Pollinators, Plants, and Pesticides

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Auburn University
Overview

Pollinators

Pesticides (not just insecticides)

New challenge area for pollinators
Pollinators
Insect pollination

- Estimated 100 crops used for food are insect pollinated
- About 35% of world crop production
- Few dietary staples—corn, rice, wheat, soybeans, tubers depend solely on insects
- 2/3 of flowering plants insect pollinated (seed banks, biodiversity)
Whole Food Market provides a striking representation of the importance of insect pollination!
Without insects…

Wind, water, other animals
Insect Pollinators Use Different Senses:

- Vision
- Olfaction
- Taste
- Touch
Angiosperm Flowers Exploit Insect Vision

- Insect vision extends from UV to yellow-orange

- Poor recognition of red

- Yellow and white are the two most common colors for day active insects
Insects see UV wavelengths…
Markings on flowers appear different to them than to human eyes!

**Nectar Guides:** Markings on Flowers that are visible to Pollinators especially under UV light
Characteristics of flowering plants that attract one pollinator may not be attractive to others.

Ex. Plants in traditional butterfly gardens likely not good for bees!
Floral Traits and Insect Pollinators

Bees: Yellow\blue flowers, nectar guides, strong flowers for landing, odors but not necessarily strong, hidden nectar

Long tongued bees - Apidae (bumble, honey, and carpenter bees) and Megachilidae
Floral Traits and Insect Pollinators

Beetles: dull yellow, white, green colors, no nectar guides, strong fruit odors, easily accessible pollen, bigger, flowers with greater floral parts

Beetles are considered ‘mess and soil’ pollinators
Floral Traits and Insect Pollinators

Flies: nectar guides, light colored dull colors, no odor*

Carrion flies-odor strong and unpleasant, no nectar guides, no rewards
Floral Traits and Insect Pollinators

Butterflies: day open flowers only, weak odor, radial flowers flat around rim, narrow tube to nectar, simple nectar guides
Floral Traits and Insect Pollinators

**Moths:** nocturnal flowers, strong heavy sweet scent, long tube with horizontal or pendant form, no nectar guides
Floral Rewards: Nectar and Pollen
Why bees?
Adaptations for pollination:

1. Body is covered with branched hairs
2. Modifications to carry pollen (brushes or baskets)
3. Larvae fed pollen and nectar (unlike any other insect pollination group)
North America BEE-auties!

Andrenidae-largest bee family (~1200 spp)
Honey bees; Ag commodity

Sept 30 2015

Apis mellifera; one species among 1,000’s

Like picking a cow as the main example of mammals!
Honey bee husbandry in decline?

Fairbrother et al. 2014

Estimated 1.7 million colonies needed

Fairbrother et al. 2014
Native bees at risk?

Overwintering is a critical difference

Whitehorn et al. 2012
Larson et al. 2013
All bees are potentially exposed to pesticides via pollen, nectar, and contact with treated plants.
Exposure to Pesticides

Residues higher in pollen than nectar

More nectar consumed

Nectar used for production of honey
Honey is main food source for larvae

Residues in plant water (dew \guttation)
Contact exposure or drinking

Hive wax\comb (chronic)
All life stage
Contact exposure\not changed; carryover

Mullin et al. 2010, Fischer 2013, Thompson et al. 2014
Pesticides and Bees

Insecticides>

Herbicides= Fungicides

All insecticides kill insects but why are neonicotinoids different?
Neonicotinoids: Chemistry & Use
Systemic and Persistent

Distribution of C\textsuperscript{14} Labeled Thiamethoxam\textsuperscript{TM} 25WG after a foliar application to cucumber leaves

1 hour after application
8 hour after application
24 hour after application
Neonics now dominate pesticides!

