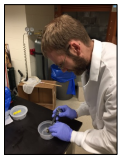
Pesticide risk to bees: What we know and what we need to know better



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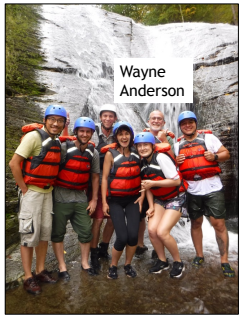
Pesticide risk to bees: What we know and what we need to know better




Aaron Iverson

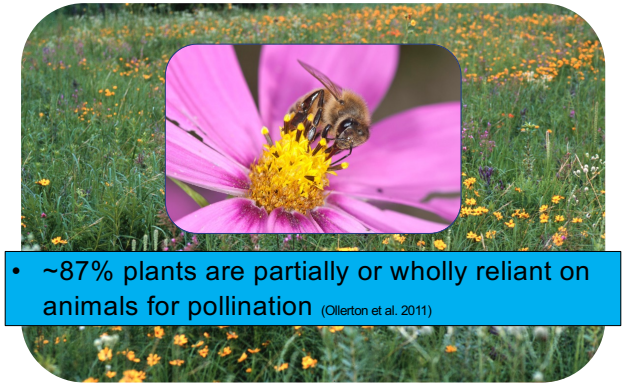
Daiana De Souza

CornellCALS College of Agriculture and Life Sciences Scott McArt, Dyce Lab for Honey Bee Studies 2

2

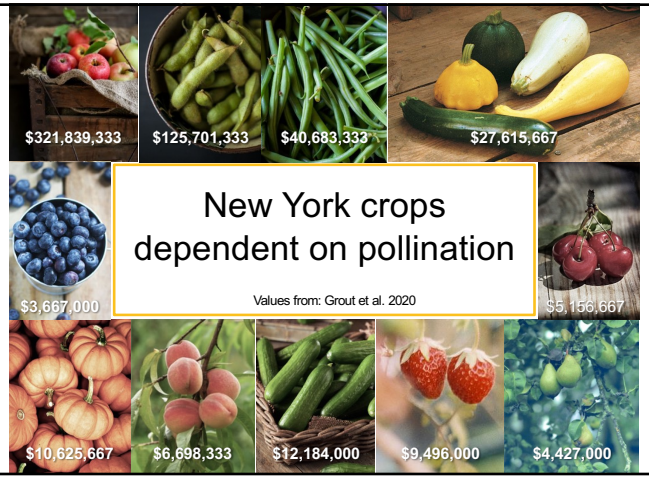
3

Which makes them excellent pollinators



- ~87% plants are partially or wholly reliant on animals for pollination (Ollerton et al. 2011)

4



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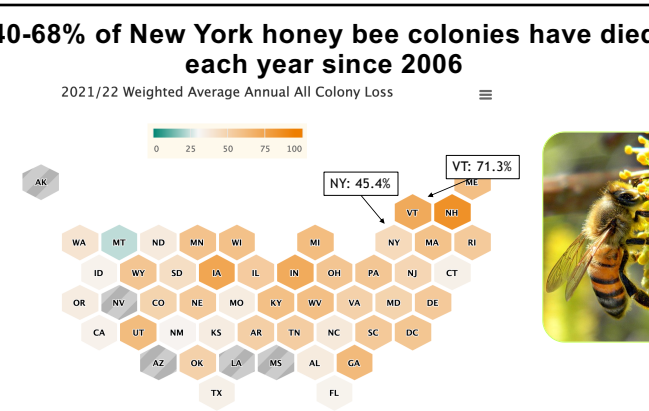

