

Interactions of Bronze Birch Borer and Emerald Ash Borer with Novel and Coevolved Hosts

Dan Herms

The Davey Tree Expert Company
Kent, OH

dan.herms@davey.com



Emerald Ash Borer: *Agrilus planipennis*



Bronze birch borer: *Agrilus anxius*



Distribution of bronze birch borer



Fig. 1. Known distribution of bronze birch borer (*A. anxius*) in North America in 2012 as determined from published records and expert testimony.



A Review of Bronze Birch Borer (Coleoptera: Buprestidae) Life History, Ecology, and Management

VANESSA L. MUILENBURG¹ AND DANIEL A. HERMS

Environ. Entomol. 41(6): 1372–1385 (2012)

Known distribution of EAB in North America



United States
Department of
Agriculture

Cooperative Emerald Ash Borer Project Initial county EAB detections in North America

September 6, 2018



BBB



EAB



Life cycle: 1-2 years



Adults: late May - August



Pupa: May – June



Prepupa:
Oct – April



Larva: July - Sept



Life cycle: 1 – 2 years



Adults: late May - August



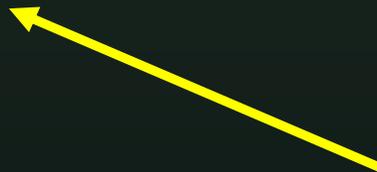
Eggs:
June - July



Larva: June - April

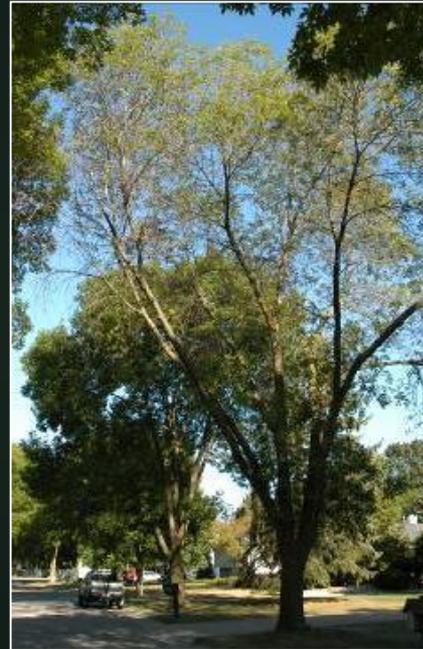
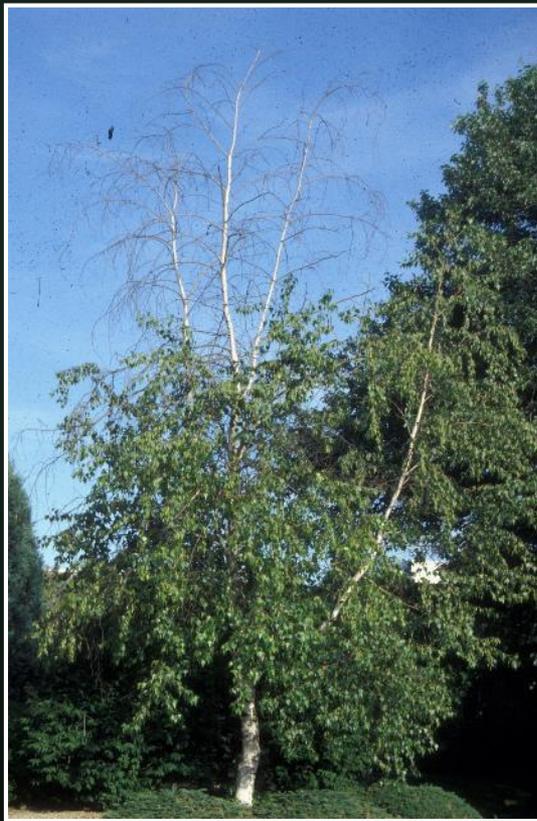


Pupa: May –
June



Contrasting patterns of decline:

Birch: gradual,
top down dieback

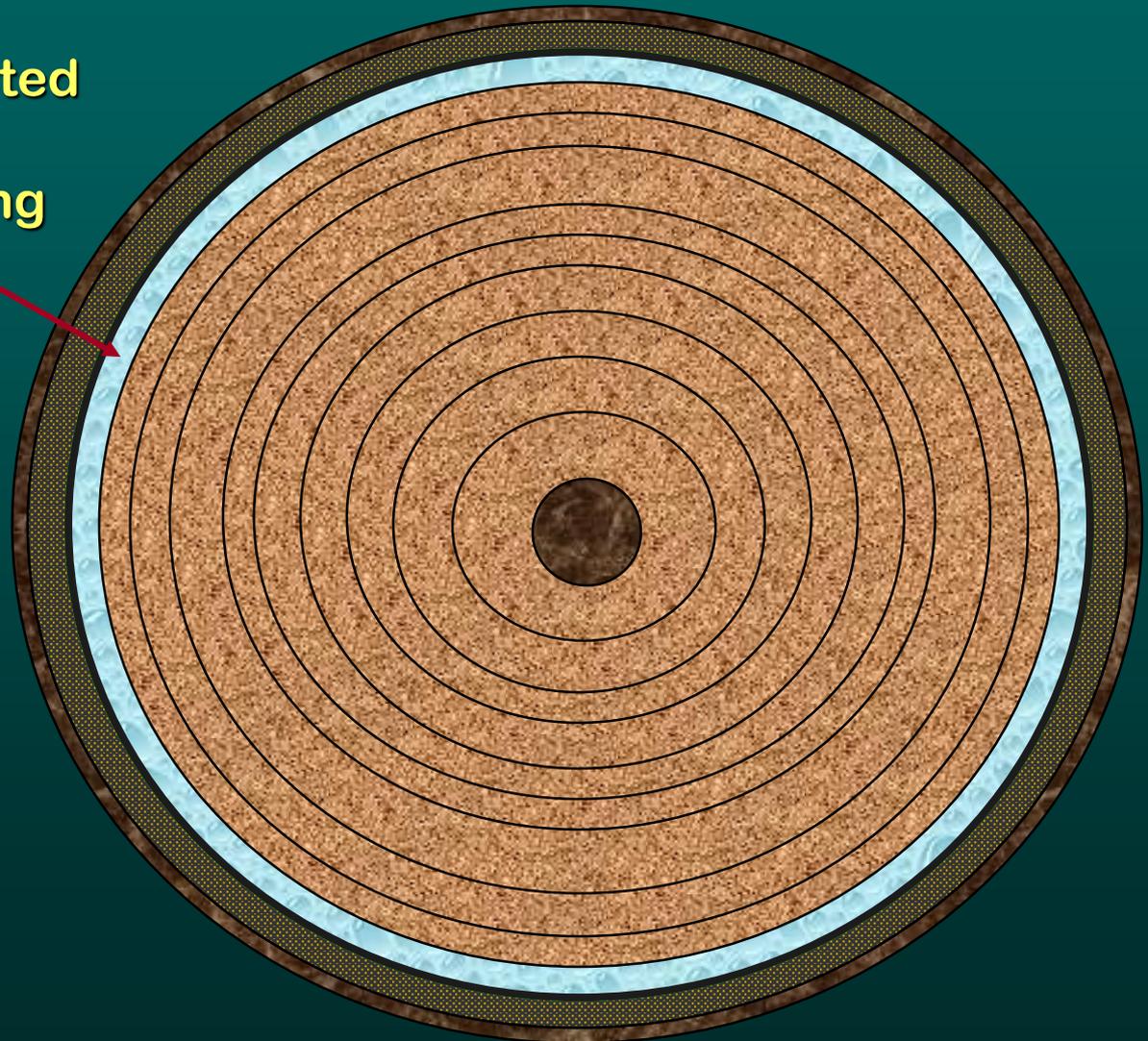


Ash: rapid, canopy
thinning

Ring Porous: Ash

Tree decline and death is rapid — 1-3 years

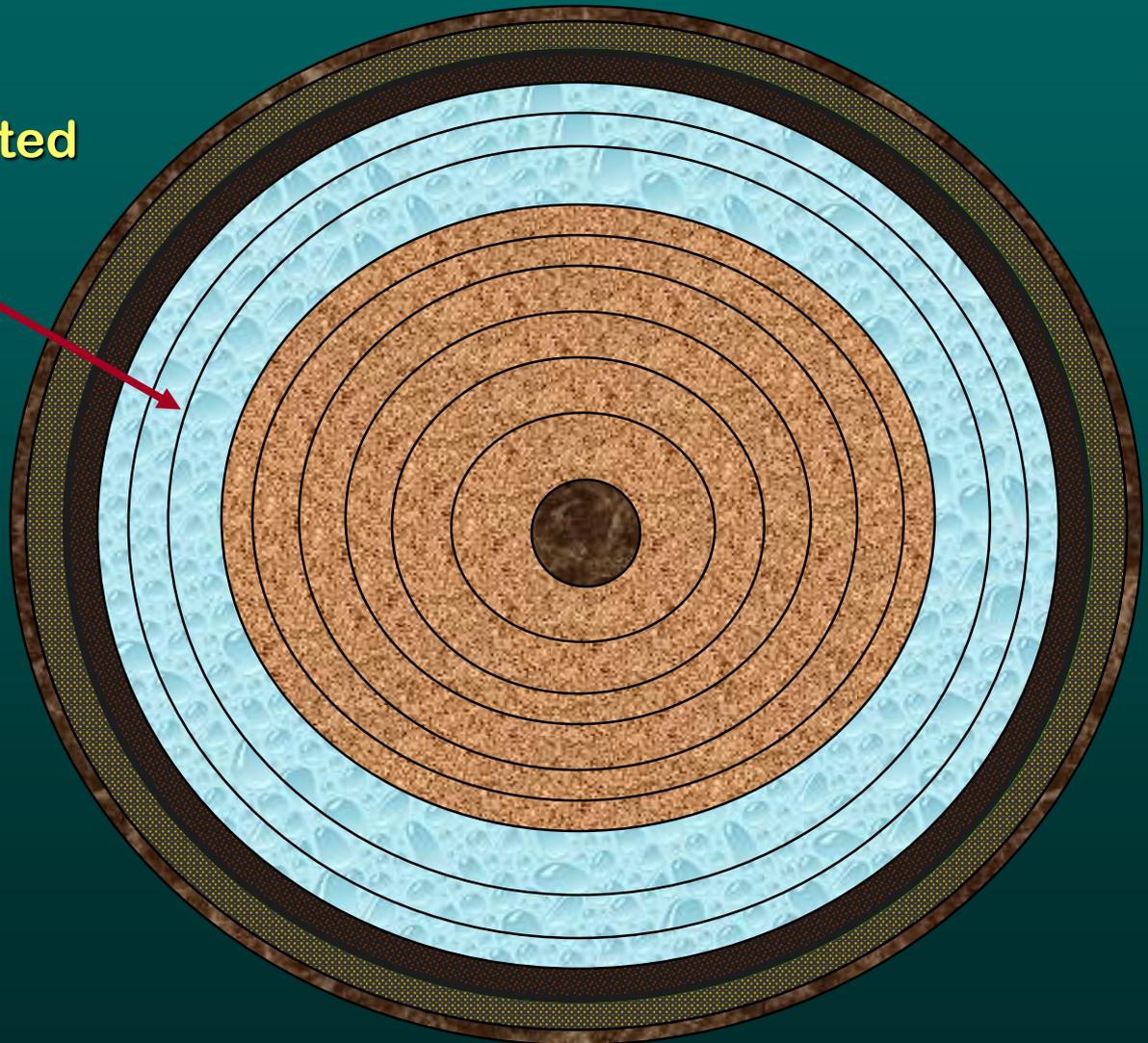
Water is transported only through the current annual ring



Diffuse Porous: Birch

Tree decline and death is gradual.

Water is transported through several annual rings



Rapid ash mortality in the urban forest



June 2006

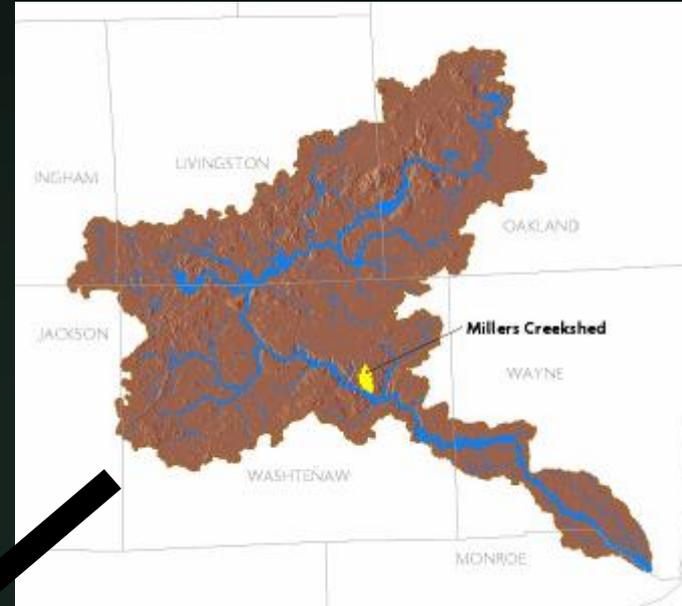
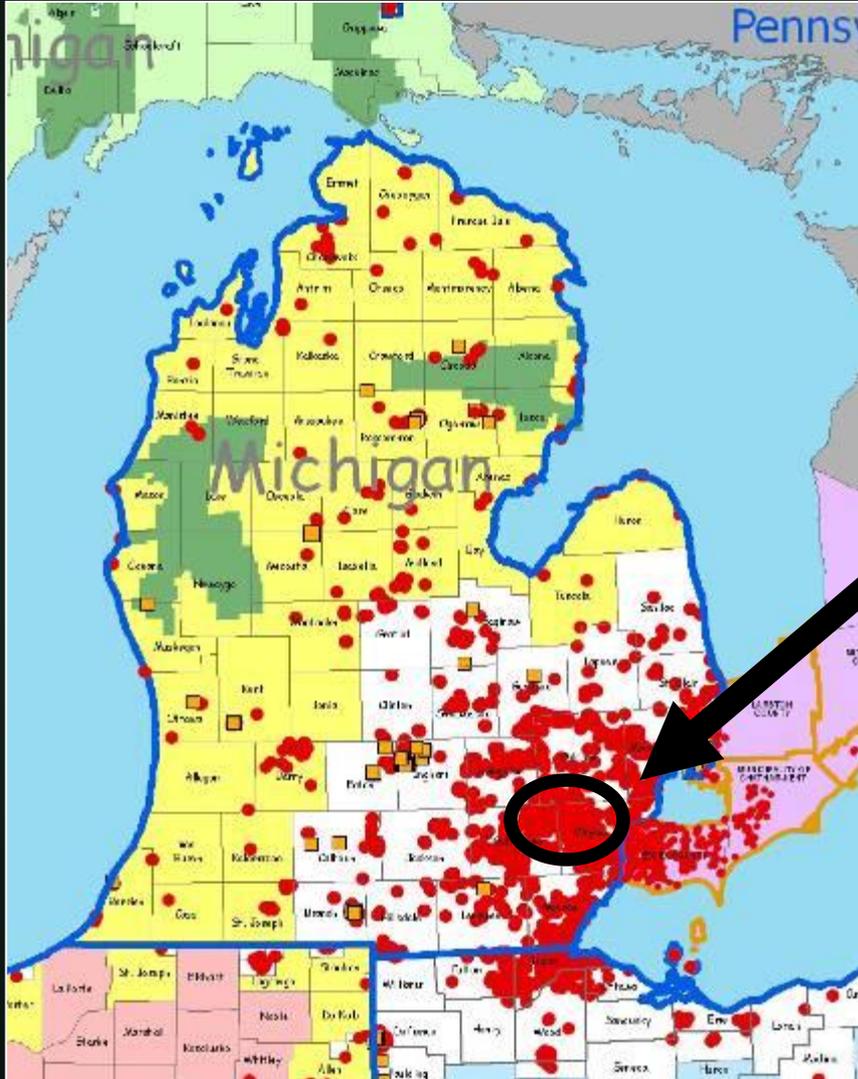


August 2009

Patterns of ash mortality in forests near the epicenter of the North American invasion



Upper Huron River Watershed



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

Huron River Watershed



White Ash



Green Ash



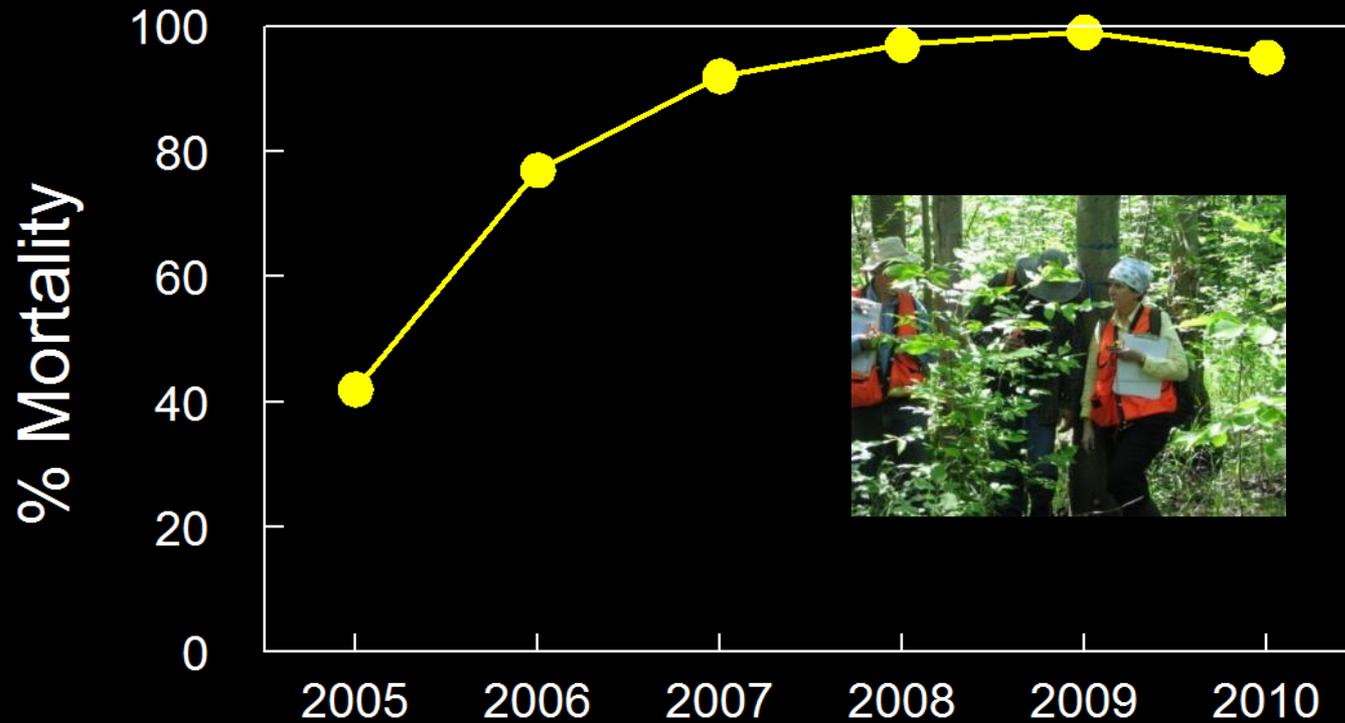
Black Ash

>50% Species Dominance



Increasing Moisture Gradient

Percent Ash Mortality (> 2.5 cm dbh)

