A Smart Trap System for the Invasive Ambrosia Beetles in Production Nurseries

Daniel Kim, David Held, Jason Bertgold

Auburn University

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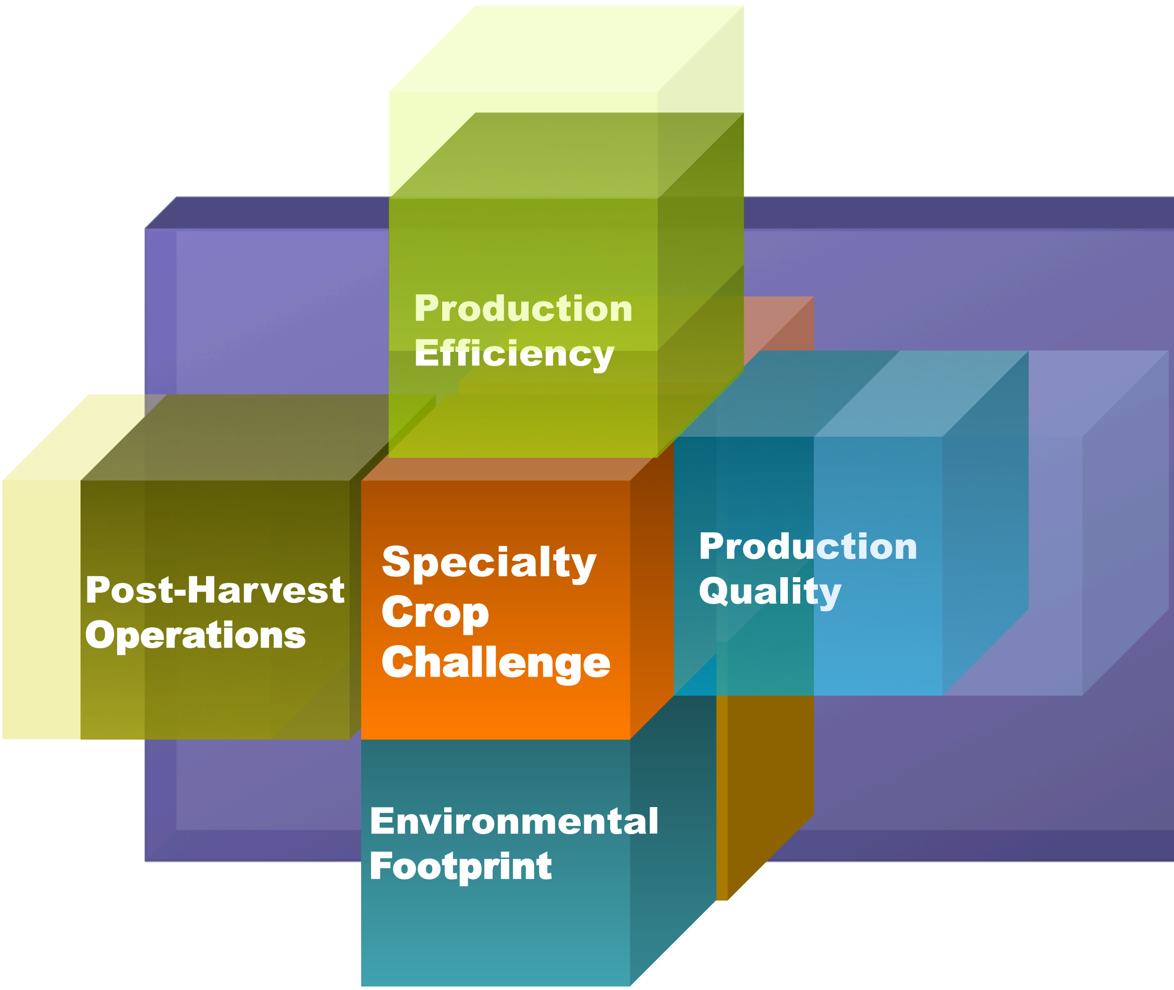
Major Industry Concerns



Many of these challenges can be met through technological advancements

Current Technology to Monitor Insect Pests

Non-specific trap
of insect pests

Sites vary in species and abundance

Year	No. genera (total)	# species (total)
1998	6-10 (11)	7-18 (21)
1999	6-9 (9)	12-18 (19)

