April 22, 2014, MN Landscape Arboretum, Earth Without Bees and Most Flowering Plants, Apply Your Sunscreen

Visit pollinator conservation website: Bulletins, posters, online workshop, research,

Vera Krischik, Associate Professor, Department of Entomology, U Minnesota and others
Why do plants make flowers?

- 250 million years crustaceans crawled onto land and evolved into insects.
- Today's insects are ancestors of shrimps, crabs, and lobsters.
- Devonian, age of fish, 350 million years ago, insect similar to basement silverfish.
Why do plants make flowers?

• Conifers, ginkgos, cycads, seed ferns are earliest plants

• Angioseperms, flowering plants evolved 150 million years, flowers and fruits containing seeds
Why do plants make flowers?

- beetles evolved ~300 million years ago,
- flies evolved ~250 million years ago,
- moths evolved ~150 million years ago
Why do plants make flowers?

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

- Plants evolved chemical defenses against insects, which evolved mechanisms to deal with plant toxins.
- Insects used these toxins for protection themselves from predators.
- Insects advertise their toxicity using warning colors.
- Over time, this led to coevolved species.
Native flowers advertise pollination by turning colors. Breeding removes this trait.
Double flowers are when stamens become petals, provides no pollen or nectar.
Family Compositae, advanced flower, multiple ray and disc flowers in one head.
American ash, rose, apple, etc, family Rosaceae, the rose family, pollinated by bees and fruits dispersed by birds
Chelone glabra (white turtlehead) family Plantaginaceae, the plantain family, pollinated by bumblebees
Catalypa, family Bigoniaceae coevolved with bumblebees
Tecoma stanz, Esperanza, family Bigoniaceae, coevolved with bumblebees
Formerly family Asclepiadaceae, now classified as the subfamily Asclepiadoideae of the dogbane family Apocynaceae.
Formerly family Asclepiadaceae, now classified as the subfamily Asclepiadoideae of the dogbane family Apocynaceae.
Passiflora caerulea, passion flower vines, family Passifloraceae, pollinated by bees and fruits dispersed by animals
Passiflora caerulea, passion flower vines, family Passifloraceae coevolved with zebra longwing butterfly, Family Nymphalidae Subfamily Heliconiinae
Zebra longwing butterfly, Family Nymphalidae
Subfamily Heliconiinae
Bee Plants

Early Season Bloomers

Serviceberry
(*Amelanchier* spp.)

Pussy willow
(*Salix discolor*)
Early Season Bloomers

Carolina lupine (Thermopsis villosa)

Siberian squill (Scilla siberica)

Photos:
Siberian squill: Heike Löchel (fotografiert von Heike Löchel) [CC-BY-SA-2.0 de (http://creativecommons.org/licenses/by-sa/2.0/de/deed.en)], via Wikimedia Commons
Early to Mid Season Bloomers

Wild rose
(*Rosa* species)

Basswood, linden
(*Tilia americana*)
Bee Plants

Early to Mid-Season Bloomers

Garden sage
*(Salvia nemorosa 'May Night')*

Catmint
*(Nepeta x faassenii)*

Photos: North Creek Nurseries, www.northcreeknurseries.com
**Bee Plants**

**Mid Season Bloomers**

**Purple prairie clover**
*Petalostemum candida*

**Swamp milkweed**
*Asclepias incarnata*

*Also consider: Common milkweed (*A. syriaca*), butterfly weed (*A. tberosa*)

Photos:
- Purple prairie clover: Prairie Moon Nursery, www.prairiemoon.com
- Swamp milkweed: North Creek Nurseries, www.northcreeknurseries.com
Bee Plants

Mid Season Bloomers

Billard's spiraea
(Spiraea x billardii 'Triumphans')

Catnip
(Nepeta cataria)

Photos:
Billard's Spiraea. Alfred Osterloh, via Hortipedia Commons
Catnip: Theodore Webster, USDA Ag Research Service, Bugwood.org
Bee Plants

Mid to Late Season Bloomers

Anise hyssop
*(Agastache foeniculum)*

Wild bergamot
*(Monarda fistulosa)*

Photos:
- Wild bergamot: North Creek Nurseries, www.northcreeknurseries.com
**Bee Plants**

