Advances in Understanding Ambrosia Beetle Chemical Ecology and Utilizing the Findings to Improve Insecticide Management

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Outline

1) General Biology and Information

2) Research

- Trapping
- Inducing Tree Attacks
- Insecticide Studies
- Plant Stress Studies

3) Management Issues / Options

Subfamily Scolytinae

Ambrosia, Bark Beetles, and Engravers

~ 5,812 species worldwide

Ambrosia Beetles

- **Many are attracted to volatiles probably related to plant stress (e.g., ethanol)**

Ethanol Lure Pack

- **Dark silhouettes**

Theysohn ("slot")

Lindgren Funnel

Vane

Panel

24 Species Trapped at Tennessee Nursery Center (1998 / 1999)

Table 1. Species of Scolytidae captured in ethanol-baited Lindgren traps at three middle Tennessee sites during 19

Species	Attacked Chestnut	1998 Site A[b]	1998 Site B[b]	1998 Site C[b]	1998 Total	1999 Site A	1999 Site B	1999 Site C	1999 Total
Xyleborinus saxeseni Ratzeburg	Yes	430	101	261	792	822	447	329	1598
Xylosandrus crassiusculus (Motschulsky)	Yes	116	9	106	231	96	109	412	617
Monarthrum fasciatum Say		500	3	11	514	50	25	11	86
Monarthrum mali Fitch		65	0	43	108	24	11	135	170
Xyleborus pelliculosus Eichhoff		140	0	0	140	51	3	3	57
Xyleborus atratus Eichhoff		74	1	3	78	31	10	17	58
Ambrosiodmus tachygraphus Zimmermann		45	0	2	47	47	5	11	63
Xylosandrus germanus Blandford	Yes	56	0	17	73	3	2	5	10
Ambrosiodmus rubricollis Eichhoff		15	0	8	23	48	2	9	59
Drvoxylon onoharaensum (Murayama)[a]		6	1	1	8	5	3	0	8
Xyleborus sayi Hopkins		0	0	8	8	0	0	6	6
Corthylus columbianus Hopkins		5	0	1	6	3	2	0	5
Hypothenemus sp. 1		4	0	1	5	4	0	1	5
Xyleborus californicus Wood		1	0	0	1	1	7	0	8
Xyleborus ferrugineus Fabricius		2	0	2	4	3	0	1	4
Hypothenemus sp. 2	Yes	2	1	0	3	2	0	0	2
Pityophthorus liquidambarus Blackman		0	0	3	3	0	0	0	0
Xyloterinus politus Say		1	0	2	3	0	0	0	0
Hypothenemus sp. 3	Yes	0	1	0	1	1	0	0	1
Xyleborus affinis Eichhoff		0	0		0	1	1		2
Gnathotrichus materiarius Fitch		0	0	0	0	1	0	0	1
Pityophthorus sp. 1		1	0	0	1	0	0	0	0
Pityophthorus sp. 2		1	0	0	1	0	0	0	0
Hypothenemus sp. 4	Yes	0	0	0	0	0	0	0	0
Total		1464	117	469	2050	1193	627	940	2760

98 and 1999

Host Information[c]	Origin[c]	Grand Total	First Report in Tennessee[c]	Host Information[c]	Origin[c]
oods and Conifers (Nearly All Genera)	Europe	1590		Hardwoods and Conifers (Nearly All Genera)	Europe
ardwoods (Very Broad Host Range)	Africa or Asia	848	Yes	Hardwoods (Very Broad Host Range)	Africa or Asia
Oaks and Other Hardwoods	Native	600		Oaks and Other Hardwoods	Native
Oaks and Other Hardwoods		278		Oaks and Other Hardwoods	
?	Asia	197	Yes	?	Asia
Hardwoods and Conifers	Asia	136		Hardwoods and Conifers	Asia
Hardwoods	Native	110	Yes	Hardwoods	Native
Hardwoods	Japan	83		Hardwoods	Japan
Hardwoods	Asia	82		Hardwoods	Asia
ak and Maple (Biology poorly known)	Prob. Asia	16	Yes	Oak and Maple (Biology poorly known)	Prob. Asia
Hardwoods		14		Hardwoods	
Maple and Other Hardwoods		11		Maple and Other Hardwoods	
Wide Variety of Hosts		10	?	Wide Variety of Hosts	?
Only Associated With Oak Stumps		9	Yes	Only Associated With Oak Stumps	Asia
Hardwoods and Some Pine	Tropical America	8		Hardwoods and Some Pine	Tropical America
Wide Variety of Hosts		5	?	Wide Variety of Hosts	?
		3	Yes		
Hardwoods (Rarely Conifers)		3		Hardwoods (Rarely Conifers)	
Wide Variety of Hosts	?	2	?	Wide Variety of Hosts	?
Hardwoods and Conifers	Tropical Amer	2	Yes	Hardwoods and Conifers	Tropical America
Fir, Larch, Pine, and Spruce	Native	1	Yes	Fir, Larch, Pine, and Spruce	Native
Probably Pines or Hardwoods	?	1	?	Probably Pines or Hardwoods	?
Probably Pines or Hardwoods	?	1	?	Probably Pines or Hardwoods	?
Wide Variety of Hosts	?	0	?	Wide Variety of Hosts	?
		4810			

Recently redescribed from *Xyleborus onoharaensis* Murayama (Bright a Rabaglia 1999).

[b] Site A = Tennessee State University Nursery Crop Research Station, Mc nnville, TN (Total of 2 Lindgren trap Counties, TN (Total of 1 Lindgren trap per site).

[c] Information from: USDA Cooperative Agricultural Pest Survey (CAPS) Database, Atkinson and Peck 1994, Br

Note: None of the beetles in this table had previously been reported in the USDA CAPS Database.

seies in northern Warren and northern Grundy

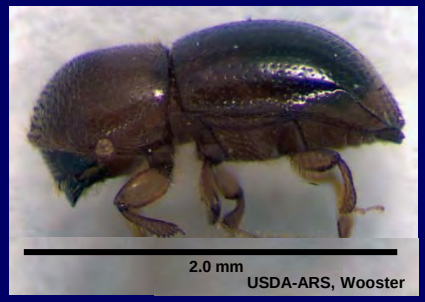
s combined). Site B Commercial nurseries in northern Warren and northern Grund

d 1977, Wood and Bright 1992

ight 1968, Vandenberg et al. 2000,

Species Attacking Nursery Stock in Tennessee

Granulated (Asian) Ambrosia Beetle
(*Xylosandrus crassiusculus* [Motschulsky])

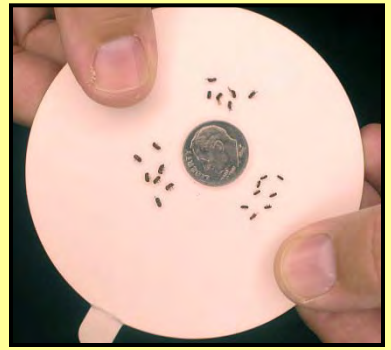


Black Stem Borer, Smaller Alnus Beetle, Tea Root Borer
(*Xylosandrus germanus* Blandford)

Lesser Shothole Borer, Fruit-Tree Pinhole Borer
(*Xyleborinus saxeseni* Ratzeburg)

Thysanoes fimbricornis LeConte

Actual Size



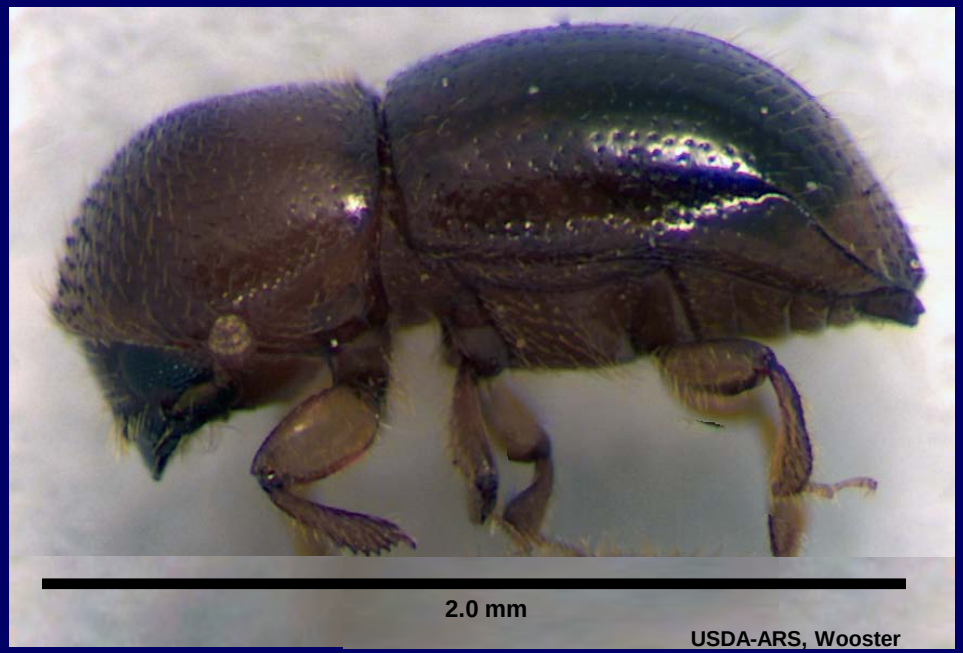
Granulated Ambrosia Beetle ("Asian AB")

- Introduced to South Carolina in 1974
- Now widely distributed
- Numerous reports of damage across eastern U.S.

5 – 10 GAB will kill most trees under 3 inch caliper (Mizell and Riddle 2004)

Black Stem Borer

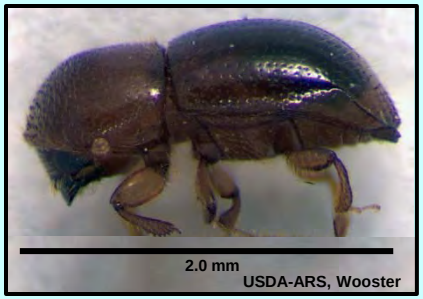
- Introduced at Long Island New York about 1932
- Now widely distributed
- Seems to be more problematic in northern states
- Multiple reports of being problematic in walnut production



Over 100 known hosts

Major Hosts

- Cherry
- Chestnut
- Elm
- Maple
- Oak
- Persimmon
- Sweetgum
- Buckeye
- Crape myrtle
- Dogwood
- Fig
- Golden raintree
- Magnolia
- Peach
- Pear
- Pecan
- Persimmon
- Plum
- Redbud
- Styrax
- Sweetgum
- Walnut???



