Biology and Control of the Annual Bluegrass Weevil

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Updated 1-18-2020
• Biology, ecology, damage (3-24)
• Monitoring (25-37)
• Insecticide resistance (38-75)
• Sustainable management: non-resistant (76-92)
• Sustainable management: resistant (93-101)
• Biorationals (102-118)
• Biology, ecology, damage
  • Monitoring
  • Insecticide resistance
  • Sustainable management: non-resistant
  • Sustainable management: resistant
  • Biorationals
• Serious expanding pest of close-cut annual bluegrass
• Serious problems throughout NJ, NY, CT, PA, RI, MA, NH, VT, DE, MD.
• Also problems in parts of OH, ME, VA, ONT, QUE.
ABW Morphology

Eggs

Adult

Larva (5th)

Prepupa

Pupa

0.08”

from Cameron & Johnson 1971
Adult

- Short, blunt snout with mouthparts at tip
- Elbowed antennae attached near snout tip
- Length of snout+head+thorax < elytra
- Body dark charcoal-gray, covered with fine yellowish hair and scales that wear off with age
- /8” – 5/32” long

from Cameron & Johnson 1971
Larva

- Cream colored body, brown head
- Body somewhat curved, pointed at tail, legless
- 0.03 (L1) to 0.2” (L5) long
Billbug

Annual Bluegrass Weevil
Adult Overwintering

Adults overwinter in the top 1-2" of soil/turf profile, under taller grass, under tree litter, around trees, even in roughs.

Adult extraction by submersion of substrate samples in warm water.
Adult Overwintering

- Overwinter up to 200’ from fairway and up to 30’ into the woods
- Must abundant near tree lines and around trees
- No beetles found within 15’ of fairway
- Pine litter not best site – prefer tall grass and mixed leaf litter
Adult spring migration to playing surfaces

- arrival spread out over several weeks because:
  - affected by variably spring temps
  - converging from different overwintering sites
  - more than 1 peak if cool temps interrupt migration
- primarily on foot
ABW Life Cycle

- Eggs laid under sheath
- Larva (3rd) feeding inside stem
- Pupation in soil
- Mature larva (5th) feeding on crown
- Mature adult
- Immature adult
1st Signs of Larval Feeding Damage (late May)

- Usually starts at edges of fairways, greens, tees.
- Small, yellowish-brown spots
- Scattered dead spots grow together.
- Tunneled stems break off at crown.
Extensive Larval Feeding Damage (early to mid June)

- Worst damage early to mid-June (1st gen.).
- Usually less damage in late July/early August (2nd gen.).
**Injury**

- Early summer damage along edge of fairway
- Leaf notching by adults
- Damage to collar
- Damaged Poa surrounded by undamaged bentgrass
ABW Seasonal Life-cycle
(average timing for NY metropolitan area)

*L1-3 = 1<sup>st</sup> thru 3<sup>rd</sup> larval stage; L4-5 = 4<sup>th</sup> thru 5<sup>th</sup> larval stage

From: Koppenhöfer et al. 2012
Host plant resistance for ABW management

- Low cost
- Highly compatible with other tactics
- Long lasting
- Environmentally sound

Host plant resistance components:

**Tolerance**: plant tolerates feeding better, but may support high pest density

**Resistance**: detrimental for pest development and reproduction → fewer/no pests
Host Plant Resistance to ABW

- Severe damage typically in areas with high *P. annua* percentage
- But: Increasing number of reports of bentgrass damage

Limited previous experimental data suggest:

- Same larval density in *P. annua* and CBG (Rothwell 2003)
- No effect of host species on spring adult and larval distribution (McGraw & Koppenhöfer 2010)
- Higher ABW tolerance of pure CBG vs. mixed stands of CBG + *P. annua* (McGraw & Koppenhöfer 2009)
Larval density and damage in mixed *Poa* – creeping bentgrass stands

Data suggest, to cause damage it takes:

up to 160 larvae per ft$^2$ in pure creeping bentgrass ....

