Managing Worms on Vegetable Crops

Celeste Welty
Extension Entomologist
January 2016

THE OHIO STATE UNIVERSITY
‘Worms’ = caterpillars

- Identification
- Insecticides
- Non-chemical controls
### 18 important caterpillar pests on veg crops

<table>
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<th>Crop</th>
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<td>Tobacco hornworm Variegated cutworm Yellow-striped armyworm Stalk borer + Beet armyworm</td>
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Caterpillars: generalities?

- External feeders: easier
- Internal feeders: harder
- Monitor
  - Scouting
  - Trapping
- Control
  - Chemical: beware species not equal
  - Microbial: B.t. spray
  - Biocontrol: can be encouraged
  - Mechanical: row covers
Life Cycle

Egg → Caterpillar (Larva) → Pupa → Moth (Adult)
Do moths matter?

- Can be easier to monitor than caterpillars
- Give advance warning of caterpillars
Worms in sweet corn

• Caterpillar i.d.
• Monitoring
• Insecticides
  – Before silking
  – During silking
  – Conclusions from trials, 2007-2015
• Alert: new species
Caterpillars in Sweet Corn

- **Corn Earworm**
- **European Corn Borer**
- **Fall Armyworm**
Caterpillars in Sweet Corn

- Key pests; can ruin the crop
- Pest management is complex
  - Several insect species
  - Sequential plantings
- The need to control them varies through the season
  - No control
  - Low intensity control
  - High intensity control
<table>
<thead>
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<th>Corn earworm</th>
<th>European corn borer</th>
<th>Fall armyworm</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Body color</strong></td>
<td>Variable: yellow, green, brown, or pink</td>
<td>Cream to light brown</td>
<td>Light brown top, dark brown sides</td>
</tr>
<tr>
<td><strong>Body marks</strong></td>
<td>Distinct stripes</td>
<td>Subtle stripes, round dots</td>
<td>Stripes</td>
</tr>
<tr>
<td><strong>Texture</strong></td>
<td>Dense microspines</td>
<td>Smooth; few sparse hairs</td>
<td>Smooth</td>
</tr>
<tr>
<td></td>
<td>Corn earworm</td>
<td>Eur. corn borer</td>
<td>Fall armyworm</td>
</tr>
<tr>
<td>--------------------------</td>
<td>--------------</td>
<td>----------------</td>
<td>---------------</td>
</tr>
<tr>
<td><strong>Head size</strong></td>
<td>Large</td>
<td>Small</td>
<td>Large</td>
</tr>
<tr>
<td><strong>Head color</strong></td>
<td>Light orange/brown</td>
<td>Dark brown</td>
<td>Dark sides, light in middle</td>
</tr>
</tbody>
</table>

**Caterpillar i.d.**
Sweet Corn Development

- Seedling
- Whorl stage
- Emerging tassel stage **
- Fresh silk ***
- Dry silk
1. Corn Earworm

- Moths migratory from South
- Arrival time varies
- Eggs laid on silk
- Eggs hatch in 48 hrs
Trap to Monitor Corn Earworm

- Pheromone lure
- Attracts male moths
- Highly effective
2. European Corn Borer

- Moths active:
  - 1\textsuperscript{st} flight:
    - Late May to late June
    - Most eggs on whorls
    - Move to tassel to ear
    - Control before silking
  - 2\textsuperscript{nd} flight:
    - Late July to late August
    - Most eggs near ear
    - Control during silking

- Monitor moths with pheromone traps
European corn borer: generations per year

• 2 generations
  – when summer has average temperatures (60% of years in Ohio)

• 3 generations
  – when summer has high temperatures (40% of years)
3. Fall Armyworm

- Also migratory from South
- Arrival time varies
- Harder to kill
Fall Armyworm During Silking

- Pheromone trap
  - All-green unitrap

- Spray every 5-7 days during silking if more than 3 moths per week in trap
Emerging-Tassel Stage

• **Scout (examine plants)**
  – 50 plants in small plantings (<2A)
  – 100 plants in large plantings (>2A)
  – Record # with fresh feeding damage

• **Action threshold**
  – Spray if fall armyworm and/or European corn borer on >10% of plants
During silking: control worms by insecticide