Insecticides largest and fastest growing pesticide in T&O market ($1.3 billion, 2013)

Neonics and pyrethroid top A.I.’s
Neonicotinoids: Mode of action
Selective action to arthropods, lower mammalian toxicity
Differences in properties and structure of receptors in insects and mammals
It is no longer debatable that neonicotinoids can negatively impact bees. So to what extent?
Sublethal Effects

– Delayed larval development
– Impaired learning and memory, navigational skills
– Reduced foraging behavior and weight gain
  *Reduced colony, queen growth*
– Weakened immunity
  • Increased susceptibility to other stressors (oxidative stress)

<table>
<thead>
<tr>
<th>Sublethal effects</th>
<th>Dose</th>
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</thead>
<tbody>
<tr>
<td>Alter honey bee behavior (foraging)</td>
<td>6-100 ppb</td>
</tr>
<tr>
<td>Alter honey bee learning</td>
<td>24 ppb</td>
</tr>
<tr>
<td>Alter bumblebee behavior</td>
<td>10-30 ppb</td>
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</table>
Neonicotinoid Pesticide Reduces Bumble Bee Colony Growth and Queen Production

Penelope R. Whitehorn, Stephanie O’Connor, Felix L. Wackers, Dave Goulson

Growing evidence for declines in bee populations has caused great concern because of the valuable ecosystem services they provide. Neonicotinoid insecticides have been implicated in these declines because they occur at trace levels in the nectar and pollen of crop plants. We exposed colonies of the bumble bee *Bombus terrestris* in the laboratory to field-realistic levels of the neonicotinoid imidacloprid, then allowed them to develop naturally under field conditions. Treated colonies had a significantly reduced growth rate and suffered an 85% reduction in production of new queens compared with control colonies. Given the scale of use of neonicotinoids, we suggest that they may be having a considerable negative impact on wild bumble bee populations across the developed world.

Larson et al. 2013 found similar results with clothianidin
Direct Toxicity

17 reported bee incidents, of those 10 were related to landscape ornamental and turfgrass uses.

EPA 2016 preliminary report on imidacloprid
Relative toxicity of insecticides

Insecticides vary significantly

<table>
<thead>
<tr>
<th>Insecticide</th>
<th>Oral LD&lt;sub&gt;50&lt;/sub&gt;</th>
<th>Contact LD&lt;sub&gt;50&lt;/sub&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbaryl</td>
<td>230 ng</td>
<td>140 ng</td>
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<tr>
<td>Bifenthrin</td>
<td>1000 ng</td>
<td>14.6 ng</td>
</tr>
<tr>
<td>Chlorantraniliprole</td>
<td>&gt;119,000 ng</td>
<td>&gt;100,000 ng</td>
</tr>
<tr>
<td>Imidacloprid</td>
<td>3.7-40.9 ng</td>
<td>59.7-242.6 ng</td>
</tr>
<tr>
<td>Dinotefuran</td>
<td>23 ng</td>
<td>47 ng</td>
</tr>
<tr>
<td>Acetamiprid</td>
<td>14530 ng</td>
<td>8090 ng</td>
</tr>
<tr>
<td>Thiamethoxam</td>
<td>5 ng</td>
<td>24 ng</td>
</tr>
<tr>
<td>Clothianidin</td>
<td>3 ng</td>
<td>22-44 ng</td>
</tr>
</tbody>
</table>
What about herbicides?
Relative toxicity of Herbicides

Herbicides Highly toxic to honey bees (direct toxicity)
    Arsenicals, Parathion

Herbicides Moderately toxic to honey bees
    Thiazopyr (not active)

Herbicides Relatively Non-toxic to honey bees (direct toxicity)
    Glyophosate, 2, 4-D, Trifluralin, Paraquat, Atrazine, Dicamba, Pronamide (Kerb), Flumioxazin, Pendimethalin, Imazapyr

Source ANR 1088
Relative toxicity of Herbicides

Far less data...

Glyphosate: Acute oral LD50: >100μg per bee

MSMA: Acute contact LD50: 68μg per bee

Imazapyr: Acute contact LD50 >100μg per bee

Source: ANR 1088
Sublethal Effects

– Glyphosate in bee diet delays honey bee return trips to hive; can decrease sensitivity to sugar; reduce short term memory

– Herbicide drift can stunt non-targets; produce smaller larvae of painted lady, reduce available flowers in margins

– Pesticides in wax comb don’t kill larvae but can slow development (mites)

– 2,4-D reduces nectar flow in cotton
Multiple interacting stressors drive bee declines. Both wild and managed bees are subject to a number of important and interacting stressors.
Bee declines driven by combined stress from parasites, pesticides, and lack of flowers

Dave Goulson,* Elizabeth Nicholls, Cristina Botías, Ellen L. Rotheray

• “…loss of habitat has been a long-term contributor to declines”
• Undisturbed nesting sites and floral resources
• Surbanization generally support bees but the urban core limits has lower abundance and diversity
What do we know about bee conservation from Europeans?

