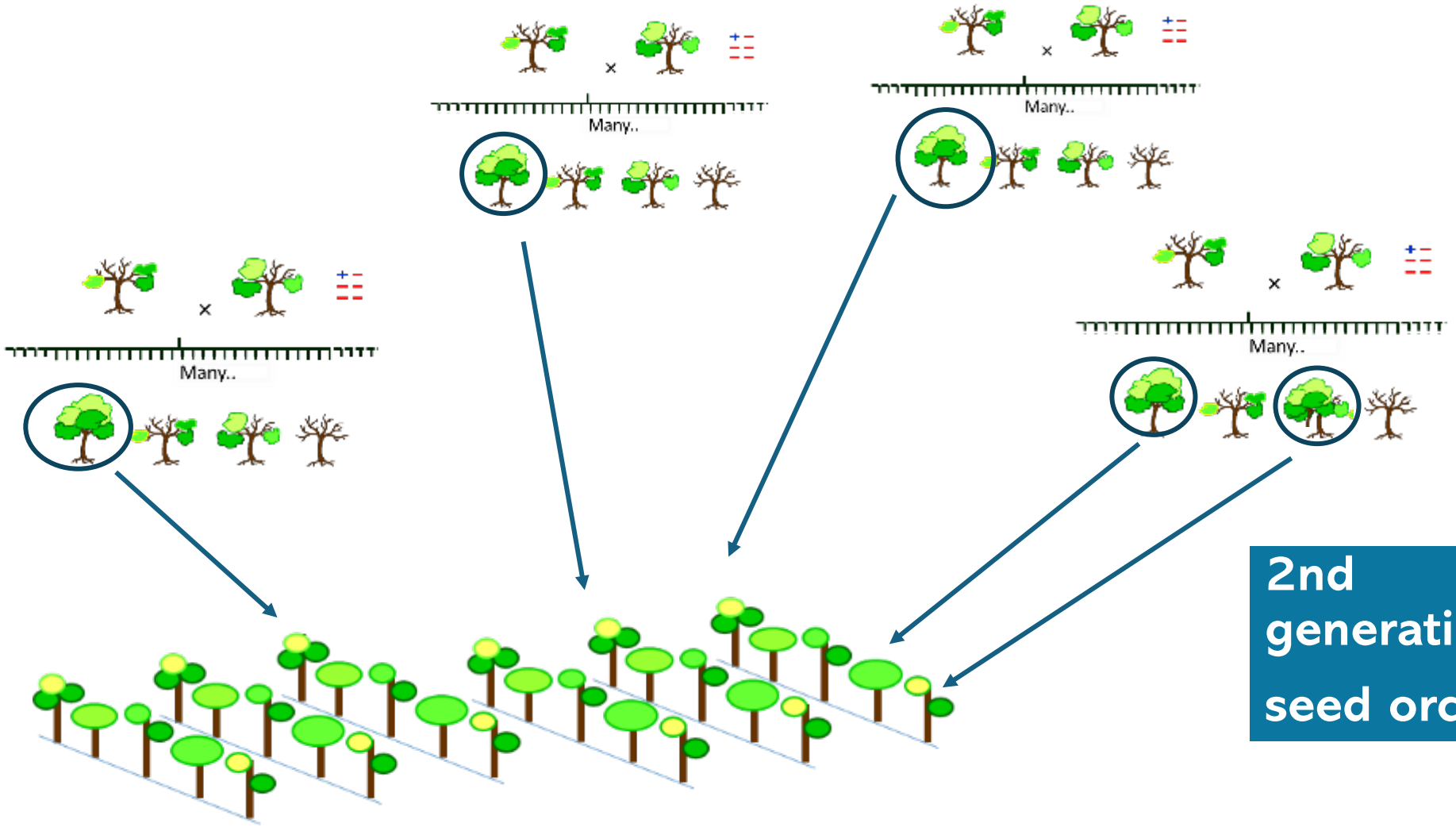
Breeding allows combining best genes from each parent!



Further improvement with each generation!

Slide: J. Koch

Best from many different L x L crosses



2nd generation seed orchard

Produce seed with increased defenses against EAB, retain genetic diversity and adaptive capacity

Slide: J. Koch

Steps in a resistance screening program

1. Identify trees with varying levels of resistance.
2. Select and graft survivors. Plant into a seed orchard or germplasm conservation area
3. Subject trees to a screening protocol to separate resistant from susceptible genotypes.
4. Make controlled crosses of unrelated lingering trees
5. Plant full-sibs into a seed orchard

I'll unpack these steps in the next slides....

1. Criteria for finding lingering green and white ash

- Large enough to have been
  Infested during peak EAB
  ≥10 cm dbh monitoring plot
  ≥20 cm dbh surviving ash
- Healthy canopy
- Alive after mortality rate leveled off
  4 years after ~50 % mortality
  2 years after > 95 % mortality

Slide: J. Koch

Range of phenotypes for ash trees in a forest infested with EAB

Susceptible

(Common)

Partial Resistance

(Rare)

Resistant

(Extremely Rare)

dead bole
dead crown

healing bole
healthy Crown

healthy bole
healthy Crown

Resistance is relative to susceptible tree response! Lingering trees may look a bit rough.

Lingering ash trees exist singly and clusters

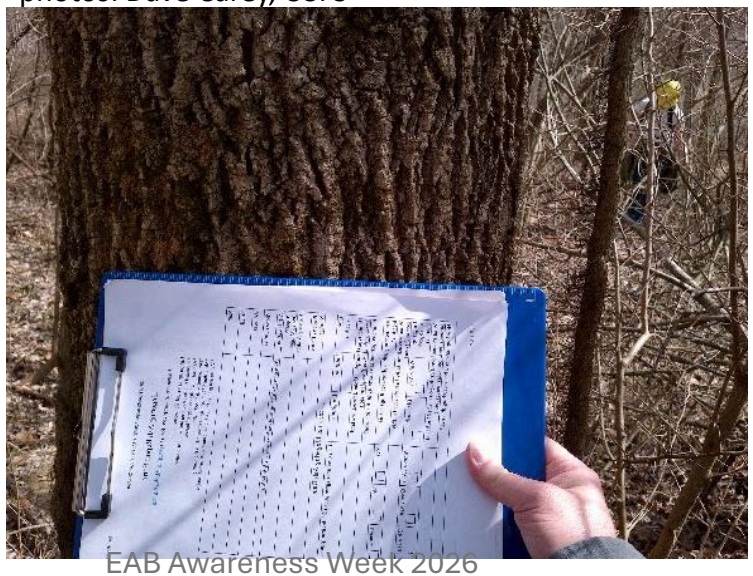
Slide by Mary Mason

Alum Creek, Ohio 2022

R: ‘bone yard’ of downed dead ash

Below: 2 heathy large ash trees a mile or so away

photos: Dave Carey, USFS



USDA
United States Department of Agriculture

Monitoring Ash (*Fraxinus* spp.) Decline and Emerald Ash Borer (*Agrilus planipennis*) Symptoms in Infested Areas