- For 3 week period before harvest
- Start spray schedule when fresh silk begins to show, **IF** moths active
- Use traps to monitor moths
## Difference in ‘Worm’ Invasion

<table>
<thead>
<tr>
<th></th>
<th>Corn earworm</th>
<th>European corn borer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Egg location</td>
<td>silks</td>
<td>ear leaf</td>
</tr>
<tr>
<td>Egg hatch</td>
<td>2-3 days</td>
<td>3-5 days</td>
</tr>
<tr>
<td>Moth source</td>
<td>migratory</td>
<td>local</td>
</tr>
</tbody>
</table>
How often to spray during silking?

<table>
<thead>
<tr>
<th>Moths active?</th>
<th>Insecticide need to control larvae</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Corn earworm</strong></td>
<td><strong>Eur. corn borer</strong></td>
</tr>
<tr>
<td>+</td>
<td>+ or -</td>
</tr>
<tr>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
### Relative importance of pests during silking

<table>
<thead>
<tr>
<th>Rank</th>
<th>Pest</th>
<th>Spray Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Corn earworm</td>
<td>2-6 d</td>
</tr>
<tr>
<td>2</td>
<td>Eur. corn borer</td>
<td>5-7 d</td>
</tr>
<tr>
<td>3</td>
<td>Fall armyworm</td>
<td>5-7 d</td>
</tr>
</tbody>
</table>
Most critical time for earworm invasion: silking

- For 3 week period before harvest
- Stages: fresh, wilting, dry & brown
- Pests attracted to fresh silk
- Silk grows rapidly (up to 1.5” per day)
- If sprayed, next day new silk unprotected
Insecticide Issues During Silking in Main Season & Late Season Corn

*** Spray interval

** Coverage of ear zone

* Choice of insecticide
## Corn Earworm Insecticide Spray Schedule
(based on Maryland & Massachusetts)

<table>
<thead>
<tr>
<th>Number moths per pheromone trap per day</th>
<th>Spray interval</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Maximum daily temp. &lt;80°F</td>
</tr>
<tr>
<td>&lt; 0.2</td>
<td>No spray</td>
</tr>
<tr>
<td>0.2 - 0.5</td>
<td>Every 6 days</td>
</tr>
<tr>
<td>0.5 - 1</td>
<td>Every 5 days</td>
</tr>
<tr>
<td>1 - 13</td>
<td>Every 4 days</td>
</tr>
<tr>
<td>&gt; 13</td>
<td>Every 3 days</td>
</tr>
</tbody>
</table>

Note, in Georgia and Florida, sweet corn is sprayed every day!
intensive schedule when >13 moths per day (>90 moths per week)
Field trial to compare spray schedule intensity, 2010

• One product: Warrior, at max rate
• Treatments (during silking):
  – Spray every 2 days (11 times)
  – Spray every 3 days (7 times)
  – Spray every 4 days (6 times)
  – Spray every 5 days (5 times)
  – Start 3-day, then 4-day (6 times)
  – No spray
Pest pressure at field trial site

Pheromone traps, South Charleston, Ohio

Corn earworm, 2010

Number of moths per day

Date


>13 moths per day
Pest pressure at field trial site

Silking began 8/10; sprays 8/10-8/30
Sweet corn, 2010, spray interval trial: % with no kernels damaged

- 2-day: 84%
- 3-day: 80%
- 4-day: 65%
- 3- to 4-day: 60%
- 5-day: 54%
- Untreated: 1%

P < 0.0001
European Corn Borer on Sweet Corn: spray during silking if moths active
(> 1 moth per night = 7 moths per week in pheromone trap)

• 1st spray when 10-20% of plants silking

• Spray every 5 - 7 days
  – 5-day during peak egg hatch
  – 5-day when temperatures hot (>80 F)
Transgenic option: B.t. sweet corn

- Less developed than field corn
- Rejected by some consumers
- Lower residue of insecticides
B.t. sweet corn

• ‘Attribute’ from Rogers, since 2003:
  – BC 0805
  – BC 0822
  – GH 0851
  – WH 0809
  – GSS 0966
  – WSS 0987
  – BSS 0977
  – BSS 0982