... as few as 10 larvae per ft$^2$ in pure *Poa*

McGraw & Koppenhöfer (2009)
Egg-laying - Choice field tests
10 females + 10 males for 1 wk

→ *P. annua* preferred for oviposition.
→ No clear differences among bentgrasses

*Kostromytska & Koppenhöfer (2014)*
Egg-laying + Larval Development

No-choice greenhouse test
5 fem. + 5 males for 1 wk
→ Stages after 5 wk

• More stages in *P. annua* than in bentgrasses

• Creeping bentgrasses have the fewest larvae.

• BUT: ABW fully develops in all bentgrasses

*Kostromytska & Koppenhöfer (2014)*
**Tolerance to larval feeding - Greenhouse tests**

3rd-4th instars introduced (0, 71, 142, 284 / ft²)

<table>
<thead>
<tr>
<th>Grass Type</th>
<th>Damage (%)</th>
</tr>
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<tbody>
<tr>
<td>P. annua</td>
<td>a</td>
</tr>
<tr>
<td>L 93</td>
<td>b</td>
</tr>
<tr>
<td>Declaration</td>
<td>cd</td>
</tr>
<tr>
<td>Penncross</td>
<td>b</td>
</tr>
<tr>
<td>Declaration</td>
<td>cd</td>
</tr>
<tr>
<td>OO7</td>
<td>d</td>
</tr>
<tr>
<td>Capri</td>
<td>ab</td>
</tr>
<tr>
<td>Villa</td>
<td>ab</td>
</tr>
</tbody>
</table>

- *P. annua* most susceptible
- ‘Capri’ (Colonial), ‘Villa’ (Velvet) most susceptible bentgrasses
- No significant difference among creeping bentgrasses

Kostromytska & Koppenhöfer (2016)
Effect of grass cultivar and adult density on grass damage by progeny larvae (greenhouse)

Pearson's correlation
\[ r (322) = 0.78 \], \( P < 0.01 \)
Host Plants – Summary:

- *Poa annua* preferred for egg laying, better for larval development, and least tolerant grass.

- Creeping bentgrasses can be damaged but much less likely, much less intensive, and can recover well.

→ **Best preventive control for ABW problems:** Keep *P. annua* percentage as low possible wherever possible using cultural practices and herbicides !!!
• Biology, ecology, damage

• Monitoring
  • Insecticide resistance
  • Sustainable management: non-resistant
  • Sustainable management: resistant
  • Biorationals
Plant Phenology for ABW

- **Forsythia full bloom** → overwintering adults become active
- Migration from overwintering sites to playing surfaces has started.
- Adult densities on playing surfaces increase during full bloom.
Plant Phenology for ABW

- **Forsythia ½ gold : ½ green** → peak adult densities on playing surfaces
  → best time to spray vs. overwintered adults
- But: blooming variable
  → Don’t rely on just 1 or 2 plants.
Plant Phenology for ABW

- *Flowering dogwood* full bloom
- *Eastern redbud* full bloom
  - egg-laying has begun
  - adulticides ineffective
Plant Phenology for ABW

- **Catawba Rhododendron** hybrid full bloom
  - larvae start appearing in soil
  - curative larvicides.
Phenological Indicator Plants for ABW
(average timing for NY metropolitan area)

* L1-3 = 1st thru 3rd larval stage; L4-5 = 4th thru 5th larval stage

From: Koppenhöfer et al. 2012
Linear Pitfall Traps to monitor adult movement
(not good estimate of adult densities)
Monitoring Adults - Grass clippings

- Many adults picked up by mowers
- Extraction: ~15% on green but < 1% on fairways
- Adult numbers in standard samples should be correlated to population built-up

- **BEWARE:** many adults survive mowing → discard clippings with significant adult numbers away from playing surface or destroy.
Monitoring Adults Vacuuming