Abundance is different between years on the same site (ranked the same)

Year	No. beetles per site (average)
1998	117-1464 (683)
1999	627-1193 (920)

Mannion and Oliver 2001 Environ Entomol

A few species dominate

	% of total species		
Species	**1998**	**1999**	**total**
Xyleborinus saxeseni Ratzeburg	38.6	57.9	49.7
Monarthrum fasciatum Say	25	<5	12.5
Xylosandrus crassiusculus (Motschulsky)	11.3	22.4	17.6
Xyleborus pelliculosus Eichhoff	6.8	<5	4.1
Monarthrum mali Fitch	5.2	6.2	5.7
Hypothenemus spp.	0.4	0.3	0.4
Xylosandrus germanus Blandford	3.6	0.4	1.7

Mannion and Oliver 2001 Environ Entomol

Table 2. Total and percent emergence of different species of ambrosia beetle from chestnut at the Nursery Crop Research Station, McMinnville, TN, in 1999

Species	No. Cages	No. emerging		
		Males	Females	Total
No Emergence	96	—	—	—
Solitary				
Hypothenemus sp. 2	2	0	4	4
Hypothenemus sp. 3	2	0	2	2
Hypothenemus sp. 4	1	0	1	1
Xyleborinus saxeseni	1	0	3	3
Xylosandrus crassiusculus	15	10	148	158
Xylosandrus germanus	61	16	257	273
Mixed				
Xylosandrus crassiusculus	4	1	28	29
Xylosandrus germanus		4	12	16
Hypothenemus sp. 2	1	0	1	1
Hypothenemus sp. 4		0	2	2
Xyleborinus saxeseni	1	0	1	1
Xylosandrus germanus		1	3	4
Total	184	32	462	494

203 galleries were not caged.

The dominant species in traps isn't always the species attacking:

Hypothenemus spp.: 0.4% of capture

X. germanus: 0.4% of capture

Mannion and Oliver 2001 Environ Entomol

Attack period coincident with peak trap collections.

Traps good for detecting activity but may provide false positives of when tress are under attack.

Mannion and Oliver 2001 Environ Entomol

Project Goals

- Auburn team will research, develop, and field test an integrated trap with sensor devices that will

➢ 1) attract the target insect pest by sight, sound and smell;

➢ 2) identify the presence of the insect;

➢ 3) measure the population of the insect

Significance

- Reduce the need for labor intensive visual scouting for insect pests
- Improve growers' ability of low infestation levels
- Intensify management inputs only during periods of greatest disease transmission
- Efficient insecticide application

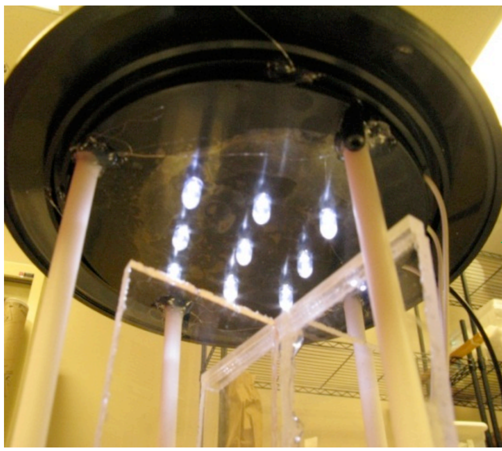
✓ Lower cost and labor

✓ Reduce the consumption of energy

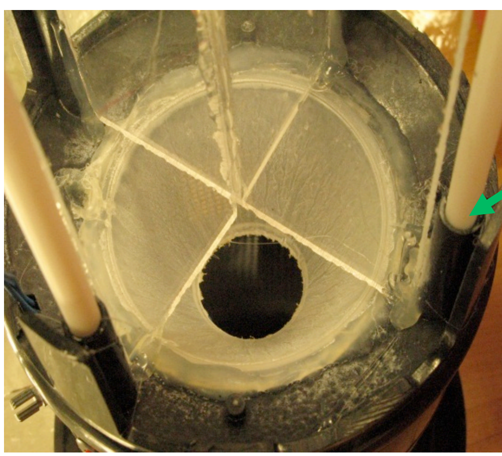
✓ Improve the cleanliness of the environment and human health