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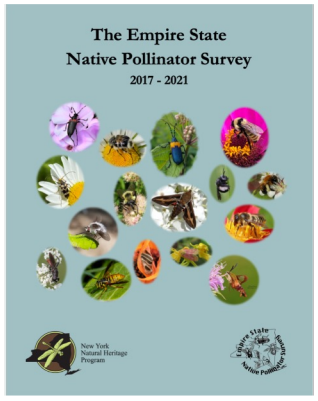
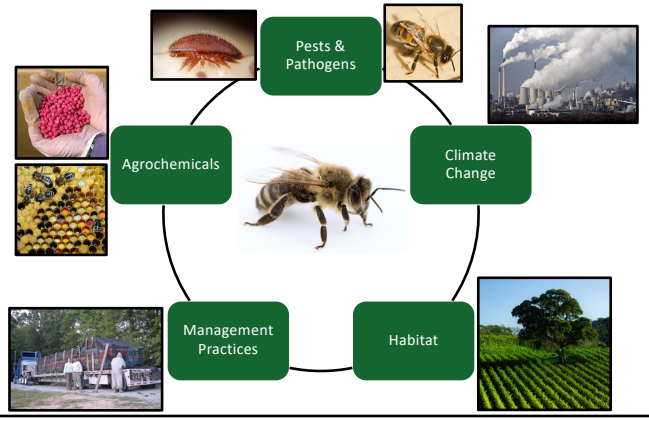


"Using conservative criteria, 38% of New York's native pollinators are at risk of extirpation from NY."

https://www.nynhp.org/projects/pollinators/

8

Why are pollinators having problems?



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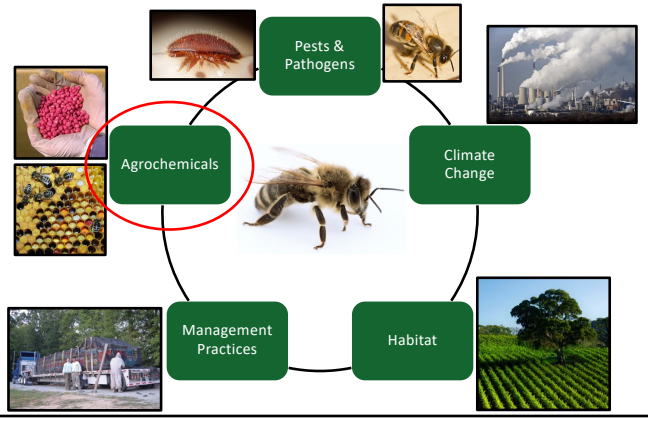
This afternoon's talk: pesticides



10

Outline

1) What we know

a) Defining risk
b) When there's risk (and when there isn't)
c) Benefits & risk in field crops

2) What we need to know better

a) Where is exposure coming from?

11

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a) Where is exposure coming from?

12

Defining pesticide risk

$$Risk = exposure \div toxicity$$

13

Defining pesticide risk

$$Risk = exposure \div toxicity$$

Poor understanding for most pesticides in most application contexts

Good understanding of honey bee LD_{50} for most pesticides

14

Defining pesticide risk

Hazard quotient (HQ)

$$Risk = exposure \div toxicity$$

15

Defining pesticide risk

Hazard quotient (HQ)

$$Risk = exposure \div toxicity$$

0.1% of LD_{50} = 10 $= 1{,}000\ ppb \div 100\ \frac{ug}{bee}$ Typical fungicide

2,500% of LD_{50} = 250,000 $= 1{,}000\ ppb \div 0.004\ \frac{ug}{bee}$ Same exposure to imidacloprid

100% of LD_{50} = 10,000 $= 40\ ppb \div 0.004\ \frac{ug}{bee}$ Realistic exposure to imidacloprid

16

Defining pesticide risk

Hazard quotient (HQ)

$$Risk = exposure \div toxicity$$

0.1% of LD_{50} = 10 = $1{,}000\ ppb \div 100\ \frac{ug}{bee}$ Typical fungicide

+

100% of LD_{50} = 10,000 = $40\ ppb \div 0.004\ \frac{ug}{bee}$ Realistic exposure to imidacloprid

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17

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18

When is there risk from pesticides?