• Inverted leaf blower to suck adults into an inserted sieve basket

• Between Forsythia full bloom and ½ gold : ½ green

• Extraction: ~5% on green, ~30% on fairways

→ number of adults sucked up indicator of ensuing larval populations
Vacuum sampling adults:
Standardize your sampling plan (1-2x/week) → count ABW and chart numbers

What I do:
5 vac samples (20 sec. ea) from 5 collars 1x per week at 11 am = 40 MINS
Monitoring Adults Disclosing (Irritant) Solutions

• 1 oz. lemon scented liquid dishwashing detergent in 2 gals of water

• Spread over 3’x3’ area

• Irritates adults to surface onto grass blades

• Most precise, consistent method (~75% extraction)

• BUT: Irrigate afterwards to avoid SCALD!!!
Monitoring – All Stages

- In spring, start with Rhododendron full bloom
- Cut turf cores with turf plugger (2.5” diam) or knife (1-2” deep).
- Break up soil and thatch on a tray and count insects.

For more detail: Submerge material in lukewarm water → remaining pupae, larvae, adults float up in 5-10 min.

**Adequately irrigated turf can tolerate 30-50 larvae/ft²**
Break 2.5” diam cores into 3-4 pieces

Submerge in lukewarm water saturated with salt for 1 hr.

Stir after 1, 20, and 40 min.

Collect and count stages floating to the surface
• Biology, ecology, damage
• Monitoring

• **Insecticide resistance**

• Sustainable management: non-resistant
• Sustainable management: resistant
• Biorationals
ABW Resistance to Insecticides

• Many GCs apply >3 treatments per season, up to 10 per season !!!

→ suggests resistance to insecticides.

• Many resistant populations detected !

• Likely that most GCs with > 5 years of intensive insecticide use vs. ABW have some level of resistance!
<table>
<thead>
<tr>
<th>Region</th>
<th>No. of responses</th>
<th>ABW applic./year</th>
<th>Resistance suspected (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td>Avg.</td>
<td>&gt; 5 (%)</td>
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<tr>
<td>All Regions</td>
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<td>3.9</td>
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<tr>
<td>North.Periph.</td>
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<tr>
<td>South.Periph.</td>
<td>16</td>
<td>2.9</td>
<td>0</td>
</tr>
</tbody>
</table>

(McGraw & Koppenhöfer 2017)
Resistance to Insecticides

• Resistance result of artificial selection pressure in favor of genes that convey ability to survive toxin exposure

• Genes controlling resistance mechanisms already present before exposure in 0.01–1% of population

• In resistant populations, frequency of resistance genes up to 97%.
Model assuming simple genetics of Resistance

- **S** = original gene version \(\rightarrow\) susceptible
- **R** = mutated gene version \(\rightarrow\) resistant
- Insects have 2 copies of each gene that controls a resistance mechanism

\[ SS = \text{individual fully susceptible} \]

\[ RR = \text{individual fully resistant} \]

\[ RS = \text{intermediate resistance level} \]
Simple Model of Resistance Development

1\textsuperscript{st} Generation: before application

Insecticide efficacy:

SS = 90%; RS = 60%; RR = 0%
Simple Model of Resistance Development

1st Generation: after application

Insecticide efficacy:
SS = 90%; RS = 60%; RR = 0%

→ 89% control
Simple Model of Resistance Development
2nd Generation: before application

Insecticide efficacy:
SS = 90%; RS = 60%; RR = 0%
Simple Model of Resistance Development
2nd Generation: after application

Insecticide efficacy:
SS = 90%; RS = 60%; RR = 0%

→ 86% control
Simple Model of Resistance Development

3rd Generation: before application

Insecticide efficacy:
SS = 90%; RS = 60%; RR = 0%
Simple Model of Resistance Development

3rd Generation: after application

Insecticide efficacy:
SS = 90%; RS = 60%; RR = 0%

→ 80% control
Simple Model of Resistance Development
4th Generation: before application

Insecticide efficacy:
SS = 90%; RS = 60%; RR = 0%
Simple Model of Resistance Development
4th Generation: after application

Insecticide efficacy:
SS = 90%; RS = 60%; RR = 0%

→ 59% control
→ Problem!
Simple Model of Resistance Development
5th Generation: before application

Insecticide efficacy:
SS = 90%; RS = 60%; RR = 0%
Insecticide efficacy:
SS = 90%; RS = 60%; RR = 0%

→ 30% control
→ Failure !!!
Rate of Resistance Development

Likely begins with 1st application but at first slow → unnoticed for several years.

