Predicting Soybean Aphid Flights, and influence on non-persistent virus transmission

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Wisconsin Crop Management Conference & Agri-Industry Showcase

Russell L. Groves¹
Ken Frost², and David Voegtlin³

Departments of Entomology¹ and Plant Pathology²
University of Illinois, Natural History Survey³

Madison, WI 53706

groves@entomology.wisc.edu
Non-Persistent Virus Transmission

Acquisition: seconds

Transmission: seconds

Retention: hours
Non-Persistent Transmission: Movement in Insects

➢ **Food Ingestion**

*Virus particles attach to stylets*

➢ **Egestion**

*Virus particles released with saliva*
Increase proportion of down-grades and rejections resulting from PVY

Percent of lots without mosaic symptoms

Year

Trajectory

Certified Seed Potatoes
Potato virus Y (PVY) re-emergence in the United States

- Recombinant strains are replacing ordinary strains

Maps showing the distribution of recombinant and non-recombinant strains in the United States for the years 2004, 2009, and 2011.
Emerging Pepper Virus: 2007

CMV – Bell pepper

CMV – Jalapeno, mature leaf

CMV – Jalapeno fruit
Emerging Virus Complex

**Major Viruses:**

Cucumber mosaic virus (CMV)
Clover yellow vein virus (CIYVV)
Alfalfa mosaic virus (AMV)
Bean common mosaic virus (BCMV)
Bean yellow mosaic virus (BYM)

**Minor Viruses:**

Soybean mosaic virus (SMV)
Tobacco ringspot virus (TRV)
Watermelon mosaic virus-2 (WMV-2)
Papaya ringspot virus (PRV - WMV-1)
Zucchini Yellow Mosaic Virus (ZYMV)
Biology and Distribution of the Soybean aphid (*Aphis glycines* Matsumura)

**Diagram:**
- Morphs on Buckthorn (Winter Host)
  - Fundatrix (Stem Mother)
  - Eggs laid by buds
  - Oviparae
  - Andropara - Male
  - Gynopara - Female
- Morphs on Soybean (Summer Host)
  - SPRING MIGRANTS
  - apterae
  - alatae
- SUMMER MORPHI
- FALL MIGRANTS (SEXUALS)
- Colonies on soybean

**Map:**
- Geographic distribution of *Aphis glycines* in the United States, with red indicating areas affected in 2000 and yellow indicating areas affected from 2001 to 2009.

**Additional Text:**
- Annu. Rev. Entomol. 56:375–99
Research Objectives

- Determine (1) the temporal patterns of virus (PVY) disease progress, (2) seasonal phenology of dispersing aphid vectors, and (3) combination of reduced-risk, foliar protectants that limit current season spread.

Goal: Accurately determine periods of elevated risk for virus transmission and develop disease management strategies to limit spread of the viral pathogen.

Goal: Evaluate the influence of well-timed, foliar control product (combinations) to limit the spread of virus.
Aphid Alert: a research/outreach program providing region-wide virus vector surveillance to the Northern Great Plains potato industry
Seasonal Dispersal - Suction Trap Network

- Weekly captures of dispersing aphid species.
- Dr. David Voegtlin, Illinois Natural History Survey

http://www.ncipmc.org/traps/

- Acyrthosiphon pisum
- Aphis craccivora
- Aphis glycines
- Aphis gossypii
- Aphis helianthi
- Aphis nasturtii
- Aphis spiraecola
- Brachycaudus helichrysi
- Lipaphis pseudobrassicae
- Macrosiphum euphorbiae
- Myzus persicae
- Rhopalosiphum insertum
- Rhopalosiphum maidis
- Rhopalosiphum padi
- Schizaphis graminum
- Sitobion avenae
- Therioaphis trifolii

- "Pea aphid"
- "Black legume aphid"
- "Soybean aphid"
- "Soybean aphid"
- "Cotton-melon aphid"
- "Sunflower or dogwood aphid"
- "Buckthorn - potato aphid"
- "Spiraea aphid"
- "Leaf curling plum aphid"
- "Turnip aphid"
- "Potato aphid"
- "Peach potato aphid"
- "Apple grass aphid"
- "Corn leaf aphid"
- "Bird cherry-oat aphid"
- "Greenbug"
- "English grain aphid"
- "Spotted Alfalfa aphid"
Seasonal Dispersal – 2007 Suction Trap Data

Week 19
(12-19 May)