**Mid to Late Season Bloomers**

- **Sunflower** *(Helianthus species)*
- **Globethistle** *(Echinops species)*

*Photos:*
- Globethistle: Barbara Tokarska-Guzik, University of Silesia, Bugwood.org
Late Season Bloomers

New England aster
*(Symphyotrichum novae-angliae)*

Goldenrod
*(Solidago species)*

Photos:
Bee Plants

Late Season Bloomers

Korean angelica
(*Angelia gigas*)

Stonecrop
(*Sedum* species)

Photos:
Korean angelica. Hardyplants at English Wikipedia (Own work) [Public domain], via Wikimedia Commons
Stonecrop: North Creek Nurseries. www.northcreeknurseries.com
Bee Plants

How are plants pollinated?

- Pollen collects on hairs and scales of insects.
- Most bees also have specialized structures called corbiculae or scopae to collect pollen.
Save the bees plant flowers and trees

1. Use contact insecticides on flowering plants, such as bifenthrin, cyfluthrin, neem, azadirachtin, and spinosad.
2. Do not use systemic insecticides.
3. Plant a seasonal phenology of native and garden plants for nectar and pollen.
4. Only single-flowered plants, not double flowers, provide pollen and nectar.
5. Provide overwintering habitat for bees.
6. Do not kill queen bees in the spring, they will not sting.
7. Understand the different types of bees and wasps so you can conserve bees.
So why should we care about bees?

Food for thought.
So why should we care about bees?

What will birds and wildlife eat without seeds and fruits?
So why should we care about bees?

- Bees pollinate native plants that produce seeds and fruits for wildlife, bears to voles.
- 300 bee pollinated plants are commonly used as a food source (McGregor 1976).
- 35% of the food we eat is pollinated by bees (Klein et al. 2007, Vaughan and Black 2007).
Native Bees in Decline

Economic value of native pollinators
1. Hundreds of species of native bee contribute significantly to crop pollination.
2. $3 billion/year

Leafcutter bee: *Megachile*

Sweat bee: *Halictidae*

Bumble bee: *Bombus*

Mason bee: *Osmia*

Digger bee: *Andrena*
January 8, 2014  In more than half of European countries, there are not enough honeybees to pollinate crops, according to new research. We face a catastrophe in future years unless we act now," said Prof Simon Potts, from the University of Reading, a co-author on the paper.

The number of honeybees in the UK and elsewhere has been in decline in recent years, with both pesticide use and disease being blamed for losses.
Percentage supply of honeybees relative to demand

- **Green**: >90%
- **Light Green**: 75 - 90%
- **Yellow**: 50 - 75%
- **Orange**: 25 - 50%
- **Red**: <25%
- **White**: Not available
Many stresses contribute to CCD in honeybees
Threats to bees: insecticides

Organophosphates + Pyrethroids, are very toxic to bees.

**Organophosphates**
- Dimethoate is highly toxic, $LD_{50} 15 \text{ ng/bee}$
- Chlorpyrifos is toxic, $LD_{50} 70 \text{ ng/bee}$

**Pyrethroids**
- Esfenvalerate is highly toxic, $LD_{50} 15 \text{ ng/bee}$
- Cyfluthrin is highly toxic, $LD_{50} 37\text{ng/bee}$
- Permethrin is extremely toxic, $LD_{50} 8 \text{ ng/bee}$
Controversy over neonicotinyls and bees

- 2014 Eugene, Oregon bans neonicotinyl insecticides in landscapes.

- 2013 June: European Union enacts a 2 year ban on neonicotinyl insecticides starting in December 2013.

- 2013 January: EFSA (European Food Safety Authority) concludes neonicotinyl treated-seed are a bee risk.