Rate depends on:

- R allele dominance: more dominant → faster
- Generation turnover: takes 10-15 generations
- Population mobility: influx of SS slows rate
- AI persistence: more persistent → faster
- Selection pressure: greater → faster
Insecticide Resistance Mechanisms

• **Behavioral**: ability to avoid lethal toxin dose (increased sensitivity/irritability)

• **Reduced cuticular penetration**

• **Target site insensitivity**: reduced affinity of receptor sites to AI

• **Increased detoxification** (metabolic): overexpression or amplification of genes coding detoxifying enzymes
Resistance Interactions

• **Cross-resistance**: resistance to one AI automatically makes resistant to another (even without exposure).

• **Multiple resistance**: different mechanisms for each of several affected insecticides

• Resistance factors normally don’t occur alone

  → Different factors may interact synergistically.
Resistance Management Strategies

1. Use of resistant natural enemies:
   • Not available for any turfgrass pest
Resistance Management Strategies

2. Use of new, unaffected MoA:
   • Increasingly difficult to find and develop new MoAs.
   • Not much in pipeline.

→ **Don’t count on the next silver bullet**!
3. Use of synergists:

- If increased detoxification involved, certain compounds can interfere with detoxifying enzymes.

- E.g., piperonyl butoxide (PBO) interferes with major detoxifying system in ABW.

- **But too unstable in sunlight for outdoor applications**
4. Use of insecticide mixtures:

- Concept: extremely unlikely that resistance mechanisms for both AIs present in same individual
- But !!!: Resistance to both AIs has in some cases developed rapidly.
- Cross-resistance possible
- Especially risky if pest already resistant to one of the AIs
5. Reducing R gene frequency:

- Use short persistence insecticides
- Leave refugia for SS (no wall-to-wall apps)
- Treat only most susceptible life stage
6. MoA rotation:

- Do not use same MoA more than once per generation
- Do not use same MoA vs. consecutive generations.
- Same MoA should skip several generations, the more the better.
- May lead to reduction of R, but only if fitness cost involved with R
7. Field monitoring of resistance:

- By the time resistance obvious through failures, R frequency too high for implementation of effective and simple resistance management → more drastic changes required.
- Petri dish test detects ABW resistance but not sensitive enough to determine level of resistance
- More sensitive tools in development
Resistance in ABW

- On GCs with history of intensive insecticide use, particularly of pyrethroids

- Resistance seems primarily based on increased enzymatic detoxification.

- Continued intensive insecticide use ➔ involvement of up to 3 detox. systems ➔ up to 343x rate required to kill in lab tests !!!
Resistance in ABW

• Increased detoxification particularly problematic because not very specific
  → Cross-resistance very common !!
  → In extreme cases most available AIs affected !!!
  → MoA rotation no guarantee for resistance delay

• Limited resistance to chlorpyrifos (up to 20x) already observed.
Baseline susceptibility and cross resistance

- Topical bioassay to determine LDs (≤ 72 h) for important AIs.
Several other MoAs also affected, lower RR_{50}s
Greenhouse Assay $\text{LC}_{50} / \text{RR}_{50} @ 72 \text{ h}$

- $\text{RR}_{50}$s similar in greenhouse

Kostromytska et al. (2018a)
Field efficacy vs. ABW populations with different resistance levels
Field efficacy vs. ABW populations with different levels of resistance