Week 23
(9-16 June)
Seasonal Dispersal – 2007 Suction Trap Data

**Week 27**
(7-14 July)

**Week 31**
(4-11 August)
Seasonal Dispersal – 2007 Suction Trap Data

Week 35 (1-8 Sept)

Week 39 (29 Sept-6 Oct)
Evaluating variability associated with aphid abundance

- The objective of our analysis is to estimate variances not to detect differences – over 7 yr interval (2004-2011)

- Factors associated with aphid abundance were considered to be random effects (RE)

- RE were structured to deal with implicit nesting (i.e. week is nested in year)

- Models were fit by maximum likelihood using lmer function in the lme4 package of R

- Likelihood ratio tests (LRT) were used to compare generalized additive, mixed effects models
# Variance Component Analysis: Detecting Seasonality & Regionality in Aphid Abundance

Variance estimates associated with year, week, and location for each aphid species on the scale of the linear predictor. Reported as a standard deviation; Percent of total variance calculated using variances (i.e. $\sigma^2$).

<table>
<thead>
<tr>
<th>Aphid Species</th>
<th>Year (Y)</th>
<th>Week (W)</th>
<th>Loc (L)</th>
<th>$Y \times W^2$</th>
<th>$Y \times L^3$</th>
<th>$Y \times W \times L^4$</th>
<th>Overall SD</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Aphis glycines</strong></td>
<td>0.95 (4.0)</td>
<td>3.33 (48.6)</td>
<td>1.50 (9.8)</td>
<td>2.07 (18.8)</td>
<td>1.03 (4.6)</td>
<td>1.79 (14.1)</td>
<td>4.78</td>
</tr>
<tr>
<td><strong>Rhopalosiphum maidis</strong></td>
<td>1.37 (16.4)</td>
<td>2.52 (55.1)</td>
<td>0.66 (3.8)</td>
<td>0.92 (7.3)</td>
<td>0.79 (5.4)</td>
<td>1.17 (12.0)</td>
<td>3.39</td>
</tr>
<tr>
<td><strong>Theroaphis trifolii</strong></td>
<td>0.56 (5.8)</td>
<td>1.59 (45.8)</td>
<td>0.57 (5.9)</td>
<td>0.58 (6.0)</td>
<td>0.70 (8.9)</td>
<td>1.23 (27.6)</td>
<td>2.35</td>
</tr>
<tr>
<td><strong>R. padi</strong></td>
<td>0.73 (11.4)</td>
<td>0.93 (18.5)</td>
<td>0.67 (9.5)</td>
<td>0.94 (18.5)</td>
<td>0.40 (3.4)</td>
<td>1.35 (38.5)</td>
<td>2.17</td>
</tr>
<tr>
<td><strong>Macrosiphum euphorbiae</strong></td>
<td>0.91 (19.7)</td>
<td>0.63 (9.4)</td>
<td>0.48 (5.4)</td>
<td>1.02 (24.8)</td>
<td>0.58 (8.0)</td>
<td>1.17 (32.7)</td>
<td>2.05</td>
</tr>
<tr>
<td><strong>Acyrthosiphon pisum</strong></td>
<td>0.57 (8.1)</td>
<td>0.92 (21.3)</td>
<td>0.50 (6.4)</td>
<td>0.85 (18.1)</td>
<td>0.41 (4.3)</td>
<td>1.28 (41.7)</td>
<td>1.99</td>
</tr>
<tr>
<td><strong>Schizaphis graminum</strong></td>
<td>0.38 (4.2)</td>
<td>0.73 (15.2)</td>
<td>0.40 (4.7)</td>
<td>0.80 (18.3)</td>
<td>0.58 (9.6)</td>
<td>1.29 (47.9)</td>
<td>1.86</td>
</tr>
<tr>
<td><strong>Myzuz persicae</strong></td>
<td>0.29 (2.6)</td>
<td>0.40 (5.0)</td>
<td>0.57 (10.0)</td>
<td>0.93 (26.5)</td>
<td>0.59 (10.6)</td>
<td>1.21 (45.3)</td>
<td>1.80</td>
</tr>
<tr>
<td><strong>Sitobion avenae</strong></td>
<td>0.53 (8.7)</td>
<td>0.24 (1.8)</td>
<td>0.67 (13.9)</td>
<td>0.91 (26.1)</td>
<td>0.53 (8.8)</td>
<td>1.14 (40.6)</td>
<td>1.79</td>
</tr>
</tbody>
</table>

1 Variance estimates associated with year, week, and location for each aphid species on the scale of the linear predictor. Reported as a standard deviation; Percent of total variance calculated using variances (i.e. $\sigma^2$).