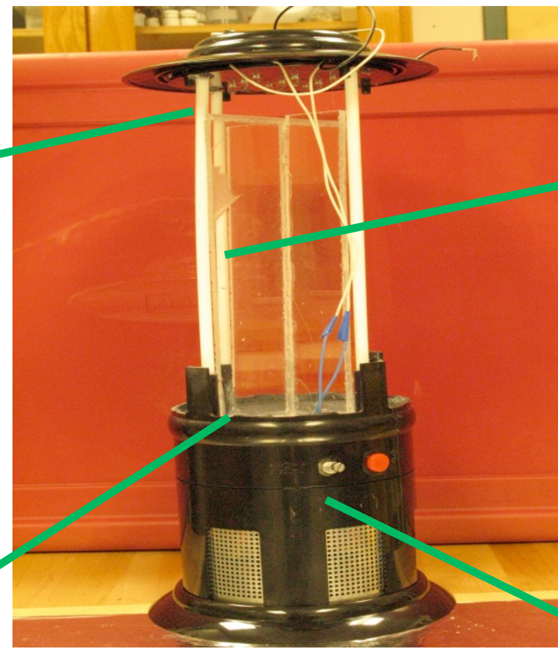
Trap Design with LED Attractant

- LED

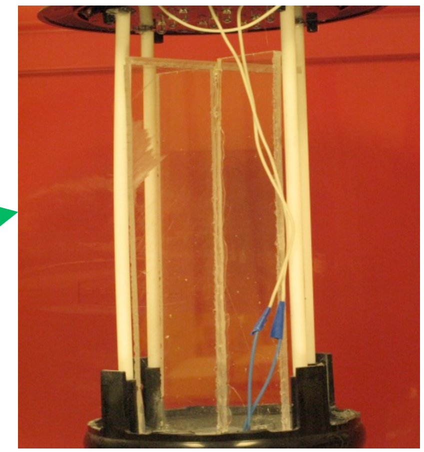


- Funnel

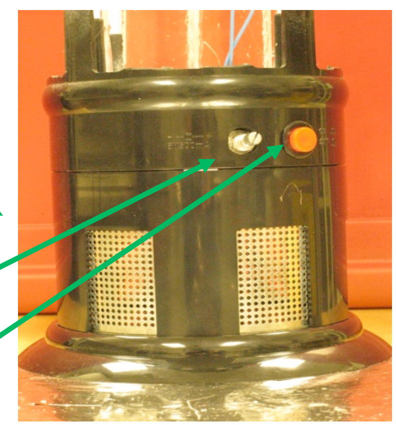




- Vane



- Catching container



Variable resistor

Power

Parameters of LED

Content	Specification	Comment
# of LED	9ea / trap	-
Color	Red, Blue, Green, UV	-
Wavelength	Red : 615nm ~ 645nm Green : 500nm ~ 530nm Blue : 450nm ~ 470nm UV : 380nm ~ 400nm	-
Voltage	12V	This LED has a resistor with 1kΩ
Max. Power	720mW	-
Intensity	-	Intensity of LED will be controlled by a variable resistor.

Examples of Captured Insect

- UV

- Green

- Blue

- Red

- Ref.

- Ref.

- Ref.

Results on LED Attractant

- ✓ **Light increases overall trap captures and the number of Xylosandrus**

  Moths are most by-catch; due to 24 h light

  Replacing battery power with solar cell

Results on LED Attractant

- ✓ **The traps installed with combined visual and volatile cues seem more effectiveness than the traps with only volatile cues.**

→ Better trapping by the use of combined cues can be found in other literature. Ref) Prokopy, R.J[1)] and G. LO´PEZ-GUILLE´N[2)]

- ✓ **Target beetles are more influenced by green and UV light than other frequencies.**

1) Environ. Entomol. 2: 953-954.(1973)
2) J. Econ. Entomol. 102(3): 954-959 (2009)

Stress volatiles are emitted from "stressed" trees

Ethanol, methanol, acetaldehyde, acetone

Ethanol>Methanol were the most attractive to *X. germanus*

Ranger et al. 2010 Agric. Forest Entomol.

