Soybean pest management in context of insecticide best management practices (BMPS)

Robert Koch
<table>
<thead>
<tr>
<th>Group</th>
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<th>Individual A.I.s</th>
<th>Formulated mixtures</th>
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<td>Lannate</td>
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<td>Lorsban Advanced, Chlorpyrifos, Govern, Hatchet, Nufos, Vulcan, Warhawk, Whirlwind, Yuma</td>
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<td>Fastac</td>
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<td>Baythroid</td>
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<td>Tundra, Sniper, Fanfare, Discipline, Brigade, Bifenture</td>
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<td>Delta Gold, Batallion</td>
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<td>sulfoxaflor</td>
<td>Transform</td>
<td>Seeker</td>
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Removal of sulfoxaflor (4C)

- Transform, Seeker, etc.
- EPA canceled registration (Nov. 15, 2015)
- Tolerances are not affected
- Existing stocks in hands of end-users can be used
- Existing inventories cannot be sold/distributed to end-users
- New registration is being sought
Threats to chlorpyrifos (1B)

- EPA proposal to revoke all tolerances
  - Due to concerns about exposure via food & drinking water in some watersheds
  - Could affect agricultural uses
  - Open for public comment until 5 January 2016
  - Final rule in December 2016
Threats to chlorpyrifos (1B)

- Surface Water Pesticide of Concern (MDA, 2012)
- Voluntary BMPs
  - Label use requirements & setbacks are legally enforceable
- If proven ineffective, mandatory restrictions on use & practices may be required
Chlorpyrifos Monitoring in MN

- 2005 to 2009 = 1 to 2 detections annually
- Increased detections in river samples since 2010
- 2010 to 2012 = 8 detections annually (4 to 7 above 40ng/L MRL).
- 2014 = 8 detections, exceeding 40ng/L MRL
- Chlorpyrifos NOT detected in a lake or wetland
Chlorpyrifos Detections, 2005-2014 (n=41)

Watershed with a chlorpyrifos detection
- Beauford Ditch
- Beaver Creek
- Black River near Thief River Falls
- Buffalo River
- Dry Weather Creek
- Grand Marais Creek
- Jack Creek
- Lac Qui Parle River
- Le Sueur River
- Pipestone Creek
- Seven Mile Creek
- Sleepy Eye Creek
- Snake River
- South Fork Crow River
- South Fork Crow River-Unnamed Ditch
- Tamarac River
- Tamarac River-Unnamed Ditch
- Three Mile Creek- Green Valley

Chlorpyrifos Detection Watershed

* Water quality impairments
2005-2014 MDA Statewide Chlorpyrifos Sample Concentrations

1 ng/L = 1 part per trillion

Acute Standard 83 ng/L
Chronic Standard 41 ng/L

Year

Chlorpyrifos Sample  Chronic Standard  Acute Standard
2005-2014 Statewide MDA Chlorpyrifos Detections by Month (n=41)

Increased detections mid-late summer likely from soybean aphid treatment.
Chlorpyrifos

- Due to repeated detections and associated concentrations in recent years, the MDA listed chlorpyrifos as a surface water pesticide of concern.

- This lead the MDA to develop Water Quality Best Management Practices.
Water Quality BMPs for “All Agricultural Insecticides” & “Chlorpyrifos”

Water Quality Best Management Practices
for All AGRICULTURAL INSECTICIDES

In order to protect Minnesota’s water resources, the Minnesota Department of Agriculture (MDA), in cooperation with the University of Minnesota Extension Service and other interested parties, has developed a set of core voluntary Best Management Practices (BMPs) for insecticides. These core voluntary BMPs should be adopted when applying agricultural insecticides in Minnesota. The BMPs may also refer to mandatory label use requirements. Always read and follow product labels. Sources of additional information are listed in these BMPs.