Rarely during day-to-day beekeeping

Fairly common during crop pollination

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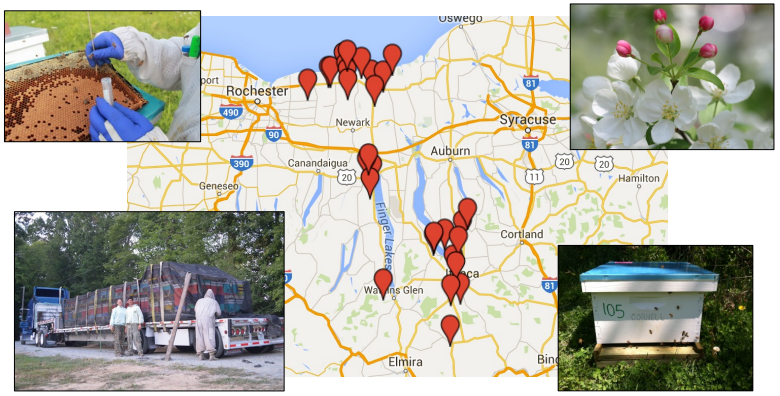
19

Pesticide risk during NY apple pollination



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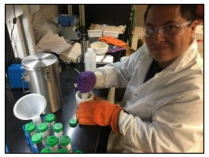
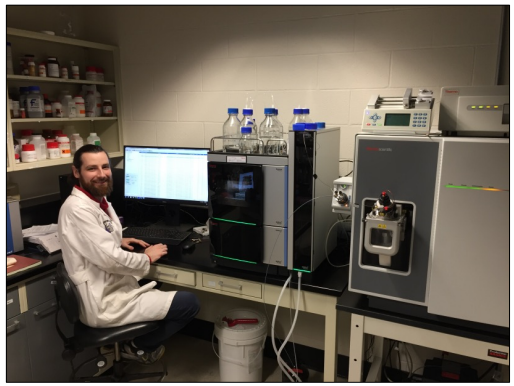
Measuring pesticide residues: Nico Baert & David Sossa





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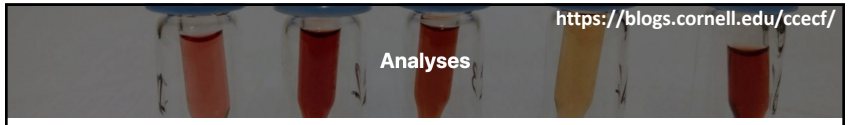

Cornell Chemical Ecology Core Facility: Available to anyone!

93-pesticide multi-residue analysis

- $90/sample for external users

Annual average: **~1,500 samples processed**

https://blogs.cornell.edu/ccecf/

22

Pesticide risk to pollinators: NY apple (2016)

Honey bee pollen (Orchard "N")

17 pesticides

Product names	Pesticide class	Pesticide	Residue (ppb)
Decco Pyr 400 SC, Scala	Fungicide	Pyrimethanil	>10000.00
Velum Prime, Broadform	Fungicide	Fluopyram	171.02
Actara, Flagship 25 WG, Platinum 75 SG, Cruiser 5FS	Insecticide	Thiamethoxam	56.39
Indar 2F	Fungicide	Fenbuconazole	42.36
Lorsban-4E, Lorsban Advanced	Insecticide	Chlorpyrifos	32.89
Sercadis	Fungicide	Fluxapyroxad	19.79
Difenoconazole 3L, Amistar Top, Quadris Top	Fungicide	Difenoconazole	12.33
Pristine, Cabrio EG, Empress, Intrinsic	Fungicide	Pyraclostrobin	9.19
Bravo ZN, Bravo Ultrex, Echo, Equus	Fungicide	4-Hydroxy-chlorothalonil	8.25
Poncho	Insecticide	Clothianidin	5.42
Vanguard WG, Vango WG	Fungicide	Cyprodinil	2.86
Spike 20P, SSI Maxim	Herbicide	Tebuthiuron	2.83
Flint, Flint Extra, Gem 500SC	Fungicide	Trifloxystrobin	2.79
Intimidator, Makaze, Matador	Herbicide	Diuron	2.00
Metolachlor 8E	Herbicide	Metolachlor	1.70
Atrazine 4L	Herbicide	Atrazine	0.89
Quadris F, Abound, Acadia, Aframe, Heritage	Fungicide	Azoxystrobin	0.20