<table>
<thead>
<tr>
<th>Insecticide class</th>
<th>AI</th>
<th>Trade name</th>
<th>Rate (lb ai/ac)</th>
<th>Targets</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pyrethroid</td>
<td>Bifenthrin</td>
<td>Talstar</td>
<td>0.100</td>
<td>X</td>
</tr>
<tr>
<td>Organo-phosphate</td>
<td>Chlorpyrifos</td>
<td>Dursban</td>
<td>1.000</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>Trichlorfon</td>
<td>Dylox</td>
<td>6.000</td>
<td>X</td>
</tr>
<tr>
<td>Spinosyn</td>
<td>Spinosad</td>
<td>Conserve</td>
<td>0.400</td>
<td>X</td>
</tr>
<tr>
<td>Oxadiazine</td>
<td>Indoxacarb</td>
<td>Provaunt</td>
<td>0.225</td>
<td>X</td>
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<tr>
<td>Anthranilic diamide</td>
<td>Chlorantraniliprole</td>
<td>Acelepryn</td>
<td>0.156</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>Cyantraniliprole</td>
<td>Ference</td>
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<td>X</td>
</tr>
<tr>
<td>Neonicotin.</td>
<td>Clothianidin</td>
<td>Arena</td>
<td>0.247</td>
<td>X</td>
</tr>
</tbody>
</table>

Koppenhöfer et al. (2018)
Resistance - Recommendations

- Reduce synthetic insecticide use.

- Shift control measure more towards larvae.

- $RR_{50} > 50$: concentrate on larvae using Ference (L1-4), Conserve/MatchPoint (L3-4), Provaunt (L3-4) (and Dylox [L3-4]).

- $RR_{50} > 100$: Ference (L1-4), Conserve/MatchPoint (L3-4) (and Provaunt [L3-4]).

- $RR_{50} > 100$: rotate with biorationals!

Koppenhöfer et al. (2018)
Petri dish Validation Assay

9 cm dish, 1 filter paper
1 ml solution, 10 adults

Bifenthrin (Talstar)

Kostromytska et al. (2018b)
Petri dish Validation Assay

9 cm dish, 1 filter paper
1 ml solution, 10 adults

Chlorpyrifos

Kostromytska et al. (2018b)
Resistance Level Assay - Conclusions

• Petri dish assay easy option for ABW resistance detection and monitoring
  – Sufficient discriminating power
  – Easy to set up and conduct

• One rate to separate susceptible and resistant population

• Two rates to estimate resistance level
1. DON’T do repeated applications with the same insecticide class (e.g. pyrethroids, OPs).

2. DON’T exceed label rates.

3. DON’T do ‘wall-to-wall’ applications.

4. Spray as little as possible by practicing good Integrated Turf Management

Don’t breed your own Super Weevil !!!
• Biology, ecology, damage
• Monitoring
• Insecticide resistance

• Sustainable management: non-resistant ABW
• Sustainable management: resistant
• Biorationals
Most Successful Programs:

1. Include monitoring to make decisions
2. Minimize sprays – in time & space
3. Get good 1st generation control of larvae
To Get Good Control…
Monitoring is Essential!!

• **Forsythia** still a good predictor
  – Start of migration (FULL BLOOM)
  – Peak densities = ½ Gold, ½ Green

• Combine with insect counts
  – Soapy flushes, vac sampling, pitfall traps
Ideal Timing of ABW Applications
(Timing for NY metropolitan area)

*Ad = adult; L1-3 = 1\textsuperscript{st} – 3\textsuperscript{rd} larval stage; L4-5 = 4\textsuperscript{th} – 5\textsuperscript{th} larval stage

Larvicides: Conserve, Provaunt, Dylox

*Adulticides: Pyrethroids, chlorpyrifos, Conserve, Provaunt

Koppenhöfer et al. 2012
Why 1st Generation Control is Important

- Overwintering adults can lay many eggs over many weeks
  - Avg. 60 to 90 eggs/female
  - Over up to 15 weeks

- Overlap in stages decrease effectiveness of controls
  - Larvae protected in stem
  - Pupae not susceptible
Does it make sense to apply adulticides before adult densities peak on playing surface?