- 2012 March: US Beekeepers petition for clothianidin to be withdrawn from sale.
Controversy over neonicotinyls and bees

- 2008-2011: Bee deaths are linked to the planting of neonicotinyl treated-seed crops.
- 2009: California calls for a review of the effects of neonicotinyl insecticides on bees.
- 1996: France bans imidacloprid use as treated-seed on sunflowers, Germany, Spain, Italy and Slovenia, follow
Contact compared to systemic insecticides

Contact insecticides
- Many used; sprayed on foliage
- Insect must eat or walk on leaf to be killed.
- Toxicity lasts 1-3 weeks.
- Flowers that open after spraying do not contain insecticides.
Contact insecticides

Pyrethroids
bifenthrin, cyfluthrin, permethrin

Microbial
Bacillus thuringiensis var. kustaki, tenebrionis, israelensis.
Beauveria bassiana, spinosad

Botanical
Neem, azadiractin

Insect growth regulator
hexathiazox, spruce spider mite
Contact insecticides

Unique mode of action, stops feeding

pyrroproxyfen

Miticide

Bifenazate

Turf and plants

Acelepryn, chlorantraniliprole
Contact compared to systemic insecticides

Systemic insecticides
- Uncommon; treated-seed, soil drench, trunk-inject
- Insect must eat leaf, pollen, or nectar to be killed
- Toxicity can last for months to years, unknown
- Flowers that open will have the insecticide in pollen and nectar for months to years, unknown
Systemic insecticides

Systemic
Organophosphates
aldiracarb (Temik), oxamyl (Vydate), dimethoate (Cygon)
Neonicotinyl
imidacloprid (Marathon, Merit), clothianidin, thiamethoxam, dinotefuran
Novel mode of action
pymetrozine (Endeavor)

Translaminar, or local, systemic activity
Microbial- abamectin (Avid)
IGR- pyriproxyfen (Distance)
PR- chlorfenapyr (Pylon)
SP- spinosad (Conserve)
OP- acephate (Orthene)
C- Carbofuran (Furadan)
Neonicotinyl insecticide toxicity
Sublethal dose: more than 20 ppb (2ng/bee) reduces foraging, memory, and navigation

Aspirin 80mg = 80,000,000microg = 80,000,000ng

<table>
<thead>
<tr>
<th>Lethal dose</th>
<th>Oral LD$_{50}$ ng/bee in 20µL</th>
<th>Pollen/nectar ppb (ng/.1gbee)</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>imidaclorpinid</td>
<td>3.7-40</td>
<td>37-400</td>
<td>Schmuck et al. 2001, EFSA 2013</td>
</tr>
<tr>
<td>clothianidin</td>
<td>3-22</td>
<td>30-220</td>
<td>Iwas et al. 2004, EFSA 2013</td>
</tr>
<tr>
<td>dinotefuran</td>
<td>23-47</td>
<td>230-470</td>
<td>EFSA 2013</td>
</tr>
<tr>
<td>thaimethoxam</td>
<td>5-30</td>
<td>50-300</td>
<td>EFSA 2013</td>
</tr>
</tbody>
</table>
Neonicotinyl insecticide use in 2011

143/442 US million acres use neonicotinyl insecticides
83+ million acres of corn have neonicotinyl treated-seed and honeybees use corn for pollen

<table>
<thead>
<tr>
<th>Active ingredient (ai) in lbs</th>
<th>imidaclonoprid</th>
<th>clothianidin</th>
<th>thiamethoxam</th>
</tr>
</thead>
<tbody>
<tr>
<td>MN</td>
<td>52,048</td>
<td>43,663</td>
<td>68,876</td>
</tr>
<tr>
<td>CA</td>
<td>348,247</td>
<td>3,812</td>
<td>30,687</td>
</tr>
<tr>
<td>US</td>
<td>700,000</td>
<td>1,2000,000</td>
<td>990,000</td>
</tr>
</tbody>
</table>
### Residue in pollen and nectar, very few papers