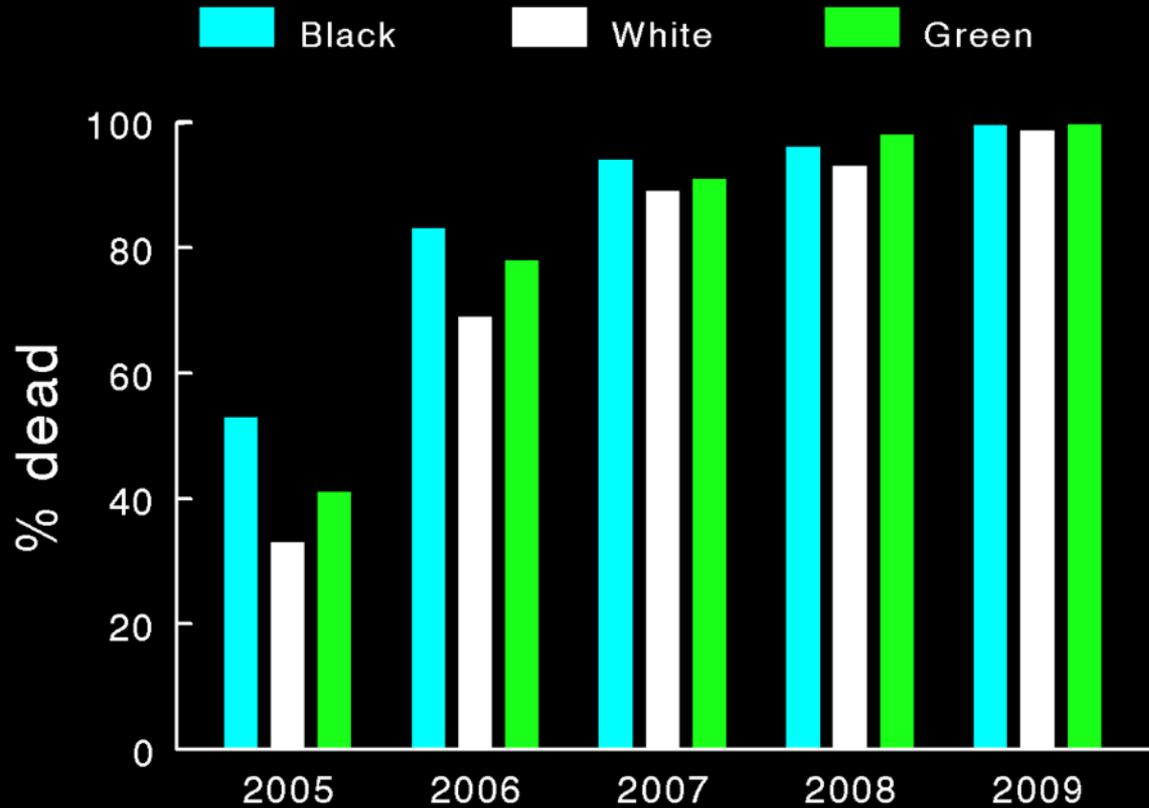


Biol Invasions
DOI 10.1007/s10530-013-0543-7

ORIGINAL PAPER

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

Wendy S. Klooster · Daniel A. Herms · Kathleen S. Knight ·
Catherine P. Herms · Deborah G. McCullough · Annemarie Smith ·
Kamal J. K. Gandhi · John Cardina



Community composition and structure had no effect on forest susceptibility to invasion by the emerald ash borer (Coleoptera: Buprestidae)

Annemarie Smith, Daniel A. Herms, Robert P. Long, Kamal J.K. Gandhi¹

Can. Entomol. **147**: 318–328 (2015)



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

No ash seed bank, no germinating seedlings



4 years x 432 soil cores / yr





How can a secondary pest threaten an entire genus?

Bronze birch borer study foretells demise of ash:



Interspecific Variation in Resistance of Asian, European, and North American Birches (*Betula* spp.) to Bronze Birch Borer (Coleoptera: Buprestidae)

DAVID G. NIELSEN, VANESSA L. MUILENBURG, AND DANIEL A. HERMS¹

Department of Entomology, Ohio Agricultural Research and Development Center, The Ohio State University,
1680 Madison Avenue, Wooster, OH 44691

20 year study of variation in birch resistance to bronze birch borer

7 species, 200 reps / species, 1400 trees total:

Native species:

B. nigra

B. papyrifera

B. populifolia

Exotic species:

B. pendula

B. pubescens

B. platyphylla

B. maximowicziana



Survival after 20 years:

Native species:

<i>B. nigra</i>	97%
<i>B. papyrifera</i>	73%
<i>B. populifolia</i>	75%

Exotic species:

<i>B. pendula</i>	0%
<i>B. pubescens</i>	0%
<i>B. platyphylla</i>	0%
<i>B. maximowicziana</i>	0%

Conclusion: no evolutionary history, no resistance.

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,^{1,2} DANIEL A. HERMS,³ AND DAVID R. SMITLEY¹

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'

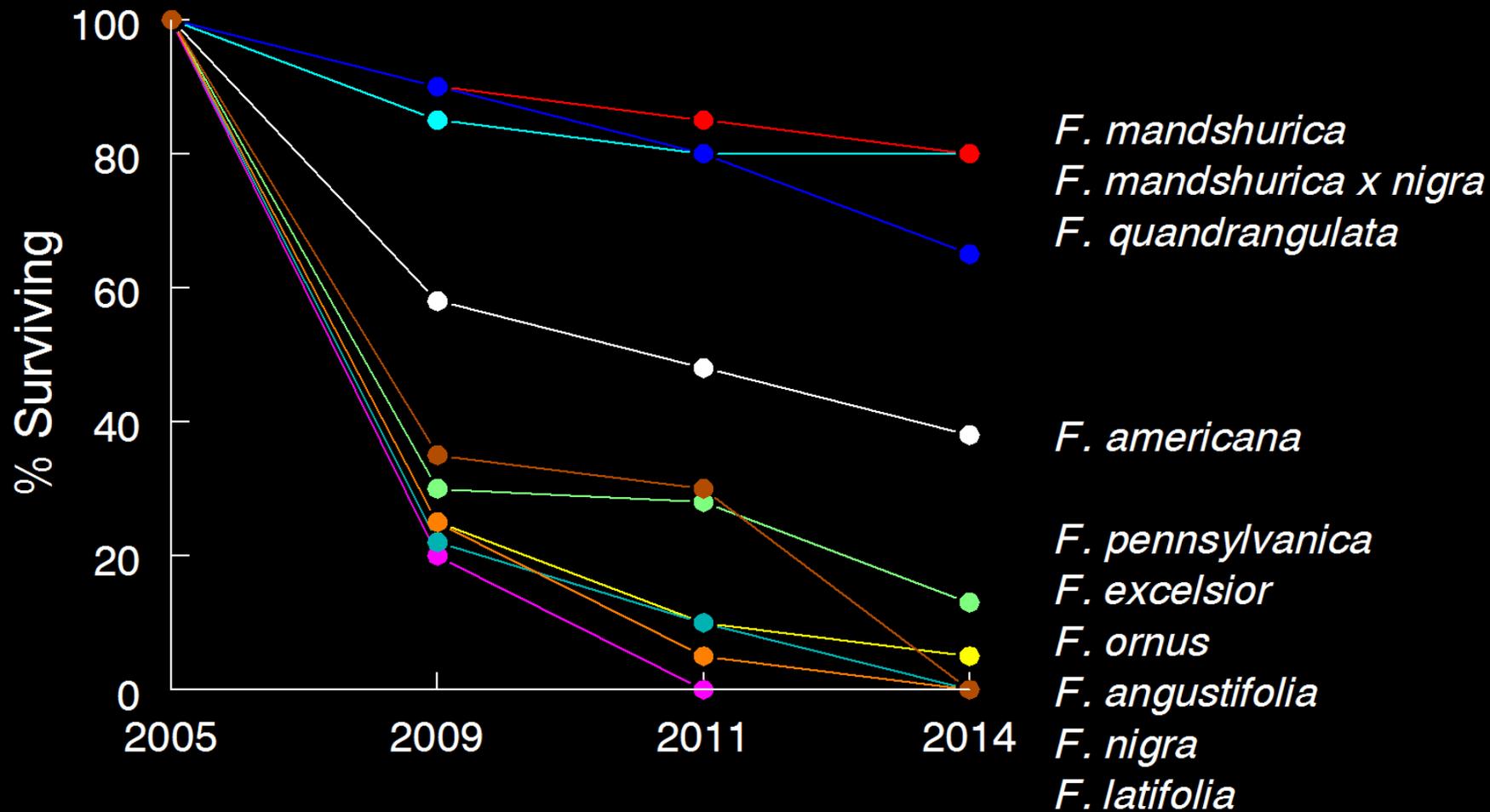
European

F. excelsior 'Aureafolia'

F. ornus

F. angustifolia ssp. *oxycarpa* 'Raywood'

Patterns of ash mortality in a common garden



Stress effects on resistance to wood-borers:
a priori predictions.

Coevolutionary history: stress decreases
resistance.

No coevolutionary history: stress has no
effect.