Kathleen S. Knight
Britton P. Flash
Rachel H. Kappler
Joel A. Throckmorton
Bernadette Grafton
Charles E. Flower

Forest Service
Northern Research Station
General Technical Report NRS-139
September 2014

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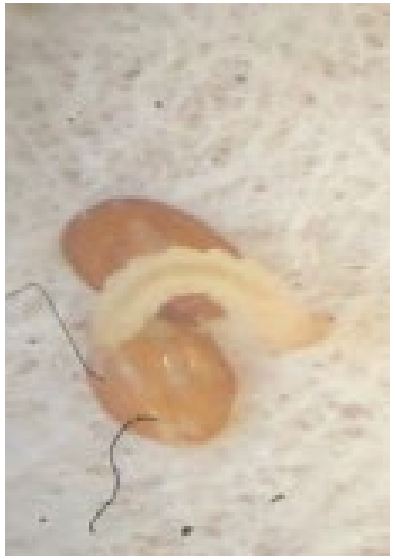
EAB Awareness Week 2026

3. EAB Egg Bioassay
(assess resistance phenotype)



Coffee filter with eggs

Coffee filter with eggs affixed to bark

Three grafted replicates of each genotype

Slide: J. Koch

EAB Egg Bioassay: metrics

- Egg hatched - Y/N?
- 8 weeks-larval outcome:
  L1 (Instar 1), L2, L3, L4,
  Host-killed
- Larval weight
- **LA are significantly different from unselected controls**

Healthy larva

Host-killed larva

We focus analysis on the proportion of larvae the tree kills!