Over 34 plant genera hosts

Major Hosts

- Cherry
- Chestnut
- Elm
- Maple
- Oak
- Persimmon
- Sweetgum
- Alder
- Apple
- Beech
- Cypress
- Grape
- Hickory
- Hornbeam
- Mulberry
- Pine
- Rhododendron
- Spruce
- Tulip poplar
- Tupelo
- Walnut

Ambrosia Beetles Reported as Problematic on Walnut (Solomon 1995)

Black Stem Borer, Smaller Alnus Beetle, Tea Root Borer
(*Xylosandrus germanus* Blandford)

Lesser Shothole Borer, Fruit-Tree Pinhole Borer
(*Xyleborinus saxeseni* Ratzeburg)

Pest & Disease Image Library, Australia, Bugwood.org

Pear Blight Beetle, European Shot-Hole Borer
(*Xyleborus dispar* [Fab.])

Pest & Disease Image Library, Australia, Bugwood.org

Cosmopolitan Ambrosia Beetle, Black Twig Borer
(*Xyleborus ferrugineus* [Fab.])

J.R. Baker & S.B. Bambara, NCSU, Bugwood.org

Oak Timber Beetle
(*Xyleborus xylographus* [Say])

Generalities Among Walnut Attacking Ambrosia Beetles

Importance: Most have broad host ranges, primarily preferring hardwoods

Range: Most introduced from Asia or Europe and occur over most of U.S.

Habits: Adults usually over-winter in galleries
Females mate before leaving galleries. Males do not fly.
Bore into sapwood, usually not the heartwood.
Galleries consist of branches or enlarged brood chambers
Larvae and adults feed on symbiotic ambrosia fungus
Adults "culture" fungi along gallery walls
Some continue to extend galleries over time
Some begin galleries and are then joined by others of their species
Some have one generation per year and others have multiple

Peak Activity: Emerge as early as February (*X. saxeseni*), but usually peak emergence is March through May

Host Preference: Unthrifty, injured, and dying trees. Moisture content important. Attracted to stressed trees.

Generalities Among Walnut Attacking Ambrosia Beetles

Damage: Prefer to attack before “bud-break”
Wilting, flagging, branch dieback, basal sprouts, tree death
Lumber staining and reduced quality from galleries
Possible vectors of other pathogenic fungi

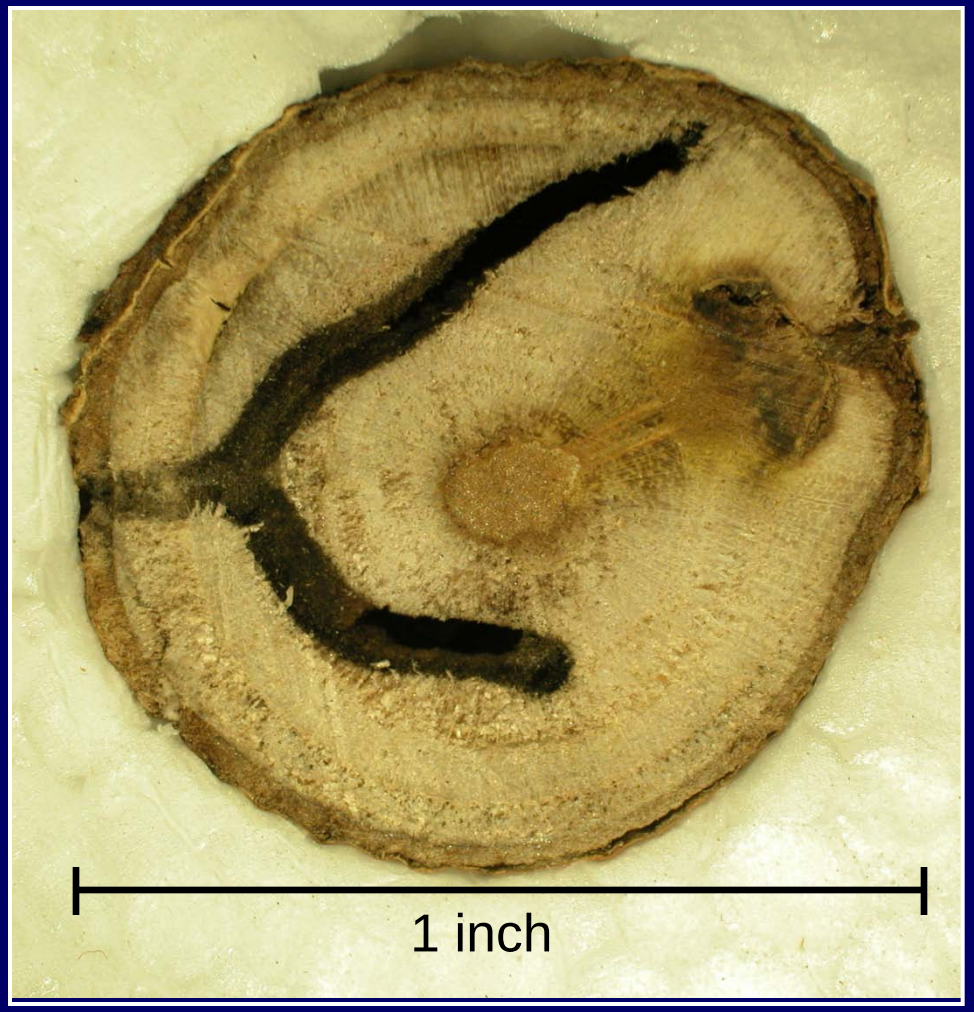
Control: Natural enemies (predaceous beetles / true bugs)
Cultural practices promoting healthy trees
Prompt harvest and use of timber
Seed sources listed as important for *X. germanus* (Weber)
Plantings near water sources may be more susceptible
Traps to time judicious insecticide treatments

- Adult boring produces “shot holes”

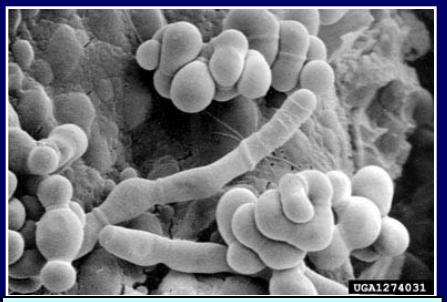
- Boring activities can result in “sawdust” or “toothpick” like particles

- Tunnels (galleries) generally made deep into sapwood

Granulated Ambrosia Beetle Gallery

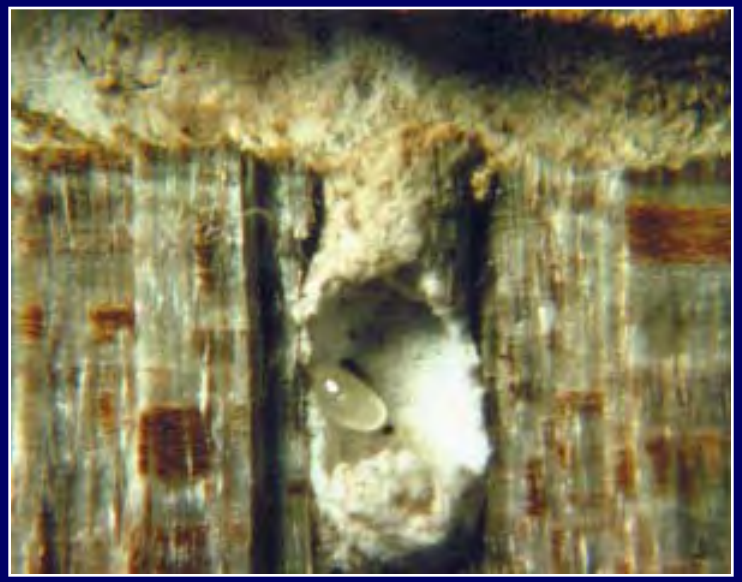


- Adults carry species-specific symbiotic “ambrosia” fungus in mycangia



Doug Stone, Miss. St. Univ., Bugwood.org

- Larvae and adults eat ambrosia fungus



Jack C. Nord, USDA For.Serv. www.forestryimages.org

Doug Stone, Miss. St. Univ., Bugwood.org

- Female progeny emerge from host trees and fly to new host trees

- Males do not fly, but will exit trees

- Ambrosia beetles are more serious nursery and landscape pests than other scolytids

- Attack living, recently killed trees, or dead trees (high moisture content)

Dead tree in river under attack

Research

Trap Studies

Value of Traps

Ambrosia beetles:

- Over-winter as adults
- No temperature dependent larval development period in spring
- Remain inactive until conditions favorable
- Emerge suddenly in large numbers
- Generally attack before bud break
- However, emergence can vary widely between years and locations

1) Used to direct scouting activities (esp. when sprays not made)

2) Used to direct timing of spray treatments

Xylosandrus crassiusculus

Xylosandrus germanus

Beetles Captured Per Day

2006

2007

Mar Apr May Jun Jul

Site 1

Site 2

- Peaks at different times in different years
- Within years, similar between sites and *X. crass* and *X. germ*

Identifying the Granulated (Asian) Ambrosia Beetle

1) Color – Reddish-brown to orange-brown
(may appear two toned)

2) Non-shiny patch on abdomen tip
(visible with 10x hand lens)

