


**Emerald Ash Borer Biology, Ecology, Management, and Implications for Natural and Urban Forest Areas in the Southeast**

April 20, 2016      1:00-2:00 pm (Eastern Time)

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**Questions?**

Dr. David Coyle, Moderator  
[dcoyle@sref.info](mailto:dcoyle@sref.info)

Forest Health and Invasive Species Specialist  
Southern Regional Extension Forestry and  
UGA – D.B. Warnell School of Forestry & Natural Resources  
<http://southernforesthealth.net/>

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Dr. David Coyle [dcoyle@sref.info](mailto:dcoyle@sref.info)  
@drdavecoyle



AND

Emerald Ash Borer University  
<http://www.emeraldashborer.info/>

Ms. Robin Usborne [robinu1@msu.edu](mailto:robinu1@msu.edu)  
@emeraldashborer




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**Webinar Portal**  
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**Emerald Ash Borer Biology, Ecology,  
Management, and Implications for Natural  
and Urban Forest Areas in the Southeast**

Dr. Dan Herms  
The Ohio State University, Wooster, OH






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## Emerald Ash Borer: Biology, Ecology, and Management

Dan Herms

Department of Entomology  
The Ohio State University  
Ohio Agricultural Research and Development Center  
Wooster, OH

herms.2@osu.edu



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Emerald Ash Borer:  
*Agrilus planipennis*



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Untold millions of dead ash trees  
(and increasing exponentially)



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**Outline:**

- Biology and distribution
- Diagnostics
- Forest impact and ecology
- Host resistance research
- Insecticide research
- Management

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**Host Impact:**

Hosts: all ash species encountered so far, and white fringetree.

Larvae feed under bark; disrupt transport of water, nutrients, carbohydrates.

Healthy trees killed within 1-3 years of first symptoms.

Trees of all size are colonized: 1/2 inch saplings to largest mature trees.



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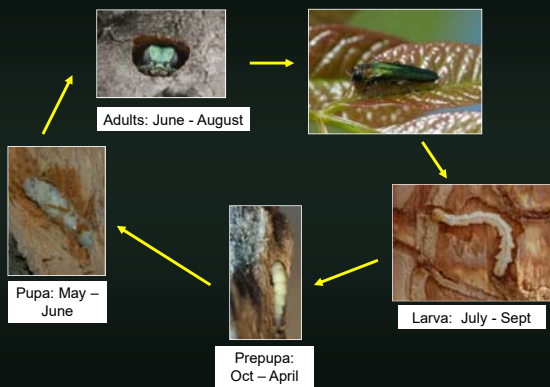
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**Life cycle: 1-2 years / generation**



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### Life cycle: 1-2 years / generation



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### Economic impact of EAB in urban areas



June 2006



August 2009

\$10.7 billion in 25 states for treatment, removal, and replacement of more than 17 million ash on developed land (Kovacs et al. 2010. *Ecol. Econ.* 69:569-578).

\$5.2 billion to remove and replace public and private ash trees in Ohio's communities (Sydnor et al. 2007. *Arbor & Urban For.* 33:48-54).

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### Old World Distribution of EAB



Eduard Jendek, Canadian Food Inspection Agency

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Outlier infestations result from movement of infested ash trees and wood.