Slide by Mary Mason

Common types of tree killed larvae

Entry Point

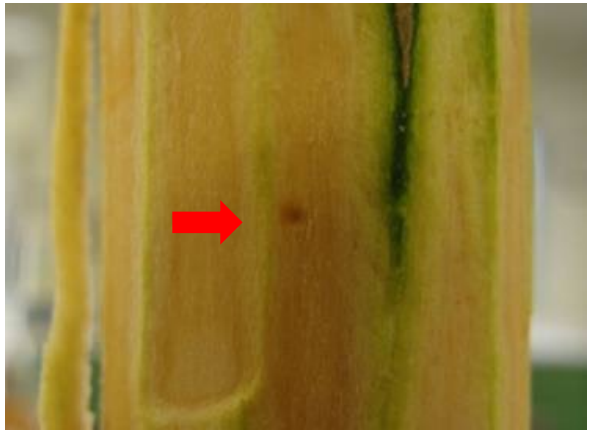
short gallery

Asian Species

Manchurian Ash

Manchurian Ash

North American Species

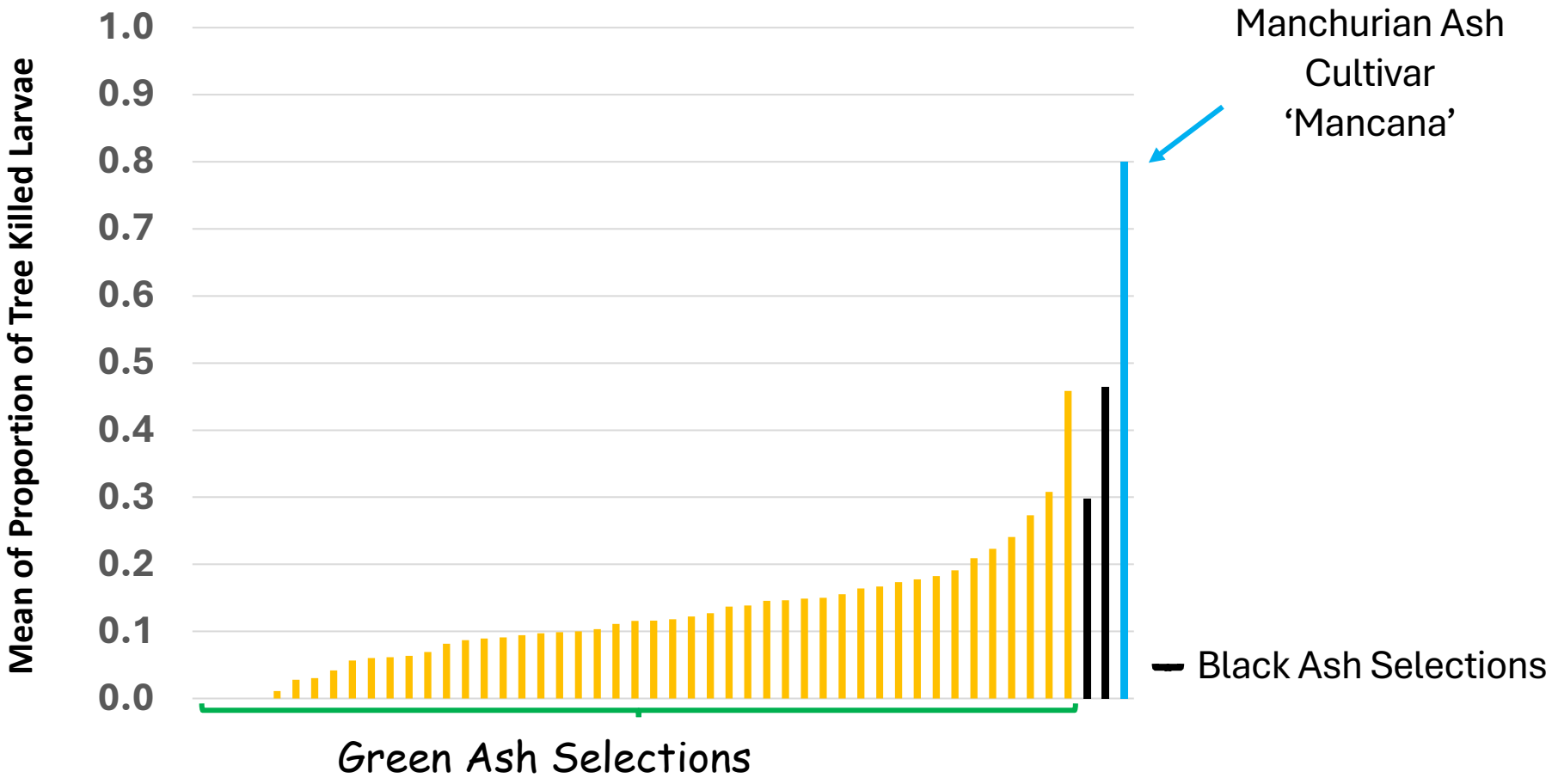


White Ash

Green Ash

Slide by Mary Mason

Average proportion of tree-killed larvae in 8-week bioassay collected on grafted lingering trees



Lingering ash do better than unselected but not as good as Asian species

Selected genotypes of white and green ash show heritable, elevated resistance to EAB
This was recently published!

Lingering ash selected: 2008-13
Bioassay experiments:

- **392 stems**
- **of 75 genotypes**
- **11 experiments from 2011-17**
- **>4500 EAB eggs**

New Forests (2026) 57:12
https://doi.org/10.1007/s11056-025-10158-x

Select genotypes of white and green ash show heritable, elevated resistance to emerald ash borer

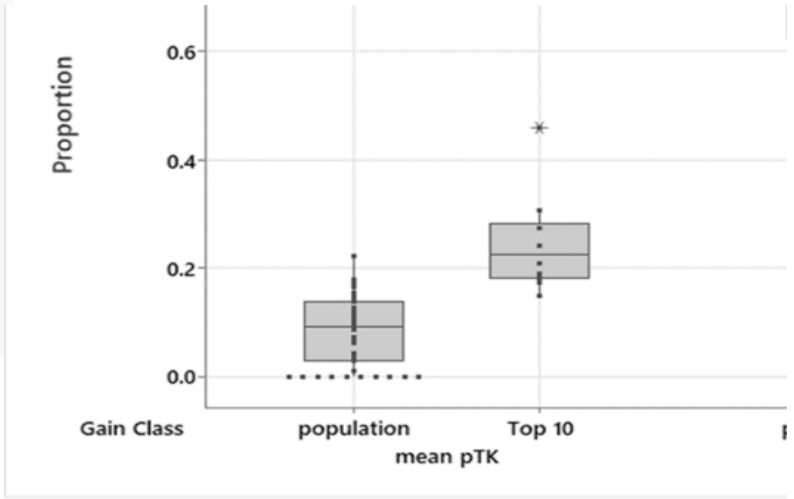
Mary E. Mason[1] · Dave W. Carey[1] · Jeanne Romero-Severson[2] · Kathleen S. Knight[1] · Therese M. Poland[3] · Jennifer L. Koch[1]

Received: 30 September 2025 / Accepted: 25 December 2025

Abstract
The emerald ash borer (*Agrilus planipennis*, EAB) poses an unprecedented threat to North American *Fraxinus* species and has already decimated ash populations in large parts of the natural range in the northeastern US. In some forest stands, a few trees remain alive with healthy crowns years after mortality from EAB has killed the majority of ash trees. These trees, called lingering ash, have been identified, replicated by grafting, and screened for resistance to EAB larvae in controlled greenhouse bioassays. This study showed that the proportion of larvae killed by tree defenses, and the average weight of EAB larvae within

Healthy larva

Host-killed larva



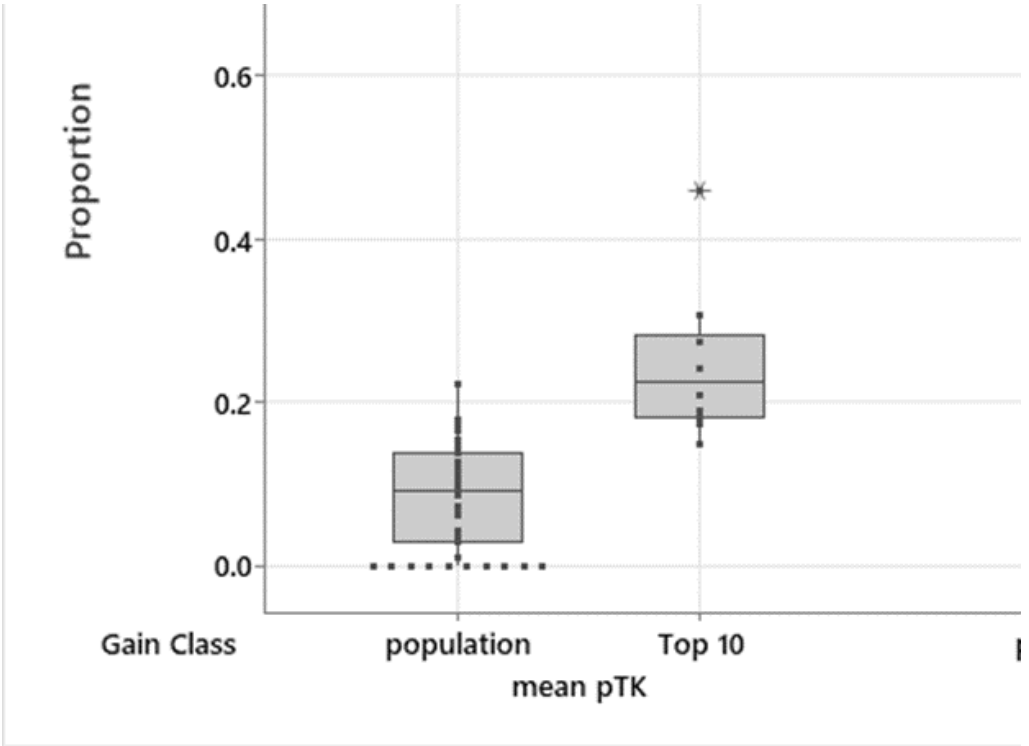
Available for free as open access and on TreeSearch soon!
New Forests (2026) 57:12

Estimates of heritability and potential gain (increase in resistance)

Heritability: similarity among relatives, from 0 to 1

Proportion tree-killed larvae	Estimate
White ash clonal	**0.45**
Green ash clonal	**0.15**
Green ash clonal family	**0.87**

Numbers consistent with other successful breeding programs, e.g. pitch canker in loblolly pine (Quesada et al. 2010) or ht and form in yellow cedar (Baltunis et al. 2013).