• From Seminis (Monsanto), since 2012:
  – ‘Obsession II’ (bicolor shQ)
  – ‘Passion II’ (yellow sh2)
  – ‘Temptation II’ (bicolor se)
B.T. sweet corn

• ‘Attribute’:
  – European corn borer:
    • Excellent control
  – Corn earworm:
    • Adequate protection if population low
    • Supplement with 2 sprays of insecticide if population high

• Seminis/Monsanto
  – Insect protection
    • Above ground (all worms, including earworm)
    • Below ground (rootworms)
  – Weed control
    • Round-up tolerant
Worm management with B.t. sweet corn

- **If corn earworm pressure low**
  - No insecticide sprays needed during silking

- **If corn earworm pressure moderate or high**
  - Use 2 sprays
  - First spray: 75% fresh silk
  - Second spray: 4 days later
Spraying for organic production

- Use same spray schedule rule
- ‘Entrust’ allowed
  - A.I.: spinosad
  - On OMRI list
  - Rate: 0.5 - 2 oz/acre
  - Cost: $571 - $649/lb
Organic alternative for worms in sweet corn: B.t. + Oil
(Ruth Hazzard, Univ. Mass.)

• ‘Zea-later II’ applicator
  – Hand-held
  – $109 (Johnny’s Selected Seeds)

• Mix:
  – 900 ml food-grade corn oil
  – Lecithin 5% (emulsifier)
  – 28.6 grams DiPel DF (a B.t.)
  – 100 ml water

• Treat:
  – Once, 5 days after silking begins
  – Squirt 0.5 ml of oil mix into each ear tip
Corn earworm control, sweet corn field trials 2007-2015

Jim Jasinski & Celeste Welty

- Concern about pyrethroid resistance
- Start spray program at 1\textsuperscript{st} silk
- 6 sprays at 3- to 4-day intervals
Conclusions from 9 years of Ohio field trial data

• Relief that pyrethroids still ok
  – When CEW low
  – Max rates needed

• Relief that new a.i.s now available
  –diamides
  –spinosyns

• Worry about whether efficacy of pyrethroids will suddenly drop
New Pest Alert for Sweet Corn: Western Bean Cutworm
How to identify it?

<table>
<thead>
<tr>
<th>WBCW</th>
<th>Western bean cutworm</th>
<th>Corn earworm</th>
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CEW
### How to identify it?

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<th>Western bean cutworm</th>
<th>Corn earworm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number of worms per ear</td>
<td>Many</td>
</tr>
<tr>
<td></td>
<td>Prothorax (segment behind head)</td>
<td>Broad dark stripes</td>
</tr>
<tr>
<td></td>
<td>Micro-spines on body</td>
<td>None</td>
</tr>
<tr>
<td></td>
<td>Net-like marks on head</td>
<td>No</td>
</tr>
</tbody>
</table>
How to monitor it?

- **Pheromone lure in trap**
  - Milk jug or unitrap
  - One generation per year
  - Adults active in July
  - Trap June to August
How to monitor it?
Where is it?

- **Confirmed catches**
  - NW Ohio since 2007
  - Central Ohio since 2009
  - But numbers very low compared to West
How to monitor?, part 2

• If any moths trapped, then scout:
  – Late July & early August
  – In plantings with tassels emerging
  – Upper 4 leaves of 100 plants/planting
  – Look for eggs
  – Look for young larvae
How to decide on control?

• Thresholds (sweet corn):
  – 4% of plants infested (processing)
  – Tentative: 1% of plants (fresh-market)
What are control options?

• **Insecticide:**
  – When eggs are hatching
  – When ~90% of tassels have emerged
  – A pyrethroid or Sevin
What are control options?

• **Insecticide:**
  – When eggs are hatching
  – When ~90% of tassels have emerged
  – A pyrethroid or Sevin

• **Transgenic BT hybrid varieties:**
  – ‘Attribute’ sweet corn and ‘YieldGard’ field corn are **not** effective
  – ‘Herculex’ field corn **is** effective
Worms in Peppers
European Corn Borer

- Key pest of bell peppers
  - Bore into fruit
  - Quality loss
  - Yield loss
European Corn Borer

• Also infests non-bell peppers

jalapeño  cayenne  cherry
Occasional pests in peppers

- Corn earworm
- Fall armyworm
- Beet armyworm
- Hornworms
Controlling borers in peppers

- **Target of insecticide:**
  - young larvae
  - cap end of fruit

- **Insecticide efficacy affected by:**
  - timing
  - coverage
  - choice of material
When does European corn borer damage peppers?