Insecticides are designed to control target insect pests. Non-target insects, fish, and other wildlife can be exposed to insecticides used from fields by surface runoff, drift, volatilization, or leaching. Applicators are required to control potential impacts by carefully following label instructions, including use of mandatory application setbacks from water bodies. Impacts to aquatic organisms can be further managed through adoption of voluntary BMPs. The MDA has also developed BMPs (published separately) for use with specific crop insecticides.

Careful and prudent insecticide use, as part of an integrated Pest Management plan, can help protect water resources from future contamination and reduce levels of insecticides found in Minnesota’s waters. Planning also promotes the efficient and economical use of insecticides which may improve efficacy, increase yields, reduce labor costs, and reduce production costs.

State and federal law can require that the use of an insecticide be limited due to the potential for adverse impacts on humans or the environment. The Minnesota Pesticide Control Law (Minn. Stat. 18B) specifies state regulatory authority to prevent these impacts. The Clean Water Act outlines a process that can lead to greater oversight of insecticide use in certain watersheds. Adopting BMPs and using pesticides properly will help growers maintain access to a variety of insecticides, which are important and diverse tools in the effort to control insect pests and protect water resources. For information on monitoring results for a variety of insecticides in Minnesota’s water resources, refer to the MDA’s Monitoring and Assessment website.

Best Management Practices (BMPs) for insecticide use

- The purpose of BMPs is to prevent and minimize the degradation of Minnesota’s water resources while considering economic factors, pest control availability, technical feasibility, effectiveness, and environmental effects.

- These BMPs are intended to reduce the loss of insecticides to the environment and to encourage the efficient use of insecticides, chemistry rotation, and non-chemical insect pest control measures as part of an integrated Pest Management program to protect crops, save costs, reduce development of insecticide resistance, and increase profitability.

- Some insecticides are "Restricted Use Pesticides" and can only be bought and applied by a Minnesota Certified Pesticide Applicator.

- Integrated Pest Management (IPM)

  Reducing crop losses by integrating multiple tactics (e.g., cultural, chemical, biological and mechanical) in ways that favor the crop and suppress insect populations. See "Additional Information & References" for more details and practical examples.

Water Quality Best Management Practices
for CHLORPYRIFOS

The Minnesota Department of Agriculture (MDA), in cooperation with the University of Minnesota Extension Service and other interested parties, has developed voluntary Best Management Practices (BMPs) to address the presence of chlorpyrifos in Minnesota’s surface water from normal agricultural use (see reverse side of page). If the voluntary BMPs are proven ineffective, mandatory restrictions on chlorpyrifos use and practices may be required. The BMPs may refer to mandatory label use requirements. Always read and follow product labels. For information on monitoring results for chlorpyrifos and other pesticides in Minnesota’s water resources, refer to the MDA’s Monitoring and Assessment website.

Chlorpyrifos BMPs are companions to a set of core water quality BMPs for use with all agricultural insecticides. If using chlorpyrifos for crop production, consult these BMPs prior to application. State and federal law can require that the use of a pesticide be limited or curtailed due to the potential for adverse impacts on humans or the environment.

Information about CHLORPYRIFOS

- Chlorpyrifos, a broad-spectrum insecticide, was first registered in 1965 and was widely used for agricultural and home pest control. Most indoor, pet, and homeowner uses were withdrawn in 1997.

- Chlorpyrifos is used to control foliar and soil-borne insect pests on a variety of crops including soybeans, corn, alfalfa, sugar beets, and a number of fruit and vegetable crops. It is also used as a seed treatment.

- Most chlorpyrifos products are "Restricted Use Pesticides" which indicates that they can only be bought and applied by a Certified Pesticide Applicator.

- Chlorpyrifos belongs to the organophosphate class of insecticides (Mode of Action Group 1B) and controls insects by disrupting normal nervous system function.

- Chlorpyrifos is highly toxic to bees and other beneficial insects exposed to direct treatment or residues on growing crops or weeds. It is also toxic to fish, aquatic invertebrates, and birds. It is moderately toxic to mammals.