Green Ash: top 10 (R) vs. all (L)

Field-trial of lingering ash trees at Holden arboretum, Cleveland Ohio

- Est. 2018
- 48 lingering ash
- 10 grafts of each genotype
- Controls starting to show canopy decline, exit holes
- Will become improved white ash seed orchard

Aerial view

June 2020

Photo: R. Kappler

[Mary Mason, USFS]

April 2024

Therese Poland, Rachel Kappler, Mary Mason, C. Obrebski Photo credit: Dave Carey, USFS

EAB Awareness Week 2026

[Mary Mason, USFS]

Photo: M. Mason, USFS

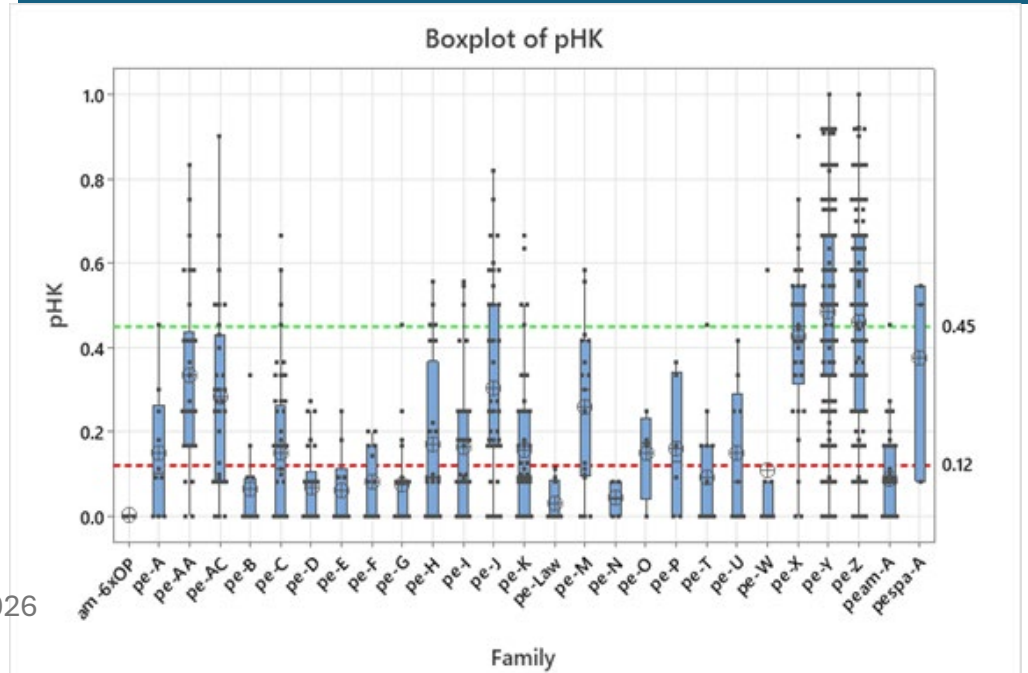
Aletta Doran checks leaf phenotypes, June 2025