<table>
<thead>
<tr>
<th>Plant</th>
<th>Imidacloprid ppb</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sunflower (treated-seed)</td>
<td>2 nectar 4 pollen</td>
<td>Schmuck et al. 2001</td>
</tr>
<tr>
<td>Pumpkin (soil drench)</td>
<td>4 - 12 nectar 37 - 87 pollen</td>
<td>Dively &amp; Hooks 2010</td>
</tr>
<tr>
<td>Milkweed (soil drench)</td>
<td>6000 ppb nectar</td>
<td>Krischik 2013</td>
</tr>
<tr>
<td>Eucalyptus tree (soil drench)</td>
<td>550 ppb nectar</td>
<td>Paine et al 2011</td>
</tr>
<tr>
<td>Horsechestnut tree (trunk injection)</td>
<td>5-283 blossom</td>
<td>Bayer, unpublished, Maus et al. 2004b</td>
</tr>
<tr>
<td>Serviceberry (soil drench)</td>
<td>1,038- 2,816 blossom</td>
<td>Bayer, unpublished, Doering et al. 2005a,b</td>
</tr>
<tr>
<td>Causes change</td>
<td>Residue level</td>
<td></td>
</tr>
<tr>
<td>---------------------------------------</td>
<td>------------------------</td>
<td></td>
</tr>
<tr>
<td>Common landscape flower residue</td>
<td>6,000 ppb</td>
<td></td>
</tr>
<tr>
<td>Kills honeybees in one sip</td>
<td>158-185 ppb</td>
<td></td>
</tr>
<tr>
<td>Altering honey bee behavior</td>
<td>6-100 ppb</td>
<td></td>
</tr>
<tr>
<td>Altering bumblebee behavior</td>
<td>10-30 ppb</td>
<td></td>
</tr>
<tr>
<td>LD50 imidacloprid</td>
<td>40 ng/bee = 400 ppb</td>
<td></td>
</tr>
<tr>
<td>LD50 clothianidin</td>
<td>43 ng/bee</td>
<td></td>
</tr>
</tbody>
</table>
Neonicotinoids and bumblebees

- 0 ppb = control
- 10 ppb = pollen from seed treatments
- 20 ppb = NOEC from Bayer, but affects behavior
- 50 ppb = Field pumpkin study
- 100 ppb = Lower level found in landscape plants

- LD50 imidacloprid 4-40 ng/bee = 40-400 ppb
- LD50 clothianidin 4 ng/bee = 40 ppb
What are bees?

» Most bees are solitary; honey bees, bumble bees, and some sweat bees are social.

» Among the social bees, only honey bee colonies are perennial (survive year to year).

» Solitary and social wasps are sometimes mistaken for bees. Social wasps have annual colonies like bumble bees.
Bumble Bees, *Bombus* spp.,
Order Hymenoptera
Family Apidae

These large (10 to 23 mm), hairy bees are the only truly social bees native to the United States.

Colonies are annual.

Fecundated queens emerge in spring and begin colonies in the ground.

Queens mate with unrelated males before overwintering in the ground.
1. A queen emerges from hibernation in spring and finds a nest site, such as an abandoned rodent burrow.

2. She creates wax pots to hold nectar and pollen, on which she lays and incubates her eggs.

3. In autumn the colony produces new queens and male bees.

4. Newly mated queens hibernate and the rest of the bees die.
Inside a commercial bumble bee colony. Note capped brood cells, shiny “honey pots” full of nectar, and size difference between workers and two large queens (one is newly produced).
Honey bee, *Apis mellifera*, Order Hymenoptera, Family Apidae

Honey bees (native to Europe) are used for pollination (almonds, for example) and for honey, beeswax, and propolis production. They are 10 to 15 mm in length and possess corbiculae like bumble bees.

Honey bee colonies are perennial. New colonies form when an old queen swarms with a group of workers. Fertilized eggs are workers; males are unfertilized eggs.
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).
Linden trees: Imidacloprid applied to linden to kill adult JB, but linden is a favorite bee plant.
Baldfaced hornets (*Dolichovespula maculata*) make enclosed nests; note larvae present in brood cells

Paper wasps (like this *Polistes dominula*) make open nests; note larvae present in brood cells

**Social Wasps**

The life cycle of social wasps is similar to that of bumble bees, except wasps are carnivorous.

