April 29 2017, Sat, 9:10-9:35am, Healthy Hives, Healthy Live, Healthy Lands, Effects on neonicotinoids on beneficial insects, and of course bees

Vera Krischik, Associate Professor, Depart of Entomology, UMinnesota and others
20 years of neonicotinoid issues

- 2018 France complete ban being discussed
- 2016 “How neonicotinoids can kill bees”, Xerces Society for Invertebrate Conservation, Dec 14
- 2016 EPA states 25 ppb is NOEL for bees (research)
- 2016 Health Canada use of imidacloprid not sustainable due to effects on insects and aquatic organism; considering a ban
- 2016 Ontario reduce seed treatment use by 2018
- 2016 EFSA may request ban of some neonicotinoids
- 2016 EU moratorium being reviewed
- 2013 EFSA confirmed imidacloprid, thiamethoxam, and clothianidin were toxic to bees.
- 1996 French beekeepers protest use of imidacloprid seed dressing and effects on honeybees
1. Established an Interagency Pollinator Protection Team to develop cross agency policies and programs.

2. The Governor's Committee on Pollinator Protection was created to advise the Governor, the Environmental Quality Board, the Interagency Pollinator Protection team.

3. DNR, MNDOT, BSWR, and MPCA shall develop an integrated pest management strategy to minimize pesticide use on public lands.

4. The Commissioner of Administration will not use neonicotinoid applied plants and neonicotinoid pesticides on the State Capitol Complex and other state sites.
Soil-applied imidacloprid alters survival + behavior

1. *Coleomegilla maculata* (Coleoptera: Coccinellidae) (Smith + Krischik 2001)
5. Ladybeetles + monarch + painted lady (Krischik et al. 2015)
Talk summary: Neonicotinoid residues

1. Seed treatments result in the low residue of neonicotinyl insecticide in nectar and pollen (less than 7.6 ppb).

2. Few studies demonstrate that seed treatments reduce honeybee colony health.

3. Bumblebees are more affected by neonicotinoid insecticides due to queen foraging, no bee bread for queen and larvae, and small colony size.
4. Many papers demonstrate that neonicotinyl insecticides affect foraging, learning, and orientation at sublethal dose starting 6 ppb below the lethal dose of 40-185 ppb.

5. Bees have 40% more n-nicotinic ACH receptors compared to other insects that are used in orientation, navigation, and learning.

6. Only 1% of insects are pests, but insecticides kill all insects, pollinators, beneficial insects, and pest insects.
Summary from research

1. Residue in linden flowers from soil drench and trunk injection will kill/alter behavior of bees. Residue in flowers growing underneath trees treated with a soil drench will kill bees.

2. Residue in flowers from small and large GH pots will kill bees at 5 and 10 wks.

3. In a field study with bumblebees 20 ppb imidacloprid in sugar syrup, the EPA NOEL, resulted in decreased movement, sugar consumption, brood, and queen production.
Summary on what YOU can do to save bees and beneficial insects by planting flowers and trees

1. Use IPM. Do not use systemic insecticides. Instead use contact insecticides.
2. Plant a seasonal phenology of native and garden plants for nectar and pollen.
3. Only single-flowered plants, not double flowers, provide pollen and nectar.
4. Provide overwintering habitat for bees.
5. Do not kill queen bees in the spring/fall, they will not sting.
6. Understand the different types of bees and wasps so you can conserve them.
### Rising Toxicity of Pesticides 1945-2003