Lingering ash progeny test: grown from seedlings

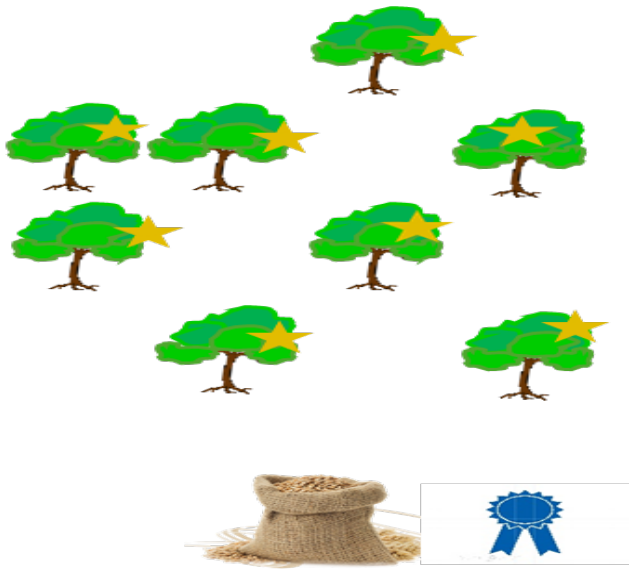
All Photo: USFS Ash Breeding Program

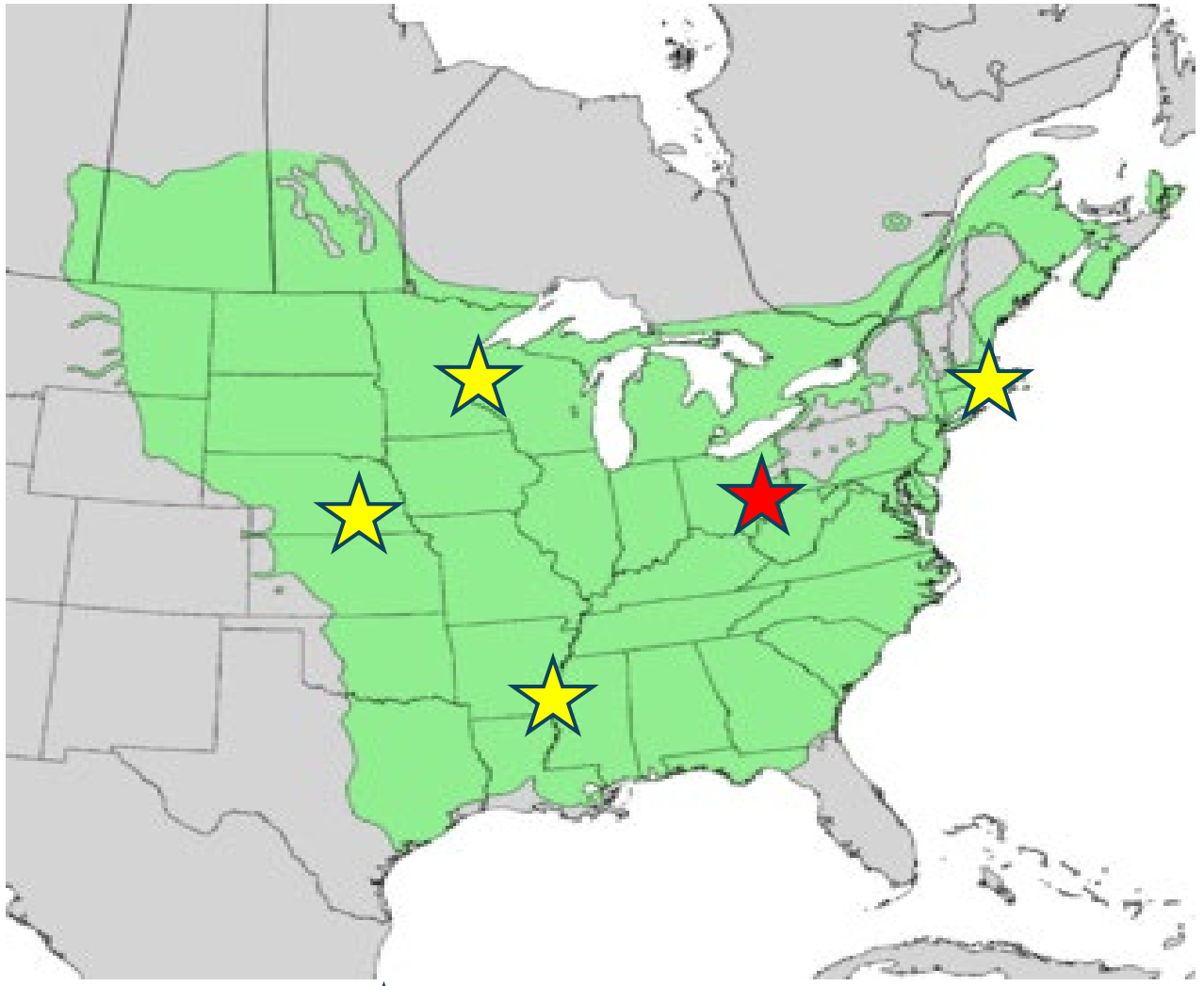
Control-pollinated families created by NRS:

- 33 families, 671 trees
- ~30 seedlings per family
- Planted 2019-22
- May be converted to a seedling-seed orchard
- Heritability = 0.63



Breeding for Range-Wide Forest Restoration





Repeat for each area/population

- Capture genetic diversity
- Adaptive capacity
- Will Rely on Partners!

seed orchard

What's the story with blue ash, *Fraxinus quadrangulata?*

Little's range map of blue ash

- **Blue ash is not closely related to any other ash species (worldwide)**
  - **No chance for hybrids with other species**
- **Limited range with 'sparse' distribution**
- **Does have specific site requirements**
- **Is attacked and killed by EAB**
- **Rated the least preferable of the North American species in terms of palatability to EAB, probably due to very different volatiles**

Blue ash bioassay results: wild seedlings

More tree-kill than green ash
They are finding lots of late instar larvae on the tree (L3-4) in assays

