Using Parasitoids to Battle the Emerald Ash Borer
Compatibility of Insecticides and Biocontrol for Managing EAB in Urban Environments

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Introduction

• PART I
  • What do we mean by biological control?
  • Biological control terms
  • Characteristics of a biological control agent
  • Types of biological control
  • Advantages and disadvantages of biological control
  • Exploration of biological control agents for EAB
  • Getting to know EAB parasitoids

• PART II
  • Integrating biological control and insecticide treatments
  • Integrating biological control with EAB management tactics
  • How to implement an EAB biological control program
Part I: What Do We Mean by Biological Control?

• **Biological control** - component of an IPM/PHC strategy

• Biological control is the reduction of pest populations by:
  • Natural enemies
  • Involves an active human role
  • Not the same as “natural control”

• **Natural control** reduces pest populations by:
  • Activity of naturally occurring organisms and/or environment
  • No human input.
Biological Control Terms

• **Natural enemies or biological agents** - predators, parasitoids, and pathogens

• **Predators** - free-living species that consume large numbers of prey during their lifetime (i.e. lady beetles, lacewings, nematodes)

• **Parasitoids ("parasite-like")** - species whose immature stage develops on or within a single insect host, ultimately killing the host (i.e. wasps and some flies)
  - **Endoparasitoids** – eggs laid inside the host
  - **Ectoparasitoids** – eggs laid externally on the host
  - **Hyperparasitoids** - parasitoids of other parasitoids

• **Pathogens** - disease-causing organisms
  - Kill or debilitate their host
  - Relatively specific to certain insect groups
  - Include bacteria, viruses, nematodes, fungi

• **Antagonists** – biological control agents of plant diseases

• **Insects and pathogens to control weeds and invasive plants**
  - Control of purple loosestrife with leaf beetles
Parasitoid versus Parasite

- **Parasitoid** - insect that lives as an immature in or on another insect
  - Kills its host
  - Comparable in size to host
  - Completes development on/in host

Parasitoid versus Parasite

- **Parasite** – insect that spends all or part of its life cycle on the host
  - Does not normally kill host
  - Usually much smaller than host
Characteristics of an Effective Biological Control Agent

- High reproductive rate
- Effective at searching for host
- Should be host specific
- Should be in synchrony with host

Types of Biological Control

- **Classical** – importation, release, and establishment of natural enemies to control a native and/or exotic pest
- **Conservation** – preserving and providing for natural enemies that already exist
- **Augmentation** – supplemental release of natural enemies
  - **Inundative release** – large numbers of natural enemies released at once
  - **Inoculative release** – a few natural enemies released at a critical time of the season
Classical Biological Control

• Used where natural enemies are not adequate to control a pest
  • Commonly used with exotic, invasive pests

• Steps in Classical Biological Control
  • Determine origin of the introduced pest
  • Search for and collect natural enemies associated with pest and its homeland
  • Natural enemy(s) pass through rigorous quarantine process
  • Reared in large numbers for release
  • Follow-up studies to evaluate dispersal and establishment

Advantages of Biological Control

• Can be permanent or sustainable

• Safe

• Economically feasible
Disadvantages of Biological Control

• Not a “silver bullet”

• Easily disrupted by chemical pesticides

• Subject to environmental factors

• Beneficials can become a potential pest

The Search for Parasitoids of Emerald Ash Borer

• 2002: EAB first discovered in Detroit, Michigan

• Eradication proves to be ineffective

• 2003-2005: Exploration in China begins for EAB parasitoids
  • Parasitoid biology
  • Host specificity
  • Impact of parasitoids on EAB population dynamics

• 2007: Approval for release of three parasitoid species in Michigan
  • Establishment was confirmed within one year of release
  • USDA EAB Biocontrol Program is launched
  • EAB parasitoid rearing facility is built in Brighton, Michigan
  • Development of Online data base
    • Requesting parasitoids
    • Data base on parasitoid releases, recoveries, and mapping
Exploring for Parasitoids in China
Exotic Parasitoids of Emerald Ash Borer

- **Gregarious larval ecto-parasitoid** (*Spathius agrili*)
- **Gregarious larval ecto-parasitoid** (*Spathius galinae*)
- **Gregarious larval endo-parasitoid** (*Tetrastichus planipennisi*)
- **Solitary egg parasitoid** (*Oobius agrili*)

Getting to Know *Spathius agrili*

- Parasitizes up to 90% of EAB larvae in China
- *Spathius* female drills through bark
  - Lays an average of eight eggs per larva
- One to two generations per year
- Overwinters as larva or pupa within host gallery
Welcome to *Spathius galinae*