<table>
<thead>
<tr>
<th>Month</th>
<th>Fruit present?</th>
<th>Moths present?</th>
</tr>
</thead>
<tbody>
<tr>
<td>May</td>
<td>no</td>
<td>no</td>
</tr>
<tr>
<td>June</td>
<td>no</td>
<td>yes (1&lt;sup&gt;st&lt;/sup&gt; gen.)</td>
</tr>
<tr>
<td>July</td>
<td>yes</td>
<td>no</td>
</tr>
<tr>
<td>August</td>
<td>yes</td>
<td>yes (2&lt;sup&gt;nd&lt;/sup&gt; gen.)</td>
</tr>
<tr>
<td>September</td>
<td>yes</td>
<td>no/yes (if 3&lt;sup&gt;rd&lt;/sup&gt; gen.)</td>
</tr>
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ECB: 2 vs 3 generations
Trap to Monitor European Corn Borer

- Pheromone lure
- Attracts male moths
Challenge: good control

- 100% control of ECB is rare
- **Due to canopy:**
  - Dense
  - Hard to cover thoroughly
- **Due to borer location:**
  - Entry on stem often oriented down
  - Protected inside fruit
- Processors demand <3% damage
Insecticide timing for borer control in pepper

• First spray:
  – within 1 week of surge in trap catch
  – when >1 moth/night in trap
  – usually late July

• Spray schedule:
  – spray every 7 days (range 5 - 14 days)
  – during time moths active, 4 - 6 weeks

• Stop spraying:
  – once trap catch falls (usually early Sept.)
  – or until harvest if other pests active
## Insecticides for borer on peppers

<table>
<thead>
<tr>
<th>Insecticide</th>
<th>PHI</th>
<th>Efficacy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coragen</td>
<td>1</td>
<td>E</td>
</tr>
<tr>
<td>Orthene</td>
<td>7</td>
<td>E</td>
</tr>
<tr>
<td>Mustang</td>
<td>1</td>
<td>G</td>
</tr>
<tr>
<td>Pounce/Ambush</td>
<td>3</td>
<td>G</td>
</tr>
<tr>
<td>Warrior</td>
<td>5</td>
<td>G</td>
</tr>
<tr>
<td>Baythroid</td>
<td>7</td>
<td>G</td>
</tr>
<tr>
<td>Brigade</td>
<td>7</td>
<td>G</td>
</tr>
<tr>
<td>Radiant</td>
<td>1</td>
<td>G</td>
</tr>
<tr>
<td>Intrepid</td>
<td>1</td>
<td>G</td>
</tr>
<tr>
<td>Confirm</td>
<td>7</td>
<td>G</td>
</tr>
<tr>
<td>Asana</td>
<td>7</td>
<td>F</td>
</tr>
<tr>
<td>Sevin</td>
<td>3</td>
<td>F</td>
</tr>
<tr>
<td>Lannate</td>
<td>3</td>
<td>F</td>
</tr>
<tr>
<td>B.t.</td>
<td>0</td>
<td>F</td>
</tr>
</tbody>
</table>
European Corn Borer on Peppers

- **When temperature average:**
  - Only 2 generations likely
  - Need 4 to 6 sprays total

- **When very hot:**
  - 3 generations likely
  - Need 8 to 10 sprays total
Spray B.t. on peppers

- *Bacillus thuringiensis* products:
  - Javelin, CryMax, Agree, Deliver (Certis)
  - DiPel, XenTari (Valent)
- Controls caterpillars:
  - European corn borer
  - Hornworms
- Apply *twice* per week
 Marketable yield of red bell peppers in 4 harvests (cumulative) after 5 insecticide applications at 10-day spray interval, Fremont, Ohio, 2013