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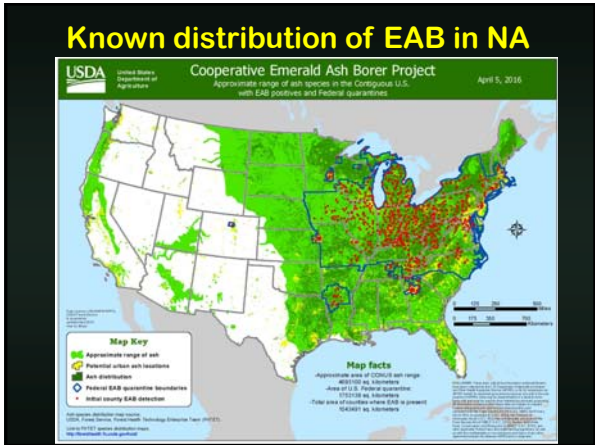
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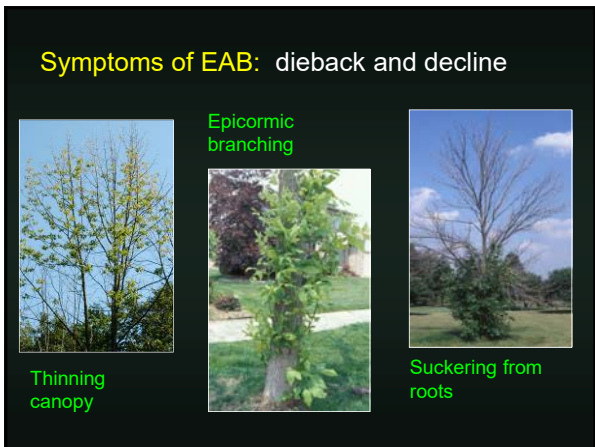
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Symptoms of EAB: dieback and decline



Thinning canopy



Epicormic branching



Suckering from roots

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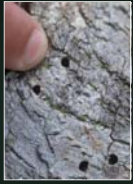
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Diagnosing emerald ash borer: 3 key signs



1. Small (1/8") D-shaped exit holes



2. Serpentine galleries just under the bark



3. Flat, tapeworm-like larvae with bell-shaped segments.

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Native ash borers are extremely common

Clearwing borers



Roundheaded borers



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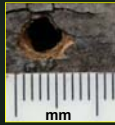
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Distinguishing exit holes of ash borers:



**Emerald ash borer**  
Shape: D-shaped  
Width: 3 mm (1/8")



**Clearwing borers**  
Shape: Round  
Width: 6 mm (1/4")



**Roundheaded borers**  
Shape: oval - round  
Width: 6 mm (1/4")

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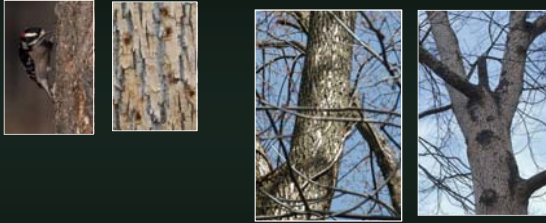
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Early warning: unusual woodpecker activity



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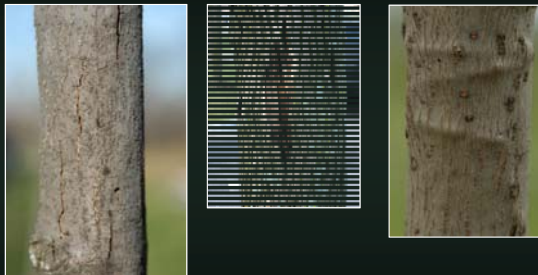
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Early warning: bark splits



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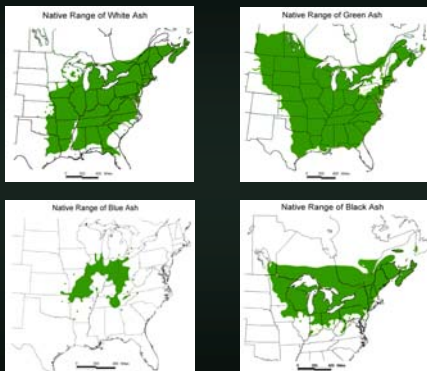
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Distribution of Ash

[www.na.fs.fed.us/fhp/eab/maps/](http://www.na.fs.fed.us/fhp/eab/maps/)



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**Ecological impacts of widespread, simultaneous ash mortality and gap formation**



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**Objectives:**

1. Forest composition and susceptibility to invasion
2. Patterns and rate of ash mortality.
3. Successional patterns: effects on overstory and understory species.
4. Ash regeneration and demography: effects on seed bank and seedling dynamics.
5. Dynamics of coarse woody debris.
6. Establishment and spread of invasive plants.
7. Direct and indirect effects on native insect fauna.

