Biologically-Based, Insect Pest Management in Brassicas

Emphasizing Bio-Control of Key Insect Pests

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Vegetable Production in Wisconsin

- Important production state nationally
- Good crop climate also limits pests
- Production linked historically to canning industry
- Recent increase in fresh market
Changing Economic Ground

- Fuel prices
- Changing consumer demand
- Major market makers redefining landscape (Wal-Mart)
- Current market makers rapidly adjusting (Whole Foods)
- New institutional buyers beginning to enter the market
- Public policy – national, state & local = sustainability standards
- Environmental costs internalized
- Food security

TIPPING POINTS???
Scoping Partners for Regional Food Strategy Project

- Blue Planet Partners
- Michael Fields Agricultural Institute
- Center for Integrated Agricultural Systems
- DATCP
- REAP
- UW – Center for Cooperatives
- Common Wealth Development, Inc.
- UW College of Agriculture
- Other key food systems leaders
Factors that regulate insect populations

1. **Physical Factors**
   - Environment
     - Temperature, rainfall
   - Pesticides

2. **Biological Factors**
   - Influence increases at higher populations
   - Competition
   - Food availability
   - Disease
   - Parasites, Predators

Insect management seeks to blend various biological and physical factors together to hold pests at acceptable levels.
Insect Management ➔ The 6-step Process

1. Identify the “key” pests
2. Look closely at:
   - Biology
   - Ecology
   - Behavior
   - Impact on crop
3. Identify weak links
4. Develop management strategies to exploit weaknesses
5. Tailor pest management to individual needs
6. Fit sporadic pests into program
Biological control: an overview of the BCIAM publication...

- uses living beneficial organisms (natural enemies) to control pests
- is an alternative to insecticides
- is knowledge-intensive
- may not control all pests all of the time, but should be the foundation of any organic pest management program
- can be effective, economical, and safe
Three categories of natural enemies:

**Predators**
- kill and eat multiple prey during lifetime
- e.g., lady beetles, praying mantids, spiders

**Parasites**
- immature stages develop within single living host, eventually killing it
- e.g., parasitic wasps, parasitic flies

**Pathogens**
- infectious microorganisms that develop & multiply within living host, sickening or killing it
- e.g., bacteria, fungi, viruses, protists, nematodes...
Three types of biological control:

**Classical / Importation of natural enemies**
- Gov’t agencies import natural enemies from elsewhere, evaluate them in quarantine, attempt to establish them for permanent control of target pest

**Augmentation of natural enemies**
- Grower increases abundance of natural enemies by purchasing and releasing them

**Conservation of natural enemies**
- Grower selects farming practices &/or manages habitats to enhance, or at least not reduce, natural enemy effectiveness
Insect Management Trends on Vegetables

1980’s to 1990’s = Problems

• Fewer insecticides
  • Resistance in pests
  • Label cancellations
    – Reregistration
    – FQPA
• Raw product residues
• Worker safety
• Environmental concerns
  • Nontarget toxicity
  • Groundwater
Insect Management Trends on Vegetables

Present and Future

Targeted insecticide use

Integration of non-chemical alternatives

Reduced risk, ecologically-based IPM
Cole Crop Insect Control

Many crops with similar insect pest complex

**Head crops**

- Cabbage
- Cauliflower
- Broccoli
- Also: Brussels sprouts, Kale, Kohlrabi, Collards, Mustard greens, Chinese cabbage, etc.

**Root crops** – Turnips, Radish, Rutabaga, etc.
Insect Pest Complex

Key Pests - Lepidoptera

- Diamond back moth
- Imported cabbageworm
- Cabbage looper

Sporadic Pests

- Cabbage maggot
- Flea beetle
- Cabbage aphid
Managing Insects on Cole Crops

★★Excellent example of potential for biological control ★★
(Mahr et. al. NCR Regional pub. 471)

History of problem

- Direct damage to marketable product by key pests
  - Worms on heads
  - Maggots on roots
- Multiple insecticide applications used
- Resistance developed as threat to production

Solution

- IPM implementation based on biological control of key pests
- Pesticides switched to specific, ‘soft’ materials to preserve natural control
Key Pests of Cole Crops

- Complex of 3 lepidopteran species
- All feed on marketed crop
- Need to identify species but can treat as a complex