Stress predicted to decrease bronze
birch borer resistance of native
paper birch (*B. papyrifera*)



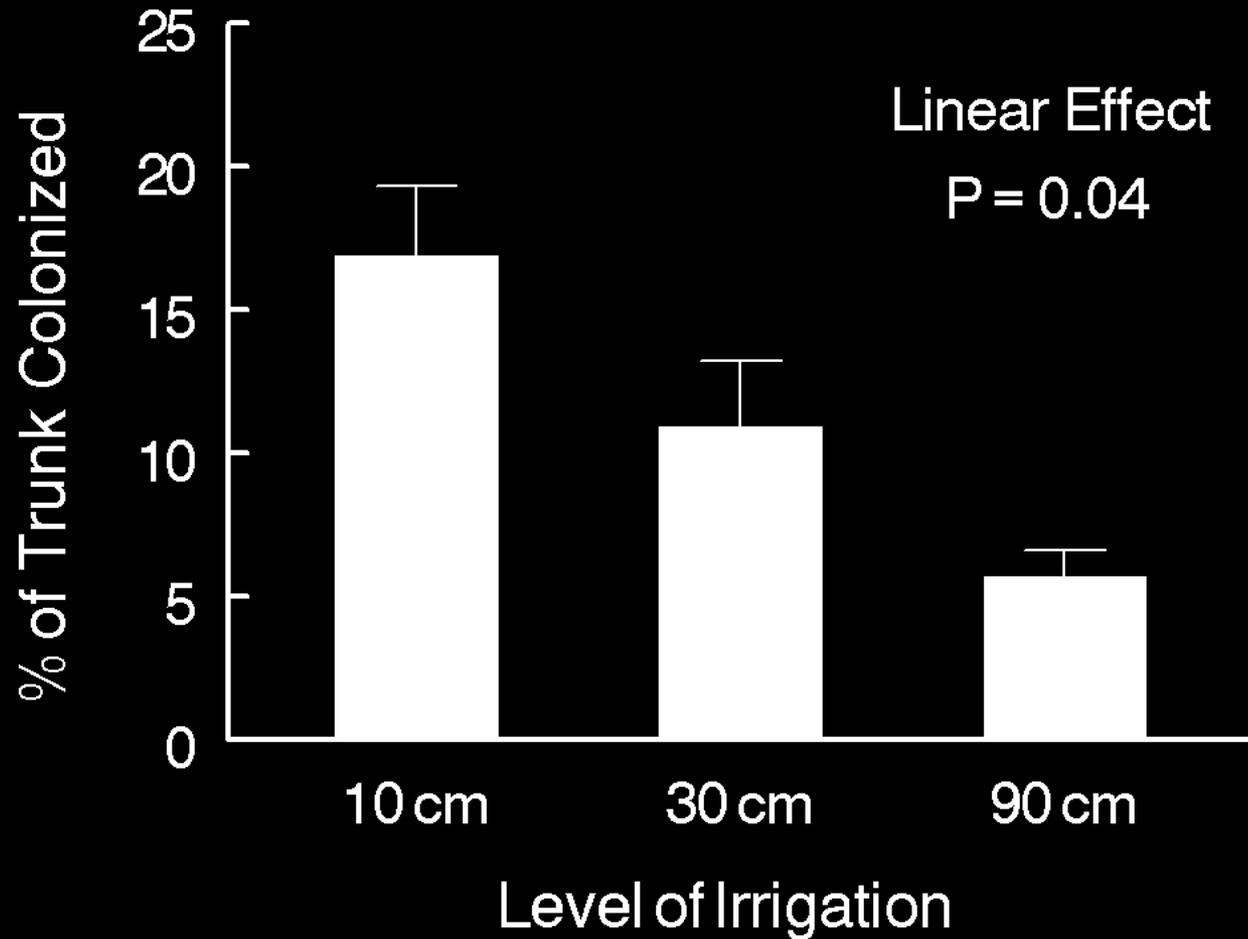
Experimental plots:



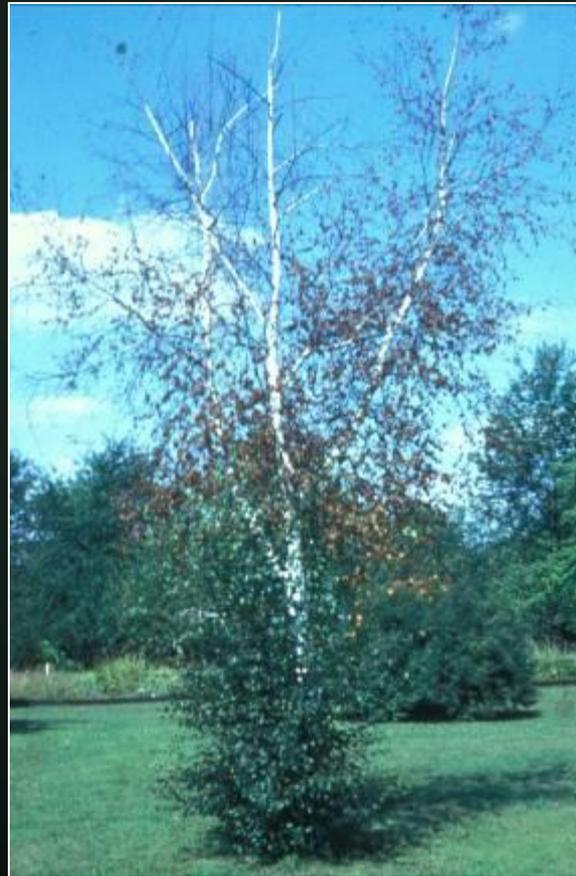
Experimental approach: manipulate water availability, create simulated outbreak.



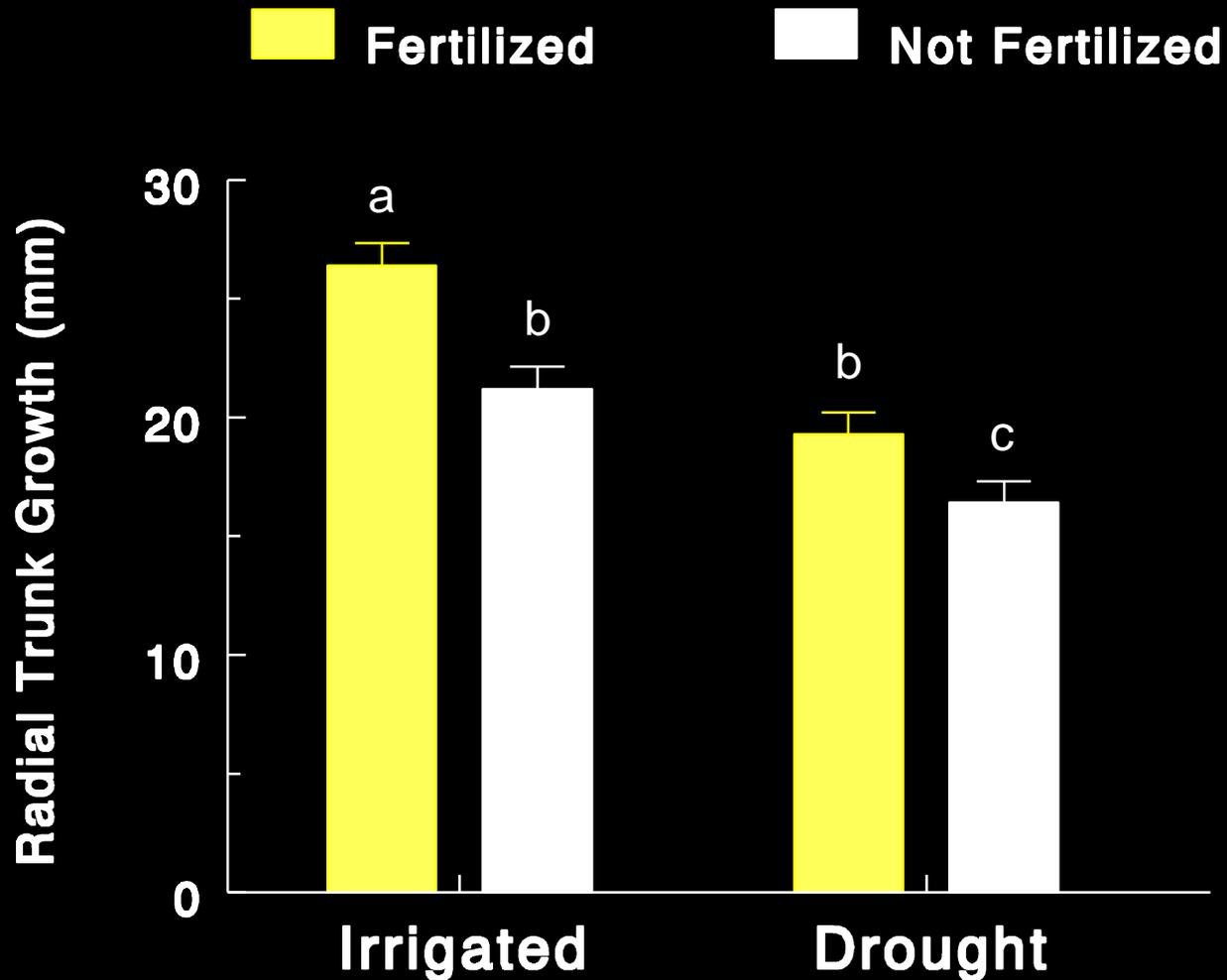
Drought stress increased
bronze birch borer colonization