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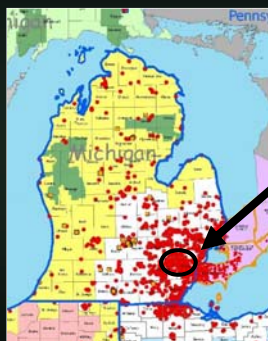
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**Huron River Watershed**



- 38 forested stands
- 3 plots (0.1 ha) / stand

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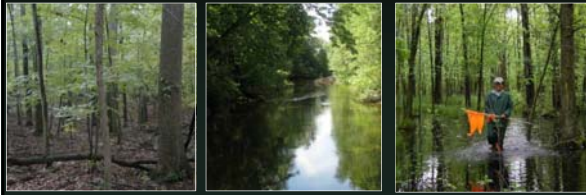
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## Huron River Watershed



White Ash

Green Ash

Black Ash

>50% Species Dominance

Increasing Moisture Gradient

Smith (2006)

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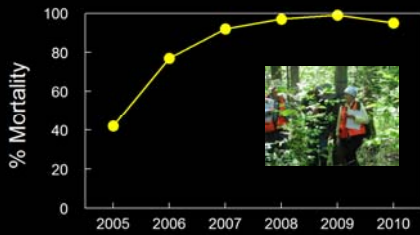
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## Percent Ash Mortality (> 2.5 cm dbh)



Ash (*Fraxinus* spp.) mortality, regeneration, and seed bank dynamics in mixed hardwood forests following invasion by emerald ash borer (*Agrilus planipennis*)

Wardle, S., Klenner, D., David, A., Brown, K., Kullback, S., Knight, C., Calhoun, P., Brown, D., Barkan, G., McCallough, J., Ammend, S., Smith, J., & Klenner, J. (2010)

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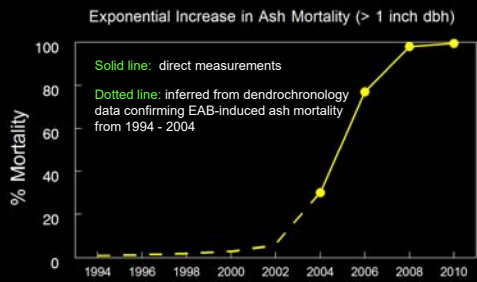
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## EAB-Induced Ash Mortality in the Upper Huron River Watershed, SE Michigan




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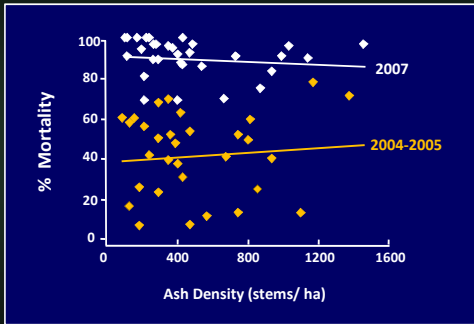
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No relationship between ash density and EAB-induced mortality



A. Smith, K. Gandhi, and D. Herms, Ohio State Univ.

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No relationship between ash mortality and:

- Ash density
- Ash basal area
- Relative dominance of ash
- Relative density of ash
- Stand density
- Stand basal area
- Any measure of species diversity.



Suggests limited potential for EAB-proofing via silviculture

Annemarie Smith, 2006

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Ash regeneration:

- Seed bank dynamics
- Ash seedling and sapling demography
- EAB populations in relation to ash density



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4 years, 432 samples / yr: no seeds since 2006



There is no ash seed bank.




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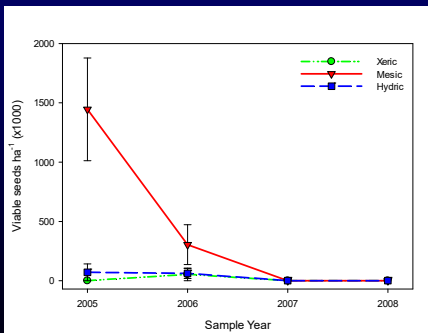
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Little to no ash seedbank exists in these stands



Klooster et al. 2014

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Ash density, 2011 (plants / ha)

- 1. New seedlings (w/ cotyledons) 0
- 2. Established seedlings < 25 cm 191
- 3. Saplings < 2.5 cm DBH 6
- 4. Trees > 2.5 cm DBH 0.1