Statewide mortality (Ohio) 2019
White 98.6%
Blue 28.3%

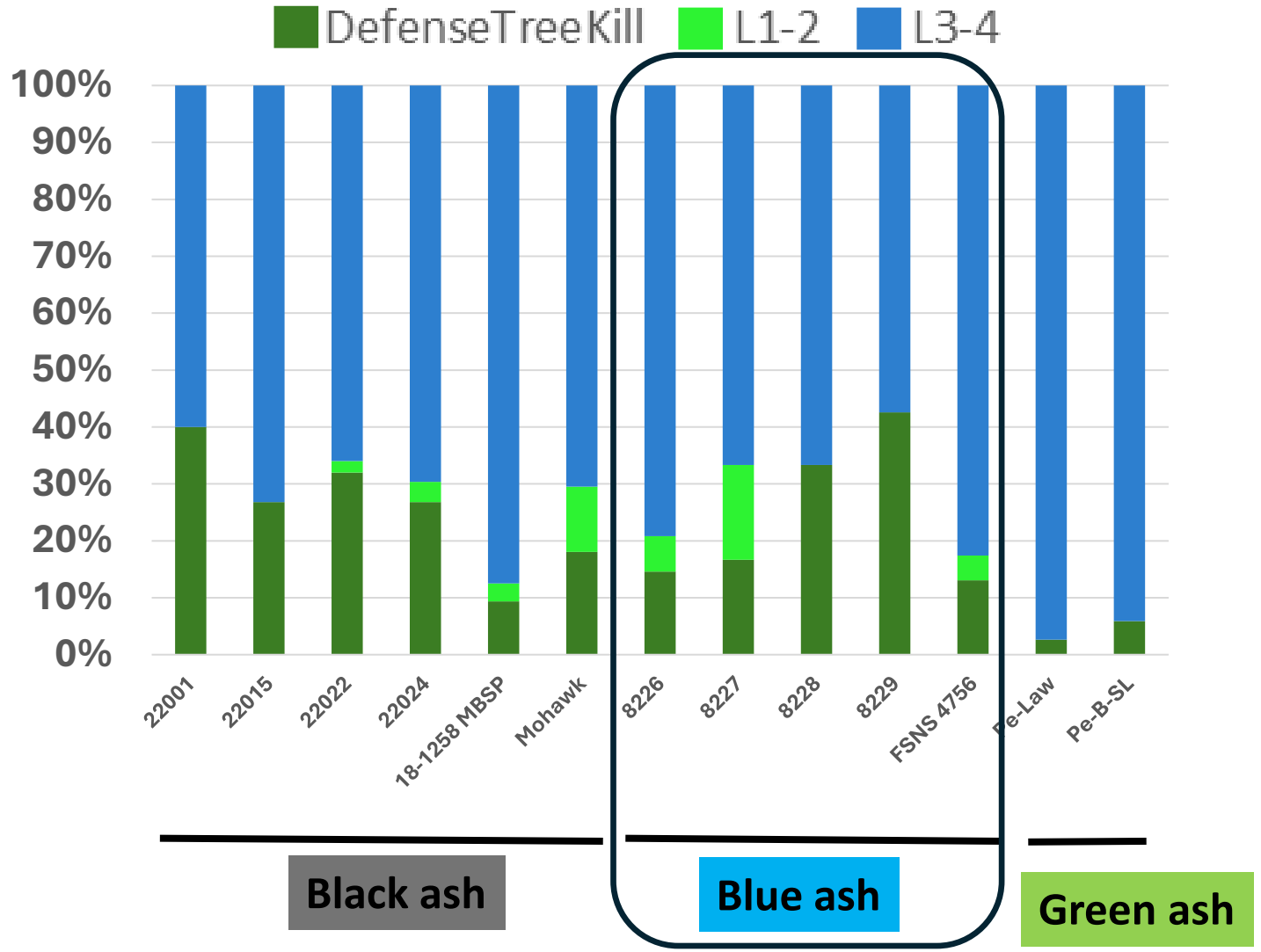


Photo: N. Seigert, USFS

Black ash, *Fraxinus nigra*

Black ash is the most susceptible to EAB: tree-kill appears to occur at lower EAB attack density

Grows in flood-plains and swamps.

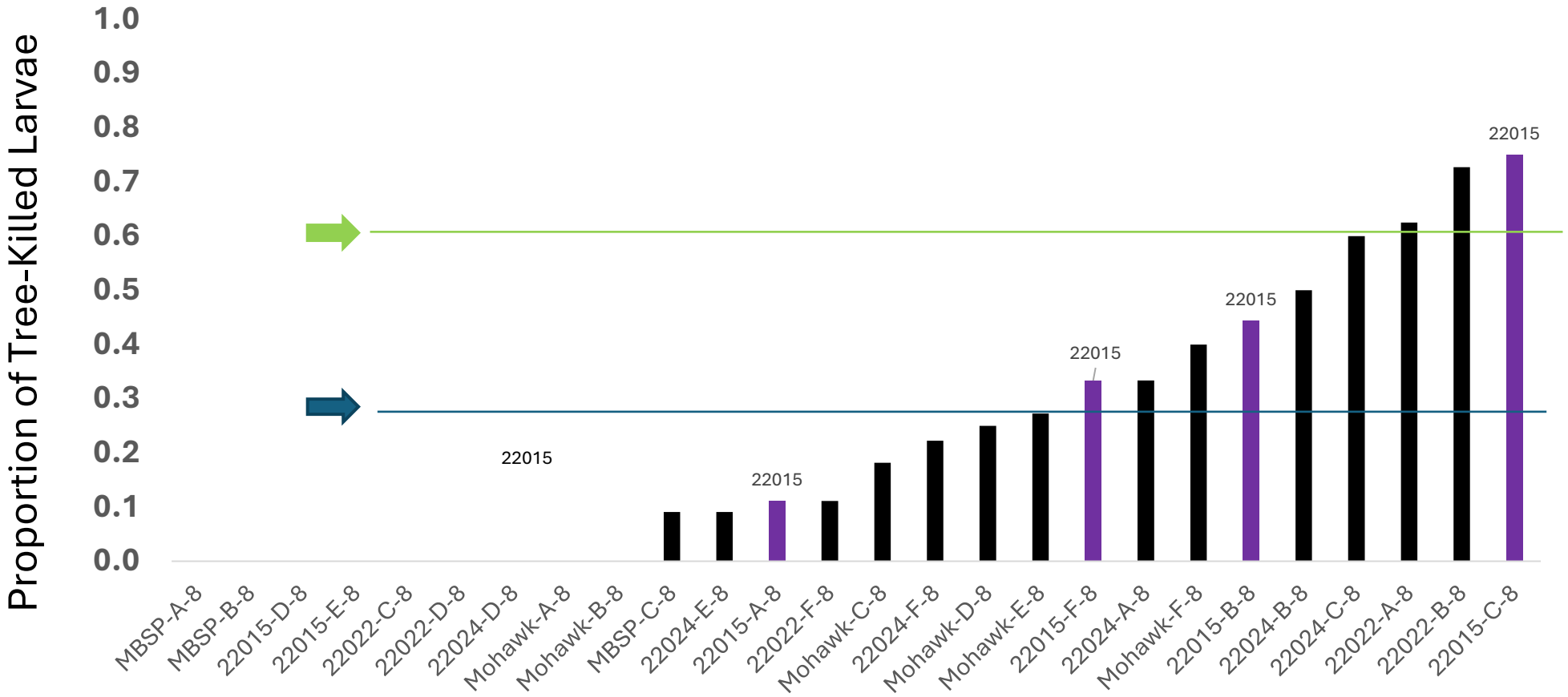
Black ash is a close relative of Manchurian ash

- They readily hybridize.
- 53 candidate genes for EAB resistance found in Manchurian ash are also found in black ash.

Lingering black ash do exist but are harder to find!

- different physiological response in bioassay
- different reproductive biology than other species

Early screening results of unselected seedlots of black ash



What does this mean? Resistance was highly variable (low to high) within a single family.

Arrow shows best individual in unselected (susceptible) green ash family.

Arrow shows best individual from lingering (green) ash selections

Black ash: tree with high tree-killed larvae doesn't have better survival
Host defense-response can, in some cases, become detrimental to the tree.

Result?