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23

Pesticide risk to pollinators: NY apple (2016)

Honey bee pollen (Orchard "N")

10 fungicides

Product names	Pesstide class	Pesticide	Residue (ppb)
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Sercadis	Fungicide	Fluxapyroxad	19.79
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Intimidator, Makaze, Matador	Herbicide	Diuron	2.00
Metolachlor 8E	Herbicide	Metolachlor	1.70
Atrazine 4L	Herbicide	Atrazine	0.89
Quadris F, Abound, Acadia, Aframe, Heritage	Fungicide	Azoxystrobin	0.20

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24

Pesticide risk to pollinators: NY apple (2016)

Honey bee pollen (Orchard "N")

3 insecticides

Product names	Pesticide class	Pesticide	Residue (ppb)
Decco Pyr 400 SC, Scala	Fungicide	Pyrimethanil	>10000.00
Velum Prime, Broadform	Fungicide	Fluopyram	171.02
Actara, Flagship 25 WG, Platinum 75 SG, Cruiser 5FS	Insecticide	Thiamethoxam	56.39
Indar 2F	Fungicide	Fenbuconazole	42.36
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Vanguard WG, Vango WG	Fungicide	Cyprodinil	2.86
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Intimidator, Makaze, Matador	Herbicide	Diuron	2.00
Metolachlor 8E	Herbicide	Metolachlor	1.70
Atrazine 4L	Herbicide	Atrazine	0.89
Quadris F, Abound, Acadia, Aframe, Heritage	Fungicide	Azoxystrobin	0.20

25

Pesticide risk to pollinators: NY apple (2016)

Honey bee pollen (Orchard "N")

4 herbicides

Product names	Pesticide class	Pesticide	Residue (ppb)
Decco Pyr 400 SC, Scala	Fungicide	Pyrimethanil	>10000.00
Velum Prime, Broadform	Fungicide	Fluopyram	171.02
Actara, Flagship 25 WG, Platinum 75 SG, Cruiser 5FS	Insecticide	Thiamethoxam	56.39
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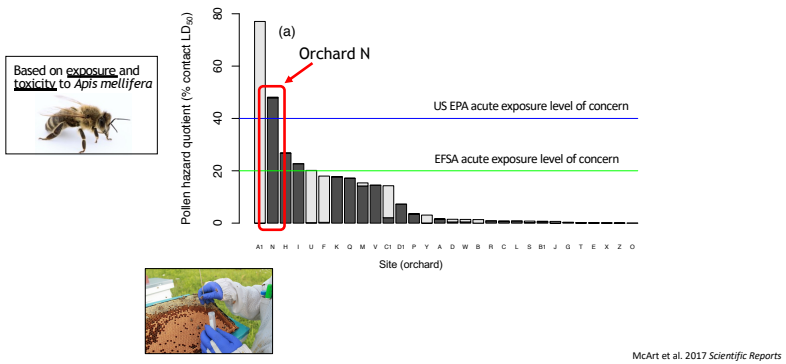
Quadris F, Abound, Acadia, Aframe, Heritage	Fungicide	Azoxystrobin	0.20