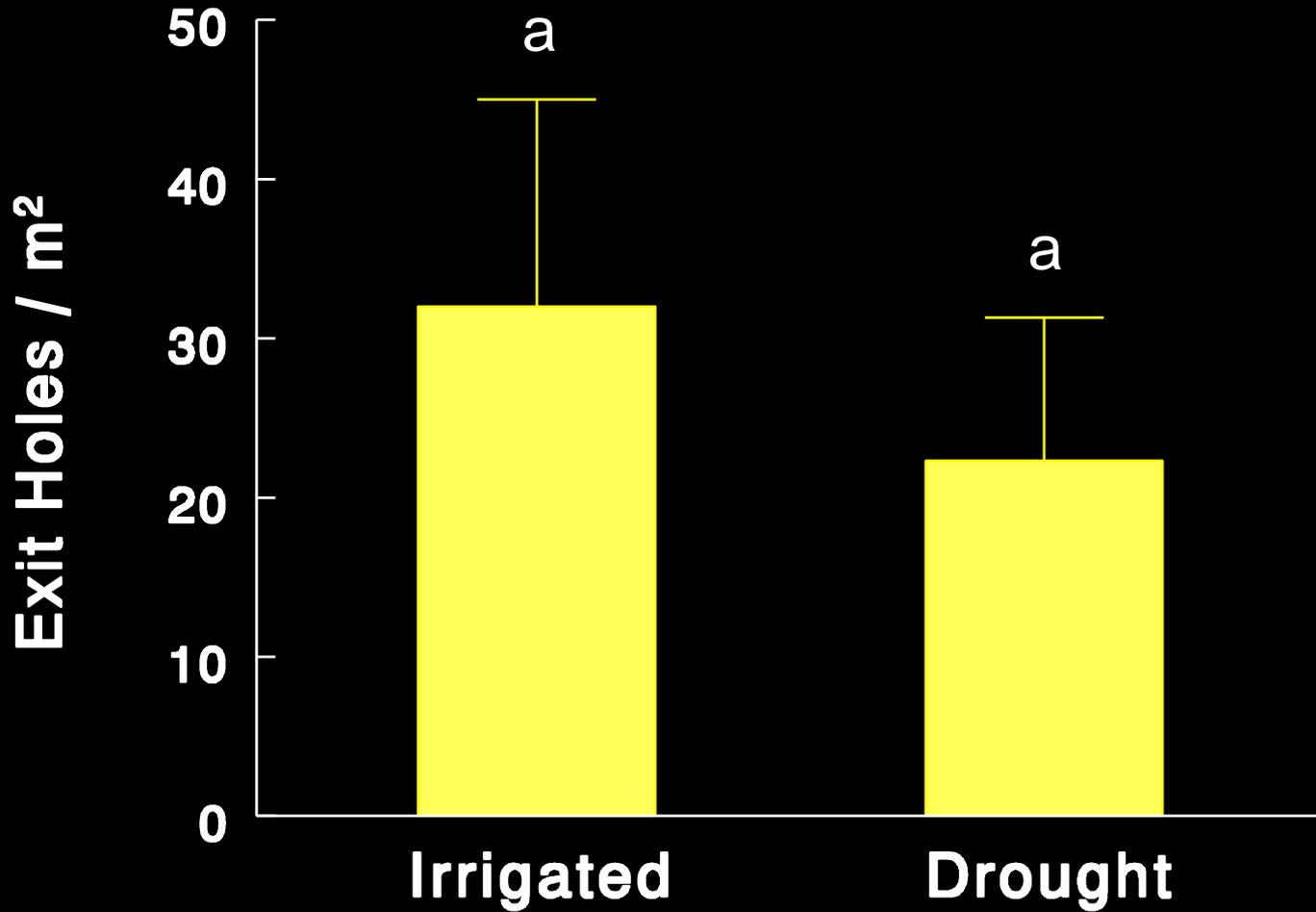
Stress predicted to have little effect on
bronze birch borer resistance of
European white birch (*B. pendula*)



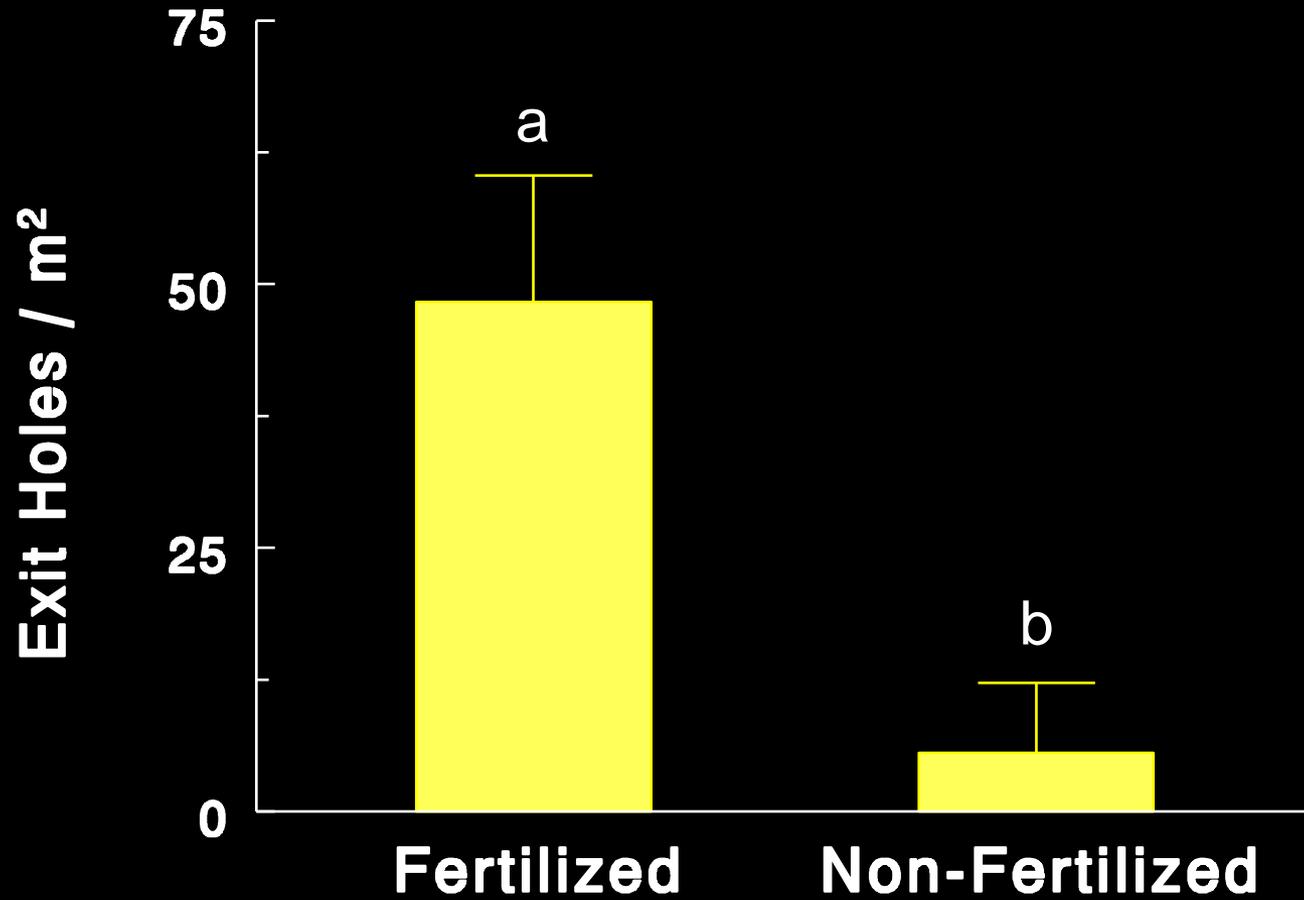
Drought stress decreased growth.
Fertilization increased growth.



Drought stress had no effect on level of bronze birch borer attack

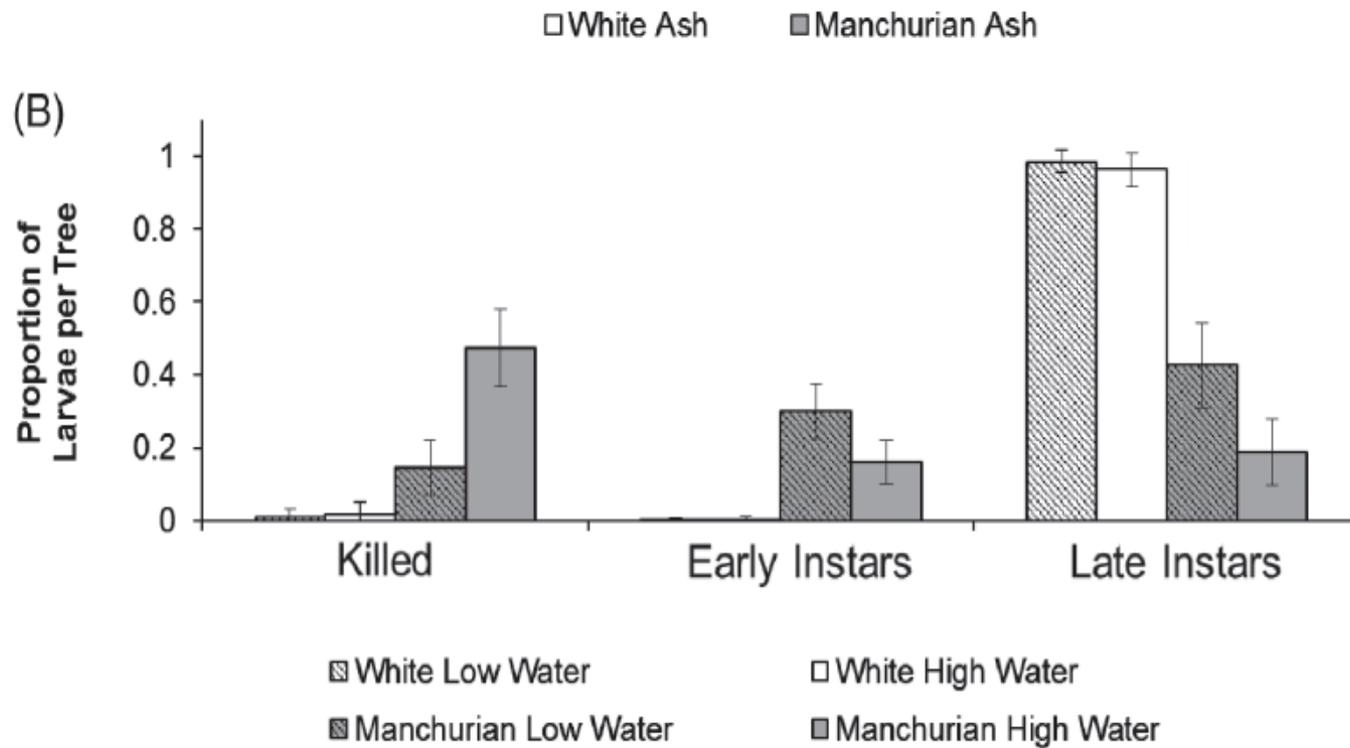


Fertilization dramatically increased bronze birch borer attack



Effects of drought stress on EAB resistance of white and Manchurian ash





Agricultural and Forest Entomology (2017), DOI: 10.1111/afe.12240

Drought stress increased survival and development of emerald ash borer larvae on coevolved Manchurian ash and implicates phloem-based traits in resistance