<table>
<thead>
<tr>
<th>Product</th>
<th>Yield in kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coragen</td>
<td>19</td>
</tr>
<tr>
<td>Orthene</td>
<td>18.4</td>
</tr>
<tr>
<td>cyclaniliprole, high</td>
<td>17.2</td>
</tr>
<tr>
<td>Glad/Hero/Mustang</td>
<td>16.6</td>
</tr>
<tr>
<td>cyclaniliprole, low</td>
<td>15.7</td>
</tr>
<tr>
<td>Avaunt</td>
<td>12.9</td>
</tr>
<tr>
<td>Radiant</td>
<td>12.7</td>
</tr>
<tr>
<td>Untreated</td>
<td>11.9</td>
</tr>
</tbody>
</table>

Significance: P = 0.0002
Marketable yield of red bell peppers after insecticides at 7-day interval, 2014

- Cyclan 16: 29 kg/plot
- Coragen: 28.1 kg/plot
- Avaunt: 27.1 kg/plot
- Cyclan 11: 26.5 kg/plot
- Radiant: 26.3 kg/plot
- Cyclan 22: 25.9 kg/plot
- Orthene: 24.8 kg/plot
- Untreated: 22.6 kg/plot
Insecticide Spray Interval Trial
on Bell versus Non-bell Peppers, 2004

Yield of uninfested fruit (kg)

Bell  |  Banana  |  Jalapeno

5-day schedule  |  7-day schedule  |  10-day schedule  |  14-day schedule  |  Untreated

Bar labels indicate significant differences.
Occasional pests in peppers

- Corn earworm
- Fall armyworm
- Beet armyworm
- Hornworms
Beet Armyworm

- Pepper & tomato
- Leaves & fruit
- Scout for window-paning on upper youngest leaves
- Green, usually striped, 1 1/4”
- Not susceptible to pyrethroids
Beet Armyworm

- Monitor moths with pheromone trap
- Scout field if any moths caught
- Abundant at some sites in Ohio 2004:
  - June: most with 1-10 moths per trap per week
  - July: most with 3-60; up to 223
  - August: most with 25-100; up to 330
Beet Armyworm

• Insecticide choices:
  – Confirm/Intrepid excellent
  – Avaunt excellent
  – Proclaim excellent
  – Radiant excellent (young worms)
  – Radiant good (older worms)
  – B.t. aizawai* fair
  – Orthene poor
  – Baythroid poor
  – Warrior poor
  – Asana poor
  – Lannate poor

*aizawai strain in Agree, XenTari
Worms in Cole Crops:
cabbage, broccoli, collards, kale, turnip

• pests & natural enemies
• scouting & thresholds
• using BT & insecticides
Caterpillars on cole crops

- Diamondback moth
- Imported cabbageworm
- Cabbage looper
Parasitoid wasps attack caterpillars

- Imported cabbageworm
- Cabbage looper
- Diamondback moth

- Cotesia larvae
- Cotesia adults emerging
- Copidosoma floridanum wasps emerging from one cocoon
- Diadegma insulare oviposits on larvae
Diadegma insulare, Parasitoid of Diamondback Moth Larvae

- small wasp, 1/4” long
- black body, red/brown marks
- adult wasp lays egg in older caterpillar
- new adult wasp emerges from pupa
Diamondback & Biocontrol

- % of diamondback larvae attacked:
  - 53 to 88% in Wisconsin study
  - 46 to 69% in Virginia study
  - 24 to 36% in Ohio study

Diamondback pupae

Healthy pupa

Parasitized pupae

Photo by J. Ogrodnick
Floral resources help biocontrol

• Provide nectar: food for adult parasitoids
  – wasps live longer
  – lay more eggs
  – sting host faster

• Attracts some biocontrol agents

• Can be scarce in conventional fields

• Wild: yellow rocket, wild mustard

• Cultivated: sweet alyssum

• Trials with alyssum, 2011 & 2012
Does cabbage need insecticide treatment for caterpillars?

• If few worms: no
• If many worms: yes
• If some worms: need help
Caterpillar management

• Decisions (weekly)
  – Need to apply insecticide?
  – Which insecticide?

• Constraints
  – Resistance to insecticidies

• Tools
  – Scouting
  – Thresholds
Management Decisions

• **Scouting** = how many worms are in the field?