Wood Science (2014), pp. 1-12  
 DOI: 10.1007/s12242-014-0001-2

**ORIGINAL PAPER**

**Ash (*Fraxinus* spp.) mortality, regeneration, and seed bank dynamics in mixed hardwood forests following invasion by emerald ash borer (*Agrilus planipennis*)**

Wendy A. Klamoer · Daniel A. Herms · Kathleen S. Kopley · Catherine P. Hovine · Deborah C. McLaughlin · Annemarie Smith · Ronald J. K. Coombs · John C. Corbett

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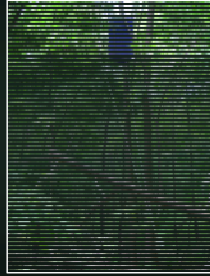
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### The orphaned cohort of ash and the trajectory of the EAB invasion



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### Key Questions:

1. Can EAB persist on a dwindling population of saplings?
2. Will any saplings survive to reproductive maturity?
3. If EAB is locally extirpated, can ash reestablish even after regeneration has functionally ceased?

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### Biocontrol of EAB and the fate of the orphaned cohort?



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### Key Conclusions:

1. > 99% mortality of ash trees > 5 cm DBH.
2. No ash seed bank.
3. No ash regeneration once mature trees have died.
4. Only one demographic "orphaned" cohort of ash (saplings less than 2.5 cm DBH).
5. EAB populations have crashed due to self-induced reduction in carrying capacity, but continue to persist at low density.

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### Direct and indirect ecological impacts of ash mortality and gap formation



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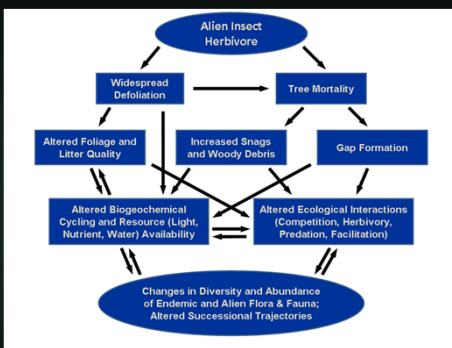
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Gandhi & Herms, 2010. Direct and indirect effects of alien insect herbivores on ecological processes and interactions in forests of eastern North America. *Biological Invasions* 12:389-405

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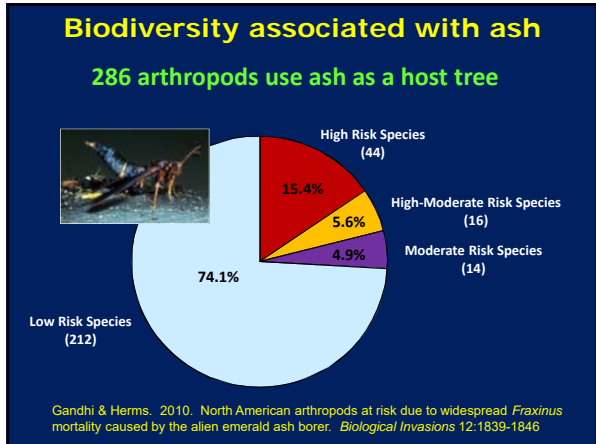
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### Effects of EAB-Induced Gap Formation on Ground Beetle Communities

Kamal Gandhi

Concurrent and Ecological Evidence  
 Indirect Effects of Emerald Ash Borer-Induced Ash Mortality and Canopy Gap Formation on Epigeic Beetles  
 KAMAL J. K. GANDHI<sup>1,2</sup>, ANNEMARIE SMITH<sup>1</sup>, DIANE M. BARTZLER<sup>3</sup> and DANIEL A. HERMS<sup>1</sup>

© Jim Brighton

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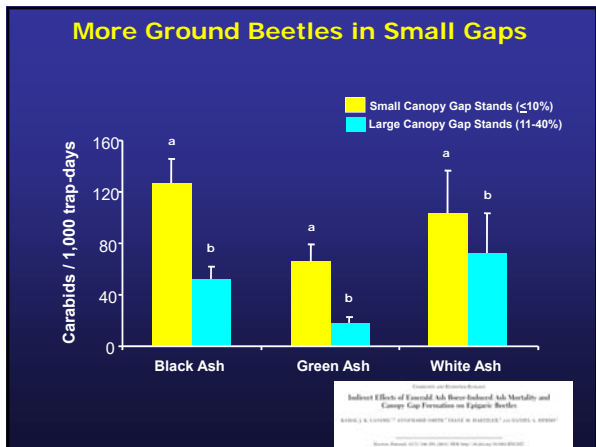
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## Invasional Meltdown:

Does EAB-induced gap formation facilitate spread of invasive plants?