Diamondback moth  Cabbage looper  Imported cabbage worm
Diamondback moth: Life cycle

**Adult**
- Small night flyer, short fast flights
- ½”, wings have diamond pattern
- Can monitor with pheromone trap

**Eggs**
- Small, hard to see
- Laid close to veins

**Larvae**
- 4-5 instars up to ¾” long
- 2-3 weeks
- Cigar shaped, pointed at ends
- ‘wiggle’ when touched
- Spin thread and hang

**Pupa**
- Usually on underside of leaves
- Neatly spun pupal case
Diamondback moth

Occurrence
- Does not overwinter in Wisconsin
- Blown in on wind or imported
- 4-8 generations per year

Damage
- ‘Window pane’ feeding, may also deform heads
- 1st instar mine in leaf
- Damage usually early-mid season (June/July)
- Resistance to many insecticides
- Major problem worldwide
Imported Cabbage Worm: Life cycle

**Adult**
- White, day flying butterfly

**Eggs**
- Laid single on undersurface
- White, turning yellow at hatch
- Cigar shaped

**Larvae**
- 5 instars; 3-4 weeks
- Velvety green with yellow dorsal line
- Slow moving
- Up to 1 ½ inches in length

**Pupa**
- Distinctive angular shape
- Usually on plant debris/old leaves
Imported Cabbage Worm

Occurrence
- Overwinters as pupae in Wisconsin
- 3 generations per year, 1st on weeds

Damage
- Usually most damaging species in Wisconsin
- Large holes in leaves and heads
- Often extensive frass
- Peak damage mid-season (June/July)
Cabbage Looper: Life cycle

**Adult**
- Large, night flying moth
- Hour glass marks

**Eggs**
- Laid singly on undersurface
- White, turning tan at hatch
- Round shaped

**Larvae**
- 5 instars; 4-5 weeks
- Green with white stripe
- Loop when moving
- Up to 2 inches in length

**Pupa**
- Roughly spun silk cocoon
- Underside of old leaves or on debris
Cabbage Looper

**Occurrence**
- Does not overwinter, adults blow in (June/July)
- 2 generations per year, persisting in late season

**Damage**
- Damage usually late season
- Extensive leaf holes and head damage
Managing the Lepidoptera Complex

**Cultural**
- Use clean transplants

**Biological**
- Good complex of parasites
  - Diamondback moth: 70-90% parasitized
  - Imported Cabbage worm: 30-60%
  - Cabbage looper: 10-30%
- Multiple species
Parasites of Diamondback Moth

*Diadegma insulare* is primary parasite

- Stings mid-stage larvae with single egg
- Kills pupa
- Replaces host pupa in case
Parasites of Imported Cabbageworm

*Cotesia glomerata*
- Stings small larvae and inserts several eggs
- Larvae develops until parasites pupate
- 20-50 parasites emerge from late instar

*Pteromalus puparum*
- Stings pupa
- Eggs divide
- Parasite larva kill host pupa
- Up to 200 parasites emerge
Parasites of Cabbage Looper

**Trichogramma**
- Tiny wasp lays egg in host egg
- Parasite kills egg and emerges

**Copidosoma floridanum**
- Tiny wasp lays egg in host egg
- Host continues to develop
- Parasite divides and kills late instar larvae
- 200-400 parasites emerge

**Voria ruralis**
- Large fly stings small host larvae
- Larva and parasites develop
- Large larva killed and 2-3 parasites emerge
Managing the Lepidoptera Complex

Chemical Pest Specific
Bacillus thuringiensis (Kurstaki; Btk, or Azaiwi; Bta)
- Many materials registered
e.g. Dipel, Agree, Biobit, Xentari, etc.
- Short persistence $$\rightarrow$$ timing critical
- Stomach poison $$\rightarrow$$ coverage important
- Weak on looper
Spinosad = Entrust

Broad Spectrum Pyrethroids
- Multiple applications
- Resistance can be a problem
- Eliminate biological controls
Key Pest of Root Crops