Among the social wasps, the hornets, aerial yellowjackets, and paper wasps are the species usually found above ground, while most yellowjackets nest in the ground or in cavities. Females chew on wood to make into papery brood cells. Workers hunt caterpillars and other insects to feed the developing larvae.
Residue data confirmed dinotefuran. Another bee kill occurred in Hillsboro, OR. Trees were covered in nets and dinotefuran was banned for 6 months until Jan 2014 in Oregon.
Incident
Around 25,000 bumblebees and others were found dead under trees at the Target store in Wilsonville, Oregon on Monday, June 17th. The neonicotinyl insecticide dinotefuran (label Safari) was applied pre-bloom according to label.
## 2011 Imidacloprid residue plants

<table>
<thead>
<tr>
<th>Dose in mg/soil</th>
<th>Dead bees on Agastache</th>
<th>Agastache spp. nectar ppb</th>
<th>Asclepias spp. nectar ppb</th>
<th>Esperanza spp. nectar ppb</th>
<th>pollen ppb</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0.6b</td>
<td>6b</td>
<td>3c</td>
<td>0c</td>
<td>26b</td>
</tr>
<tr>
<td>25</td>
<td>0.6b</td>
<td>52b</td>
<td>80c</td>
<td>8c</td>
<td>36b</td>
</tr>
<tr>
<td>50</td>
<td>0.5b</td>
<td>133b</td>
<td>175bc</td>
<td>21c</td>
<td>30b</td>
</tr>
<tr>
<td>300 1X 3 gal</td>
<td>1.1ab</td>
<td>1973b</td>
<td>1568bc</td>
<td>106c</td>
<td>95b</td>
</tr>
<tr>
<td>600 2X 3 gal</td>
<td>2.4a</td>
<td>5265ab</td>
<td>2950b</td>
<td>276b</td>
<td>332b</td>
</tr>
</tbody>
</table>
### 2009-2011 Imidacloprid residue rose

<table>
<thead>
<tr>
<th>Dose in mg/soil Marathon 1%G</th>
<th>Rose 2009 field</th>
<th>Rose 2010 GH</th>
<th>Rose 2011 field</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>9d</td>
<td>0c</td>
<td>26b</td>
</tr>
<tr>
<td>25</td>
<td>na</td>
<td>5c</td>
<td>36b</td>
</tr>
<tr>
<td>50</td>
<td>na</td>
<td>7c</td>
<td>30b</td>
</tr>
<tr>
<td>Homeowner 1X, 270 mg</td>
<td>812c</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>Homeowner 2X, 540 mg</td>
<td>1648a</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>300 1X 3 gal</td>
<td>1175b</td>
<td>32bc</td>
<td>95b</td>
</tr>
<tr>
<td>600 2X 3 gal</td>
<td>na</td>
<td>161ab</td>
<td>332b</td>
</tr>
<tr>
<td>1200</td>
<td>na</td>
<td>268a</td>
<td>720a</td>
</tr>
</tbody>
</table>

- F=256, 0.0001
- F=4.9, 0.0045
- F=5.7, 0.0025
Bumble bee colonies in the greenhouse
Annual life cycle: *Bombus impatiens*

Queen starts colony in May

New queen + drone production in late summer

Mating in fall

Winter
Bumble bee colonies with flight box

Brood box

Flight box
Queen mortality (week 8)

Neonicotinoid (ppb)

Percent Mortality

- Imidacloprid
- Clothianidin

Neonicotinoid (ppb)

- 0: 1/8
- 10: 3/8
- 20: 2/9
- 50: 7/8
- 100: 8/8

Percent Mortality

- 1/8
- 3/8
- 2/9
- 7/8
- 8/8

Neonicotinoid (ppb)

- 0
- 10
- 20
- 50
- 100
Sugar syrup consumption (Week 8)

ANOVA: F = 22.2, df = 4, 35, p = 0.0001
ANOVA: F = 34.5, df = 4, 28, p = 0.0001
Mean colony weight (final)

ANOVA: $F = 16.2$, df = 4, 35, $p = 0.0001$

ANOVA: $F = 16.1$, df = 4, 37, $p = 0.0001$

Neonicotinoid (ppb)

Imidacloprid
Clothianidin
Mean number of honey pots (final)