Pesticide applications near water bodies and in certain regions and habitats are more likely to result in potential water quality impacts from runoff, drift, and volatilization. Other sensitive areas include those that provide runoff to surface water systems, areas near tile surface inlets, highly erodible soils, areas with seasonally high water tables, and highly permeable soils. Note: Many fields are adjacent to water bodies, and portions of every Minnesota county may contain sensitive soils, water tables, and geology.

Contact your Natural Resources Conservation Service or Soil & Water Conservation District for further information on specific soil and water resource conditions on and near your farm. Then work with Extension educators, crop consultants, and other agricultural advisors to select and adopt the Best Management Practices that are appropriate for your field and farm.
BMPs: All Agricultural Insecticides

• Use integrated pest management (IPM)
• Use sound agronomic practices
• Avoid conditions that promote drift
• Ensure equipment will apply correct rate
• Target applications to infested areas
• Rotate modes of action (groups)
• Protect water from drift & runoff
• Dispose of insecticides properly
BMPs: Chlorpyrifos

- Adopt “Agricultural Insecticide” BMPs
- Use labeled rates
- Apply according to label directions
- Maintain setbacks from permanent water bodies
- Use IPM
- Rotate modes of action (groups)
- Dispose of insecticide properly
Threat to pyrethroids (3A)

• Pyrethroid performance issues in 2015
• Resistance documented in a field with failure
• Importance of our management decisions:
  – Continued overuse & misuse will worsen situation
  – Wise use should lessen or prevent future problems
Insecticide resistance

- Genetically-based decrease in susceptibility
  (Tabashnik et al. 2014)
Measuring resistance

The graph illustrates the proportion of mortality (vertical axis) in relation to increasing insecticide concentration (horizontal axis) for both susceptible and resistant populations. The point of intersection for the susceptible curve with a 50% mortality level (0.5 on the y-axis) is marked as the LC50, indicating the concentration at which 50% of the population is killed.
Soybean aphid

• A matter of when, not if, SBA will develop resistance
• “Light resistance” to organophosphates in China (Quin et al. 2011)
• In MN, reports of reduced efficacy of pyrethroids
Soybean aphid

• Closely related *Aphis gossypii* has developed resistance to:
  – \(\lambda\)-cyhalothrin (& other pyrethroids) in Pakistan (Ahmad et al. 2003)
  – Esfenvalerate in Hawaii (Hollingsworth et al. 1994)
  – Chlorpyrifos in Australia (Herron & Powis 2005)
  – Dimethoate in Pakistan (Amad & Arif 2008)
Soybean aphid resistance monitoring, 2013-2015

- Field-collected aphids
- Leaf-dip bioassay
  - λ-cyhalothrin (Warrior II)
  - 8 concentrations of insecticide & untreated
  - 20 adults per leaf disk
  - Mortality assessed after 48 hours
LC$_{50}$ s for λ-cyhalothrin

2013

- St. Paul
- Rosemount
- Rochester
- Lamberton
- Fergus Falls
- Brooten
- Becker
- Biotype 1

PPM active (95%CI)

0.00  1.00  2.00  3.00  4.00  5.00  6.00

Koch et al.
LC$_{50}$s for λ-cyhalothrin

2014

- St. Paul
- Rosemount
- Rochester
- Lamberton
- Brooten
- Becker
- Biotype 1

PPM active (95%CI)

Koch et al.
What happened in 2015 in MN?