3) Extension assistance

Procoxae

Widely-spaced

Xylosandrus

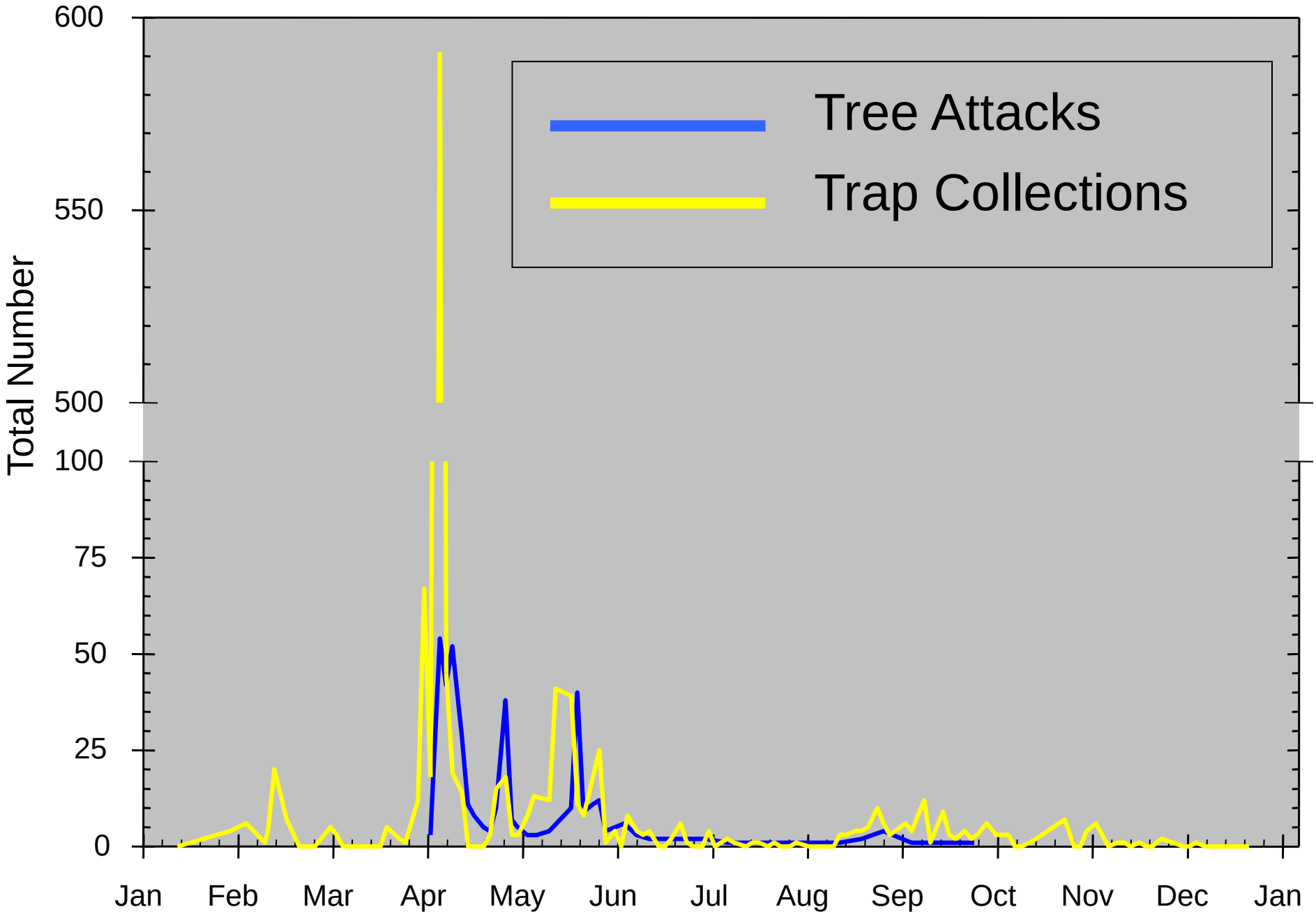
Contiguous

Other

Trapping / Tree Attack Study (1999)

Lindgren Trap

Chestnut Trees with Gallery Cages


600
550
500
100
75
50
25
0
Total Number
Tree Attacks
Trap Collections
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan

Other Findings During Study

- More galleries on southwest side of tree
  - *X. germanus* – 195.2 ± 13.1
  - *X. crassiusculus* – 238.6 ± 22.0

- Females vs. Males emerging
  - *X. germanus* – 16 : 1
  - *X. crassiusculus* – 15 : 1

Males did emerge

- Greater progeny production by *X. crassiusculus*
  - *X. germanus* – 4.4 ± 0.5 per gallery
  - *X. crassiusculus* – 9.9 ± 4.0 per gallery

- Mixed species emergence from same gallery

- Emergence occurred in spurts
  - *X. germanus* – Up to 7 events from 54 to 89 days
  - *X. crassiusculus* – Up to 4 events from 55 to 94 days

Ambrosia Beetle Trap Comparisons (2003)

Trap Features Evaluated:

- Trap type
- Lure type
- Killing agents
- Cost
- Ease of use

Traps With Greater Collections Than a Non-Baited Lindgren Trap

All baited with pill bottle ethanol lure

Species										
X.crass	✓	✓	✓	✓	✓	✓	✓			
X.germ	✓		✓				✓			
X.sax			✓	✓						

- Traps with highest capture rates



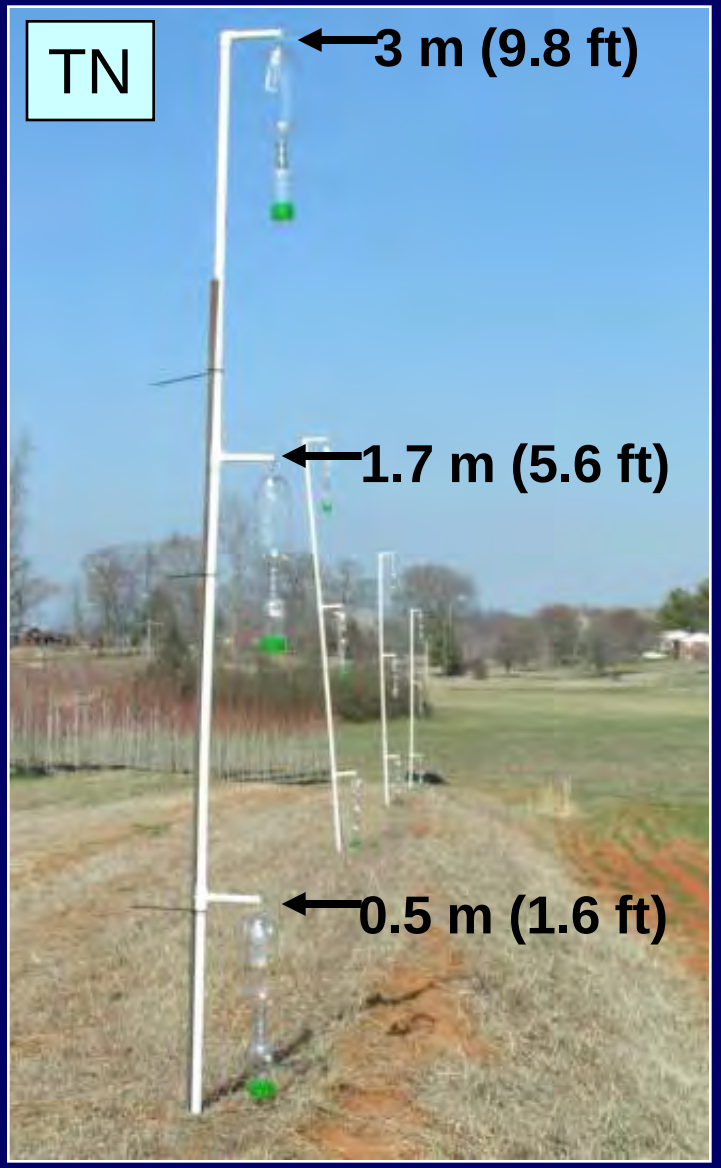

- Best lure (pill bottle with wick) had highest ethanol release rate)

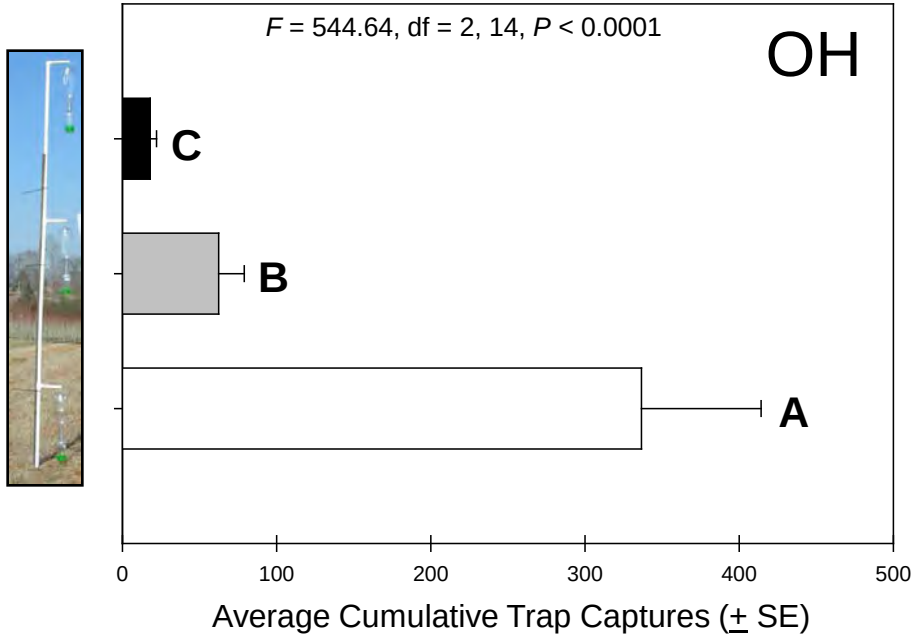


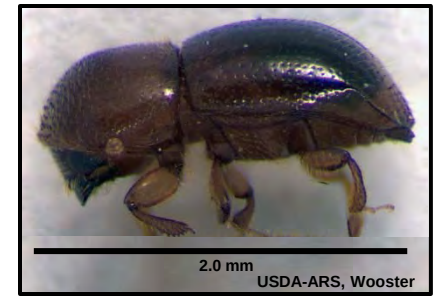
- Bottle trap was best all around trap
  - Cheapest to make
  - Easiest to operate
  - Effective on problem ambrosia beetles

Improved

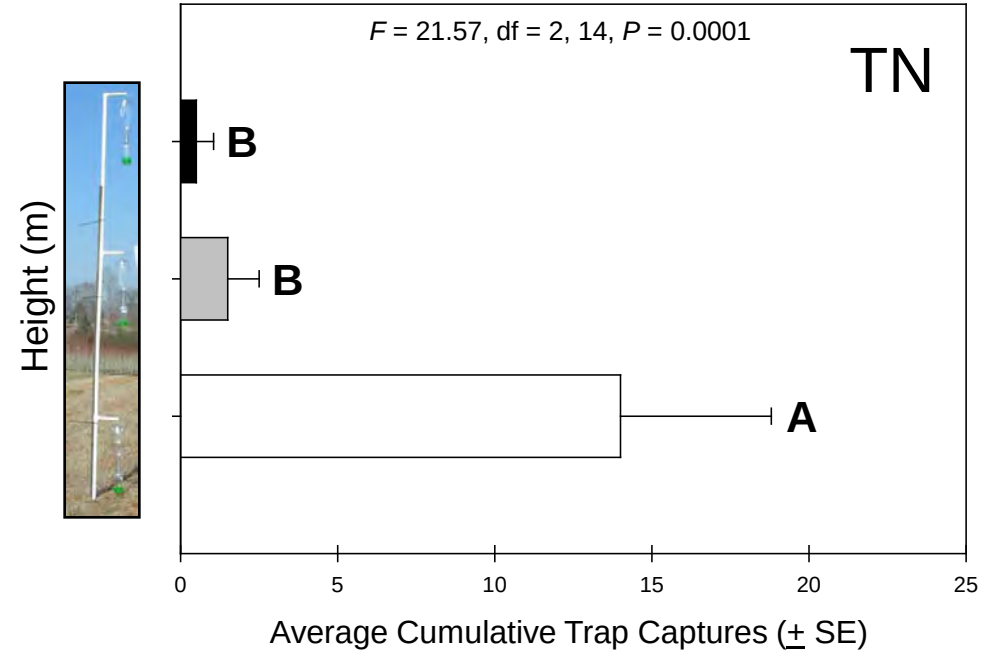
Trap Height Study – Bottle Trap (2006 - 2008)