• **Thresholds** = is the number of worms more or less than what the plant can tolerate?
Management decisions using scouting & thresholds

- **Formal: at start**
- **Casual: after experience**
Basis for cabbage thresholds

- Number of worms tolerated by crop depends on plant size
- Different worm species eat at different rates
- Air temperature affects feeding rate of worms
Larval Units (LU)

1 LU = 1 large cabbage looper
1 LU = 1.4 small cabbage loopers
1 LU = 1.4 large imported cabbageworms
1 LU = 10 small imported cabbageworms
1 LU = 10 diamondback larvae
Caterpillar thresholds

- Processing cabbage
- Fresh-market cabbage

# leaves: 1 5 10 15 20
LU 2 3
1 2 3

2 4 6 8 10 12” head
### Thresholds, Processing Cabbage

<table>
<thead>
<tr>
<th>Avg temp</th>
<th>Threshold (Avg Larval Units per plant)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>4-leaf</td>
</tr>
<tr>
<td>60°F</td>
<td>0.08</td>
</tr>
<tr>
<td>70°F</td>
<td>0.04</td>
</tr>
<tr>
<td>80°F</td>
<td>0.03</td>
</tr>
</tbody>
</table>

See handout for complete list of temperatures and plant stages
Cabbage weekly scouting steps

1. Determine crop stage
2. Determine sample size
   - Fixed:
     • young (<8 leaf): 4 plants @ 10 segments
     • older (>8 leaf): 2 plants @ 10 segments
   - Variable: 1 - 4 plants @ 10 segments
3. Randomly choose plants to inspect
4. Inspect plants for target pests
5. Record # of pests per category
Decision-making steps

1. Determine average number of caterpillars per plant for 3 species
2. Convert to total Larval Units
3. Find action threshold (for crop growth stage & temperature)
4. Compare current LU with threshold LU
Caterpillar Response to Insecticides

• **Imported cabbageworm:**
  – Easiest to kill

• **Cabbage looper:**
  – Most difficult to kill

• **Diamondback:**
  – Usually difficult but varies with population’s history of resistance
## Cabbage Insecticide Efficacy

<table>
<thead>
<tr>
<th>Product</th>
<th>Imported cab’wm</th>
<th>Diamond back</th>
<th>Cabbage looper</th>
</tr>
</thead>
<tbody>
<tr>
<td>Avaunt</td>
<td>good</td>
<td>excel.</td>
<td>excel.</td>
</tr>
<tr>
<td>B.t. (DiPel)</td>
<td>good</td>
<td>good</td>
<td>fair</td>
</tr>
<tr>
<td>Confirm, Intrepid</td>
<td>good</td>
<td>fair</td>
<td>good/excel</td>
</tr>
<tr>
<td>Proclaim</td>
<td>good</td>
<td>excel.</td>
<td>fair/good</td>
</tr>
<tr>
<td>SpinTor, Radiant</td>
<td>good</td>
<td>excel.</td>
<td>good</td>
</tr>
<tr>
<td>pyrethroids</td>
<td>good</td>
<td>good</td>
<td>good</td>
</tr>
<tr>
<td>Lannate</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sevin</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Integration of chemical control & biological control

- Depends on choosing a selective insecticide
  - Kills caterpillars
  - Does not kill parasitoids
  - Use microbial insecticide, BT
### Insecticides for caterpillar management on cole crops

<table>
<thead>
<tr>
<th>Insecticide</th>
<th>Imported cabbage-worm</th>
<th>Diamondback moth</th>
<th>Cabbage looper</th>
<th>Natural enemies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional</td>
<td>Excellent control</td>
<td>Fair control</td>
<td>Good control</td>
<td>Poor survival</td>
</tr>
<tr>
<td>B.t.</td>
<td>Good control</td>
<td>Good control</td>
<td>Fair control</td>
<td><strong>Excellent survival</strong></td>
</tr>
</tbody>
</table>

Thus B.t. works best when diamondback moth or imported cabbage worm is dominant pest.
Caterpillar Calendar

April | May | June | July | Aug | Sept

Imported cabbageworm

Diamondback moth

Cabbage looper
Calendar for integrated bio & chemical control in cabbage

• **Early & mid-season (April to July)**
  – if imported cabbageworm &/or diamondback dominant
  – use only B.t.