- Pyrethroid failures in southern MN (grower fields & U of MN research stations)
- Dealers, consultants & grower reports
  - Rumors and panic
- Multiple applications needed
- Sorting out what went wrong
  - Multiple pyrethroid compounds and application methods

B. Potter
Efficacy of insecticides in a field with previous performance problem with Hero insecticide
Sanborn, MN, 2015  7 DAT

% increase

B. Potter
LC$_{50}$s for $\lambda$-cyhalothrin

2015

- St. Paul
- Rochester
- Lamberton (2)
- Lamberton
- Brooten
- Becker
- Biotype 1

PPM active (95%CI)

Koch et al.
Soybean aphid resistance monitoring, 2015

• Aphids from field with bifenthrin failure
• Glass-vial assays
  – Bifenthrin or λ-cyhalothrin
  – 10 concentrations of insecticide & untreated
  – 10 adults per vial
  – Mortality assessed after 4 h

Collaboration with FMC
Glass-vial bioassays

![Graph showing the effect of Bifenthrin on proportion mortality (± 95% C.I.) with respect to ppm. The graph includes two lines representing different biotypes: Biotype 1 and Lamberton. The LC$_{50}$ values are 0.003 ± 0.001 for Biotype 1 and 0.133 ± 0.045 for Lamberton. The graph also indicates a 44-fold difference between the biotypes.]

Koch et al.
Glass-vial bioassays

Lambda-cyhalothrin

Proportion Mortality (± 95% C.I.)

ANCOVA LS means difference between populations:
$df = 85$, $t = 9.11$, $p < 0.001$

LC$_{50}$ = 0.012 ± 0.003
LC$_{50}$ = 0.123 ± 0.053

10-fold

Koch et al.
Two-spotted spider mite

B. Potter

USDA-ARS Systematic Entomology Lab-Beltsville, MD
Dual infestations

How bad could this get???

<table>
<thead>
<tr>
<th></th>
<th>Mites</th>
<th>Aphids</th>
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<tbody>
<tr>
<td>Chlorpyrifos</td>
<td>Recommended</td>
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</tr>
<tr>
<td>Dimethoate</td>
<td>Recommended</td>
<td>Variable performance</td>
</tr>
<tr>
<td>Bifenthrin</td>
<td>Recommended</td>
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Identifying cases of potential resistance

Before assuming resistance, rule out:

• Misapplication of pesticide
  – Incorrect pesticide or rate, poor coverage

• Unfavorable conditions during application
  – Wind, rain, temperature

• Improper timing of application
  – Differential susceptibility among life stages

• Re-colonization by pest
Resistance management

• What: Collection of strategies used to prevent or slow development of resistance

• Why: Prolong utility of management tools (e.g., insecticides)

http://z.umn.edu/soybeanirm
Overlap between BMPs and IRM

• Reduction in insecticide inputs to crops will decrease risk of water contamination & pest resistance
• Key water quality BMPs overlap with insecticide resistance management (IRM) strategies
• Combined risk reduction strategies
Strategies for risk reduction

• Alternate modes of action

• Use pesticides properly

• Treat only when necessary

• Reduce likelihood of needing to treat
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Group 1: Acetylcholinesterase inhibitors

- Carbamates (1A) & Organophosphates (1B)
Group 1: Acetylcholinesterase inhibitors

- Carbamates (1A) & Organophosphates (1B)

Inhibit the enzyme that removes acetylcholine from receptor
Group 4: Nicotinic acetylcholine receptor agonists

- Neonicotinoids (4A) & Sulfoxamines (4C)
Group 4: Nicotinic acetylcholine receptor agonists

- Neonicotinoids (4A) & Sulfoxamines (4C)

Bind to the receptor so acetylcholine cannot bind
Group 3: Sodium channel modulators

• Pyrethroids (3A)
Alternate modes of action (groups)

• Insecticide groups
  – Group numbers on labels
  – Alternate individual groups
Alternate modes of action (groups)

- Mixtures
  - Less effective for resistance management
  - Consider:
    - Pest susceptibility
    - Registered rates
    - Duration of residual activity
    - Cross-resistance
Strategies for risk reduction