Cabbage Maggot Life Cycle

**Adult**
- Small grey/black fly
- Similar to house fly

**Eggs**
- Small, white
- Laid in soil at base of plants

**Larvae**
- White, legless maggots
- 4 instars; up to 1/4”
- 3-4 weeks per generation
- 3 generations per year

**Pupa**
- Brown, oval shaped
- In or close to the roots
Cabbage Maggot Life Cycle

**Occurrence**
- Overwinters in soil as pupa
- Adults emerge in spring
- 3 flight peaks
- First peak is most serious and occurs at 300 heat units or when lilacs bloom (May)

**Damage**
- Larvae tunnel on root surface
- May be secondary rot
- Major importance on root crops
- Causes wilting, death on head crops

Prediction of Cabbage maggot oviposition

- 300 DD
- May
- July
- September
Cabbage Maggot Management

Cultural
- Rotate crop away from overwintering site (1/4-1/2 mile)
- Prevent egg laying with barrier, row cover
- Predict egg laying with heat units (300 HU with 43°F base)
- Plant early or late to avoid eggs = fly free periods

Biological
- Some egg predation by beetles

Chemical
- None currently available
- Experimental seed treatments in review (Entrust®)
Sporadic Pests of Cole Crops

Flea beetle (several species)

**Appearance**
- Small, shiny black beetles
- Hind legs enlarged for jumping
- Overwinter as adults
- 2 generations per year

**Damage**
- Adults chew small circular holes
- Can kill small plants
- Larvae in soil are not damaging
Flea Beetle Management

**Cultural**
- Exclude adults with row cover
- Attract adults to alternate trap crop (Indian mustard)
- Avoid early planting

**Biological**
- No effective controls

**Chemical**
- Repeat applications of natural pyrethrums
- DO NOT disrupt biological controls for Lepidoptera
Sporadic Pests of Cole Crops

Cabbage aphids

Appearance
- Grey, waxy covered aphids in dense colonies
- Multiple generations

Damage
- Feeding results in leaf distortion
- Head malformation can occur
- Dense colonies disfigure heads
- Contamination of produce is common
Cabbage Aphid Management

Cultural
- None available; except exclusion

Biological
- Parasites and predators are effective

Chemical
- Neem extracts (Aza-Direct, Azatin)
- Insecticidal soap may suppress colonies
Cabbage Aphid Natural Controls
Putting together a biologically-based management program for cole crops

3 requirements

1. Existing or obtainable natural enemies for key pests
2. Pest specific insecticides to conserve natural enemy control
3. Non-disruptive controls for sporadic pests
Natural Occurring Parasitization of Lepidoptera

Diamondback moth 70-90%

Imported cabbage worm 30-60%

Cabbage looper 10-30%
Pest Specific Insecticides for Key Pests

- Control Lepidoptera at thresholds when needed
- Conserve beneficial organisms
- Btk, Bta, or Entrust

<table>
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<tr>
<th>Crop</th>
<th>Growth stage</th>
<th>Threshold (% infestation)</th>
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<tbody>
<tr>
<td>Cabbage</td>
<td>Seed bed</td>
<td>10%</td>
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<tr>
<td></td>
<td>Transplant-cupping</td>
<td>30%</td>
</tr>
<tr>
<td></td>
<td>Cupping-early head</td>
<td>20%</td>
</tr>
<tr>
<td></td>
<td>Mature head</td>
<td>10%</td>
</tr>
<tr>
<td>Broccoli/cauliflower</td>
<td>Seed bed</td>
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<tr>
<td></td>
<td>Transplant-first curd</td>
<td>50%</td>
</tr>
<tr>
<td></td>
<td>Curd present</td>
<td>10%</td>
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Cole Crop insect control - Summary

Pesticide-reliant crop where biological control can replace insecticides as the predominant approach

- Manage key lepidopteran pest complex with combinations of:
  - Biological control with parasites
  - Soft biological insecticides

- Manage other pest with tactics which will not interfere with biological control
Problem and pest... Onion thrips

Onion thrips damage

Unprotected

Protected

Adult

Larva

Onion Thrips, *Thrips tabaci* Lindeman
Onion thrips: Lifecycle

- **Egg**: Hatch in 4-10 days
- **Prepupa + Pupa**: In soil for 5-7 days
- **Larva (2 instars)**: Lasts 7-14 days
- **Adult**: *17-30 days total