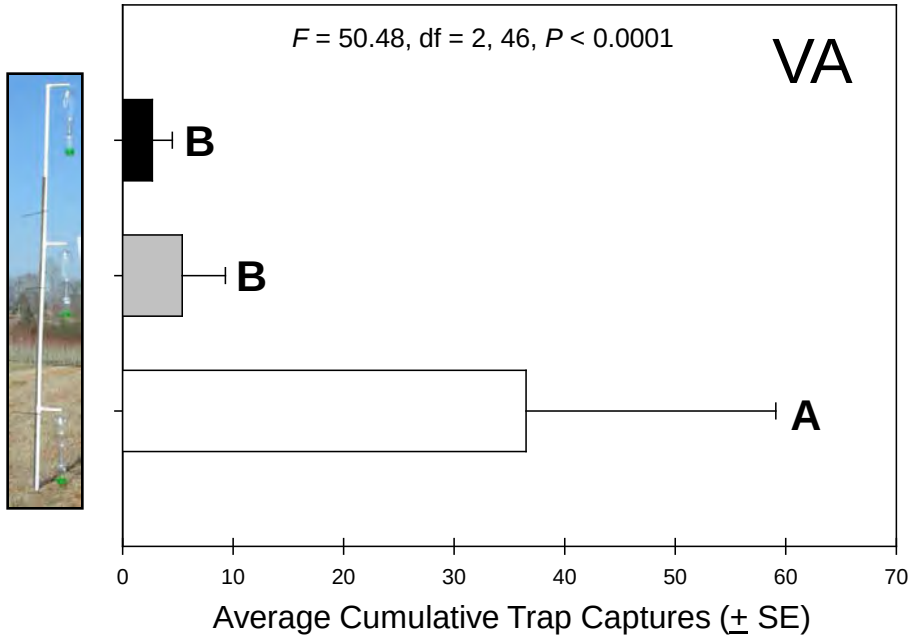




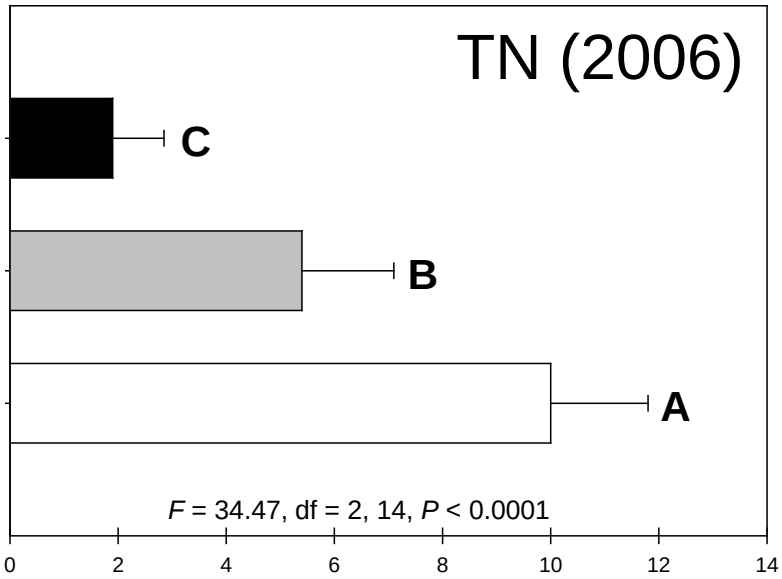


Xylosandrus germanus

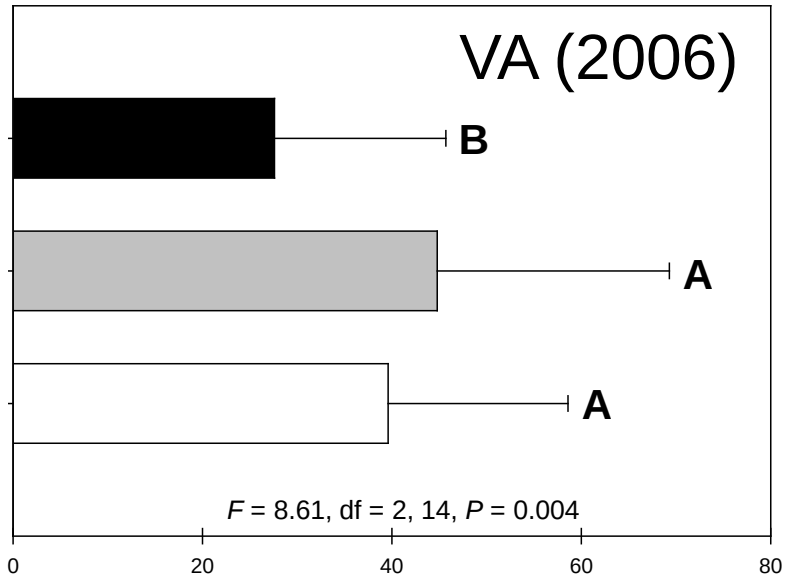




Xylosandrus crassiusculus



Height



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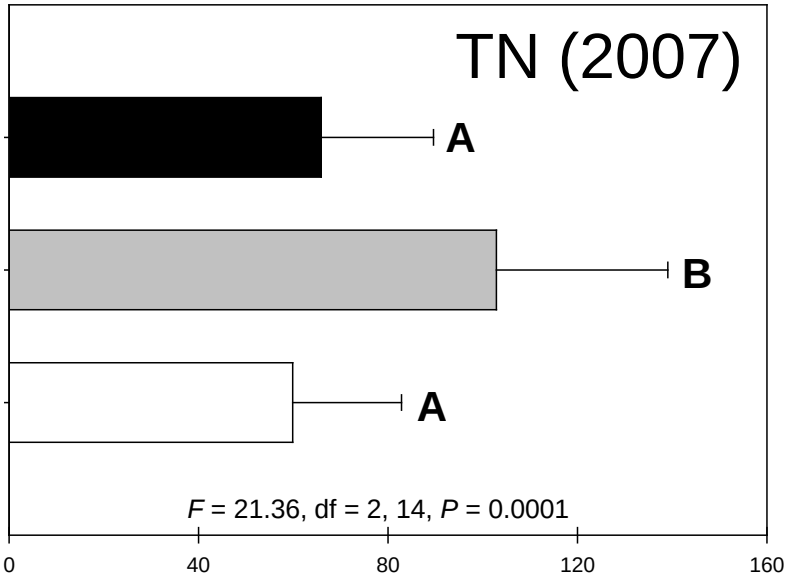

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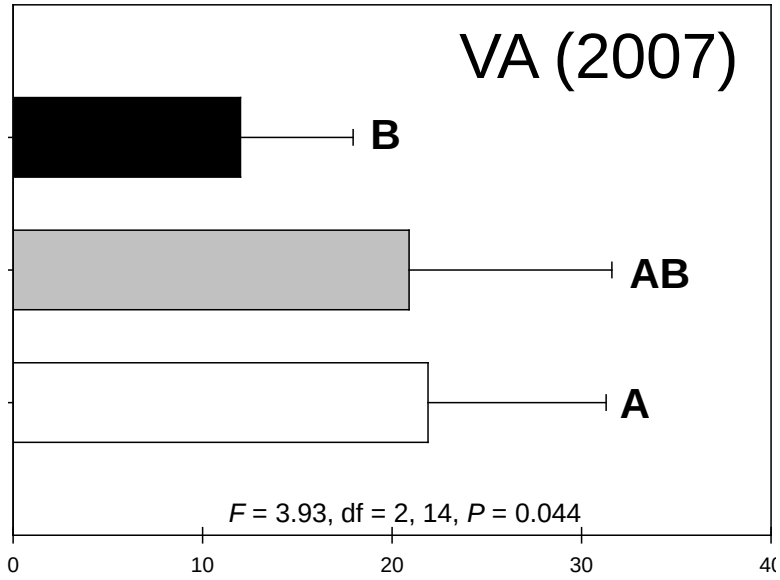
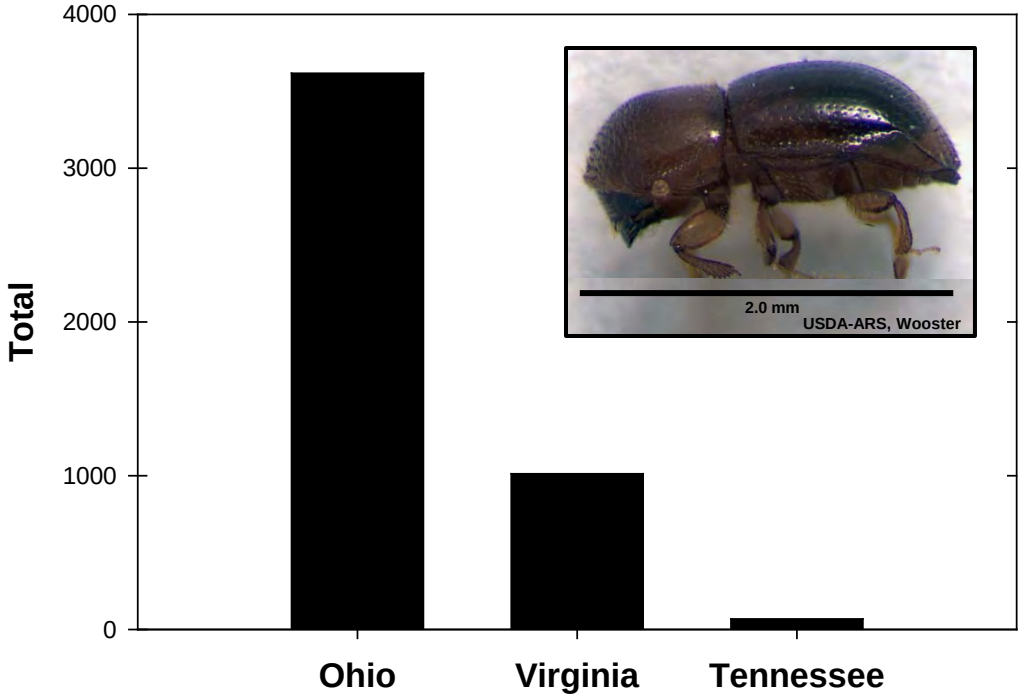
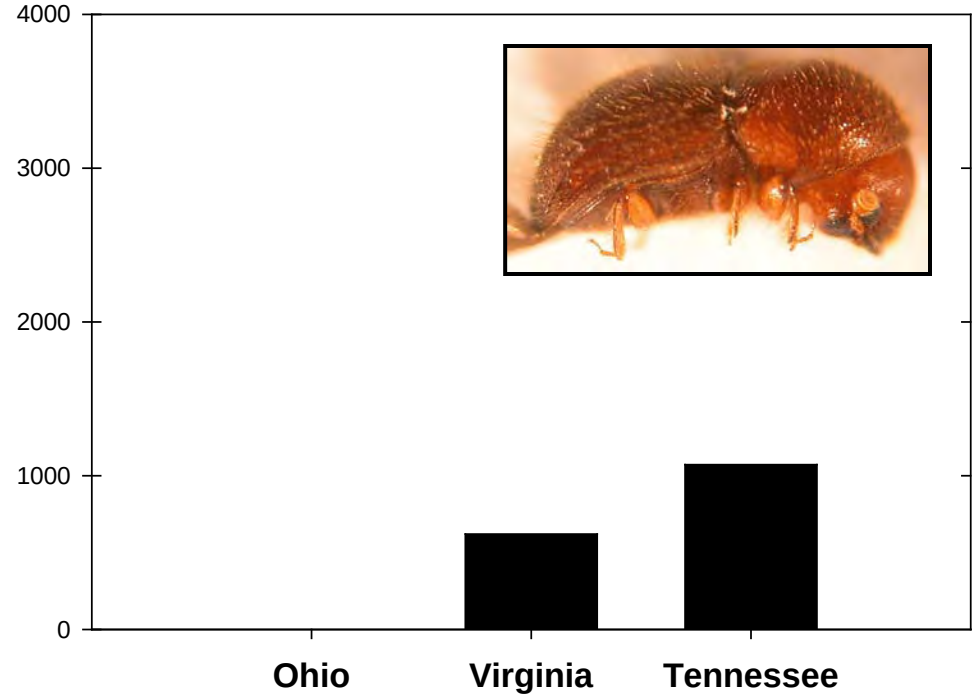