ANOVA: $F = 5.3$, df = 4, 35, $p = 0.0020$

ANOVA: $F = 12.7$, df = 4, 37, $p = 0.0001$

Honey pots

Neonicotinoid (ppb)
Save the bees plant flowers and trees

1. Use contact insecticides on flowering plants, such as bifenthrin, cyfluthrin, neem, azadirachtin, and spinosad.

2. Do not use systemic insecticides.

3. Plant a seasonal phenology of native and garden plants for nectar and pollen.

4. Only single-flowered plants, not double flowers, provide pollen and nectar.

5. Provide overwintering habitat for bees.

6. Do not kill queen bees in the spring, they will not sting.

7. Understand the different types of bees and wasps so you can conserve bees.
Save the bees plant flowers and trees
1. Use contact insecticides on flowering plants, such as bifenthrin, cyfluthrin, neem, azadirachtin, and spinosad.
2. Do not use systemic insecticides.
3. Plant a seasonal phenology of native and garden plants for nectar and pollen.
4. Only single-flowered plants, not double flowers, provide pollen and nectar.
5. Provide overwintering habitat for bees.
6. Do not kill queen bees in the spring, they will not sting.
7. Understand the different types of bees and wasps so you can conserve bees.
Cedarburg, WI
Annual Cost To Treat
Ash Trees
= $70,000
(city of 11,000)
Economic and environmental risk from EAB

- MN has the second largest population of ash trees in the US.
- Since 2002, EAB killed over 50 million ash trees.
- Estimated Ohio will spend as much as 1.3 billion dollars.
EAB life cycle
• Native to Asia
• 1-to 2 year
• Larvae feed under bark
• Adults emerge in May
• Asian ash defended with chemicals absent in NA ash.
• Landscape management is removal or insecticides.
Landscape Management

Three application methods
• Passive soil drench
• Soil injection
• Trunk injection
St Paul and Minneapolis Park and Rec. Board (MPRB) issue permits for trunk injection on public property.

- Minneapolis passed a resolution asking homeowners to replace trees rather than treat on private property.

- Long term use of insecticides carries environmental risk.
Economic risk and high insecticide use from EAB

- Insecticide use will continue for many years until effectiveness of biocontrol is determined
- Milwaukee, WI treated 33,000 trees with 1,300 liters ($475/liter). Estimates are 1.6 million for insecticide and personnel to treat the trees.
Landscape Management

- Movement away from tree of insecticide in water to surface or ground water.
- Uptake of insecticides from ash by other plants.
- Non-target effects on nectar/pollen feeding insects.
Landscape Management

- Imidacloprid and dinotefuran used for EAB management are water soluble and can leach. NY declared imidacloprid a reduced risk insecticide on LI due to well contamination.
- CA initiated a review of imidacloprid's potential to move offsite and to harm non-targets.
- Both the EPA and MDA are interested in data that addresses these concerns.
Landscape Management

• Imidacloprid and emamectin benzoate are toxic to birds and bees.

• Imidacloprid can be used on other trees, especially linden and maple, which are used by bees, sapsuckers, and hummingbirds.

• Emamectin benzoate is a restricted use insecticide due to hazards to applicators. It was previously registered for salmon and for cole crop. The Proclaim label states it is highly toxic to bees.
Woodpeckers remove EAB from trees

- In some trees, woodpeckers have removed up to 95% of EAB larvae (Cappaert et al. 2005b).
- Birds are exposed to emamectin benzoate and imidacloprid when foraging for EAB on ash trees.
Its habit of making shallow holes in trees to get sap is exploited by other bird species, and the sapsucker can be considered a "keystone" species, one whose existence is vital for the maintenance of a community (Cornell Ornithology Lab).

yellow-bellied sapsucker
Hummingbirds are attracted to sapsucker holes (MN DNR 1997 and Smitley et al. 2007).