2 Represents year by week interaction.

3 Represents year by location interaction.

4 Represents year by week by location interaction.
Variance Component Analysis:
Visualizing Regionality: *A. glycines* (N-S)
Variance Component Analysis:
Visualizing Regionality: *A. glycines* (W-E)
Detection of seasonal trends in aphid movement

Methods modified from Frost et. al. (2013) Environ. Entomol.

Our methods:

- Suction trap data were averaged for each year, location, and week combination.
- Data were standardized using both a random effects models together with regression splines.
- Cubic polynomials were fit to the resulting “conditional” or “deseasonalized” data (linear model) with generalized additive mixed models (GAMM’s).
Modeling Aphid Phenology: GAMM’s (2005-11)

Model: \( Y \sim f_{\text{aphid}}(\text{Week}) \)

- **Aphis glycines**
  - \( P=0.0079 \)
  - Jul. 8
  - Oct. 27

- **Rhopalosiphum maidis**
  - \( P<0.0001 \)
  - Jul. 19
  - Oct. 25

- **Rhopalosiphum padi**
  - \( P=0.0205 \)
  - Aug. 9
  - Oct. 13

- **Theroaphis trifolii**
  - \( P=0.0003 \)
  - May 11
  - Sept. 19
Modeling Aphid Phenology: Wisconsin GAMM’s (2005-11)

Wisconsin subset

<table>
<thead>
<tr>
<th>Aphis glycines</th>
<th>Rhopalosiphum maidis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Midseason Flight?</td>
<td>Movement to overwintering host?</td>
</tr>
<tr>
<td>July 9</td>
<td>Oct. 16</td>
</tr>
<tr>
<td></td>
<td>July 23</td>
</tr>
<tr>
<td></td>
<td>Oct. 27</td>
</tr>
</tbody>
</table>

Model: $Y = f_{aphid}(\text{Week})$

Week Conditional Modes

<table>
<thead>
<tr>
<th>Rhopalosiphum padi</th>
<th>Therioaphis trifolii</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aug. 3</td>
<td>June 7</td>
</tr>
<tr>
<td>Oct. 31</td>
<td>Sept. 17</td>
</tr>
</tbody>
</table>

Week of Year
Modeling Aphid Phenology: Minnesota GAMM’s (2005-11)

<table>
<thead>
<tr>
<th>Louisiana subset</th>
<th>Model: $Y \sim f_{aphid}(Week)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aphid glycines</td>
<td>Rhopalosiphum maidis</td>
</tr>
<tr>
<td>July 11</td>
<td>July 18</td>
</tr>
<tr>
<td>Oct. 18</td>
<td>Oct. 12</td>
</tr>
<tr>
<td>Aphid glycines</td>
<td>Rhopalosiphum maidis</td>
</tr>
<tr>
<td>July 11</td>
<td>July 18</td>
</tr>
<tr>
<td>Oct. 18</td>
<td>Oct. 12</td>
</tr>
<tr>
<td>Aphid glycines</td>
<td>Rhopalosiphum maidis</td>
</tr>
<tr>
<td>July 11</td>
<td>July 18</td>
</tr>
<tr>
<td>Oct. 18</td>
<td>Oct. 12</td>
</tr>
</tbody>
</table>

Week of Year


Week of Year

Modeling Aphid Phenology: Michigan GAMM’s (2005-11)

Michigan subset

Model: $Y \sim f_{\text{aphid}}(\text{Week})$

- **Aphis glycinester**
  - July 28
  - Oct. 29

- **Rhopalosiphum maidis**
  - July 27
  - Oct. 30

- **Rhopalosiphum padi**
  - June 28
  - Aug. 14
  - Oct. 17

- **Theroaphis trifolii**
  - June 10
  - Sept. 17

Week of Year
Seasonal Dispersal of PVY Aphid-Vectors: ‘Risk Windows’ for Wisconsin Crops