- Parasitizes up to 63% of EAB larvae in China

- Originates from northern areas of Russian Far East and better adapted to northern U.S. states

- Able to attack EAB larvae in large ash trees with thick bark

- Females produce up to 94 progeny over lifetime
  - Average of eight parasitoids per host

- Completes one generation in about 35 days

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**Distribution of *Spathius* agrili and *S. galinae* Releases**
Hello to *Tetrastichus planipennisi*

- Parasitizes up to 50% of EAB larvae in China
- Female drills through bark and lays eggs inside EAB larva
- Produces up to 130 *Tetrastichus* adults per EAB larva
- Completes several generations per year
- Overwinter as larva or pupa within host gallery

Introducing *Oobius agrili*

- Parasitizes up to 60% of EAB eggs in China
- Female inserts one egg into EAB egg
- At least two generations per year
- Each female parasitizes up to 80 EAB eggs during life time
- Overwinters as larva within EAB egg
Part II: Integrating Biocontrol and Insecticide Treatments in Urban Areas

- Can systemic insecticides save large ash trees while parasitoid populations establish, disperse, and increase?

- Will suppression of EAB populations allow parasitoids to increase more quickly relative to host?

- Can we cease using insecticides because biocontrol agents and native natural enemies cause sufficient EAB mortality?

Why this Might Work

- *Tetrastichus planipennisi* and *Oobius agrili* are establishing and dispersing

- Insecticides can be very effective at keeping ash trees alive even in areas of high EAB density.
Why this Might Work

- EAB populations peak and then decline at the same time percentage parasitism by *T. planipennisi* and *O. agrili* are increasing.

- Woodpeckers find and remove approximately 40% of mature EAB larvae as EAB density declines.

EAB Biological Control Study Sites

- **Bolingbrook-Naperville, Illinois**
- **Syracuse, New York**
- **Boulder Colorado**

- **Three Treatments of 50 trees each:**
  - Insecticide Treatments Long-Term
  - Insecticide Treatments + Biocontrol
  - Insecticides stopped after parasitoids establish

- Biocontrol Only
### Numbers of Parasitoids Released by Date

#### Bolingbrook-Naperville, Illinois

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Tetrastichus planipennis</em></td>
<td>2,300</td>
<td>9 June – 7 July 1 – 15 September</td>
<td>2,412</td>
<td>1 June – 30 June 17- 31 August</td>
</tr>
<tr>
<td><em>Spathius galinae</em></td>
<td>400</td>
<td>9 June and 18 August (200 per release date)</td>
<td>349</td>
<td>15 and 29 June</td>
</tr>
<tr>
<td><em>Oobius agrili</em></td>
<td>1,200</td>
<td>14 July – 4 August (300 released weekly)</td>
<td>1,200</td>
<td>13 July – 17 August (200 released weekly)</td>
</tr>
<tr>
<td><strong>Totals</strong></td>
<td><strong>3,900</strong></td>
<td></td>
<td><strong>3,961</strong></td>
<td></td>
</tr>
</tbody>
</table>
Yellow Pan Trap (YPT) Data Collection for Determining Parasitoid Dispersal

- Yellow pan traps (YTP’s) deployed every 250 m (750 ft) in grid pattern in both release and control plots.
- Trap contents collected weekly from mid-May to mid-September.
- Parasitoids sent to Dr. Julie Gould (USDA-APHIS) for positive ID.

Branch Sampling for Determining Parasitoid Establishment

- **Sampled 15 trees from control plot** for each treatment group.
- **Samples 15 trees from release plot** for each treatment group.
- **Removed two, 3-4 foot long branch samples** from mid-canopy of each tree (Total = 180 branch samples).
- **Basal 20 inches of each branch sample** was peeled and examined for evidence of:
  - EAB galleries
  - Parasitized larvae
  - Parasitoids
Rearing of Parasitoids from Branch Samples

- Unpeeled branch sections were placed in plastic rearing containers and held at room temperature

- Examined weekly for evidence of EAB and parasitoid adult emergence

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Ash Tree Condition Assessment Ratings

- Annual ash tree condition assessments conducted annually on all study trees
  - (1=Full crown to 5=Tree dead)

- Data collected data on signs of EAB infestation
  - Crown class
  - Epicormic branching
  - Woodpecker foraging
YELLOW PAN TRAP (YPT) PARASITOID RECOVERY OVER TIME
BOLINGBROOK-NAPERVILLE, ILLINOIS
2015 - 2018