• Alternate modes of action

• **Use pesticides properly**

• Treat only when necessary

• Reduce likelihood of needing to treat
Proper use of pesticides

• Use labeled rates
  – Below-label rates may increase selection for resistance

• Use proper nozzles, pressure & volume
  – Herbicide & fungicide specifications may not be optimal for insecticides
  – Drift prevention
Strategies for risk reduction

• Alternate modes of action
• Use pesticides properly
• Treat only when necessary
• Reduce likelihood of needing to treat

Integrated Pest Management (IPM)
Scouting & thresholds

• Maintain scouting through R6.5 (pods & leaves yellowing), regardless of calendar date

• Through R5 (seeds developing, but pod cavity not filled), use economic threshold of:
  – 250 aphids/plant, &
  – At least 80% of plants infested, &
  – Aphid populations increasing
“Speed scouting”

• Pros:
  – Saves time
  – Easy to use

• Cons:
  – Less detailed
  – Over-recommends treatment

Aphid Speed Scout App (Android & Iphone/Ipad)

Blank, hard-copy worksheets:
Strategies for risk reduction

• Alternate modes of action

• Use pesticides properly

• Treat only when necessary

• Reduce likelihood of needing to treat

Integrated Pest Management (IPM)
Host plant resistance

- Heritable resistance of plants to pests
- Cost effective & environmentally safe tactic
- Categories
  - Antibiosis: affects pest biology
  - Antixensosis: affects pest preference
  - Tolerance: plant can withstand or recover from injury
# Aphid resistance genes

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<th>Gene</th>
<th>Source(s)</th>
<th>Category</th>
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<td><strong>Rag1</strong></td>
<td>PI 548657 (Jackson) PI 548663 (Dowling)</td>
<td>Antibiosis &amp; Antixenosis</td>
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<td><strong>rag1c</strong></td>
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</table>

Hesler et al. 2013
Rag genes reduce CAD
Pyramids extremely effective

McCarville et al. 2014
Virulent biotypes of soybean aphid

- Biotype 1: Avirulent
- Biotype 2: Virulent to Rag1
- Biotype 3: Virulent to Rag2
- Biotype 4: Virulent to Rag1 & Rag2

Hill et al. 2012.

- New sources of resistance & pyramiding of genes needed
Biological control

- Predators
- Parasitic wasps
- Fungal outbreaks

Lady Beetles

Fungal cadaver
Biological control

• *Aphelinus certus*
  – Attacks many aphid species
  – Unintentionally introduced to N. America
  – Effective against soybean aphid in Canada
  – First detected in MN in 2012
  – Now, occurs throughout MN
Biological control

- *Aphelinus glycinis*
  - Attacks mainly soybean aphid
  - Approved for release in 2012
  - Has been released
  - Confirmed to have overwintered

- *Aphelinus rhamni*
  - Attacks mainly soybean aphid
  - Approved for release in 2014

Heimpel et al., U of MN
We must use insecticides wisely

• Management of soybean aphid outbreaks depends on insecticides
  – Group 1: Organophosphates & carbamates
  – Group 3: Pyrethroids
  – Group 4: Neonicotinoids & sulfoxamines

• This short list may get shorter
  – Regulation & resistance

• IPM & IRM can help preserve these tools
Summary

• Scouting & threshold recommendations remain unchanged (250 aphids / plant)

• Host plant resistance
  – Pyramided resistance highly effective
  – Need for new sources of resistance & pyramids

• Biological control
  – Asian wasps increasing in importance
What to do in 2016…

• Treat based on scouting & threshold
• If experienced failure in 2015, consider different mode of action (group) if needed in 2016
  – Otherwise, utilize effective labeled products
• If retreat is required in 2016, alternate modes of action (groups)
• Mixtures are generally less effective for IRM
Questions?

• Bob Koch
  – U of MN, soybean entomologist
  – koch0125@umn.edu

• Soybean insects and mites:
  www.extension.umn.edu/agriculture/soybean/pest/