**Aphids of greatest concern in Wisconsin**

<table>
<thead>
<tr>
<th>Month</th>
<th>May</th>
<th>June</th>
<th>July</th>
<th>August</th>
<th>Sept</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soybean aphid**</td>
<td></td>
<td></td>
<td>9 July</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corn leaf aphid**</td>
<td></td>
<td></td>
<td>23 July</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Green peach aphid**</td>
<td></td>
<td></td>
<td>3 Aug</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bird-cherry oat aphid**</td>
<td>12 June</td>
<td></td>
<td></td>
<td>17 Sep</td>
<td></td>
</tr>
</tbody>
</table>
# Aphid Management: Potato / PVY

<table>
<thead>
<tr>
<th>Mode of Action Class (Group)</th>
<th>Active Ingredient</th>
<th>Trade Names</th>
<th>Application / Delivery</th>
<th>Registration Status</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Nicotinic acetylcholine receptor (nAChR) agonists (4A &amp; 4C)</strong></td>
<td>imidacloprid</td>
<td>Admire Pro®, Gaucho®, Provado®</td>
<td>IF, ST, F, SD</td>
<td>Registered</td>
</tr>
<tr>
<td></td>
<td>thiamethoxam</td>
<td>Platinum®, Cruiser®, Actara®</td>
<td>IF, ST, F, SD</td>
<td>Registered</td>
</tr>
<tr>
<td></td>
<td>clothianadin</td>
<td>Belay®</td>
<td>IF, ST, F, SD</td>
<td>Registered</td>
</tr>
<tr>
<td></td>
<td>dinotefuran</td>
<td>Scorpion™</td>
<td>F</td>
<td>Registered</td>
</tr>
<tr>
<td></td>
<td>acetamiprid</td>
<td>Assail®</td>
<td>F</td>
<td>Registered</td>
</tr>
<tr>
<td></td>
<td>sulfoxaflor</td>
<td>Transform®</td>
<td>F</td>
<td>Registered (2012)</td>
</tr>
<tr>
<td><strong>Selective Homopteran feeding blockers (9B &amp; 9C)</strong></td>
<td>pymetrozine</td>
<td>Fulfill®</td>
<td>F</td>
<td>Registered</td>
</tr>
<tr>
<td></td>
<td>flonicamid</td>
<td>Beleaf®</td>
<td>F</td>
<td>Registered</td>
</tr>
<tr>
<td><strong>Narrow-range mineral and paraffinic oils (UN)</strong></td>
<td>petroleum oil</td>
<td>Aphoil™, JMS Stylet oil®</td>
<td>F</td>
<td>Registered</td>
</tr>
<tr>
<td><strong>Terpene constituents (C. album) (UN)</strong></td>
<td>terpene</td>
<td>Requiem®</td>
<td>F</td>
<td>Registered (2010)</td>
</tr>
<tr>
<td><strong>Inhibitors of acetyl CoA carboxylase (23)</strong></td>
<td>spirotetramat</td>
<td>Movento®</td>
<td>F</td>
<td>Registered (2011)</td>
</tr>
<tr>
<td><strong>Ryanodine receptor modulators (28)</strong></td>
<td>cyazypyr</td>
<td>Verimark™, Exirel™</td>
<td>IF, F</td>
<td>Not Registered</td>
</tr>
</tbody>
</table>

*Insecticide Resistance Action Committee (http://www.irac-online.org)*

*Application types include: in-furrow (IF), seed treatment (ST), foliar (F) and side-dress (SD)*

*Several generic formulations exist*
### Aphid Management: Snap Beans / CMV

<table>
<thead>
<tr>
<th>Mode of Action Class (Group)</th>
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<tr>
<td>Nicotinic acetylcholine receptor (nAChR) agonists (4A &amp; 4C)</td>
<td>imidacloprid&lt;sup&gt;c&lt;/sup&gt;</td>
<td>Admire Pro®, Gaucho®, Provado®</td>
<td>ST, F</td>
<td>Registered</td>
</tr>
<tr>
<td></td>
<td>thiamethoxam</td>
<td>Cruiser®, Actara®</td>
<td>ST, F</td>
<td>Registered</td>
</tr>
<tr>
<td></td>
<td>acetamiprid</td>
<td>Assail®</td>
<td>F</td>
<td>Registered</td>
</tr>
<tr>
<td></td>
<td>sulfoxaflor</td>
<td>Transform®</td>
<td>F</td>
<td>Registered (2012)</td>
</tr>
<tr>
<td>Narrow-range mineral and paraffinic oils (UN)</td>
<td>petroleum oil</td>
<td>Biocover, Damoil, Glacial, Omni, etc…</td>
<td>F</td>
<td>Registered</td>
</tr>
<tr>
<td>Inhibitors of acetyl CoA carboxylase (23)</td>
<td>spirotetramat</td>
<td>Movento®</td>
<td>F</td>
<td>Registered (2011)</td>
</tr>
</tbody>
</table>