Bumble bees like nectariferous perennials and biennials

Floral suitability depends on bee tongue length
What do we know about bee conservation from Europeans?

Many suitable plants are non-native here
Filipendula ulmaria (meadowsweet)
Lamiastrum galeobdolon
What do we know about bee conservation from Europeans?

Many suitable plants are non-native here

*Senecio jacobaea*  Ragwort \ Stinking willie

Noxious weed
What do we know about bee conservation from Europeans?

Many suitable plants are non-native here
- Centaurae nigra* Introduced, noxious
- Cirsium palustre, C. arvense, C. vulgare (thistles)
- Epilobium hirsutum*, Introduced, noxious
- Rubus fructicosus*, Federal noxious

Chamerion angustifolium, Native to NA
- Lotus corniculatus, Introduced, weedy
- Odontites vernus, Introduced
- Prunella vulgaris, Native
What do we know about bee conservation from US studies?

Many suitable plants are either weed species or have little value in horticulture.

- 50-100 species of pollinators on lawn weeds
- 37 bee species, hoverflies
- 25 bee on dandelion
- 21 bee on clover

Larson et al. 2014; Lerman et al. 2015
What do we know about bee conservation from US studies?

**Xerces Society lists of native plants**

Yarrow, hyssop, thistle, wild carrot, larkspur, buckwheat, gaillardia, sunflower, penstemon, stonecrop, goldenrod

Mostly based on anecdotes or unreplicated observations
Hollyhock, coreopsis, cosmos, coneflower, lantana, lavender, salvia, clover, zinnia
<table>
<thead>
<tr>
<th>Relative ranking of ornamentals to honey bees</th>
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<tbody>
<tr>
<td><strong>0</strong></td>
</tr>
<tr>
<td>Hosta</td>
</tr>
<tr>
<td>Ivy geranium</td>
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<tr>
<td>Petunia</td>
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<tr>
<td>Portulaca (most)</td>
</tr>
<tr>
<td>Verbena</td>
</tr>
<tr>
<td>Vinca</td>
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<tr>
<td>Viola (pansy)</td>
</tr>
<tr>
<td>Columbine</td>
</tr>
<tr>
<td>Most mums</td>
</tr>
<tr>
<td><strong>1</strong></td>
</tr>
<tr>
<td>Daylily</td>
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<tr>
<td>Zonal geranium</td>
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<tr>
<td>Impatiens</td>
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<tr>
<td>Coral bells</td>
</tr>
<tr>
<td>Hydrangea</td>
</tr>
<tr>
<td>Ageratum</td>
</tr>
<tr>
<td>Peony</td>
</tr>
<tr>
<td>Monarda*</td>
</tr>
<tr>
<td>Zinnia</td>
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<tr>
<td><strong>2</strong></td>
</tr>
<tr>
<td>Lantana</td>
</tr>
<tr>
<td>Pentas</td>
</tr>
<tr>
<td>Russian sage</td>
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<tr>
<td><strong>3</strong></td>
</tr>
<tr>
<td>Catnip</td>
</tr>
<tr>
<td>Cleome</td>
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<tr>
<td>Cotoneaster</td>
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<tr>
<td>Goldenrod</td>
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<tr>
<td>Gallardia</td>
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<tr>
<td>Agastache</td>
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<tr>
<td>Salvia</td>
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<tr>
<td>Marigolds</td>
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<tr>
<td>Roses</td>
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</tbody>
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0, not visited; 3 is heavily visited

Source: Cranshaw 2010
Summary

Pollinators are many groups of insects; each with different floral interests.

Honey bees are one bee species among thousands; all are equally important.

Pesticides vary in their impacts on bees but most studied effects sublethal.

Adequate floral resources as important as pesticide impacts (phenology).
Resources

- @held_david
- Facebook: Ornamental and Turfgrass Entomology at Auburn University
- david.held@auburn.edu