Total Captures in Three States During 2007





Research

Inducing Tree Attacks

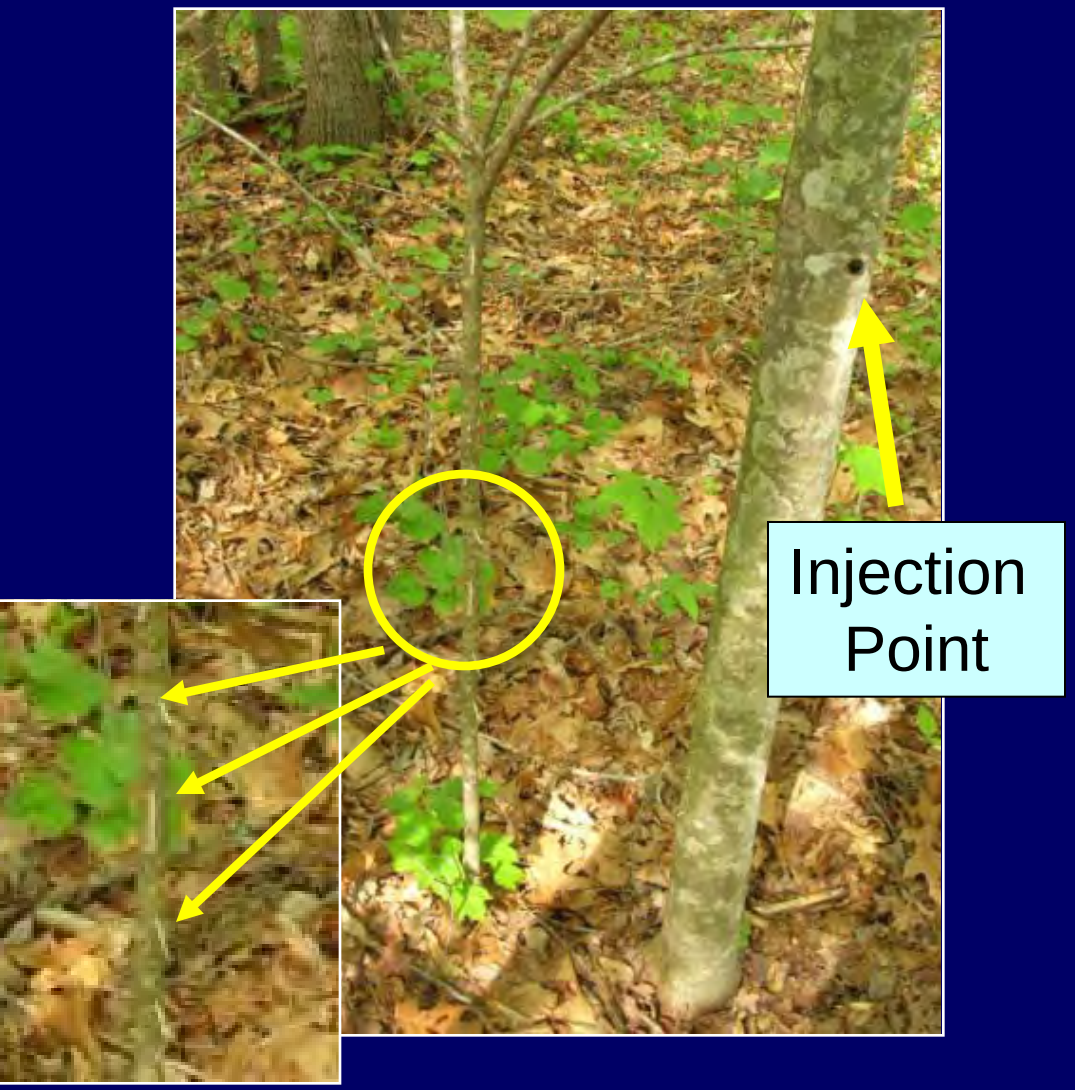
Injecting Trees With Ethanol

After Ethanol Injection

Attacks Induced on Previously Healthy Trees (Trunk Size ~ 4 Inches)

After Ethanol Injection

Attacks on Adjacent Tree Shoots



Attacks High in Tree

After Ethanol Injection

Beetle Attempting to Enter Tree

Checkered Beetle Attacking Ambrosia Beetle Boring Into the Tree

Ethanol-Baited Trap

Versus

Trap with Ethanol-Injected Bolt

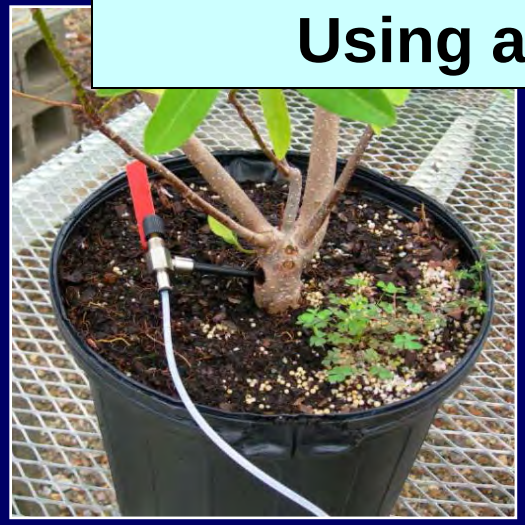
Research

Insecticide Studies

Insecticide / Biopesticide Sprays

Ambrosia Beetle Attacks Triggered

Injecting Trees With Ethanol Using an Arbojet



Insecticide Test – April 24 to May 22, 2009

I. Trees Treated:

	Rate / 100 gallons
A. Systemic Soil Drenches	
- Acelepryn	32 floz
- Safari	24 oz
B. Systemic Trunk Sprays	
- Safari	8 oz
- Safari + PentraBark (wetting agent)	8 oz
C. Contact Pyrethroid Trunk Sprays	
- Onyx Pro Insecticide	32 floz
- Perm-Up 3.2 EC	160 floz
- Scimitar CS	5 floz

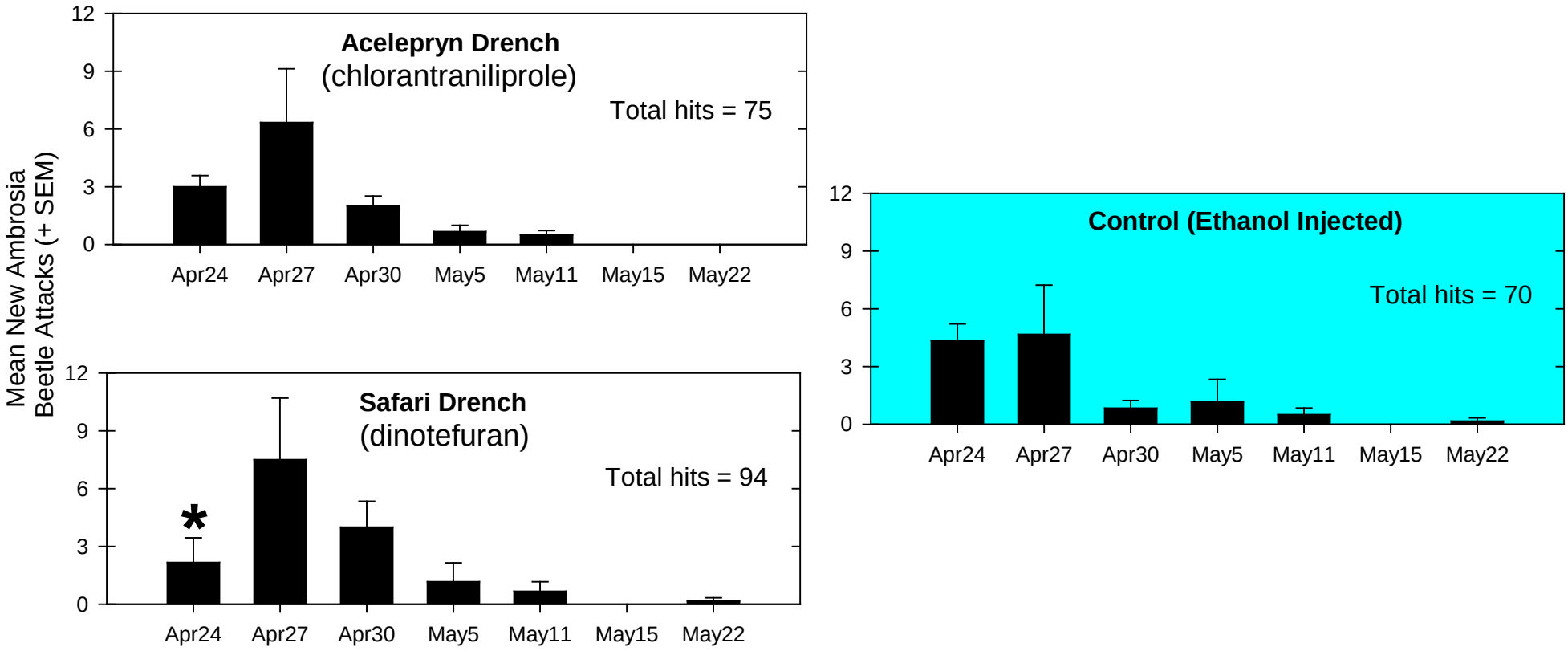
II. Trees Injected With Ethanol (75 ml of 50% ETOH)