<sup>a</sup> Insecticide Resistance Action Committee (http://www.irac-online.org)<br>
<sup>b</sup> Application types include: in-furrow (IF), seed treatment (ST), foliar (F) and side-dress (SD)<br>
<sup>c</sup> Several generic formulations exist

**Note:** Special attention should be paid to the existing synthetic pyrethroid registrations – can increase virus transmission
### Aphid Management: Peppers / CMV

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<tbody>
<tr>
<td>Nicotinic acetylcholine receptor (nAChR) agonists (4A &amp; 4C)</td>
<td>imidacloprid&lt;sup&gt;c&lt;/sup&gt;</td>
<td>Admire Pro®, Provado®</td>
<td>IF, F, SD</td>
<td>Registered</td>
</tr>
<tr>
<td></td>
<td>thiamethoxam</td>
<td>Platinum®, Actara®</td>
<td>IF, F, SD</td>
<td>Registered</td>
</tr>
<tr>
<td></td>
<td>clothianadin</td>
<td>Belay®</td>
<td>IF, F, SD</td>
<td>Registered</td>
</tr>
<tr>
<td></td>
<td>dinotefuran</td>
<td>Scorpion®, Venom®</td>
<td>F</td>
<td>Registered</td>
</tr>
<tr>
<td></td>
<td>acetamiprid</td>
<td>Assail®, TriStar®</td>
<td>F</td>
<td>Registered</td>
</tr>
<tr>
<td></td>
<td>sulfoxaflor</td>
<td>Closer®</td>
<td>F</td>
<td>Registered (2012)</td>
</tr>
<tr>
<td>Selective Homopteran feeding blockers (9B &amp; 9C)</td>
<td>pymetrozine</td>
<td>Fulfill®</td>
<td>F</td>
<td>Registered</td>
</tr>
<tr>
<td></td>
<td>flonicamid</td>
<td>Beleaf®</td>
<td>F</td>
<td>Registered</td>
</tr>
<tr>
<td>Narrow-range mineral and paraffinic oils (UN)</td>
<td>petroleum oil</td>
<td>Aphoil™, JMS Stylet oil®</td>
<td>F</td>
<td>Registered</td>
</tr>
<tr>
<td>Inhibitors of acetyl CoA carboxylase (23)</td>
<td>spirotetramat</td>
<td>Movento®, Kontos®</td>
<td>F</td>
<td>Registered (2011)</td>
</tr>
</tbody>
</table>

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<sup>b</sup>Application types include: in-furrow (IF), seed treatment (ST), foliar (F) and side-dress (SD)

<sup>c</sup>Several generic formulations exist

**Note:** Special attention should be paid to the existing synthetic pyrethroid registrations – can increase virus transmission.
Current Season Management of PVY/seed
Potato - Application Thresholds

- Early grain aphid migrations (mid-June)
- Colonizing aphids and mass flights (late July – early August)

Need to protect potato crop from PVY for nearly 8-10 weeks

- At-plant systemic
- Weekly oil
- Weekly oil + insecticides
- Weekly oil

Corn leaf aphid
Soybean aphid
Spotted alfalfa aphid
Bird-cherry oat aphid

Vine Kill

Current Season Management of CMV/Snap Beans - Application Thresholds & Planting Dates

- Soybean aphid flights (mid-July)

Need to protect snap bean crop from virus for only 21 days

2X Weekly oil

Bean Crop

Soybean aphid flights (mid-July)
Green peach aphids (early August)

Need to protect snap bean crop from virus for only 21 days

Weekly oil + insecticides
Drench Trt
Pepper Crop

Green peach aphid
Soybean aphid
Acknowledgements

- **USDA SCRI**

- **Wisconsin Certified Seed Potato Program**
  Bob Coltman, Kevin Bula, Rick Hafner

- **Wisconsin Potato and Vegetable Growers Association**

- **University of Illinois**
  Drs. David Voegtlin and Doris Lagos

- **University of Wisconsin**
  Agricultural Research Stations

- **Cooperating Industry Partners**