Fewer larvae are needed to kill a black ash tree

We need to screen for larval kill & ability to contain defense responses

Live tissue next to gallery – limited host response to EAB attack

Green Ash

Dead tissue next to gallery – excessive host response to EAB attack kills large amount of host tissue

Black Ash

Black ash: host killed larvae (in bioassay) with little to no hypersensitive reaction

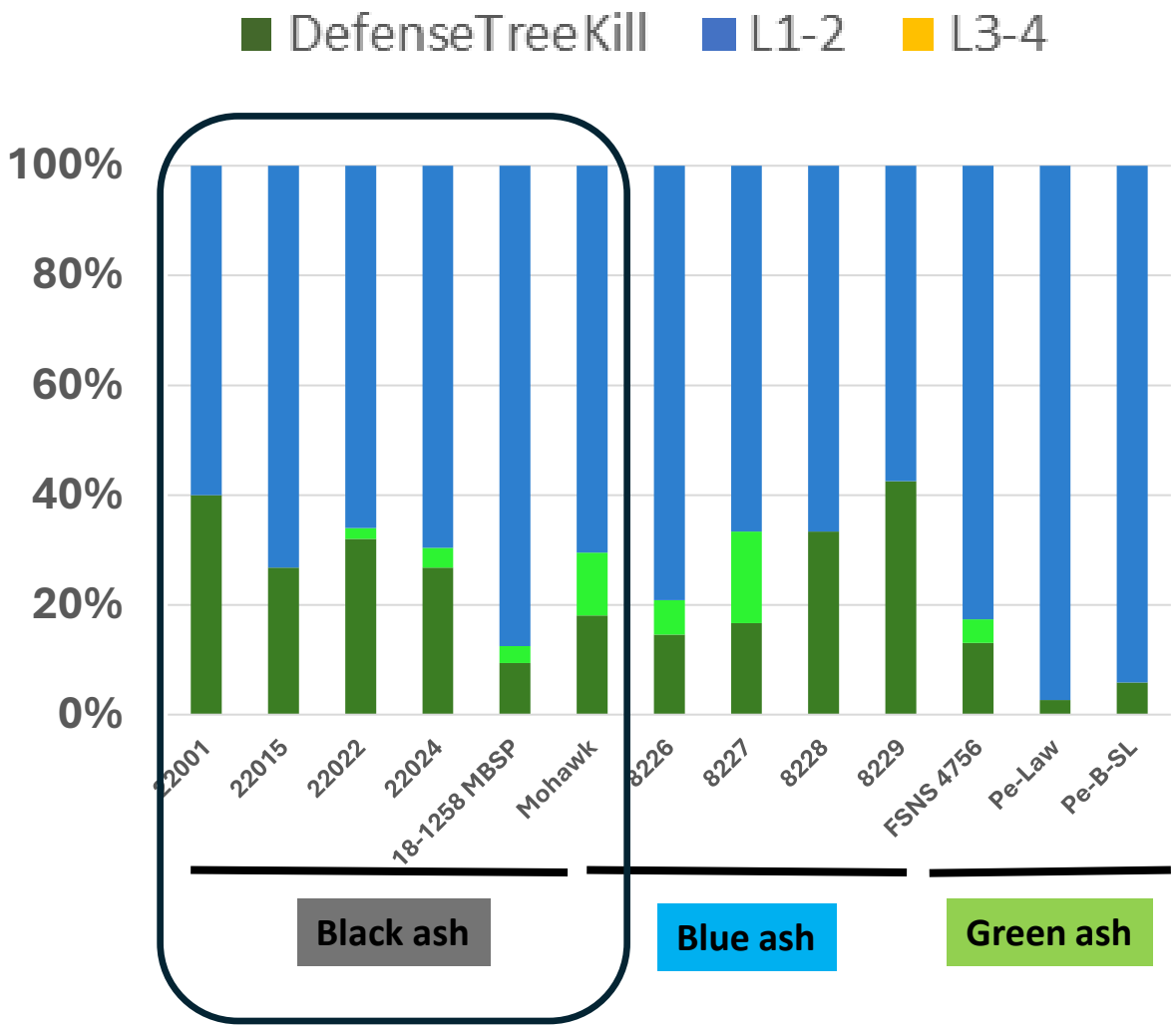
BB8 Ni-Mohawk TK L1

BB8 Ni-22015 TK L1

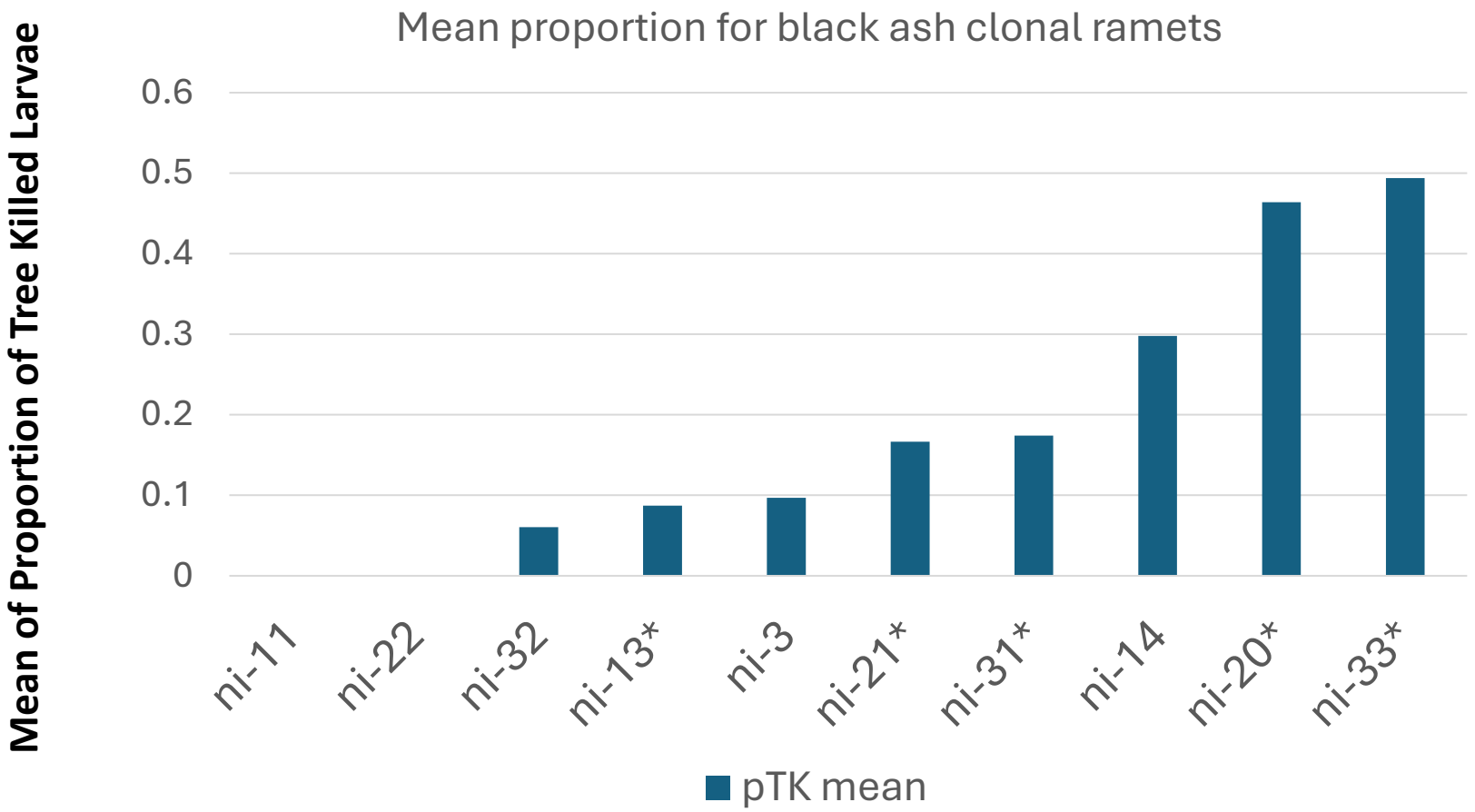
Black ash bioassay results: wild seedlings