- NY: 3-year study:
  - Few adults feed on migration
  - Adults don’t lay eggs before peak densities reached

- Our recommendation: **Wait for peak adult densities!**
Problems with pre-peak applications

- unnecessary kill of beneficials
- increased exposure of adult ABW to sublethal insecticide concentrations
  → less control
  → additional applications
  → faster resistance development !!
Most effective and sustainable option:

• **Work to reduce** *Poa* **as much as possible wherever possible.**

• **Start on fairways.**
Sustainable ABW Management

- **Minimize adult treatments**
- **Concentrate on larvae**

→ Allows more precise monitoring → more targeted treatments → less R selection

→ Softer on natural enemies → rebuild safety net of biological control → less R selection
Managing **non-resistant ABW**
while reducing risk for resistance development

- Tailor applications to pest pressure.
- You cannot eradicate ABW!
- Excessive insecticide use may release ABW (and other pests) from suppression by natural enemies and can lead to resistant populations.
  
  → Don’t follow a ‘program’ blindly.
  
  → Monitor populations throughout season
  
  → Applications only when/where needed.
Risk assessment

Determine risk for ABW damage based on:

- Percentage *Poa annua* in turf area
  -> *P. annua* particularly susceptible

- History of ABW problems
  -> tend to show up in same areas.

- Monitoring
  -> base treatment decisions on observed larval and/or adult densities.
Insecticide Efficacy vs. ABW

DeltaGard (deltamethrin)
Tempo (cyfluthrin)
Talstar (bifenthrin)
Scimitar (λ-cyhalothrin)
Dursban (chlorpyrifos)
Dylox (trichlorfon)
Arena (clothianidin)
Merit (imidacloprid)
Mach 2 (halofenozide)
Acelepryn (chlorantraniliprole)
Conserve (spinosad)
Provaunt (indoxacarb)
Aloft (clothia.+bifen.)
Allectus (imida.+bifen.)

Koppenhöfer et al. 2012
ABW +/- preventive white grub management

• If no preventive white grub (WG) management or if limited overlap in space → manage separately.

• If large areas receiving preventive white grub treatments also at risk from ABW → coordinate management to reduce treatments.
Managing **non-resistant ABW**

1. **ABW management only & low ABW risk:**
   - Monitor for larvae (full to late bloom Rhodod.).
   - If significant densities $\rightarrow$ larvicide.
Managing non-resistant ABW

2. ABW management only & higher ABW risk:

- Monitor for adults (until forsythia $\frac{1}{2}$ gold : $\frac{1}{2}$ green).

- If significant densities $\rightarrow$ Acelepryn / Ference (late bl. dogwood/eastern red bud).

- In areas with particularly high risk, monitor for larvae and apply larvicide if necessary.
2. **ABW management only & higher ABW risk:**

- Monitor for adults (until forsythia $\frac{1}{2}$ gold : $\frac{1}{2}$ green).

- If significant densities $\rightarrow$ adulticide (forsythia $\frac{1}{2}$ gold : $\frac{1}{2}$ green).

- Areas with particularly high risk: monitor for larvae and, if necessary, apply larvicide.
3. ABW & preventive WG management **combined**:  
- Apply Acelepryn (at onset full bl. dogwood): 0.1 lb ai/ac for WG + 0.06-0.1 lb ai/ac for ABW areas  
- Areas with very high ABW risk, monitor for larvae and, if necessary, apply larvicide.  
- Rotate every ~3rd year: neonicotinoid for WG → ABW separately.
• Biology, ecology, damage
• Monitoring
• Insecticide resistance
• Sustainable management: non-resistant
• Sustainable management: resistant ABW
• Biorationals
ABW Resistance and Insecticide Efficacy

*Koppenhöfer et al. 2012

*a, b, c = ~4/15-5/3, ~5/4-17, ~5/18-6/10 application timing; NY Met. area
Managing resistant ABW

• Chlorpyrifos less effective than pyrethroids vs. adults!!!