David N. Showalter*¹, Caterina Villari*², Daniel A. Herms³ and Pierluigi Bonello*

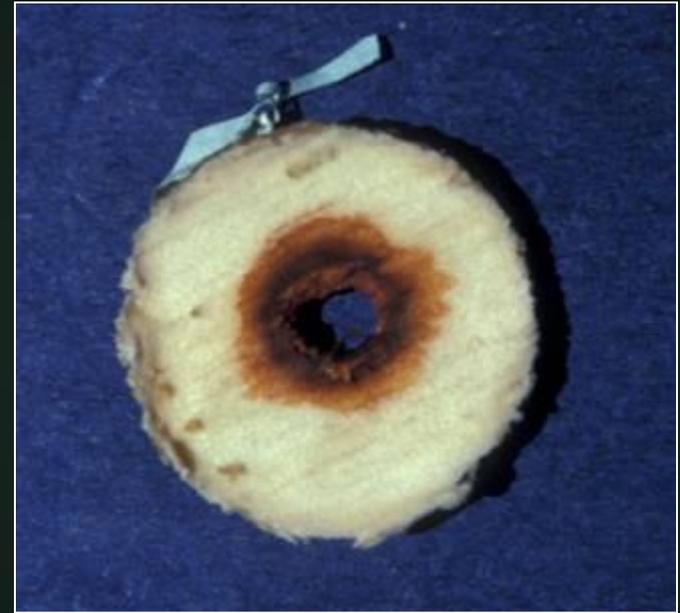
Conclusions

Species with evolutionary history with wood-boring buprestids are inherently resistant.

Naïve hosts are inherently susceptible to these lethal parasites.

Stress weakens resistance of defended hosts; no effect on resistance of undefended hosts.

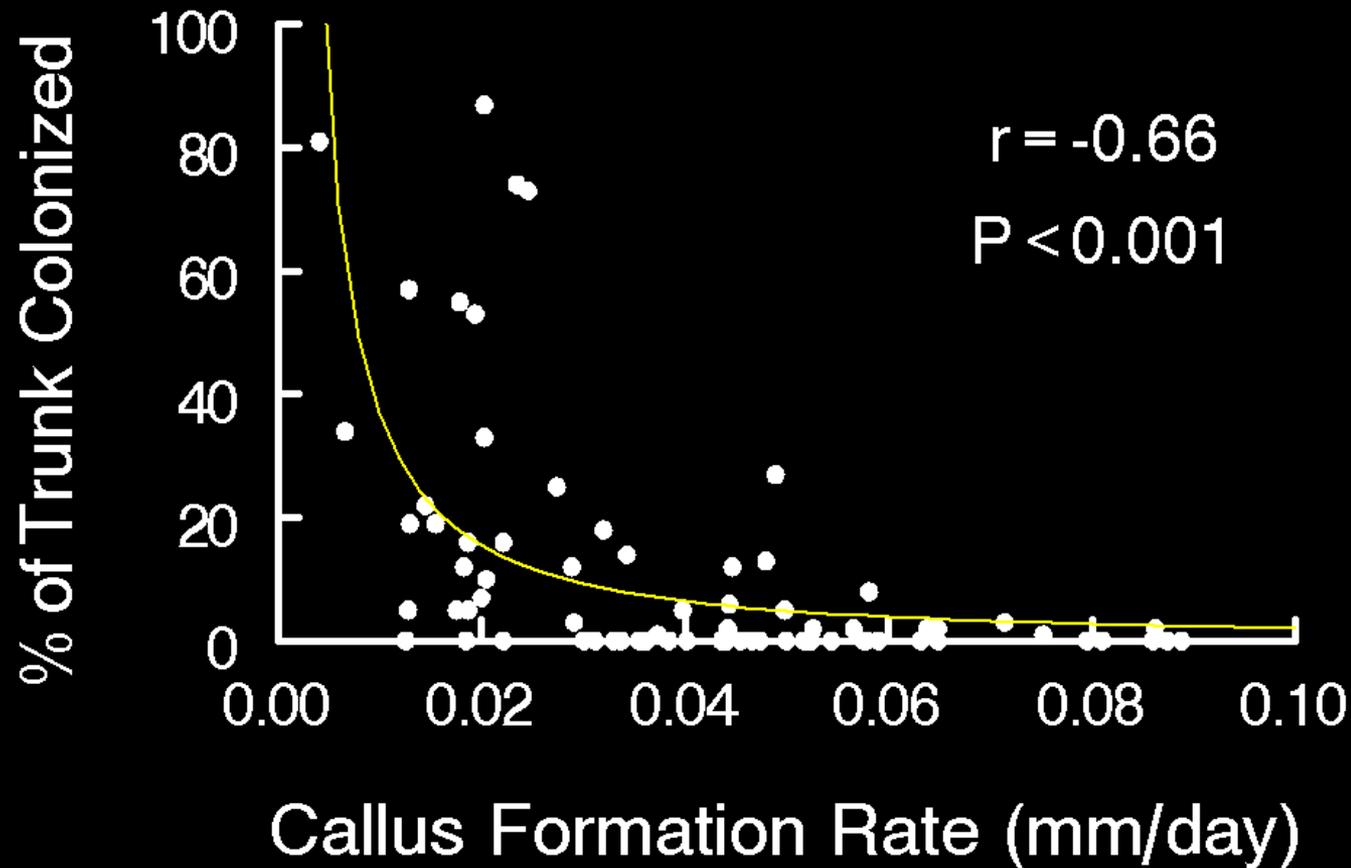
Resistance mechanism: integrated physical and chemical defense

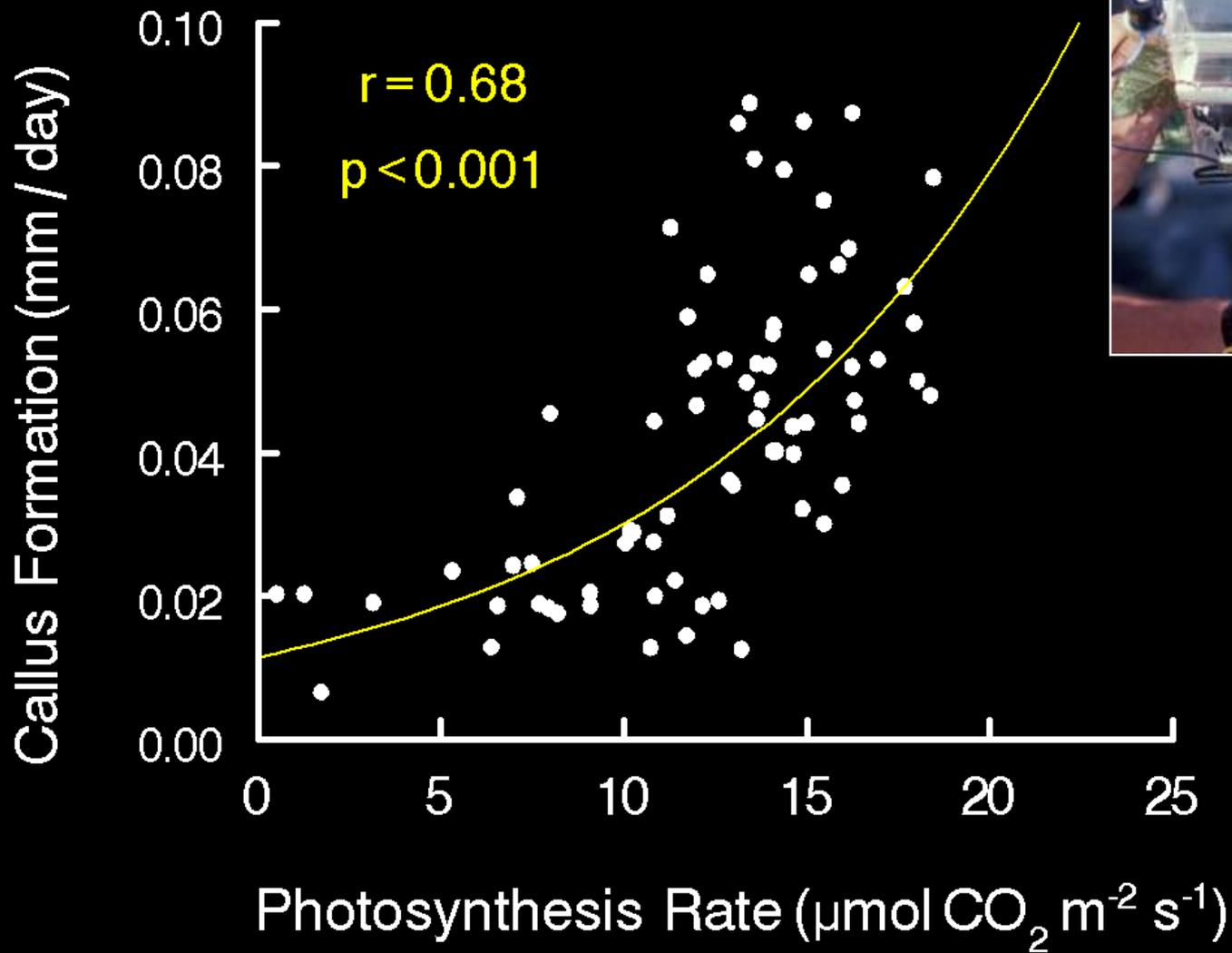


Wound-induced periderm (callus) tissue as a mechanism of resistance.