26

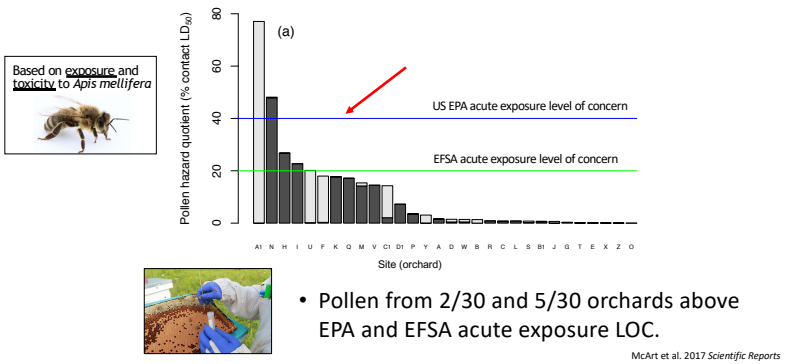
Pesticide risk to pollinators: NY apple (2016)



McArt et al. 2017 *Scientific Reports*

27

Pesticide risk to pollinators: NY apple (2016)



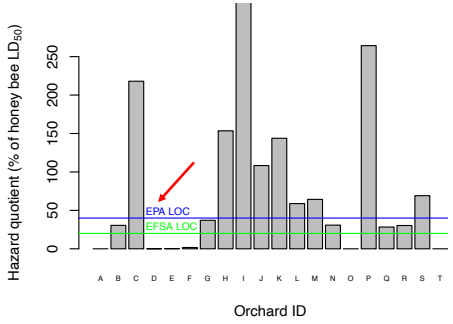
- Pollen from 2/30 and 5/30 orchards above EPA and EFSA acute exposure LOC.

McArt et al. 2017 *Scientific Reports*

28

2019: much greater risk

9/20 orchards above EPA LOC



29

2019: much greater risk

9/20 abov

- Similar risk in Michigan blueberry, New Jersey blueberry, New York strawberry, OR apple, CA almond.
- Year-to-year variation, on average 20 and 40% of orchards exceed EPA and EFSA acute exposure LOC.

Orchard ID

30

Defining pesticide risk

$$Risk = exposure \div toxicity$$

Should LD_{50} be the measure of toxicity?

31

Defining pesticide risk

The problem: Changes in pollinator ***populations***

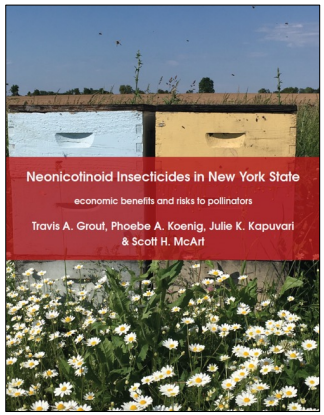
What explains changes in populations?

$$\frac{dN}{dt} = B - D$$

Birth Death

Pesticides impact ability to reproduce before killing bees, so this sublethal response is particularly important.

32



432-page risk-benefit analysis

- Side-by-side analysis of economic benefits and risks to pollinators in:
  - **Field Crops** (corn, soybean, wheat)
  - **Fruit Crops** (e.g., apple, blueberry)
  - **Vegetable Crops** (e.g., squash, pumpkin)
  - **Ornamentals, Turf, & Landscape Management** (e.g., golf courses, ornamental plant nurseries)
  - **Conservation & Forestry**

Outline

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a) Defining risk
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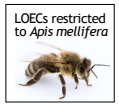
2) What we need to know better

a) Where is exposure coming from?

What do we know about sublethal risk from neonicotinoids?

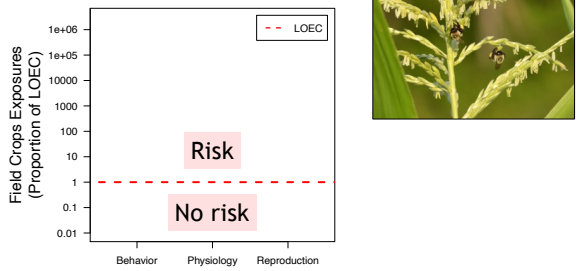
Systematic literature review of **327 peer-reviewed studies**:

- 169 pollinator exposure assessments (clothianidin, imidacloprid, thiamethoxam)
- Compared to lowest observed effects concentration (LOEC) for each neonic that's been shown to impact:
  - Physiology (gene expression, enzyme activity, cellular respiration)
  - Behavior (foraging efficiency, grooming, learning, motor function)
  - Reproduction (fecundity and survival of new queens)

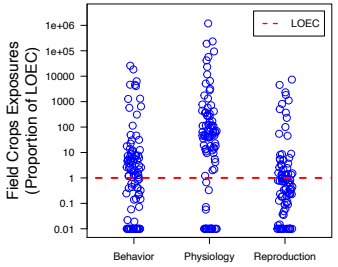


Abdelkader et al. 2019 *J Apic Res*; Morfin et al. 2019 *Sci Reports*; Skerl & Gregorc 2010 *Apidologie*; Tavares et al. 2015 *Chemosphere*; Williams et al. 2015 *Sci Reports*; Williamson et al. 2014 *Ecotoxicology*; Wright et al. 2015 *Sci Reports*; Wu-Smart & Spivak 2016 *Sci Reports*

Risk to pollinators near field crops (corn & soybean)



Risk to pollinators near field crops (corn & soybean)



Exposures predicted to impact
Physiology: 74%
Behavior: 58%
Reproduction: 37%

Grout et al. 2020 37
https://pollinator.cals.cornell.edu/pollinator-research-cornell/neonicotinoid-report/

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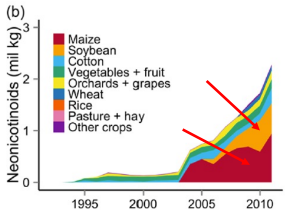
37

Most neonic usage in US is field crops seed treatments

- 79-100% field corn and majority of soybeans are planted with neonic seed treatments



Douglas & Tooker 2015 *Env Sci & Tech*; Douglas et al. 2020 *Sci Reports*

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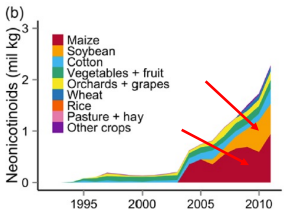
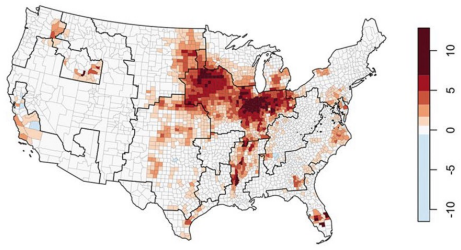
38

Large increase in pesticide loading to the environment

- 79-100% field corn and majority of soybeans are planted with neonic seed treatments



d Change in oral toxic load, 1997-2012 (bil bee LD50/ha)



Douglas & Tooker 2015 *Env Sci & Tech*; Douglas et al. 2020 *Sci Reports*

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39

Misinformation from industry

- **Testimony at NYS Assembly hearing in Sept. 2021**
- **Bayer representative:** ***"The Cornell report is fundamentally flawed because it doesn't consider exposure when assessing risk."***

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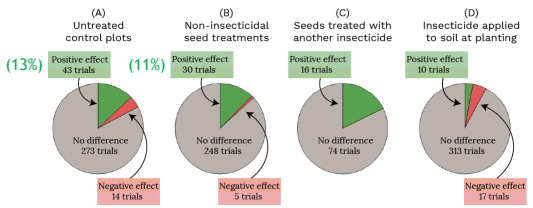
40

Benefits: field corn seed treatments

Effect of neonicotinoid-treated corn seeds on yield compared to:



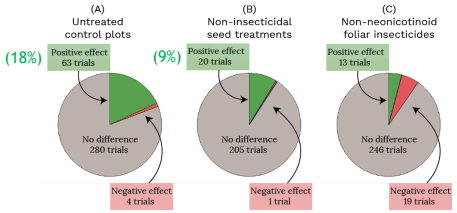
Changed expected net income per acre:

- ***No difference*** compared to **untreated seeds**
- 1.4% to 3.7% benefit compared to **fungicide-treated seeds**
- ***No difference*** compared to **other seed treatments or soil-applied insecticides**

41

Benefits: soybean seed treatments

Effect of neonicotinoid-treated soybean seeds on yield compared to:



Changed expected net income per acre:

- 1.4% to 2.0% loss compared to **untreated seeds**
- 1.4% to 2.3% benefit compared to **fungicide-treated seeds**
- 2.2% to 3.8% benefit compared to **non-neonicotinoid foliar insecticides**

42

Two large recent studies from Quebec and Ontario


PLOS ONE

OPEN ACCESS PEER-REVIEWED
RESEARCH ARTICLE

Impacts of neonicotinoid seed treatments on soil-dwelling pest populations and agronomic parameters in corn and soybean in Quebec (Canada)

Geneviève Labrie, Annie-Ève Gagnon, Anne Vanasse, Alexis Latraverse, Gilles Tremblay

Published: February 26, 2020 • https://doi.org/10.1371/journal.pone.0229136

Article | Authors | Metrics | Comments | Media Coverage

Four years of paired seed-treated & control fields

- 84 corn & soybean sites
- <5% sites experience positive yield response
- Financial cost of using neonics always outweighs economic benefit

43

Two large recent studies from Quebec and Ontario


JOURNAL ARTICLE

Quantifying Early-Season Pest Injury and Yield Protection of Insecticide Seed Treatments in Corn and Soybean Production in Ontario, Canada

Jocelyn L Smith, Tracey S Baute, Arthur W Schaafsma

Journal of Economic Entomology, Volume 113, Issue 5, October 2020, Pages 2197–2212, https://doi.org/10.1093/jee/toaa132

Published: 11 July 2020 **Article history**

Four years of paired seed-treated & control fields

- 129 corn sites (8% sites positive yield response)
- 31 soybean sites (6% sites positive yield response)
- Financial cost of neonics only recouped in 3% of fields

"These data highlight an opportunity for reducing input costs, environmental loading, and nontarget effects without adverse outcomes for Ontario producers."

44

Restrictions on neonics in New York?

Senate Bill S1856A

2023-2024 Legislative Session

Enacts the birds and bees protection act

DOWNLOAD BILL TEXT PDF

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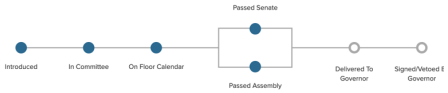
(D, WF) 47TH SENATE DISTRICT

CURRENT BILL STATUS - PASSED SENATE & ASSEMBLY



CornellCALS College of Agriculture and Life Sciences https://www.nysenate.gov/legislation/bills/2023/S1856 45

45

Restrictions on neonics in New York?

- Many policymakers recognize industry misinformation.
- Why does the EPA rely on death (LD_{50}) as the definition of toxicity during pesticide registration?
- Why aren't there requirements to assess real-world exposure after releasing a product? (e.g., Pro-active pharmacovigilance)

CornellCALS College of Agriculture and Life Sciences https://www.nysenate.gov/legislation/bills/2023/S1856 46

46

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   a) Where is exposure coming from?

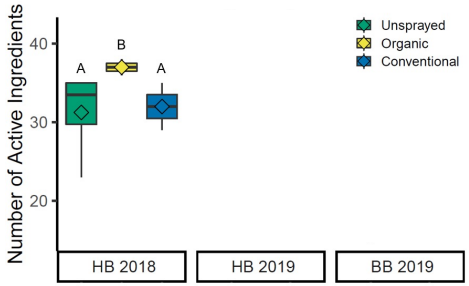
47

Pesticide exposure during Michigan blueberry pollination

Kelsey Graham, USDA ARS, Logan, Utah
Meghan Milbrath, Michigan State University
Rufus Isaacs, Michigan State University
Scott McArt, Cornell University