• Depending on degree of resistance, only effective compounds: Conserve / MatchPoooint and Ference vs. larvae (≥ 80% control).

• BUT: Conserve / Ference overuse likely to lead to resistance, too!!!

• If you see something clearly not working: stop wasting time and money on it !!!

• NO MORE PYRETHROIDS !!!
Managing **resistant** ABW – Strategy

- **1st year spring:** Conserve/MatchPoint or Ference to all playing surfaces with ABW damage history.
  - **Ference** full bloom dogwood thru late bloom rhododendron.
  - **Conserve / MatchPoint** full to late bloom rhodo.
  - **Water in:** Conserve immediately with 0.25”!!! Ference / MatchPoint soon with 0.1”.
  - During summer apply only if high larval densities or onset of damage (monitor!!!)
  - Rotate MoAs
Managing resistant ABW – Strategy

• In following years, start reducing applications.
• Base treatments on monitoring.
• Start reducing treatments on fairways.
• Then work your way up to higher profile areas.
• Rotate Conserve / MatchPoint and Ference w/ Provaunt (test if still effective).
• In areas with moderate larval densities (< 70/ft²) rotate with biorationalals.
How late do larvicides work? Why apply later?

- Acelepryn, Ference efficacy: late bloom dogwood (L1.0) = start full bloom rhododendron (L2.5)
- Assessment of damage potential becomes easier and more precise.
- Late applications, if effective, cover a greater part of the population
- Sometimes infestations are missed until larvae large.
ABW larval stage average on insecticide efficacy – Field (2 years)

- **L2.5**: beginning full bloom Rhododendron
- **L3.2**: ~ 1 wk into full bl. Rhodo.
- **L4.0**: just past bloom; ~ 2 wk after beginning
ABW larval stage average on insecticide efficacy – Field (2 years)

- MatchPoint: L2.5, L3.2 ≥ L4.0
- Ference, Provaunt: L2.5, L3.2 > L4.0
- Dylox: L2.5 < L.3.2 > L4.0
Timing- Summary / Recommendations

- Ference, Acelepryn: $L_{1.0} = L_{2.5}$.
- Ference, MatchPoint, Provaunt: $L_{2.5} = L_{3.2}$
- Dylox: $L_{3.2} > L_{2.5}$
- $L_{4.0}$ generally lower but MatchPoint best
- Concentrate on larvae
- Assess damage potential at start of or during full bloom rhododendron
- If necessary, apply asap
- Less applications, less resistance development
• Biology, ecology, damage
• Monitoring
• Insecticide resistance
• Sustainable management: non-resistant
• Sustainable management: resistant
• Biorationals
Entomopathogenic nematodes (EPN)

- obligate lethal parasites of insects
- mutualistic association with bacteria
- > 26 *Heterorhabditis* & 100 *Steinernema* spp.
- host searching capacity
- host range +/- broad
- ease of production
- recycling capacity
Entomopathogenic nematode life cycle

- Infective juvenile
- Host finding in soil
- Infective juvenile emergence
- Host penetration
- Reproduction & development (1-3 generations)
- Release of bacteria, host death, development
EPN Infections

S. scarabaei

H. bacteriophora

S. carpocapsae

H. bacteriophora
### Nematode products for US turf market

<table>
<thead>
<tr>
<th>Nematode</th>
<th>Targets¹</th>
<th>Product (Producer)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steinernema carpocapsae</td>
<td>BCW, SWW, AW, BB, Fleas</td>
<td>Millenium (BASF), Capsanem (Koppert), Ecomask (BioLogic)</td>
</tr>
<tr>
<td>Heterorhabditis bacteriophora</td>
<td>WG, BB</td>
<td>Nemasys G (BASF), Terranem NAm (Koppert), Heteromask (BioLogic)</td>
</tr>
</tbody>
</table>

¹BCW = black cutworm; SWW = sod webworm; AW = armyworm; BB = billbugs; WG = white grubs; MC = mole crickets
EPN vs. ABW larvae
- Fairway trials
vs. spring gen. L3-L5
2.5 b IJs/ha

