Unintended consequences of field crop seed treatments upon honeybees

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Study origins

- Spring 2010: Reports of dead bees at Indiana apiaries, coincided with local corn planting

- Bees exhibited neurotoxic symptoms, analysis of dead bees revealed traces of thiamethoxam/clothianidin in each case

Seed treatments of field crops (primarily corn) are the only major source of these compounds

All corn is treated, most soybeans, canola etc.

Background:
Why care about honey bees?

- Honey is a minor part of how bees benefit our diet
- The following foods are dependent upon pollination, by (mostly) honey bees and other pollinators:

- Apples, oranges, lemons, limes
- Broccoli, cauliflower, cabbage
- Onions, okra
- Blueberries, cherries, cranberries, raspberries
- Cucumbers, squashes, pumpkins
- Cantaloupes, watermelons
- Carrots, canola
- Almonds, macadamia and other nut crops

Determining causes of bee mortality in spring 2010/11

- Samples collected in 2011: dying bees, nectar and pollen from frames of affected hives
- Analyzed using LC/MS-MS,screens for over 100 pesticides/sample

Understanding ppb: Analogies

- Hamburgers: One Big Mac in a chain circling the equator 2.5 times
- Corn: One kernel of corn in a full silo measuring 45' high, 16' wide
- Toilet paper: One sheet in a roll stretching from N.Y.C. to London, England
- Time: One second in 32 years
- Clothianidin (Poncho®): contact LD50: 22-44 ng/bee, oral LD50 = 2.8-3.7 ng/bee, thiamethoxam (Cruiser®) is toxic at similar levels

Results:
Bees and frame contents

- All dead/dying bees had traces of seed treatment insecticides
- Stored pollen from hive with dead bees outside had very high levels of pesticides, lower in "healthy" hives

Sample	Thiamethoxam (Cruiser)	Clothianidin (Poncho)	Metolachlor (Dual)	Atrazine
Dead bees *Mean (SE)*	ND	7.9 (±4.0)	2.4 (±0.8)	5.7 (±1.1)
Healthy bees	ND	ND	ND	3.9
Nectar	ND	ND	0.5, ND	0.3, 0.6
Beebread sick hive	18.5, 22.3	9.1, 12.4	81, 82	34, 39
Beebread healthy hive	2.7, 9.7	2.0, 3.8	26, 31	15, 17

ND = Not detected

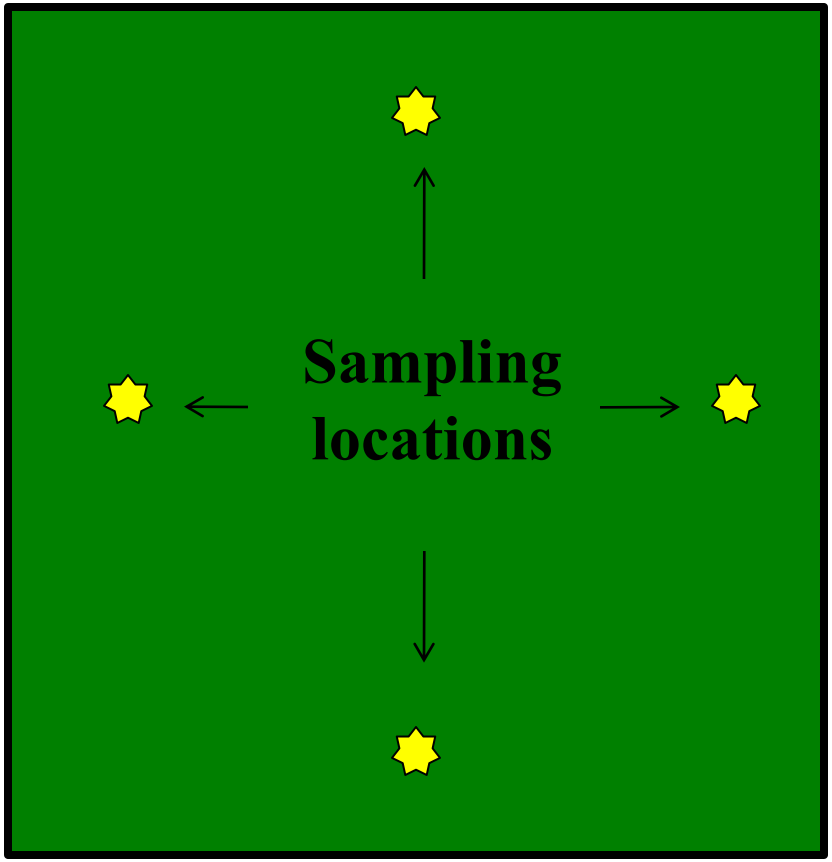
Goals of 2010/11 research

- Investigate how/when honeybees are exposed to neonicotinoids used for treating corn seed