<table>
<thead>
<tr>
<th>Pesticide</th>
<th>Brand Name</th>
<th>Use</th>
<th>LD50 (ng/bee)</th>
<th>Toxicity DDT = 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>DDT</td>
<td>Dinocide</td>
<td>Insecticide</td>
<td>27,000.0</td>
<td>1</td>
</tr>
<tr>
<td>Amitraz</td>
<td>Apivar</td>
<td>Acaricide</td>
<td>12,000</td>
<td>2</td>
</tr>
<tr>
<td>Coumafos</td>
<td>Perizin</td>
<td>Acaricide</td>
<td>3,000</td>
<td>9</td>
</tr>
<tr>
<td>Taufluvalinate</td>
<td>Apistan</td>
<td>Acaricide</td>
<td>2,000</td>
<td>14</td>
</tr>
<tr>
<td>Metiocarb</td>
<td>Mesurol</td>
<td>Insecticide</td>
<td>230</td>
<td>117</td>
</tr>
<tr>
<td>Carbofuran</td>
<td>Curater</td>
<td>Insecticide</td>
<td>160</td>
<td>169</td>
</tr>
<tr>
<td>Lambda-cyhalothrin</td>
<td>Karate</td>
<td>Insecticide</td>
<td>38</td>
<td>711</td>
</tr>
<tr>
<td>Deltamethrin</td>
<td>Decis</td>
<td>Insecticide</td>
<td>10</td>
<td>2,700</td>
</tr>
<tr>
<td>Thiametoxam</td>
<td>Cruiser</td>
<td>Insecticide</td>
<td>5</td>
<td>5,400</td>
</tr>
<tr>
<td>Fipronil</td>
<td>Regent</td>
<td>Insecticide</td>
<td>4.2</td>
<td>6,429</td>
</tr>
<tr>
<td>Clothianidin</td>
<td>Poncho</td>
<td>Insecticide</td>
<td>4.0</td>
<td>6,750</td>
</tr>
<tr>
<td>Imidacloprid</td>
<td>Gaucho</td>
<td>Insecticide</td>
<td>3.7</td>
<td>7,297</td>
</tr>
</tbody>
</table>

Source: Dr. J.M. Bonmatin, CNRS (France)
1945 to 2003 imidacloprid is 7,000X more toxic than DDT to bees

LD50 DDT ... 27,0000ng/bee
LD50 neonicotinoid insecticides
Imidacloprid ........4 ng/bee....40 ppb
Clothianidin .......4 ng/bee....40 ppb
Dinotefuran ........4 ng/bee....40 ppb
Thiamethoxam .....5 ng/bee....50 ppb

aspirin 80mg=80,000microg=80,000,000ng
Contact and systemic insecticides

Contact insecticides:
- Many, sprayed on foliage
- Eat leaf or walk on leaf to be killed
- Toxicity lasts 1-3 weeks
- Flowers that open after spraying do not contain insecticides.

Systemic insecticides:
- Treated-seed, soil drench, trunk-inject
- Eat leaf, pollen, or nectar to be killed.
- Toxicity lasts 2-12mos, unknown
- Flowers that open will have the insecticide
Imidacloprid rates vary among sites

Agricultural field
0.1 mg imid/canola seed (Gaucho)
1.2 mg imid/corn seed (Gaucho)
4 mg imid/sg ft ag field (soil, Admire Pro)
2.5 mg imid/sg ft ag field (foliar, Admire Pro)

Nursery/greenhouse
300 mg /3 gallon pot (~1 sg ft surface) (Marathon1%G)

Landscape
3.7 mg/sg ft turf (Bayer Adv Season Long Grub)
122 mg rose @ 4 times/yr (Bayer Adv Rose Fl)
10.2mg/sq ft beds @ 4 times/yr (Bayer Adv Rose Fl)
Why do plants make flowers?

• 150 million years, Angiosperms evolved, flowering plants coevolved with insects to pollinate flowers.
• Flower color, shape, nectar and pollen rewards are due to insects.
Why do plants make leaves that are aromatic?

- Plants evolved chemical defenses against insects and insects evolved mechanisms to deal with plant toxins.
- Insects used these toxins for protection from predators.
- Insects advertise their toxicity using warning colors.
- Over time, this led to coevolved species.
American ash, rose, apple, family Rosaceae, rose family, pollinated by bees and fruits dispersed by birds
Catalpa, family Bigoniaceae coevolved with bumblebees
Formerly family Asclepiadaceae, are coevolved with Monarch butterflies.
Native flowers advertise pollination by turning a new color. Breeding removes this trait.
In double flowers the stamens become petals, and flowers provide no pollen or nectar.
Effects on neonicotinoids on beneficial insects, and of course bees

Objective 1. How much imidacloprid is found in flowers from a soil treatment.

Objective 2. Lab study: Determine the effects of 0, 10, 20, 50, and 100 ppb imidacloprid and clothianidin on bumble bees. Field Study: 20 ppm imidacloprid

Objective 3. Determine the effects of 0, 50, 100, and 200 ppb imidacloprid on honeybees.
Objective 1. How much imidacloprid is found in flowers from a soil treatment.