Methanol and ethanol blends are more effective than single component volatile lures for coffee shoot borer (Hypothenemus hampei)

Dufour and Frerot 2008 J. Appl. Entomol.

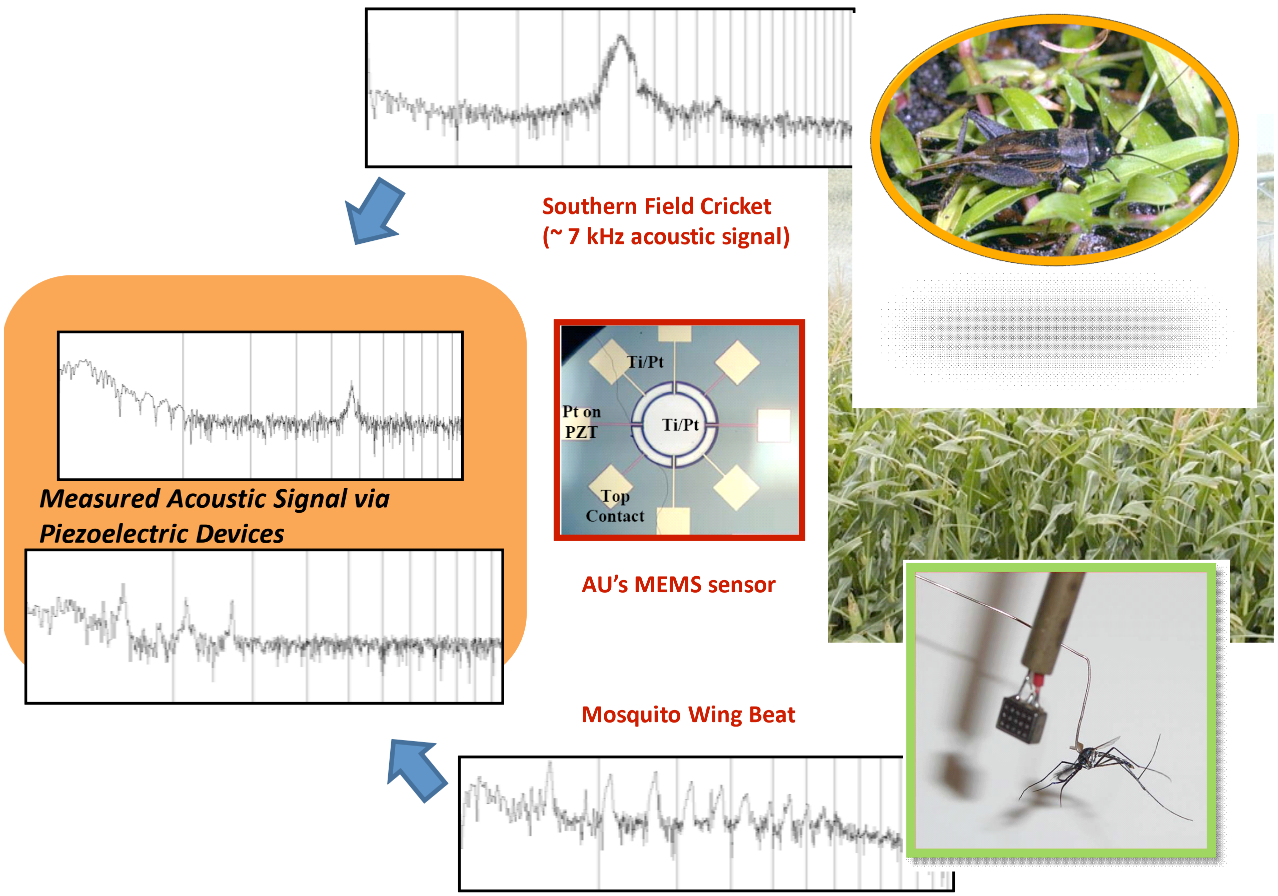
Field Trial Results in Alabama

Ratio of methanol to ethanol influences captures of Xylosandrus

Mixed blends better than 100% of either

Evaluating additional volatiles

Sound Sensor



MEMS sound sensor to identify insects

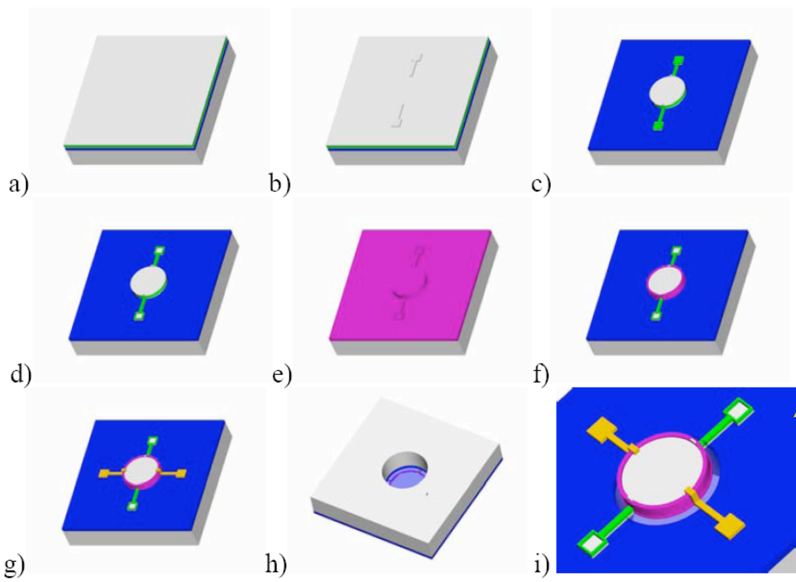
Sound Sensor

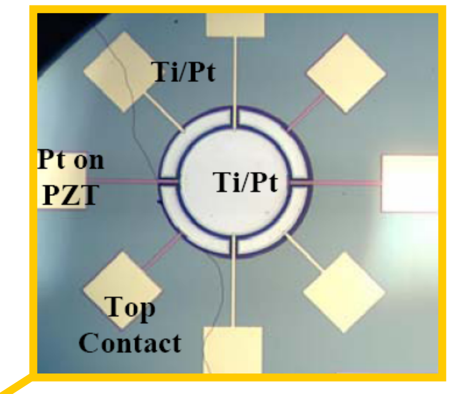
Species	Ref. no.	*N*	Wing beat frequency (Hz)	Body mass (mg)
Gyrinidae				
Dineutus americanus Fabricius	1	29	73·8 ± 16·10	49·16 ± 7·34
Scarabaeidae				
Diplotaxis frondicola Say	2	50	78·9 ± 5·16	23·80 ± 6·47
Hoplia limbata LeConte	3	20	80·8 ± 10·70	56·70 ± 9·40