48

Pesticides in trapped pollen: honey bees vs. bumble bees

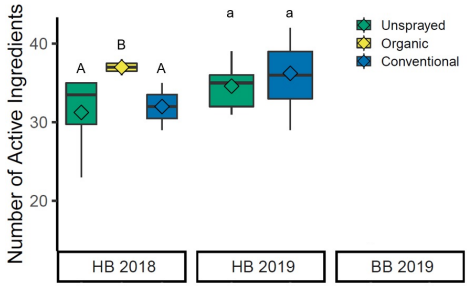



Honey bee pollen: **35 pesticides**, on average

Graham et al. 2021 *Scientific Reports*

49

Pesticides in trapped pollen: honey bees vs. bumble bees

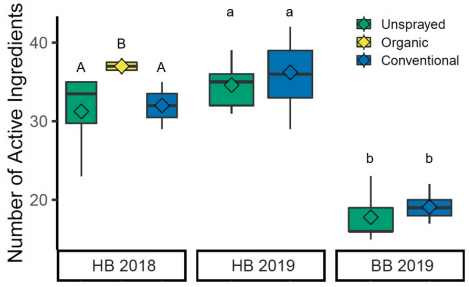



Honey bee pollen: **35 pesticides**, on average

Graham et al. 2021 *Scientific Reports*

50

Pesticides in trapped pollen: honey bees vs. bumble bees

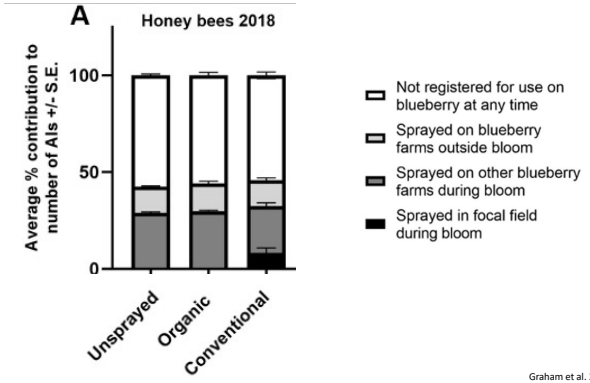
Honey bee pollen: **35 pesticides**, on average

Bumble bee pollen: **19 pesticides**, on average

Graham et al. 2021 *Scientific Reports*

51

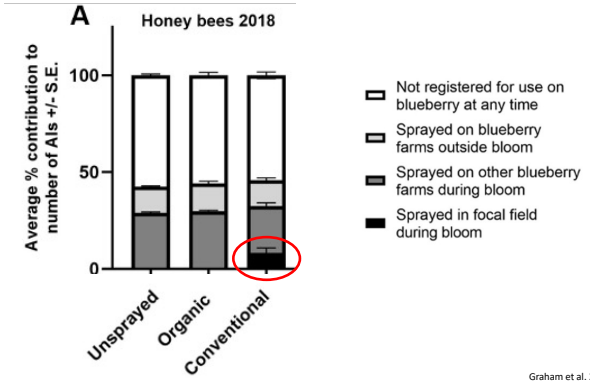
Where are the pesticides coming from?



Graham et al. 2021 *Scientific Reports*

52

Where are the pesticides coming from?



Graham et al. 2021 *Scientific Reports*

53

Where are the pesticides coming from?

- **Many high-risk exposures come from outside of focal farms.**
- **Several high-risk exposures lingering from pre-bloom sprays.**
- **<u>Pesticide exposure is a landscape-scale problem</u>. What does this mean for pesticide labels?**

Graham et al. 2021 *Scientific Reports*

54

Monthly column in American Bee Journal

http://blogs.cornell.edu/mcartlab/notes-from-the-lab/

55

Questions?

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http://blogs.cornell.edu/mcartlab/

NIH National Institutes of Health

USDA United States Department of Agriculture | National Institute of Food and Agriculture

56