John Cardina, Cathy Herms, and Wendy Klooster  
Ohio State University



Kathleen Knight  
US Forest Service

Funding: USDA NRI Weedy and Invasive Species Program

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## The Quest for Resistance:

1. Identify resistant germplasm via inter-specific comparisons in common gardens: E. Rebek & D. Smitley (Michigan State University)
2. Identify resistant germplasm via search for "lingering ash." J. Koch and K. Knight (USDA Forest Service)
3. Identify biochemical mechanisms of resistance: E. Bonello (OSU) & D. Cipollini (Wright State University)
4. Identify resistance genes and markers via comparative proteomics and genomics of ash and EAB: E. Bonello, J. Whitehill, and O. Mittapalli (OSU)
5. Hybridization and backcrossing to generate resistant genotypes (e.g. chestnut blight program): J. Koch (USDA Forest Service)

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## Healthy Asian ash surrounded by declining North American ashes



PLANT INSECT INTERACTIONS  
Interspecific Variation in Resistance to Emerald Ash Borer  
(Coleoptera: Buprestidae) Among North American and  
Asian Ash (*Fraxinus* spp.)  
ERIC J. REBEK,<sup>1,2</sup> DANIEL A. HERMS,<sup>3</sup> and DAVID B. SMITLEY<sup>4</sup>  
Electronic Journal of Plant Invention 07(1): 142-148 (2008)

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### Common Garden Taxa

#### North American

- F. americana*
- F. americana* 'Autumn Applause'
- F. americana* 'Autumn Purple'
- F. americana* 'Spartacus'
- F. latifolia*
- F. nigra*
- F. nigra* 'Fallgold'
- F. pennsylvanica* 'Cimmaron'
- F. pennsylvanica* 'Patmore'
- F. pennsylvanica* 'Summit'
- F. quadrangulata*

#### Asian

- F. mandshurica*

#### Asian x North American

- F. mandshurica* x *F. nigra* 'Northern Treasure'

#### European

- F. excelsior* 'Aureaefolia'
- F. ornus*
- F. angustifolia* ssp. *oxycarpa* 'Raywood'

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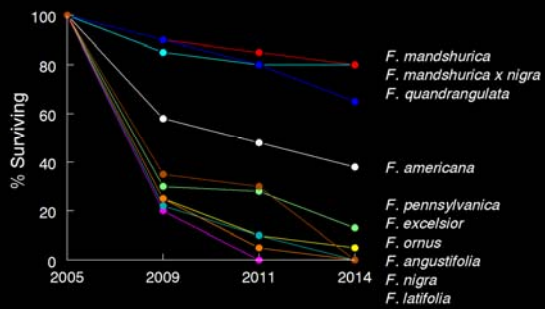
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### Patterns of ash mortality in a common garden




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### Constitutive and wound-induced defensive chemistry of ash




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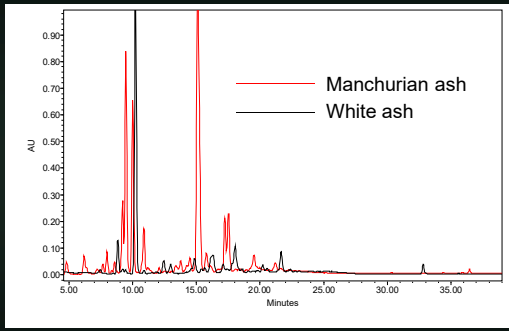
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### Phenolic profile of white and Manchurian ash phloem



Eyles et al. 2007. *J. Chem. Ecol.* 33:1430-1448

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### Potential Resistance Mechanisms of Manchurian Ash

Eyles et al. 2007; Cipollini et al. 2011; Chakraborty et al. 2013; Rigsby et al. 2015, in review; Whitehill et al. 2011, 2012, 2014

#### Manchurian ash phloem characterized by:

- High constitutive concentrations of unique lignans.
- Overexpression of defensive proteins.
- Phenolic profiles very similar to black ash.
- Much higher concentration of peroxidase activity, lignin polymerization, and rate of enzymatic phenolic oxidation, which stress feeding larvae.