Phyllophaga ephilida Say	4	25	61·6 ± 6·30	205·89 ± 95·91
Popillia japonica Newman	5	100	118·5 ± 8·91	93·20 ± 19·99
Elateridae				
Ctenicera sp. Latreille	6	10	89·9 ± 9·31	28·40 ± 12·04
Agriotes sp. Eschscholtz	7	17	109·1 ± 14·30	11·90 ± 6·87
Cantharidae				
Chauliognathus pennsylvanicus DeGeer	8	102	88·7 ± 5·80	38·49 ± 15·01
Chauliognathus marginatus Fabricius	9	12	86·7 ± 7·31	21·08 ± 9·01
Cantharis bilineatus Say	10	25	89·8 ± 7·95	16·68 ± 7·59
Lampyridae				
Lucidota atra Fabricius	11	22	64·7 ± 7·60	42·50 ± 19·67
Photinus pyralis Linné	12	75	60·9 ± 4·90	25·91 ± 8·96
Coccinellidae				
Coccinella septempunctata Linné	13	30	76·9 ± 9·10	30·60 ± 11·55
Coleomegilla fuscilabris Mulsant	14	61	95·2 ± 10·81	12·14 ± 2·96
Cycloneda sanguinea Linné	15	21	96·1 ± 10·21	9·80 ± 3·30
Hippodamia convergens Guérin	16	35	78·0 ± 9·90	13·00 ± 4·51