- 34 days after systemic drenches
- 1 day after trunk sprays

III. Trees Monitored for New Attacks (~ 1 month)

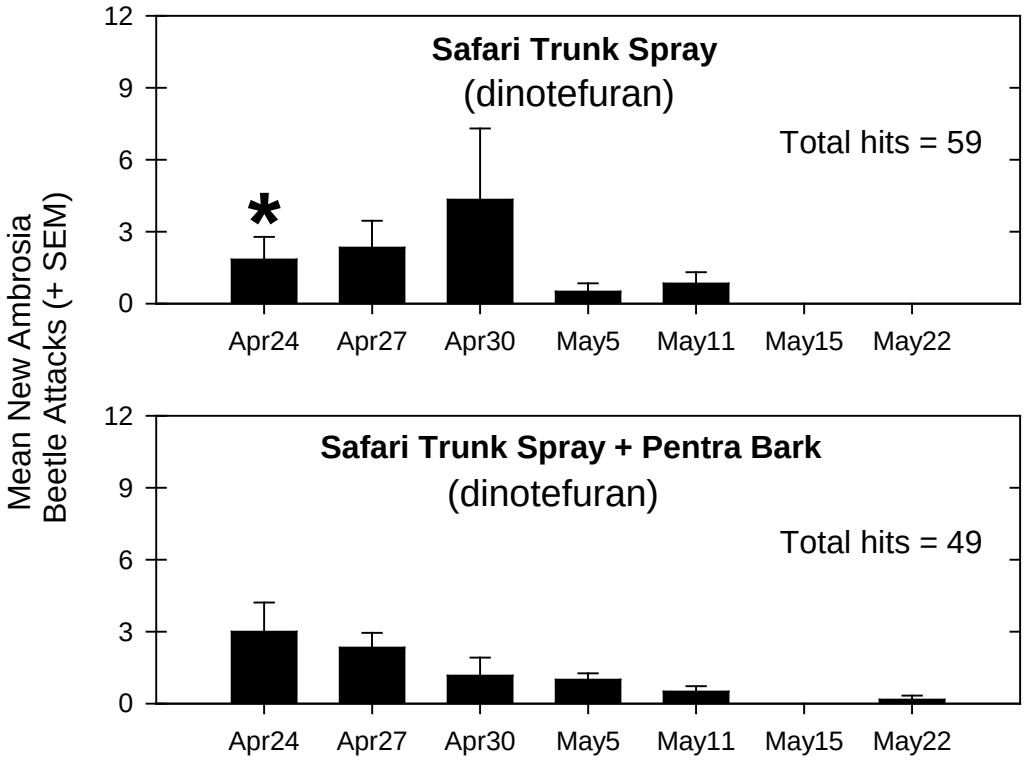
IV. Attacked Trees Then Held in Lab to Rear Beetles

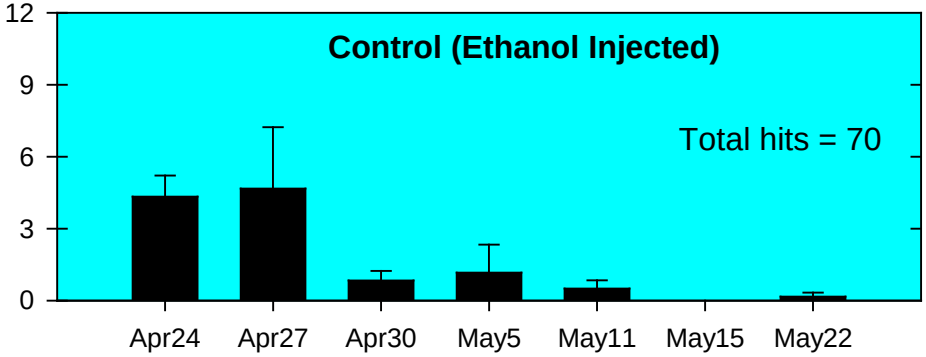
Systemic Soil Drenches



* Indicates significant difference from control ($P < 0.05$)

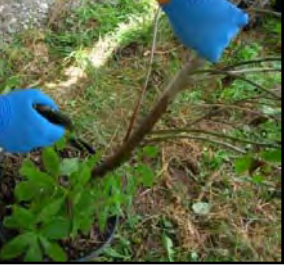
Systemic Trunk Sprays

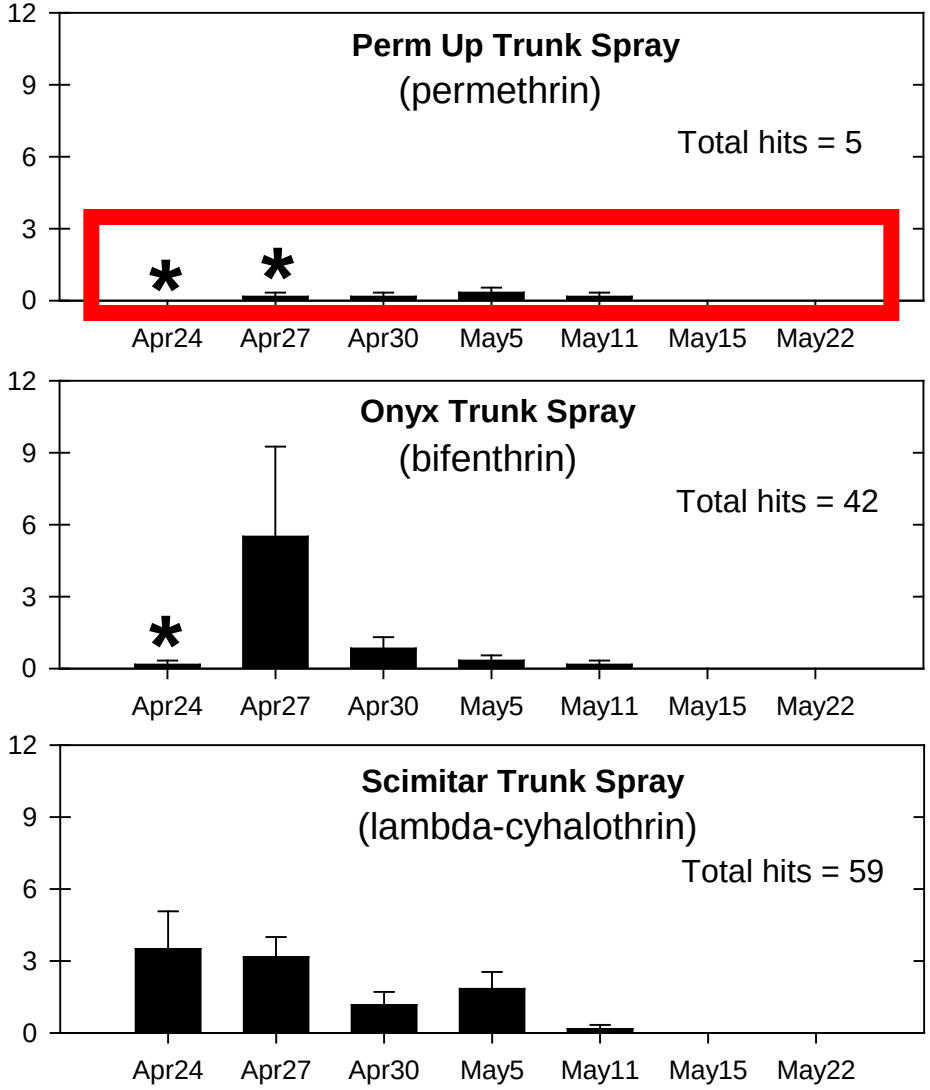


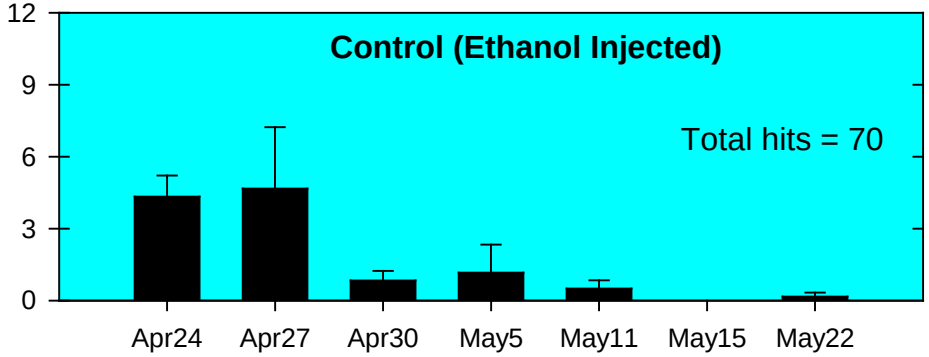


* Indicates significant difference from control ($P < 0.05$)

Contact Pyrethroid Trunk Sprays







* Indicates significant difference from control ($P < 0.05$)

Biopesticide / Insecticide Test – June 24 to July 16, 2009

I. Trees Treated:

A. Contact Pyrethroid Trunk Sprays (160 ml / 100 gal)
- Perm-Up 3.2 EC
- Perm-Up 3.2 EC + PentraBark

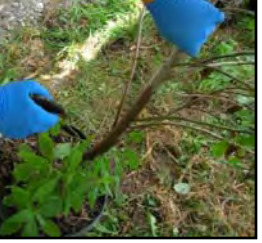
B. Biopesticides (421 ml / gallon ~ 10%)
- Cinnacure (30% cinnamaldehyde)
- Cinnacure + PentraBark
- EcoTrol (10% rosemary oil; 2% peppermint oil)

Most antennally active on *X. germanus*

II. Trees Injected With Ethanol (75 ml of 10% ETOH)
- 1 day after trunk sprays

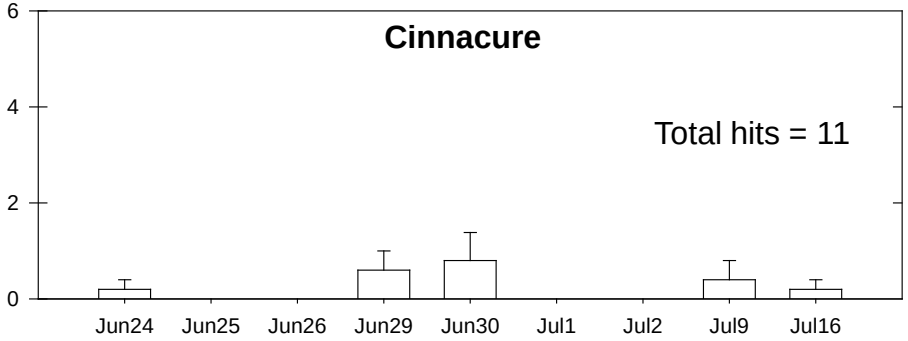
III. Trees Monitored for New Attacks (~ 1 month)