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New Phytologist Review

New Phytologist (2016) 209: 63–79  
doi: 10.1111/nph.13604

**Tansley review**

Progress and gaps in understanding mechanisms of ash tree resistance to emerald ash borer, a model for wood-boring insects that kill angiosperms

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**Caterina Villari<sup>1</sup>, Daniel A. Herms<sup>2</sup>, Justin G. A. Whitehill<sup>3</sup>, Don Cipollini<sup>4</sup> and Pierluigi Bonello<sup>1</sup>**  
<sup>1</sup>Department of Plant Pathology, The Ohio State University, Columbus, OH 43210, USA; <sup>2</sup>Department of Entomology, The Ohio State University, Ohio Agricultural Research and Development Center, Wooster, OH 44691, USA; <sup>3</sup>Michael Smith Laboratories, The University of British Columbia, Vancouver, BC V6T 1Z4, Canada; <sup>4</sup>Department of Biological Sciences, Wright State University, Dayton, OH 45425, USA

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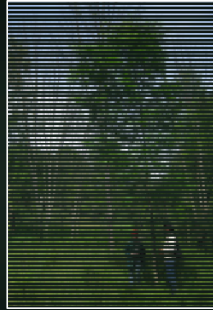
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**Lingering ash:** allopatric resistance, tale end of the survivorship curve, or blind luck?



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**General Conclusions:**

1. Virtually 100% ash mortality in all size classes.
2. Ash regeneration has ceased.
3. Little potential for silvicultural approaches for EAB-proofing a stand.
4. Widespread mortality and gap formation are having pervasive ecological impacts.
5. Manchurian ash is a source of resistance genes.
6. Very low frequency of "lingering ash" may also be a source of resistance genes.
7. Resistance research in support of breeding.

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**Multi-year evaluation of systemic insecticides for control of EAB on street trees**

- **Soil treatments:** Imidacloprid and Dinotefuran
- **Trunk injections:** Imidacloprid, Emamectin Benzoate, Azadirachtin
- **Systemic basal trunk sprays:** Dinotefuran



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**Key questions:**

Will systemic treatments work on larger trees?

What are optimal application rates?

Are fall treatments effective?

How long will treatments remain effective?

How do various products compare?

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Canopy decline (thinning) rating scale:  
0-100%

Smitley et al. 2008. *J. Econ. Entomol.*  
101:1643-1650.

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**Emamectin Benzoate: duration of control at different rates (DBH: 20-25")**

**Emamectin benzoate (Tree-äge)**

0.1 g ai / inch DBH (2.5 ml / inch - low)

0.2 g ai / inch DBH (5 ml / inch - med)

0.4 g ai / inch DBH (10 ml / inch - med / high)

Treat in 2006 and see how long they work.



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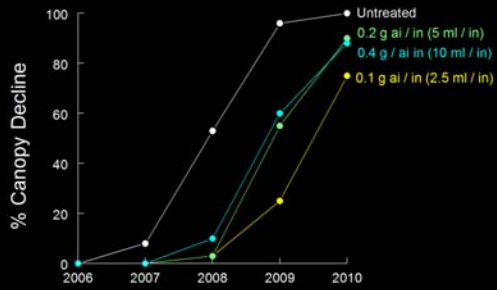
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Tree-age rate study: 2 yrs control even at low rate (20-25 inch DBH)




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2006

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2009

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## Imidacloprid Soil Drenches

1X rate (1.4 g ai / inch DBH)	spring
1X rate (1.4 g ai / inch DBH)	fall
2X rate (2.8 g ai / inch DBH)	spring
2x rate (2.8 g ai / inch DBH)	fall