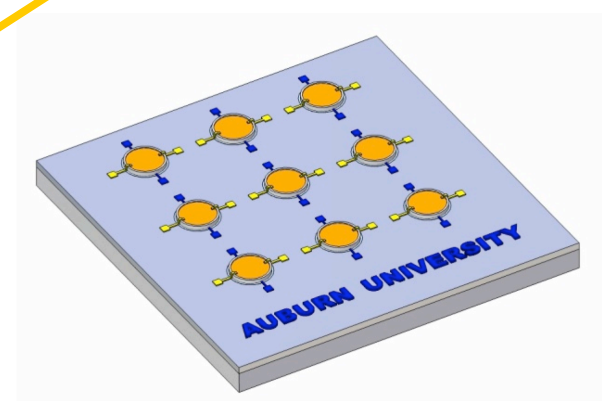
- Many beetles exhibited low value of wing beat frequency (~ 70 – 100 Hz)
- While measuring wing beat frequencies of Ambrosia beetles, the design study of the sound sensor is based on low freq. of acoustic signals.

- *Oertli et al. J. ex. Biol. 145, 321-338 (1989)*

Fabrication Technology







Similar technique used in semiconductor industry is employed for producing higher performance and economic devices

Stage 1 Economic Analysis:
Economic Loss Evaluation at Nursery Scale

Step 1: *Identify costs of beetle identification* – Determine costs of smart traps versus use of ethanol traps with visual identification methods (e.g. time, microscope, traps, etc.).

Step 2: *Identify costs of treatment* – Identify treatment methods, chemicals used, equipment, required labor and associated costs.

Step 3: *Identify costs of crop management* – Obtain all pertinent management practices, applied inputs and associated economic costs. Obtain detailed management records for experimental plots at each nursery.

Step 4: *Develop cost budgets* – From cost data, develop flexible enterprise budgets that can be utilized for partial budgeting and economic optimization analyses.

Stage 1 Economic Analysis:
Economic Loss Evaluation at Nursery Scale

Step 5: *Estimate response functions* – Using experimental data, estimate yield loss response functions as a function of trap identification efficacy and pesticide application rates.

Step 6: *Optimal Economic Management Response* – Develop a math programming model to maximize net returns above variable costs for different nursery enterprises subject to yield loss response, time and other identified resource constraints. Purpose is to identify economically optimal trap management schemes and pesticide rates.

Step 7: *Determine the spatial economic impact at the nursery level* - Using GPS data collected examine the economic impact spatially across the tested nurseries using the collected data, yield loss response functions, and optimization models from the previous steps.

Summary

<table>
<tr><th></th><th>Research</th><th>Test</th><th>Technical Deliverables</th><th>Education & Evaluation</th></tr>
<tr><td>YR 4</td><td></td><td>In-field test</td><td>Smart trap installed with
✓ attractants
✓ sound sensor
✓ dust sensor
✓ wireless unit</td><td>✓ Education and trap training
✓ Dissemination of research findings
✓ Sustainability index
✓ Commercialization</td></tr>
<tr><td>YR 3</td><td></td><td>In-field test
Greenhouse test</td><td>Smart trap installed with
✓ attractants
✓ sound sensor
✓ dust sensor</td><td>✓ Traps set at key nurseries
✓ Trap demonstration
✓ Education and dissemination of research findings
✓ Smart trap economics</td></tr>
<tr><td>YR 2</td><td rowspan="2">Determination of
✓ Volatile attractants
✓ Visual attractants
✓ Characteristic audible patterns
✓ Fungal associates</td><td>In-field test
Greenhouse test
Laboratory test</td><td>Smart trap installed with
✓ attractants
✓ sound sensor</td><td>✓ Education and dissemination of research
✓ Economic loss evaluation</td></tr>
<tr><td>YR 1</td><td>Greenhouse test
Laboratory test</td><td>Smart trap installed with
✓ attractants</td><td>✓ Education on ambrosia beetles
✓ Website setup</td></tr>
</table>

- The prototype installed with combined LED and ethanol cues promote the trap efficiency (~ 2.5 times)
- On-going efforts to fabricate sound and MSP sensors were made to produce economic and reliable devices.