<table>
<thead>
<tr>
<th>SITE</th>
<th>PARASITOID SPECIES</th>
<th>2015</th>
<th>2016</th>
<th>2017</th>
<th>2018</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control Site</td>
<td>T. planipennisi</td>
<td>17</td>
<td>5</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>Release Site</td>
<td>T. planipennisi</td>
<td>6</td>
<td>6</td>
<td>9</td>
<td>7</td>
</tr>
<tr>
<td>Totals</td>
<td></td>
<td>23</td>
<td>11</td>
<td>13</td>
<td>13</td>
</tr>
</tbody>
</table>
### PERCENT PEELED BRANCH SAMPLES CONTAINING *Tetrastichus planipennis* LIFESTAGES
Bolingbrook-Naperville, Illinois 2015-2017

<table>
<thead>
<tr>
<th>SITE</th>
<th># OF BRANCHES PEELED</th>
<th>2015</th>
<th>2016</th>
<th>2017</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control Site-Untreated Trees</td>
<td>60</td>
<td>4%</td>
<td>13%</td>
<td>28%</td>
</tr>
<tr>
<td>Control Site-Treated Trees</td>
<td>30</td>
<td>0%</td>
<td>2%</td>
<td>2%</td>
</tr>
<tr>
<td>Release Site-Untreated Trees</td>
<td>60</td>
<td>0%</td>
<td>10%</td>
<td>23%</td>
</tr>
<tr>
<td>Release Site-Treated Trees</td>
<td>30</td>
<td>8%</td>
<td>2%</td>
<td>2%</td>
</tr>
<tr>
<td>TOTAL</td>
<td>180</td>
<td></td>
<td></td>
<td></td>
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</tbody>
</table>

### TOTAL # OF *Tetrastichus planipennis* LIFESTAGES RECOVERED FROM PEELED BRANCH SAMPLES
Bolingbrook-Naperville, Illinois 2015-2017

<table>
<thead>
<tr>
<th>SITE</th>
<th>2015</th>
<th>2016</th>
<th>2017</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control Site-Untreated Trees</td>
<td>4</td>
<td>99</td>
<td>84</td>
</tr>
<tr>
<td>Control Site-Treated Trees</td>
<td>0</td>
<td>93</td>
<td>24</td>
</tr>
<tr>
<td>Release Site-Untreated Trees</td>
<td>0</td>
<td>144</td>
<td>82</td>
</tr>
<tr>
<td>Release Site-Treated Trees</td>
<td>5</td>
<td>50</td>
<td>71</td>
</tr>
<tr>
<td>TOTAL</td>
<td>9</td>
<td>386</td>
<td>261</td>
</tr>
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### TREE CONDITION RATINGS FOR ALL STUDY TREES WITHIN YEARS
Bolingbrook-Naperville, Illinois  
2015-2017

<table>
<thead>
<tr>
<th>LOCATION</th>
<th>N</th>
<th>2015</th>
<th>2016</th>
<th>2017</th>
<th>DBH (cm.)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Control Site</strong> – Treated Trees</td>
<td>117</td>
<td>1.07a</td>
<td>2.15a</td>
<td>1.08a</td>
<td>34.5b</td>
</tr>
<tr>
<td><strong>Control Site</strong> – Untreated Trees</td>
<td>50</td>
<td>1.70b</td>
<td>2.65b</td>
<td>2.70b</td>
<td>20.8a</td>
</tr>
<tr>
<td><strong>Significance</strong></td>
<td></td>
<td>P&lt;0.001</td>
<td>P=0.03</td>
<td>P&lt;0.001</td>
<td>P&lt;0.001</td>
</tr>
<tr>
<td><strong>Release Site</strong> – Treated Trees</td>
<td>116</td>
<td>1.35a</td>
<td>1.40a</td>
<td>1.80a</td>
<td>37.6b</td>
</tr>
<tr>
<td><strong>Release site</strong> – Untreated Trees</td>
<td>50</td>
<td>1.87b</td>
<td>3.78b</td>
<td>1.90a</td>
<td>24.1a</td>
</tr>
<tr>
<td><strong>Significance</strong></td>
<td></td>
<td>P&lt;0.001</td>
<td>P&lt;0.001</td>
<td>NS</td>
<td>P&lt;0.001</td>
</tr>
</tbody>
</table>

*Significance levels indicate statistical significance of differences between treatments.