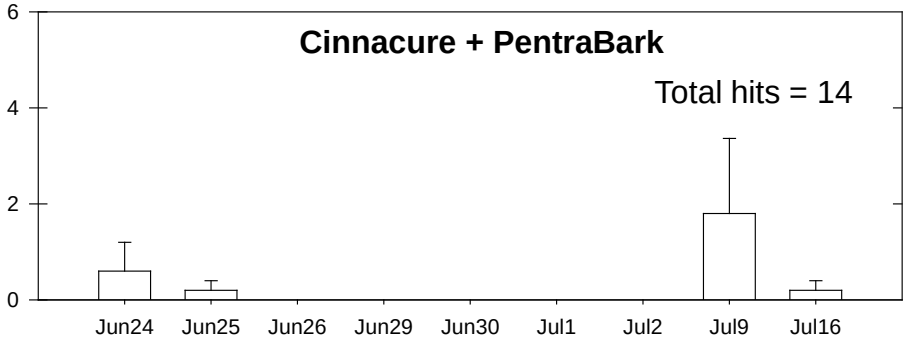
IV. Attacked Trees Then Held in Lab to Rear Beetles

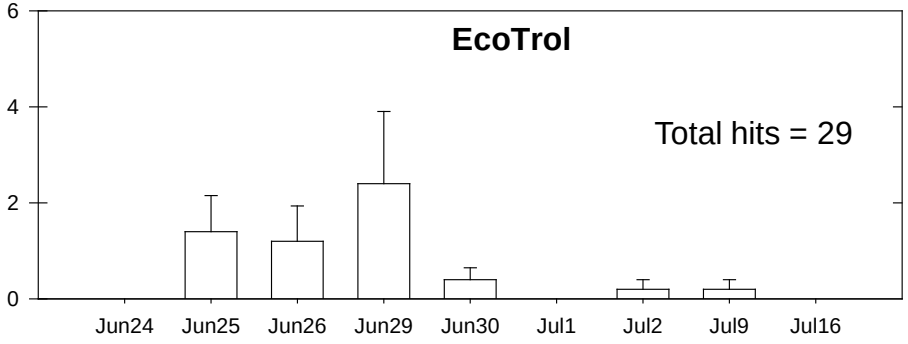


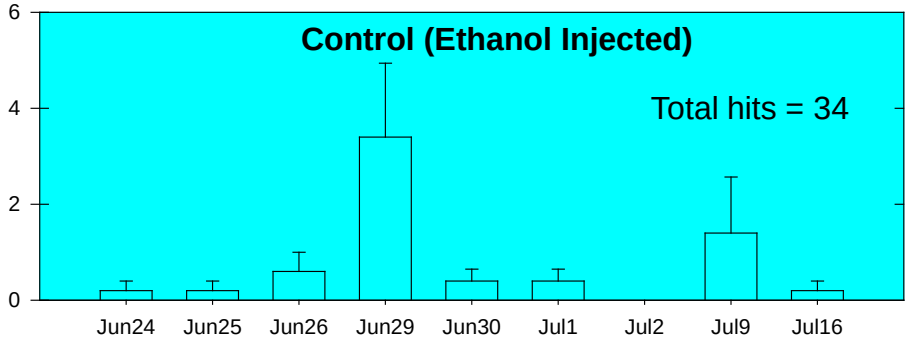
Biopesticide Trunk Sprays

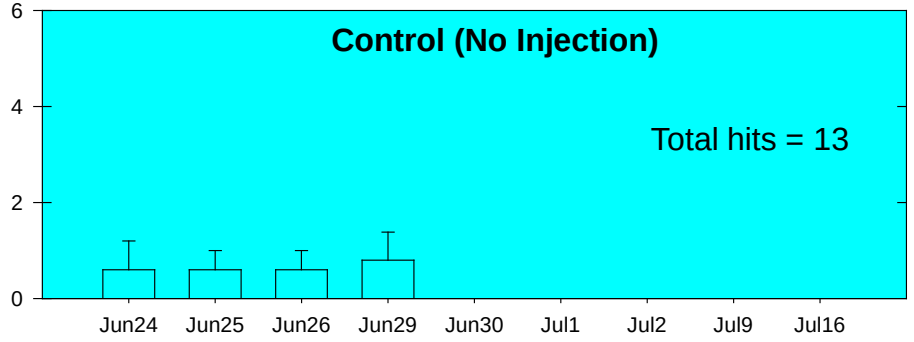
Mean New Ambrosia Beetle Attacks (+ SEM)



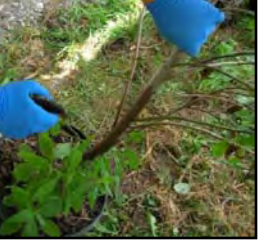




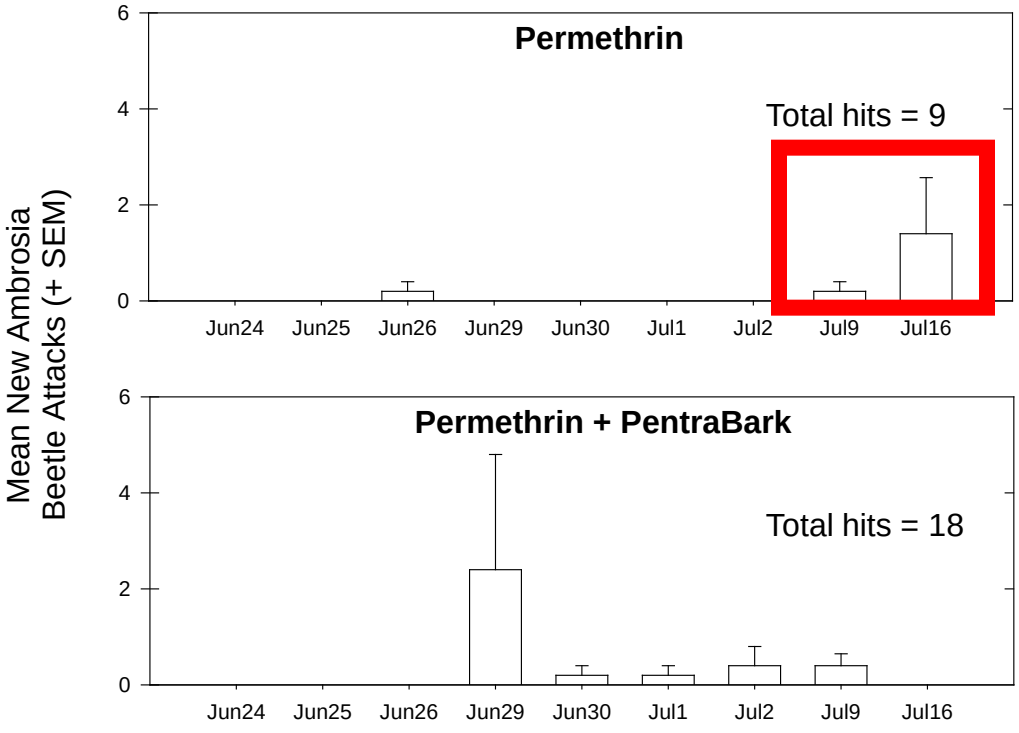


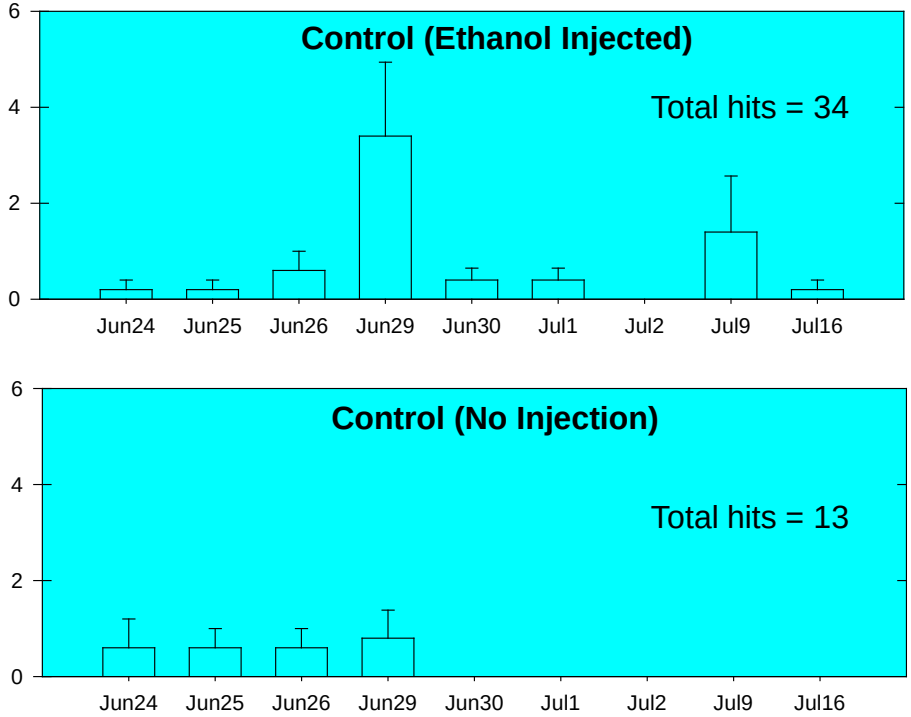


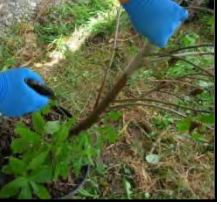
* Indicates significant difference from control ($P < 0.05$)



Pyrethroid Trunk Sprays







Biopesticide ambrosia beetle test - 2009
Total Average Attacks

Research

Plant Stress Studies

Ambrosia Beetle Tree Stress Test

Stress Treatments:

1) Planting to deep
2) Root drowning
3) Delayed dormancy break
4) Defoliation
5) Drought stress