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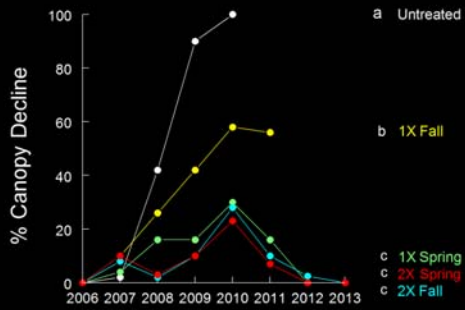
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## Imidacloprid Soil Drenches (16-23 inch DBH)




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2006



2009

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## Implications for long-term management of EAB



2013

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## Safari (Dinotefuran) Trials in Bowling Green

- Basal trunk sprays
- Low volume soil injection



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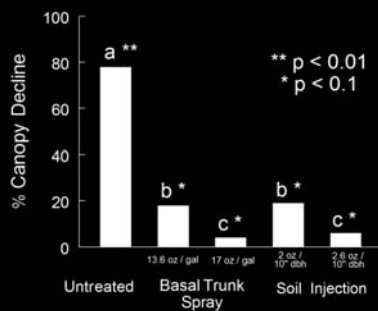
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## Dinotefuran (Safari) Treatments for EAB

Treated 2008-2012; evaluated 2013



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Effect of Enamectin Benzoate for Control of EAB  
on big trees (32-47 inch DBH)




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Effect of Enamectin Benzoate for Control of EAB  
on big trees (32-51 inch DBH)  
treated 2010, 2012, 2014

Treatment	% Canopy Decline				
	2010	2011	2012	2013	2015
0.2 g ai / inch DBH (5 ml / in)	10	13	6	1	1
0.4 g ai / inch DBH (10 ml / in)	11	14	7	1	2

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Management of EAB infestations:

1. Do nothing, let nature take its course.
2. Removal, replacement (tree inventories are critical for planning / preparation).
3. Sustained insecticide treatments.
4. Integration of all of the above.

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Economic value of environmental services provided by trees increases exponentially with tree size.

The probability that a tree reaches a large size on urban streets is increasingly low.



Roman & Scatena (2011) Street tree survival rates: meta-analysis of previous studies and field survey in Philadelphia, PA, USA. *Urban Forestry & Urban Greening* 10:269-274.

Sydner & Subburayalu (2011) Should we consider expected environmental benefits when planting larger or smaller tree species? *Arboriculture & Urban Forestry* 37:167-172.

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Economics of treatment vs. removal is dependent on many factors:

...urban ash conservation can be less costly than removal, especially when the significant environmental and economic benefits of established trees are considered...

Purdue EAB Cost Calculator:

<http://extension.entm.purdue.edu/treecomputer/>

Vannatta et al. (2012) Economic analysis of emerald ash borer (Coleoptera: Buprestidae) management options. *J. Econ. Entomol.* 105:196-206

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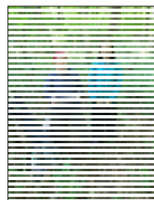
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### Management of ash populations in forests

Treating 600 mature ash trees in a forest to determine if we can:

1. Conserve genetic diversity in order to maintain healthy and sustainable populations
2. Protect reproductive individuals, to promote continued seed production and new regeneration



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Will they impact ground and surface water?

Will they impact aquatic organisms?

What about residues in leaves that fall in autumn?

Will they harm honey bees? Other insects? Woodpeckers?

Will injection wounds harm the tree?

Will EAB evolve insecticide resistance?

[emeraldashborer.info](http://emeraldashborer.info)

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- General Conclusions:**
1. Virtually 100% ash mortality in all size classes.
  2. Ash regeneration has ceased.
  3. Little potential for silvicultural approaches for EAB-proofing a stand.
  4. Widespread mortality and gap formation are having pervasive ecological impacts.
  5. Manchurian ash is a source of resistance genes.
  6. Very low frequency of "lingering ash" may also be a source of resistance genes.
  7. Tree resistance research in support of breeding program is underway.
  8. Insecticides can effectively protect trees.

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