More tree-kill than green ash trees

They are finding lots of late instar larvae on the tree (L3-4) in assays



Proportion Tree Killed Larvae for Lingering Ash Selections



Grafted black ash: unselected and Lingering (*)

Field planting result of black ash (2019)

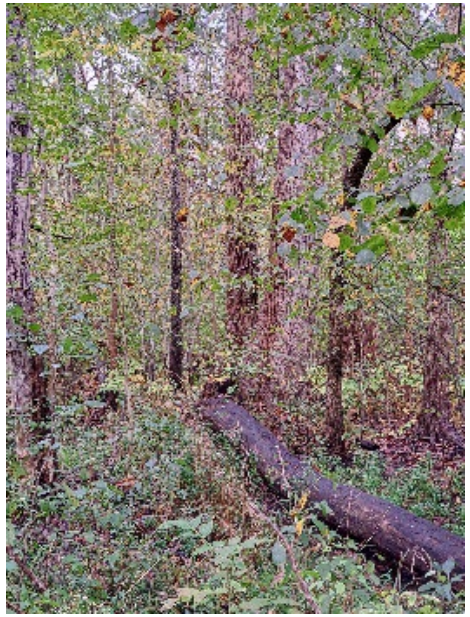
8 OP families
160 seedlings

Seedlings from same families tested in bioassay

28 % alive, 16 % healthy

5 with no EAB damage
(from 3 different families)

Black ash: One Forest Story – Cedar Bog Nature Preserve, Champaign county, Ohio



First infested: 2011-12 (2010 None)

Peak mortality: 2015-16?

- 2014, 80% dead; 2019 100%

Percent mortality in plots: 100%

- no known adult trees survived

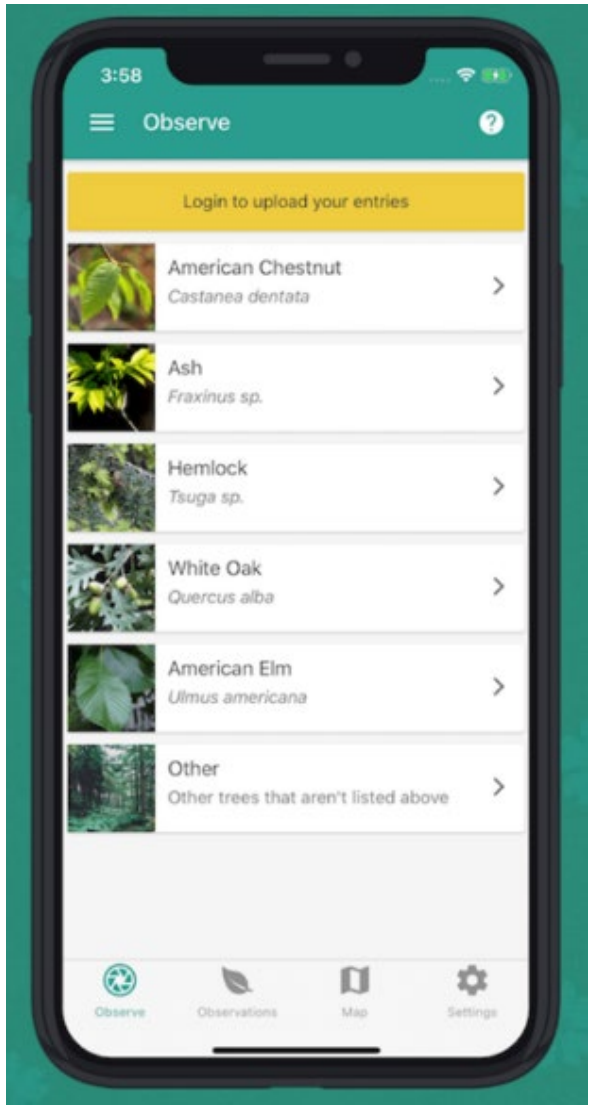
Current situation:

- small trees, many seedlings!
- lots of EAB, parasitoids
- many declining, some holding?

Pair: L healthy, 7.9cm,
R dying, 7.1cm

How you can help: TreeSnap App

- Watch for and preserve lingering ash
- Submit them to Treesnap at: https://treesnap.org/
- Available at the apple or android playstore
- Add your affiliation!
    - For example, Mary Mason USFS



Plus:
Beech
Hemlock
Sassafras
Butternut
American elm

Host a EAB test planting!
2+ acres
15 years
Needs mowing, deer control, herbicide early
Keep some nice ash trees after the research is done

Partners may host sites for testing or for seed production

AOA Poston, planted and summer. Photos: M Mason

Herman Keifer urban renewal site.
Photo: T. Poland USFS

The Greening of Detroit volunteers build deer browse cage at Palmer Park.
Photo: F. Foen
←

In summary: breeding programs…

- **Produce seed**
  - For nurseries to grow seedlings
  - That people want to plant
- **Three main steps**
  - Select good trees
  - Show they are good parents
  - Produce good seed

Photo by R. Kappler, Holden Forests and Gardens

Acknowledgements

Funding sources

Partners

And many teams of summer interns!

Thanks for listening!!

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QUESTIONS?