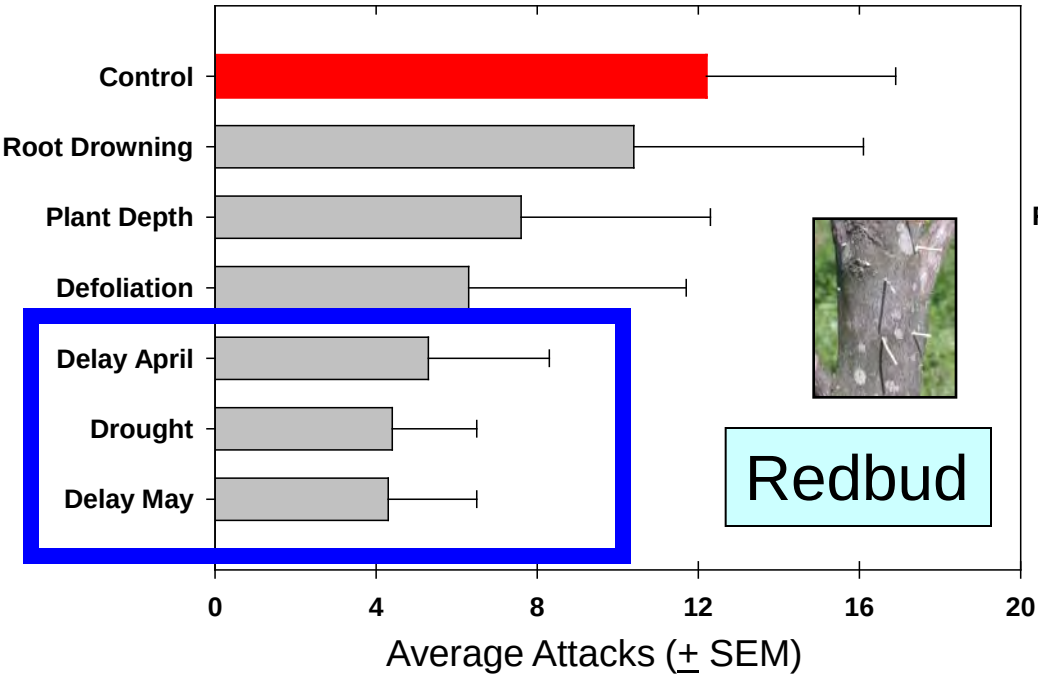
Data Collected:

1) Number of new galleries (3 times / week)
2) Sticky trap catches
3) Species reared from trees

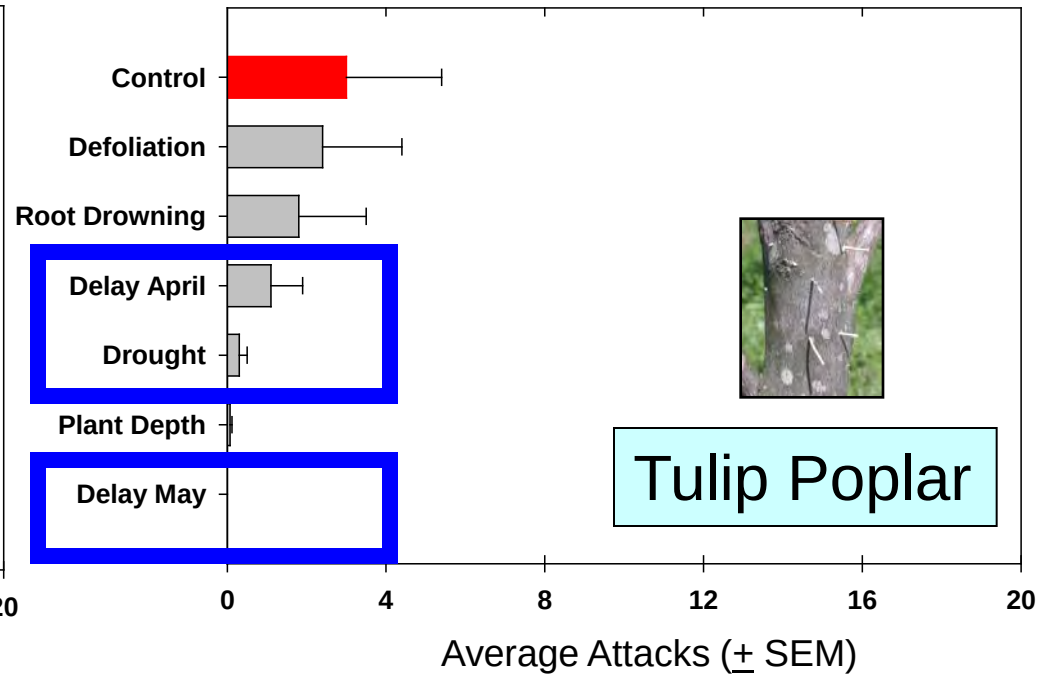
Stress Treatments – Average Total Attacks (April 24 to May 15, 2009)

Thysanoes fimbricornis

Asian or Granulated Ambrosia Beetle



Redbud

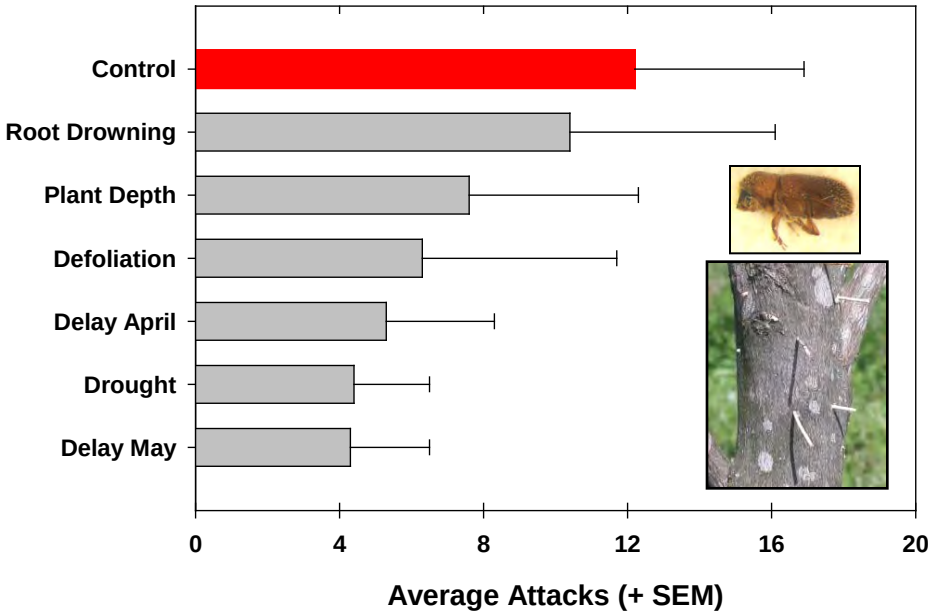


Tulip Poplar

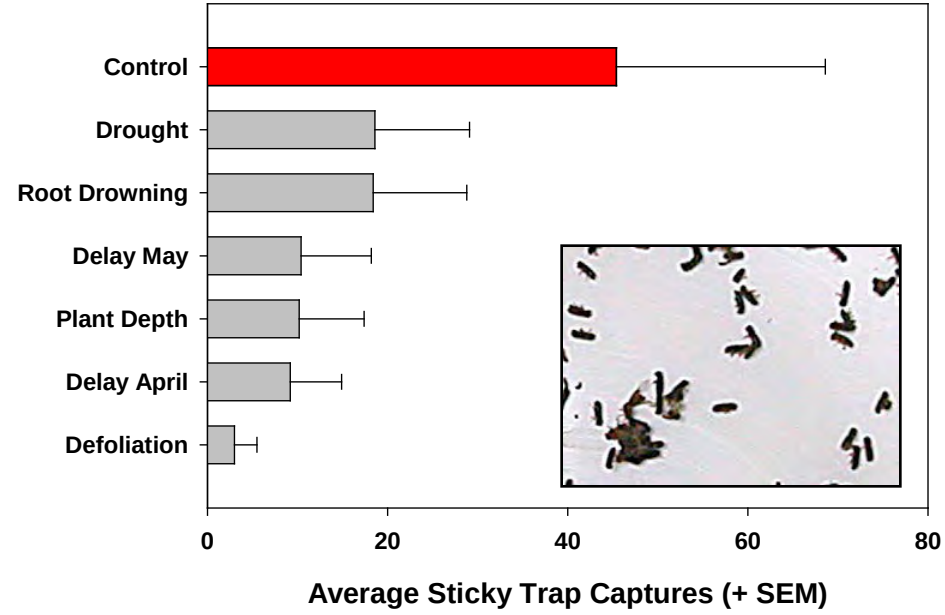
No significant differences between treatments ($P < 0.05$)

Stress Treatments – Redbud Trees (Apr. 24 to May 15, 2009)

Tree Attacks
(*Thysanoes fimbricornis*)



Sticky Trap Captures
(all Scolytids)



No significant differences between treatments ($P < 0.05$)

Management Plan

Preventing Damage

Factors Increasing Attack Risk

1) Plants still dormant, but beetles being trapped

2) Susceptible species

(Cherry, chestnut, dogwood, golden rain tree, lilac, maple, hydrangea, redbud, weeping mulberry, yellowwood, or others with past problems)

3) Stressed crop → Ethanol release

(New transplant, drought, disease, freeze, poor drainage, trunk injury, etc.)

4) Last pyrethroid spray over 4 weeks ago

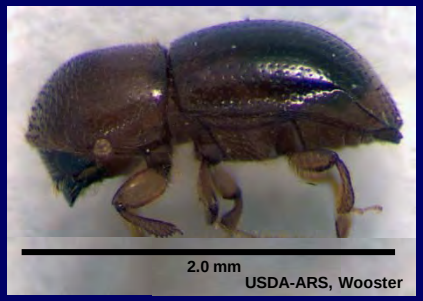
5) Fertilization terminated after July

6) Time of year (March to May)

7) Planting near water sites (high humidity)

Use Traps for Early Detection of Activity

Look for Key Indicator Species



Insecticide Management

Management too late
if toothpick strands are present

- Thorough spray coverage

- Use effective insecticides:

  Permethrin: Perm-Up 3.2 EC
  Biopesticides ???? (Future)

Not labeled for ambrosia beetles in walnut

Label Site: http://www.cdms.net/manuf/default.asp

Some Conclusions

- 3 species problematic in Tennessee nurseries (Xcrass, Xgerm, Xsax)

- Ethanol-baited traps catch large variety of ambrosia beetles
    - Different species have different activity periods
    - Within species peak captures varies by year (value of traps)
    - Trapping Xcrass, Xgerm, and Xsax coincides with tree attacks
    - Bottle trap was cheap and effective
    - Low height settings are best

- Ethanol injections induce Xylosandrus attacks - Value:
    - Trap trees ????
    - Timing insecticide sprays
    - Facilitate insecticide studies

- Attacks were induced in summer with ethanol

- Most induced attacks occurred during first week and then declined:
    - Change in host suitability ?????
    - Drop in ethanol release ????

Some Conclusions

- Need more work to understand relationship between:
  - Types of plant damage and associated stress signals
  - Ambrosia beetle host selection factors
  - Host quality factors for the ambrosia fungus

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Multiple Commercial Nurseries

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