Shelton et al. (2006)
Biological attributes that make onion thrips a pest

- Short developmental time
- Parthenogenic (do not need to find a mate)
- Highly mobile
- Wide host range
- Overwinter adjacent to onion
- Capability of developing resistance to insecticides
Environmental Effects

Leptothrips

Minute pirate bug

Hot and Dry Conditions, 2004-2006
Onion thrips population growth

<table>
<thead>
<tr>
<th>Date</th>
<th>Number of Females</th>
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<tr>
<td></td>
<td>$68^0 F$</td>
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<td>July 1</td>
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<td>September 2</td>
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</tr>
<tr>
<td>Number generations</td>
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</tr>
</tbody>
</table>

Murai (2000)
Spray Coverage an Issue??
Combination of insecticide product and action threshold used to time sprays affects control

- Entrust sprayed at 1 thrips/leaf provided good control
- Spraying at 5 thrips/leaf allowed too much damage
Insecticide Control Options

- Rotate insecticides (classes if possible)
  - e.g., spinosyns (Entrust), neem oils (Aza-Direct)
- Two successive applications of one product to control a generation
- Time applications based on most appropriate threshold
- Avoid tank mixing insecticides
Thrips Resistant Varieties

- Late, compact head development
- Low dry matter
- Increased leaf wax

[Images of 'Blue Gem', 'Super Red 80', 'Bravo', 'Green Cup']
European honey bee

(*Apis mellifera*)
Can we rely on honey bees to pollinate our crops?
Factors Harming Honey Bee Populations

- Diseases (e.g., American foul brood)
- Parasitic mites (NRC 2006)

Tracheal mite
\( (Acarapis woodi) \)

Varroa mite
\( (Varroa destructor) \)
Factors Harming Honey Bee Populations

- **Insecticides** (Kevan et al. 1997)
  - Do not apply to crops in bloom
  - Application timing: apply in the late afternoon or early evening
  - Choose short residual products
  - Adjust spray to weather conditions
    ** low temps extend residual
    ** protract foraging times
  - Application formulation(s):
    EC > WP, WSP, D
Factors Harming Honey Bee Populations

- Colony Collapse Disorder (CCD)
  - caused by the Israeli Acute Paralysis Virus (IAPV) that weakens bee’s immune system (Stokstad 2007)
  - honey bee colonies lose all of their worker bees
  - responsible for a loss of 50-90% of colonies in beekeeping operations across the U.S.
Understanding Colony Collapse Disorder (CCD)

- Israeli Acute Paralysis Virus (IAPV)
  - May not be the sole cause (ESA 2007)

- Bee colony attrition may be linked to a combination of factors:
  - Mites & associated acaricides
  - Stress associated with production
  - Pesticides
  - IAPV
Resistance

- A genetically controlled decrease in susceptibility of a population to a control measure
  - resistance to insecticides (IRAC 2006)
    - 500+ insect species resistant to 1 or more insecticides
    - 1800+ species/insecticide resistance combinations
  - adaptation to pest resistant crop varieties
  - adaptation to crop rotation
Resistance Development

- Resistance genes occur naturally at low frequencies
  - $10^{-8}$ to $10^{-12}$
- Proportionately more insects with $R$-genes survive and leave offspring when exposed to toxin than insects with only $S$-genes
Measuring Resistance

LD_{50} (or LC_{50}) = dose (or concentration) that is lethal to 50% of the test population under defined conditions

LD_{90} = dose that is lethal to 90% of the test population
Insecticide Resistance Management

I. **Problem Identification**: If you suspect resistance, first eliminate other possible causes. In many instances, lack of control can be attributed to application error, equipment failure, or less-than-optimal environmental conditions.

II. **Product Rotation**: Avoid the consecutive use of a single product, or multiple products with similar modes of action (IRAC).

III. **Cultural Control(s)**: Where possible, consider selecting early-maturing or pest-tolerant varieties of crop plants. Adopt all non-chemical techniques known to control or suppress pest populations.
IV. *Preserve Natural Control(s):* Where possible, select insecticides and other pest management tools which preserve beneficial insects.

V. *Pest Surveillance and Scouting:* Monitor the pest population during the growing season. Regularly monitor fields to identify pests and natural enemies, estimate insect populations and track stage of development.

V. *Rates and Spray Intervals:* Use insecticides at labeled rates and follow prescribed spray intervals.