*Agastache*, Anise hyssop  *Asclepias*, tropical milkweed

*Rosa*, rose  *Brassica*, canola  *Tecoma*, Yellow bells, YB
<table>
<thead>
<tr>
<th>mg/soil</th>
<th>Dead Hbees hyssop</th>
<th>Hyssop wflow ppb</th>
<th>Milkw wflow ppb</th>
<th>Canola pollen ppb</th>
<th>YB pollen ppb</th>
<th>Rose pollen GH ppb</th>
<th>Rose pollen Field ppb</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0.4</td>
<td>6</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>15</td>
<td>9</td>
</tr>
<tr>
<td>25</td>
<td>0.8</td>
<td>52*</td>
<td>79*</td>
<td>14</td>
<td>8</td>
<td>36</td>
<td></td>
</tr>
<tr>
<td>50</td>
<td>1.7</td>
<td>133*</td>
<td>186*</td>
<td>461*</td>
<td>21</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>160</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>300-1X</td>
<td>4.0*</td>
<td>1973* (197)</td>
<td>1568* (156)</td>
<td></td>
<td>106*</td>
<td>95</td>
<td>812* Marathon</td>
</tr>
<tr>
<td>600-2X</td>
<td>6.5*</td>
<td>5265*</td>
<td>2774*</td>
<td></td>
<td>276*</td>
<td>332*</td>
<td>1175* 1x consumer</td>
</tr>
<tr>
<td>1200-3X</td>
<td>7.5**</td>
<td>9335*</td>
<td>8337*</td>
<td></td>
<td>9162*</td>
<td>720*</td>
<td>1648* 2x consumer</td>
</tr>
</tbody>
</table>
2015 St. Paul large linden drench

Imidacloprid ppb

<table>
<thead>
<tr>
<th>Month</th>
<th>Year 1</th>
<th>Year 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>June</td>
<td>28 ppb</td>
<td>727 ppb</td>
</tr>
<tr>
<td>August</td>
<td>81 ppb</td>
<td>534 ppb</td>
</tr>
</tbody>
</table>

Flow: 0 ppb
Soil: 15,430 ppb
Lvs: 727 ppb

P < 0.0011
JB herbivory reduced
2015 UM small linden drench, dogwood below

- **June 2015**: 21,061 ppb
- **Aug 2015**: 16,787 ppb
- **Sept 2015**: 24,298 ppb
2015 UM small linden trunk injection

ppb imidacloprid

- **flow**
- **soil**
- **lvs**

<table>
<thead>
<tr>
<th></th>
<th>June 2015</th>
<th>Aug 2015</th>
</tr>
</thead>
<tbody>
<tr>
<td>soil</td>
<td>14 ppb (6)</td>
<td>14 ppb (6)</td>
</tr>
<tr>
<td>lvs</td>
<td>848 ppb (6)</td>
<td>36,283 ppb (6)</td>
</tr>
<tr>
<td>flow</td>
<td>1,340 ppb (6)</td>
<td>0</td>
</tr>
</tbody>
</table>
Objective 1. How much imidacloprid is found in flowers from a soil treatment.

Greenhouse and tree rates are higher than agricultural rates and result in residue that kills beneficial insects.
Objective 2. Lab study: Determine the effects of 0, 10, 20, 50, and 100 ppb imidacloprid and clothianidin on bumble bees.
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10 ppb = pollen from seed treatments
20 ppb = NOEC Bayer, alters behavior
50 ppb = Field pumpkin study
100 ppb = Lower level in landscape plants

LD50 imidacloprid 4-40 ng/bee = 40-400 ppb
LD50 clothianidin 4 ng/bee = 40 ppb
Objective 2. Lab study: Determine the effects of 0, 10, 20, 50, and 100 ppb imidacloprid and clothianidin on bumble bees.
Measuring colony growth
Summary

Objective 2. Lab study: Determine the effects of 0, 10, 20, 50, and 100 ppb imidacloprid and clothianidin on bumble bees.

In a lab study with bumble bees, colonies starting at 20 ppb had:
- higher queen mortality,
- less stored nectar,
- lower consumption, and
- lower colony weight.
Objective 2. Field study: Determine the effects 0 and 20 ppb imidacloprid on bumble bees.

20 ppb in syrup, NOEL <25ppb EPA March 2016
2016 bee movement

- **Control**
- **Treated**

### June
- Control: 80
- Treated: 20

### August
- Control: 120
- Treated: 20

- Vertical axis: Number of bees
- Horizontal axis: Month (June, August)
June 2016 sugar syrup consumption

Days from imidacloprid treatment

Sugar syrup volume (ml)

control
treated
August 2016 sugar syrup consumption

Days from imidacloprid treatment

Sugar syrup volume (ml)

control
treated
June 2016 total brood cells

Days from imidacloprid treatment

-14 -7 0 7 14 21 27 34

# of brood cells
August 2016 total brood cells

Days from imidacloprid treatment

# of brood cells

control
treated
Summary field study

In a field study with bumble bees at 20 ppb imidacloprid in sugar syrup resulted in decreased movement, sugar consumption, brood, and queen production.