Borer resistance vanished as callus formation slowed below 0.02 mm / day





Prediction:

Trunk girdling, which restricts transport of photosynthate from canopy to trunk, will decrease rate of callus formation and bronze birch borer resistance in the portion of the trunk below the girdle.

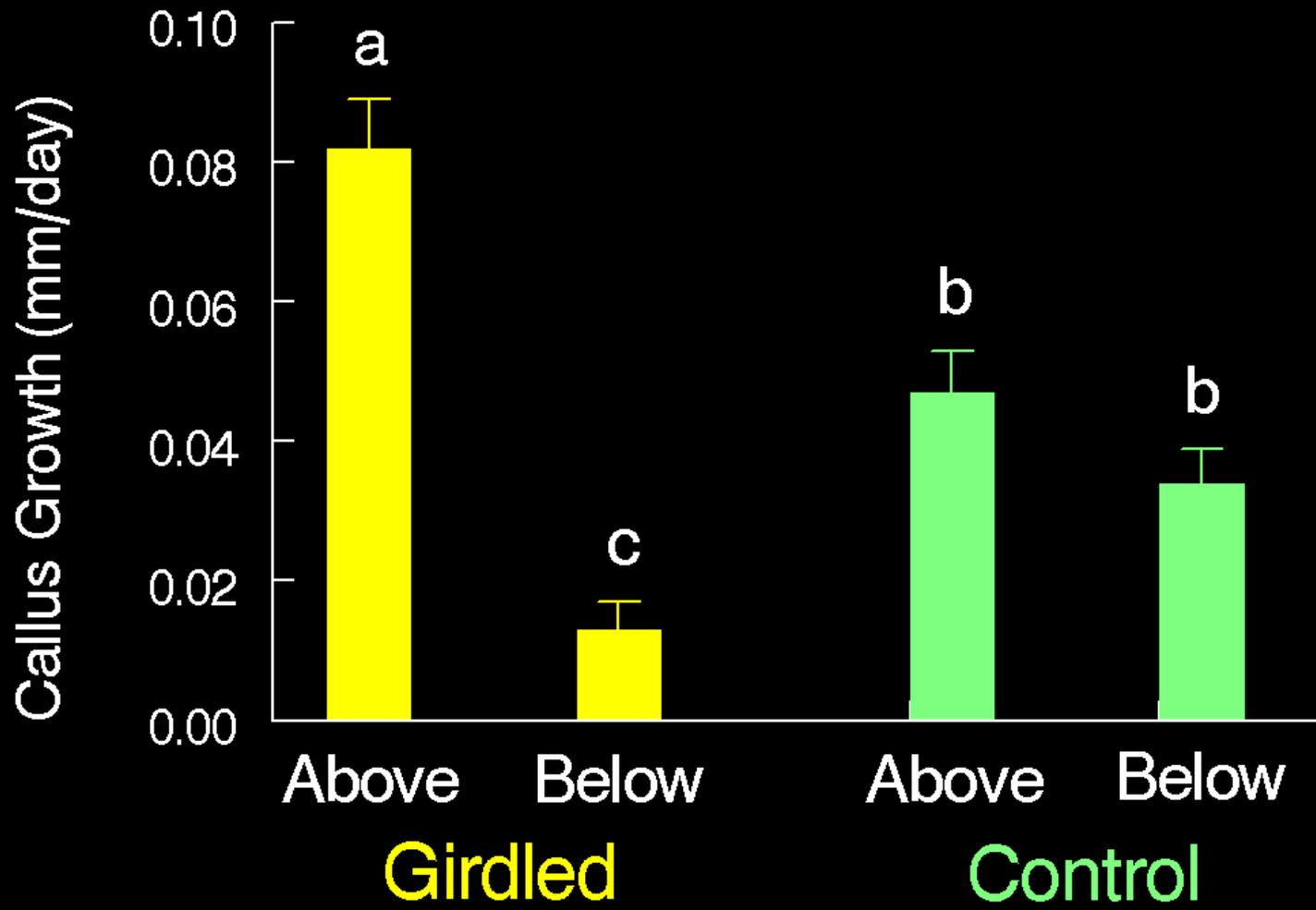
Girdling experiment to test prediction:

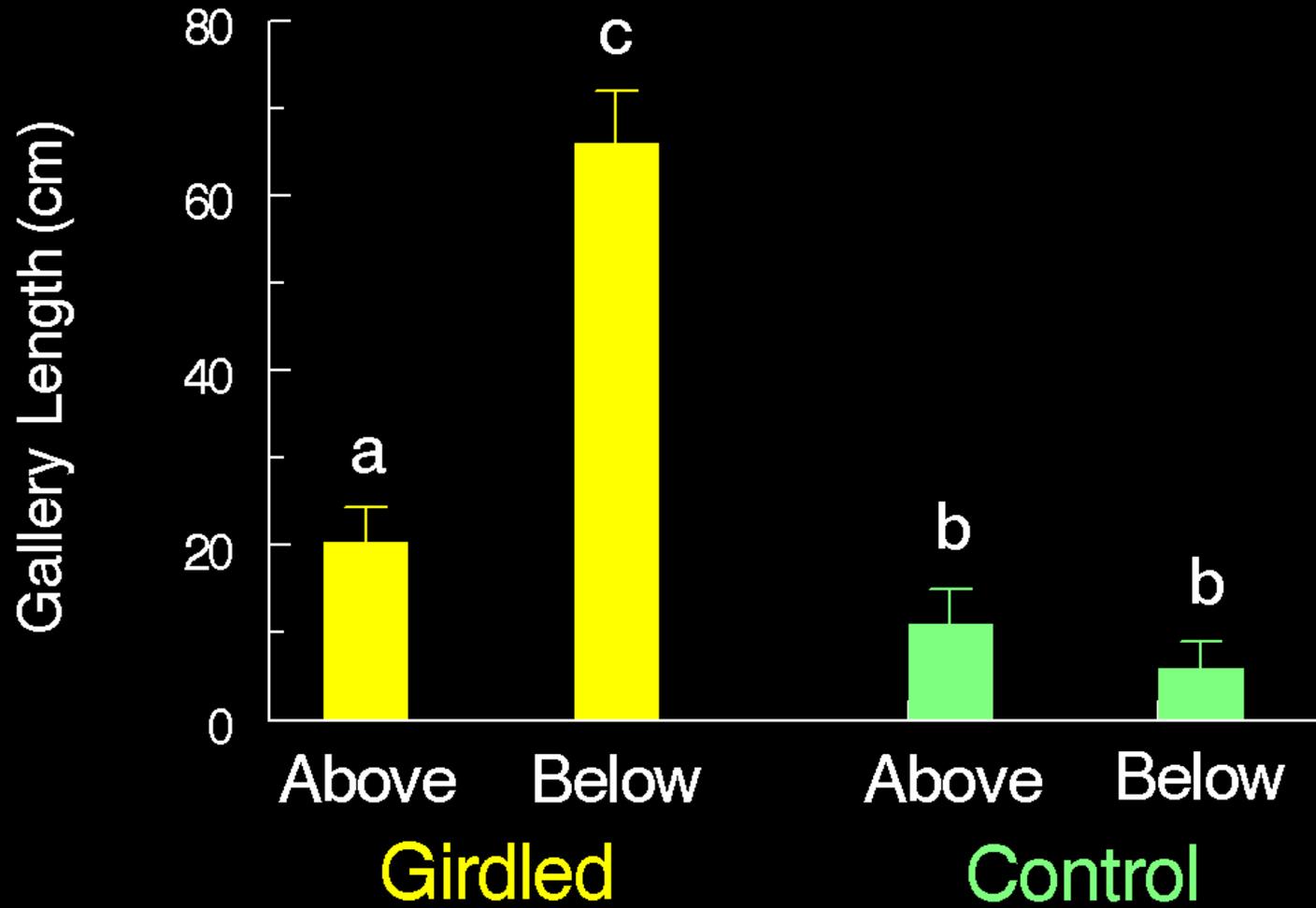


Autopsies



Treatment Effect





Interspecific variation: comparison of phloem phenolic profiles of paper birch and European birch



Dr. Vanessa Muilenburg

J Chem Ecol (2011) 37:1193–1202
DOI 10.1007/s10886-011-0028-z

Inter- and Intra-Specific Variation in Stem Phloem Phenolics of Paper Birch (*Betula papyrifera*) and European White Birch (*Betula pendula*)