• **Mid- to late-season (August)**
  – if cabbage looper dominant pest
  – use Confirm, SpinTor, or Proclaim

• **Late season (Sept.-October)**
  – if cabbage looper dominant pest
  – use pyrethroids
B.t. for control of caterpillars
What is B.t.?

• A natural soil-borne bacterium
• Species: *Bacillus thuringiensis*
• This bacterium produces crystal-like proteins that kill certain insects
• Found world-wide
• Produced by fermentation methods
• Discovered 1915; used since 1957
How does B.t. work?

- B.t. must be eaten by target insect
- B.t. contains toxins that are activated by insect’s gut enzymes
- toxins paralyze digestive tract
- feeding stops within 2 hours
- death takes 1 - 5 days
B.t. products

• For caterpillar control:
  – DiPel, XenTari, Biobit (Valent)
  – Javelin, Agree, CryMax, Deliver (Certis)

• For Colorado potato beetle:
  – Novodor (Valent)
B.t. performance

• Sometimes erratic:
  – Breakdown in U.V. light
  – Reduced toxicity against older larvae
  – Incomplete spray coverage
  – Too long a spray interval
• Best if:
  – Target young larvae
  – Apply at frequent intervals
  – Get thorough coverage
    • Lot of water (>35 gal/A)
    • Good pressure (60 psi)
How are B.t. sprays most effective?

• Rate?
• Frequency?
• Time of day?
Field trial on B.t. in cabbage, 2012

- cv ‘Bravo’
- Transplanted 18 May
- Scouted weekly for insects
- 1st spray 18 days after planting
- Sprays for 11 weeks
- Harvest 20 August
# B.t. trial: Treatments

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Rate of Dipel DF</th>
<th>Frequency</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
<td>Low (0.5 lb/A)</td>
<td>Every 7 days</td>
<td>daytime</td>
</tr>
<tr>
<td>3</td>
<td>Low (0.5 lb/A)</td>
<td>Every 14 days</td>
<td>daytime</td>
</tr>
<tr>
<td>4</td>
<td>High (1.0 lb/A)</td>
<td>Every 7 days</td>
<td>daytime</td>
</tr>
<tr>
<td>5</td>
<td>High (1.0 lb/A)</td>
<td>Every 14 days</td>
<td>daytime</td>
</tr>
<tr>
<td>6</td>
<td>Low (0.5 lb/A)</td>
<td>Every 14 days</td>
<td>evening</td>
</tr>
</tbody>
</table>
Cabbage B.t. trial:
Insect damage at harvest,
mean of 10 heads per plot

high rate, 7 d, day  
1.98

low rate, 7 d, day  
2.15

low rate, 14 d, evening  
2.57

low rate, 14 d, day  
2.6

high rate, 14 d, day  
2.62

untreated  
4.85

Rating (Greene's scale, 1 to 6)
B.t. trial: Conclusions

• Frequency more important than rate
  – Every 7 days better than every 14 days
  – Low rate as effective as high rate

• Daytime spray as effective as evening spray
Cole crop pests: mechanical control by row covers
## 18 important caterpillar pests on veg crops

<table>
<thead>
<tr>
<th>Crop</th>
<th>Pest</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sweet corn</td>
<td>Corn earworm + European corn borer + Fall armyworm + Western bean cutworm Armyworm Black cutworm +</td>
</tr>
<tr>
<td>Pepper, tomato</td>
<td>Tobacco hornworm Variegated cutworm Yellow-striped armyworm Stalk borer + Beet armyworm</td>
</tr>
<tr>
<td>Cole crops &amp; greens</td>
<td>Imported cabbageworm Diamondback moth Cabbage looper + Cross-striped cabbageworm Zebra caterpillar +</td>
</tr>
<tr>
<td>Squash &amp; pumpkins</td>
<td>Squash vine borer</td>
</tr>
<tr>
<td>Parsley</td>
<td>Parsleyworm</td>
</tr>
</tbody>
</table>
Info on fruit & veg. pests
u.osu.edu/pestmanagement/

Questions?
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cell phone: 614 746 2429