The NOEL (no observable effect level) stated by the EPA in March 2016 was 25 ppb. Bumblebee colonies are negatively affected by 20 ppb imidacloprid and 25 ppb is NOT the NOEL.
Objective 3. Lab study: Determine the effects of 0, 10, 20, 50, and 100 ppb imidacloprid on honeybees.
Inside a honey bee colony. Note capped brood cells containing pupae and open brood cells with larvae (unlike bumble bees, who cap cells immediately after laying eggs).
<table>
<thead>
<tr>
<th>Objective 3</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>June-Sept, 5 assessments</td>
<td>F df, P</td>
</tr>
<tr>
<td>June 8, July 6, Aug 3, 31, Sept 22</td>
<td>Treatment</td>
</tr>
<tr>
<td><strong>Adult population bees</strong></td>
<td>(1.43 3, 34), 0.2362</td>
</tr>
<tr>
<td><strong>Sealed brood area pupae</strong></td>
<td>(4.95 3, 34), 0.0028, lower Sept 200 ppb</td>
</tr>
<tr>
<td><strong>Open brood area 1-5\textsuperscript{th} instar</strong></td>
<td>(0.59 3, 34), 0.6224</td>
</tr>
<tr>
<td><strong>Pollen area</strong></td>
<td>(11.38 3, 34), &lt;0.0001, Sept 100, 200 ppb</td>
</tr>
<tr>
<td><strong>Mean missing cell area</strong></td>
<td>(3.06 3, 34), 0.0412, Sept 200 ppb</td>
</tr>
<tr>
<td><strong>Brood pattern</strong></td>
<td>(2.35 3, 34), 0.0901</td>
</tr>
<tr>
<td><strong>Nosema spp. levels</strong></td>
<td>(4.85 3, 34), 0.0065, higher Sept 200 ppb</td>
</tr>
<tr>
<td><strong>Varroa destructor levels</strong></td>
<td>(1.49 3, 34), 0.2358</td>
</tr>
<tr>
<td><strong>Total returning foragers</strong></td>
<td>(1.79 3, 34), 0.1670</td>
</tr>
<tr>
<td><strong>Percent return pollen foragers</strong></td>
<td>(6.42 3, 34), 0.0015, lower Aug 200 ppb</td>
</tr>
<tr>
<td><strong>Dead bees</strong></td>
<td>(0.90 3, 34), 0.4528</td>
</tr>
<tr>
<td><strong>Consumption 48 hours</strong></td>
<td>(2.98 3, 34), 0.0450, lower Aug, Sept 200 ppb</td>
</tr>
<tr>
<td><strong>Consumption 1 week</strong></td>
<td>(3.07 3, 34), 0.0407, lower June 100 ppb</td>
</tr>
<tr>
<td><strong>Queen replacement Date:</strong></td>
<td>70% in control in July and August</td>
</tr>
<tr>
<td><strong>Virus</strong></td>
<td>higher DWV 50, 100, 200 ppb; BQV 200ppb</td>
</tr>
</tbody>
</table>
Objective 2. Determine the effects imidacloprid at 0, 50, 100, and 200 ppb imidacloprid on honey bees.

In a field study with honeybees, few effects were observed on 15 parameters of colony health, except in Sept decreased brood cells, consumption, stored pollen, and pollen foraging and increased virus at the higher imidacloprid levels of 100 or 200 ppb.
Why are bumblebee more susceptible to neonicotinoids?

• Honeybee queens never forage.  
  Bumble bee queens forage in fall + spring.
• Honeybee colonies have 50,000 workers  
  Bumble bee colonies have 30 workers.
• Honeybee forager is the last stage in lifecycle.  
  Bumble bee workers forage at any age.
• Honeybee bread=pollen+ nectar+ saliva+  
  +hypo pharyngeal secretion, detoxifies
• Bumble bees do not make bee bread.
Summary of research

1. Residue in landscape plants higher than crop residue from ag field treatments.

2. Honeybees in colony studies are less susceptible to imidaclorpid.

3. Bumblebees in lab and field studies very sensitive starting at 20 ppb, a field realistic dose for landscapes. The EPA NOEL is wrong.

4. Read for more information from research papers 2016 “How neonicotinoids can kill bees”, Xerces Society Invert Conservation.