V. L. Muilenburg · P. L. Phelan · P. Bonello ·
D. A. Herms

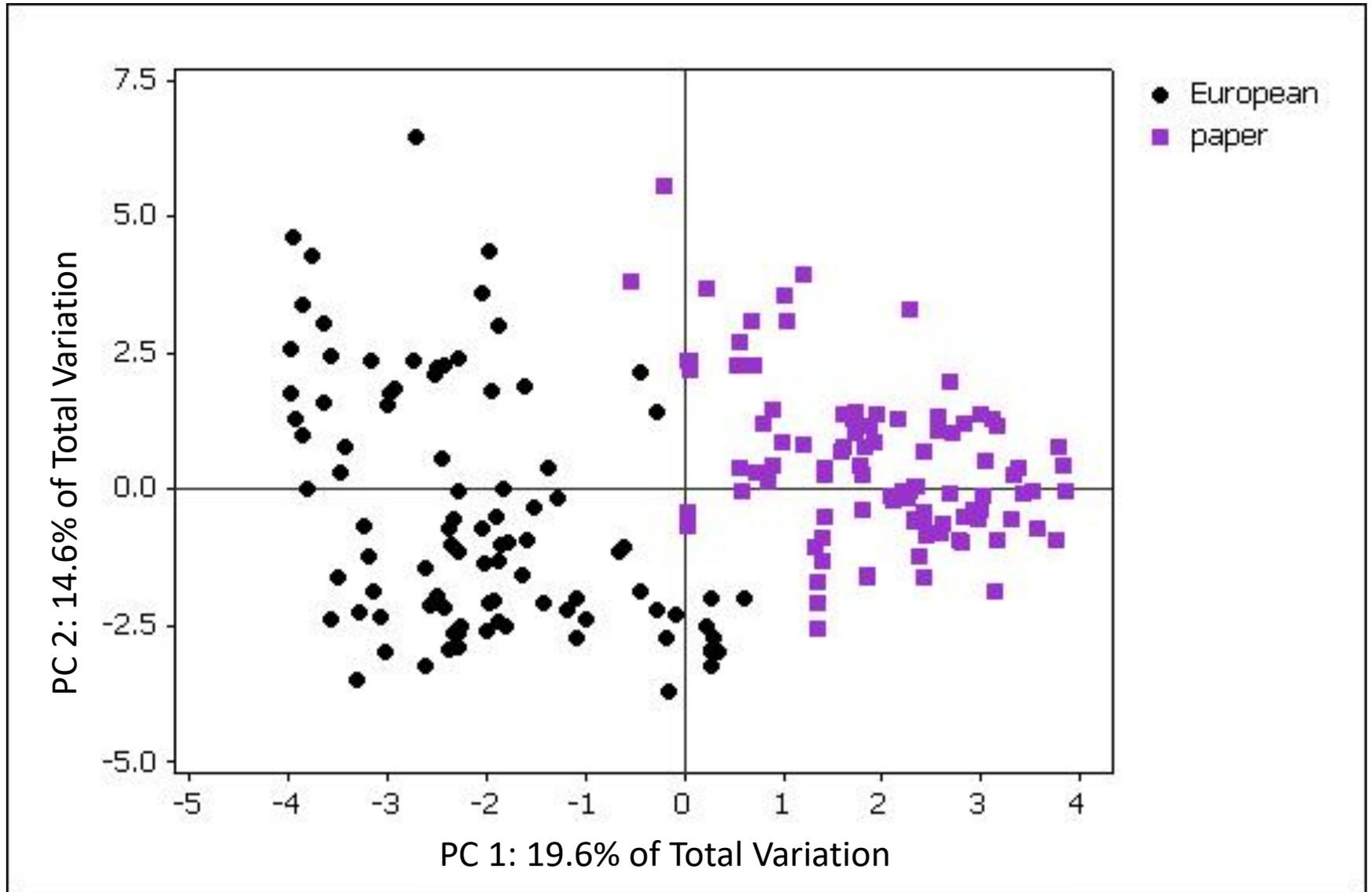
Trees (2013) 27:851–863
DOI 10.1007/s00468-013-0839-3

ORIGINAL PAPER

Characterization of wound responses of stems of paper birch (*Betula papyrifera*) and European white birch (*Betula pendula*)

Vanessa L. Muilenburg · P. L. Phelan ·
P. Bonello · P. F. Loess · D. A. Herms

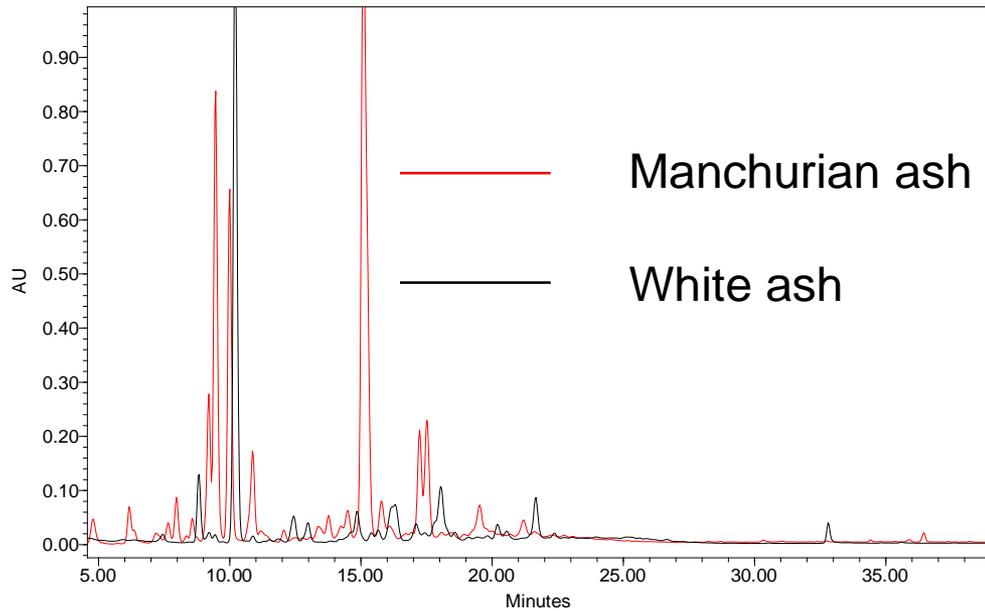
Divergent Phloem Phenolic Profiles



Constitutive and wound-induced defensive chemistry of ash.



Comparative metabolomics of phloem of resistant and susceptible ash species



J Chem Ecol (2007) 33:1430–1448
DOI 10.1007/s10886-007-9312-3

Comparative Phloem Chemistry of Manchurian (*Fraxinus mandshurica*) and Two North American Ash Species (*Fraxinus americana* and *Fraxinus pennsylvanica*)

Alieta Eyles · William Jones · Ken Riedl ·
Don Cipollini · Steven Schwartz · Kenneth Chan ·
Daniel A. Herms · Pierluigi Bonello

J Chem Ecol (2011) 37:450–459
DOI 10.1007/s10886-011-9954-z

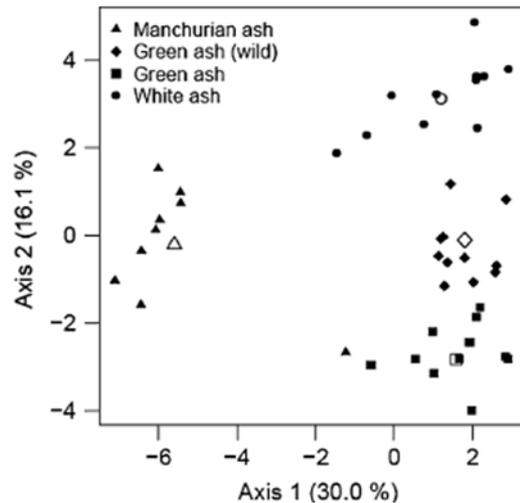
Distinguishing Defensive Characteristics in the Phloem of Ash Species Resistant and Susceptible to Emerald Ash Borer

Don Cipollini · Qin Wang · Justin G. A. Whitehill ·
Jeff R. Powell · Pierluigi Bonello · Daniel A. Herms

J Chem Ecol (2012) 38:499–511
DOI 10.1007/s10886-012-0125-7

Interspecific Comparison of Constitutive Ash Phloem Phenolic Chemistry Reveals Compounds Unique to Manchurian Ash, a Species Resistant to Emerald Ash Borer

Justin G. A. Whitehill · Stephen O. Opiyo ·
Jennifer L. Koch · Daniel A. Herms ·
Donald F. Cipollini · Pierluigi Bonello



Rapid oxidation of phenolics in Manchurian Ash

Larvae feeding on Manchurian ash experience greater oxidative stress in mid-gut.

J Chem Ecol (2016) 42:782–792

Higher Activities of Defense-Associated Enzymes may Contribute to Greater Resistance of Manchurian Ash to Emerald Ash Borer Than A closely Related and Susceptible Congener

Chad M. Rigsby^{1,2} · Daniel A. Herms³ · Pierluigi Bonello⁴ · Don Cipollini¹

Journal of Insect Physiology 78 (2015) 47–54

Physiological responses of emerald ash borer larvae to feeding on different ash species reveal putative resistance mechanisms and insect counter-adaptations

C.M. Rigsby^{a,*}, D.N. Showalter^b, D.A. Herms^c, J.L. Koch^d, P. Bonello^b, D. Cipollini^a



Chad Rigsby

EAB counteradaptations to ash defenses

Comparative Biochemistry and Physiology, Part B 165 (2013) 66–72



Contents lists available at SciVerse ScienceDirect

Comparative Biochemistry and Physiology, Part B

journal homepage: www.elsevier.com/locate/cbpb

Glutathione-S-transferase profiles in the emerald ash borer, *Agrilus planipennis*

Swapna Priya Rajarapu, Omprakash Mittapalli *

Department of Entomology, The Ohio State University, Ohio Agricultural Research and Development, Wooster, OH 44691, USA



Priya Rajarapu

Journal of Insect Physiology 57 (2011) 819–824



Contents lists available at ScienceDirect

Journal of Insect Physiology

journal homepage: www.elsevier.com/locate/jinsphys

Antioxidant genes of the emerald ash borer (*Agrilus planipennis*): Gene characterization and expression profiles

Swapna Priya Rajarapu^a, Praveen Mamidala^a, Daniel A. Herms^a,
Pierluigi Bonello^b, Omprakash Mittapalli^{a,*}

Conclusions

Species with evolutionary history to BBB and EAB are inherently resistant.

Naïve hosts are inherently susceptible.

Stress weakens resistance of defended hosts; no effect on resistance of undefended hosts.

Lack of resistance genes facilitates devastating invasions in defense-free space.