- **Sc** most consistent suppression

*McGraw et al. (2010)*
- Split application improves EPN
- Additive Merit-EPN interaction
- Merit + split Sc $\rightarrow$ excellent control
- Merit simultaneously controls white grubs
EPN vs. ABW

- *Steinernema carpocapsae* or *Heterorhabditis bacteriophora*.
- Apply when larvae start to appear in soil.
- If soil dry and/or hot, ~0.1” irrigation before application.
- ~0.25” post-treatment irrigation.
- Keep soil moderately moist at least 1 wk.
- Split application tend to improve efficacy.
- No effect of resistance.
**Chromobacterium subtsugae**

- GRANDEVO® CG ! - 30% ai
- *C. subtsugae* strain PRAA4-1 and spent fermentation media
- 2-4 lbs/ac f. surface feeders
- 10-20 lbs/ac f. white grubs
- OMRI approved
- Activity vs. white grubs (varies with species), chinch bugs, billbugs, sod webworms.
Burkholderia spp.

- VENERATE® xc ! – 94.46% ai
- *Burkholderia* spp. strain A396 cells and spent fermentation media
- For fruit and vegetables
- Turfgrass not on label yet
- OMRI approved
- Activity vs. caterpillars and billbugs
Azadirachtin

- Molt-x® – 3.0% ai
- *Azadirachtin*, botanical extract from neem tree
- 8-10 (max. 22.5) fl oz/ac
- OMRI approved
- Activity vs. numerous insects incl. weevils
Field Efficacy vs. ABW
Adults
susceptible (2x) resistant (60x)

Grandevo
2x 4-8 lbs/ac

Venerate
2x 8-16 pt/ac
Field Efficacy vs. ABW Larvae
susceptible (2x)
resistant (60x)

**Grandevo**
2x 4-8 lbs/ac

**Venerate**
2x 8-16 pt/ac

**Molt-X**
2x 1.4 pt/ac
Civitas Turf Defense
a.i. Mineral oil (88.8%)

• Primarily fungicide, also insects on label
• Insects rec. 8.5 - 17 fl.oz. in 1.5 gal/1,000 ft²
• Greenhouse: best if soil saturated, 2-4 gal/1000 ft² spray volume, 0.05-0.1” post-spray irrigation.
• Field results highly variable: 13-55% control. Probably best if 17 floz at peak adults or 2x 8.5 floz ~7 days apart around peak adults.
• Not affected by resistance
Entomopathogenic Fungi

- facultative lethal parasites of insects
- *Beauveria* & *Metarhizium* species
- host range +/- broad; many different strains

Before spore germination: *Metarhizium* sp. (white grub)

After spore germination: *Beauveria* sp. (chinch bug)
F52 conidia-based liquid formulation

- **Met 52 EC**
- 11% a.i, 89% petroleum distillates
- \(~5.5\times10^9\) CFU g\(^{-1}\)
- Rec. field rates: 6.4-9.6 kg ha\(^{-1}\)
- Field rates: 9.6-19.2 kg ha\(^{-1}\)
  \(\rightarrow\) \(~5-10\times10^{13}\) CFU ha\(^{-1}\)
- Microsclerotia: ineffective
- Imidacloprid: low efficacy
- Conidia: low efficacy
- Microsclerotia & Conidia + imi: additive mortality
**REMEMBER**

- Intensive insecticide use is very likely to lead to ABW resistance.

- Getting on the pesticide treadmill with ABW is a 1-way road that over time gets ever uglier and harder to leave.

- The sooner you leave the better!

- Best not to get there in the first place!
My Rutgers Entomology Webpage:

http://entomology.rutgers.edu/personnel/albrecht-koppenhofer/

→ Extension presentations
→ Extension publications
Funding:
Rutgers Ctr f. Turfgrass Sci.,
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OJ Noer, Tri-State, USGA, USDA-
NIFA