N = # of Trees Evaluated

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**What About Native Parasitoids?**

**Conservation Biological Control**

The Role of Native Parasitoids in EAB Population Dynamics
Impact of Native Natural Enemies in EAB Population Dynamics

- Woodpeckers are the dominant natural EAB enemy
  - Average around 35% to 40% mortality and as high as 95%

- Entomopathogenic fungi (*Beaveria bassiana*)
  - Account for about 2% in field studies

- Native parasitoids
  - Account for <1% to 5%
  - No known egg parasitoids
  - More specific to niche than host

- Predators
  - Larvae and adult Coleopterans (i.e. Cleridae, Passandridae, and Trogossitidae)

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*Atanycolus cappaerti*

- Solitary, ectoparasites of late stage larvae

- One to two generations in northern regions

- Large wasps (5-7 mm.) with long ovipositors (4-6 mm)

- Parasitizes EAB larvae in large ash trees (>57 mm) with thick outer bark (up to 9 mm thick)
**Atanycolus cappaerti**

- Life cycle well synchronized with EAB
- Overwinters as mature larva or pre-pupa inside cocoons
- Parasitize medium to large EAB
- Parasitizes other *Agrilus* spp.
  - Two-lined chestnut borer, Poplar borer

**Balcha indica**

- Native to southeast Asia, has naturalized in eastern U.S.
- Solitary, ectoparasite of EAB larvae, pre-pupae, and pupae
- Generation time of 83 days with one unsynchronized generation per year
- Potential in helping suppress EAB populations
**Phasgonophora sulcata**

- Native to eastern North America
- Solitary, endoparasite
- One generation per year
- Reared from bronze birch borer, two-lined chestnut borer, poplar borer, and EAB

**Phasgonophora sulcata**

- Adult emergence about two weeks behind adult EAB emergence
- Parasitizes 1st and 2nd instar EAB larvae
- Pupation occurs in spring inside host pre-pupae
### TOTAL NATIVE EAB PARASITOIDS RECOVERED

**FROM YELLOW PAN TRAPS (YPTs)**

Bolingbrook-Naperville, Illinois  
2018

<table>
<thead>
<tr>
<th>SITE</th>
<th>NATIVE PARASITOID SPECIES</th>
<th># RECOVERED</th>
<th>% OF TOTAL PARASITOIDS RECOVERED</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td><em>Atanycolus cappaerti</em></td>
<td>1</td>
<td>2%</td>
</tr>
<tr>
<td>Release</td>
<td><em>Atanycolus cappaerti</em></td>
<td>2</td>
<td>4%</td>
</tr>
<tr>
<td>Control</td>
<td><em>Balcha indica</em></td>
<td>4</td>
<td>9%</td>
</tr>
<tr>
<td>Release</td>
<td><em>Balcha indica</em></td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>Control</td>
<td><em>Phasgonophora sulcata</em></td>
<td>8</td>
<td>17%</td>
</tr>
<tr>
<td>Release</td>
<td><em>Phasgonophora sulcata</em></td>
<td>32</td>
<td>68%</td>
</tr>
<tr>
<td><strong>Totals</strong></td>
<td></td>
<td><strong>47</strong></td>
<td></td>
</tr>
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</table>

### TOTAL EAB PARASITOIDS RECOVERED

**FROM YELLOW PAN TRAPS (YPTs)**

Naperville, Illinois  
2018

<table>
<thead>
<tr>
<th>SITE</th>
<th>PARASITOID SPECIES</th>
<th># RECOVERED</th>
<th>% OF TOTAL PARASITOIDS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td><em>Atanycolus cappaerti</em></td>
<td>1</td>
<td>2%</td>
</tr>
<tr>
<td>Release</td>
<td><em>Atanycolus cappaerti</em></td>
<td>2</td>
<td>3%</td>
</tr>
<tr>
<td>Control</td>
<td><em>Balcha indica</em></td>
<td>4</td>
<td>6%</td>
</tr>
<tr>
<td>Release</td>
<td><em>Balcha indica</em></td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>Control</td>
<td><em>Phasgonophora sulcata</em></td>
<td>8</td>
<td>13%</td>
</tr>
<tr>
<td>Release</td>
<td><em>Phasgonophora sulcata</em></td>
<td>32</td>
<td>52%</td>
</tr>
<tr>
<td>Control</td>
<td><em>Tetrastichus planipennis</em></td>
<td>7</td>
<td>11%</td>
</tr>
<tr>
<td>Release</td>
<td><em>Tetrastichus planipennis</em></td>
<td>8</td>
<td>13%</td>
</tr>
</tbody>
</table>
How to Integrate Biological Control into an EAB Management Plan

- Obtain or make use of an existing tree inventory
- Consider protecting valuable ash trees instead of total tree removal
- “Cull the Herd”
- Practice sanitation and remove trees dying from EAB
- Commence a parasitoid release program
- Monitor for parasitoid dispersal and establishment over time

How to Participate in the EAB Biocontrol Program?

Refer to the EAB Biological Control Release and Recovery Guidelines or contact EAB.Biocontrol.Program@aphis.usda.gov with any questions.

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