Colorado broad-tailed hummingbird
Landscape management imidacloprid

1. Need to manage invasive species.
2. Imidacloprid and dinotefuran used for management can move with water away from target trees.
3. Amount of imidacloprid in plants growing under treated trees not researched.
4. Imidacloprid can be used on other trees, especially linden and maple.
### 2005, 2007, 2011 Imidacloprid residue buckwheat, milkweed

<table>
<thead>
<tr>
<th>Dose in mg/soil Marathon 1%G</th>
<th>Buckwheat 2005 Nectar ppb</th>
<th>Milkweed 2007 Nectar ppb</th>
<th>2011 Milkweed Nectar ppb</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td></td>
<td></td>
<td>3c</td>
</tr>
<tr>
<td>25</td>
<td>na</td>
<td>na</td>
<td>80c</td>
</tr>
<tr>
<td>50</td>
<td>na</td>
<td>na</td>
<td>175bc</td>
</tr>
<tr>
<td>Homeowner 1X</td>
<td>na</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>270 mg</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Homeowner 2X</td>
<td>na</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>270 mg</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>300 1X 3 gal pot</td>
<td>6000</td>
<td>6000</td>
<td>1568bc</td>
</tr>
<tr>
<td>600 2X 3 gal pot</td>
<td>12000</td>
<td>12000</td>
<td>2950b</td>
</tr>
<tr>
<td>300 21 days later</td>
<td>na</td>
<td>20000</td>
<td>na</td>
</tr>
<tr>
<td>600 21 days later</td>
<td>na</td>
<td>34000</td>
<td>na</td>
</tr>
<tr>
<td>1200</td>
<td>na</td>
<td>na</td>
<td>8337a</td>
</tr>
</tbody>
</table>

F=25.86, (2,22) 0.001
F=22.72, (2,6) 0.0016
F=25.8, 0.0001
### 2012 Imidacloprid residue canola pollen

<table>
<thead>
<tr>
<th>Dose in mg/soil</th>
<th>April 5 2010, E June 1 flowers 1 app April</th>
<th>May 19, 2010, W July 2 flowers 1 app May</th>
<th>July 2, 2010, E August 18 flowers 2 app April+July</th>
<th>July 29, W Sept 15 flowered 1 app May</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black WI aust</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Poncho blue invigor 601</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Gaucho red invigor 701</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>0</td>
<td>0c</td>
<td>0b</td>
<td>0b</td>
<td>0b</td>
</tr>
<tr>
<td>4</td>
<td>0c</td>
<td>0b</td>
<td>313b</td>
<td>5b</td>
</tr>
<tr>
<td>8</td>
<td>14c</td>
<td>7b</td>
<td>179b</td>
<td>8b</td>
</tr>
<tr>
<td>80</td>
<td>461b</td>
<td>15b</td>
<td>342b</td>
<td>24b</td>
</tr>
<tr>
<td>160</td>
<td>2072a</td>
<td>341a</td>
<td>3860a</td>
<td>162a</td>
</tr>
<tr>
<td></td>
<td>F=410, 0.0001</td>
<td>F=271, 0.001</td>
<td>F=7.5, 0.0002</td>
<td>F=70.6, 0.0001</td>
</tr>
</tbody>
</table>
## 2012 Imidacloprid residue canola soil

<table>
<thead>
<tr>
<th>Dose in mg/soil</th>
<th>April 5 June 1 flowers</th>
<th>May 19 July 2 flowers</th>
<th>July 2 August 18 flowers</th>
<th>July 29 Sept 15 flowered</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>April</td>
<td>May</td>
<td>April + July 6</td>
<td>May 7</td>
</tr>
<tr>
<td>Seed trt</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>no insect</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Poncho</td>
<td>na</td>
<td>na</td>
<td>na</td>
<td>51</td>
</tr>
<tr>
<td>Gaucho</td>
<td>na</td>
<td>na</td>
<td>na</td>
<td>77</td>
</tr>
<tr>
<td>0</td>
<td>na</td>
<td>na</td>
<td>0</td>
<td>1316</td>
</tr>
<tr>
<td>4</td>
<td>na</td>
<td>na</td>
<td>1552</td>
<td>199</td>
</tr>
<tr>
<td>8</td>
<td>na</td>
<td>na</td>
<td>743</td>
<td>257</td>
</tr>
<tr>
<td>80</td>
<td>na</td>
<td>na</td>
<td>1816</td>
<td>517</td>
</tr>
<tr>
<td>160</td>
<td>na</td>
<td>na</td>
<td>9727</td>
<td>3913</td>
</tr>
</tbody>
</table>

F=2.8, p=0.07

F=5.3, p=0.0009