Spring planting = dusty, windy

Methods:
Soil sampling

- Sampled topsoil (upper 2-3”) at 4 locations/field, removed approx. 1 lb. of soil at each
- Fields of known histories were analyzed
- All fields that had been corn = treated seed, soybean = untreated seed
- 5 gram subsample analyzed by LC/MS-MS



Results:
Soil samples

- Soil samples contained clothianidin even 2+ years after application*
- Half-life of clothianidin in soil is listed at 148-1155 days

Source: EPA, Office of Pesticide Programs. Factsheet Clothianidin. 2003. 19 pp.

Field history	Thiamethoxam (Cruiser)	Clothianidin (Poncho)	Metolachlor (Dual)	Atrazine
Corn-corn	ND	6.3	5.9	52
Soy-soy*	ND	9.6	11.1	7.8
Corn-soy	ND	4.9	6.1	8.5
Soy-corn	ND	2.1	ND	22

Dandelions + honeybees

- Agricultural fields have abundant dandelion flowers within and nearby in early spring
- Dandelions are important early-season resource for honeybees
- Sampled flowers to determine whether pesticides are on/in dandelions

Methods:
Dandelion sampling cont'd

- Removed flowers from field borders and first 3-6’ into unplanted fields in early May 2011
- Honeybees foraging on dandelions at time of sampling
- Dandelions from non-ag area served as controls

Results:
Soil and dandelions

- Dandelion flowers from unplanted fields consistently contained neonicotinoids, not found in non-ag samples

Sample: history	Thiamethoxam (Cruiser)	Clothianidin (Poncho)	Metolachlor (Dual)	Atrazine
Dandelions: non-ag area	ND	ND	ND	ND
Dandelions: unplanted cornfields	1.15 (±0.44)	3.75(±1.34)	84(±43)	622(±162)

Corn planting background

- Most planting throughout the Midwest occurs in late April - early May (when fields are dry)
- Most planters use a vacuum system to move/plant seeds
- Treated seeds are sticky - require talc in planter to ensure uniform planting

Planter exhaust

- Virtually all modern planters must use talc (typical) or graphite to plant treated seed
- Some exits with seed, some leaves the system with exhaust, remainder (ca. 30%) must be purged from the system following planting

> **Operating Vacuum (Vacuum Meters)**
>
> - Clean the vacuum system per the Operator's Manual to purge the system of dirt and talc buildup. Dusty planting conditions and heavily treated seed will require the system to be cleaned more often.

Excerpt from John Deere publication: "Ready to plant guide: Optimizing planter performance"

- No information given on how/where to dispose of used talc
- Rates of talc use: 80 grams of talc/bag of corn seed * 28 million bags planted/year
- = 2.24 million kg (5 million pounds) of talc used each year…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Planter cleaning demonstration

Results:
Planter exhaust (used talc)

- Extremely high concentrations of seed coatings found in used talc

Seed type	Thiamethoxam (Cruiser)	Clothianidin (Poncho)	Metalaxyl (Apron)	Trifloxystrobin (Stratego)
Unused talc	ND	ND	ND	ND
Treated seed 1	735, 000 ppb	3,400,000 ppb	116, 000 ppb	66,000 ppb
Treated seed 2	68,000 ppb	10,000,000 ppb	92,000 ppb	50,000 ppb
Treated seed 3	13,240,000 ppb	4,900,000 ppb	263,000 ppb	503,000 ppb
Treated seed 4	70,000 ppb	15,030,000* ppb	131,000 ppb	313,000 ppb
Untreated corn seed	ND	*47,000 ppb*	ND	ND

* = equivalent to 700,000X the contact LD50 (20 ng)

Results:
Used talc (cont'd)

- Talc abrades and attaches to seed coating, particles are very small and potentially mobile
- Sifting large seed pieces out had little effect on toxicity

Seed type	Thiamethoxam (Cruiser 600)	Clothianidin (Poncho 1250)	Metalaxyl (Apron Max)
Mixed seed lot, straight from planter	11,282,000 ppb	2,985,000 ppb	281, 000 ppb
Mixed seed lot, sifted	8,042,000 ppb	5,871,000 ppb	251,000 ppb

Later season effects

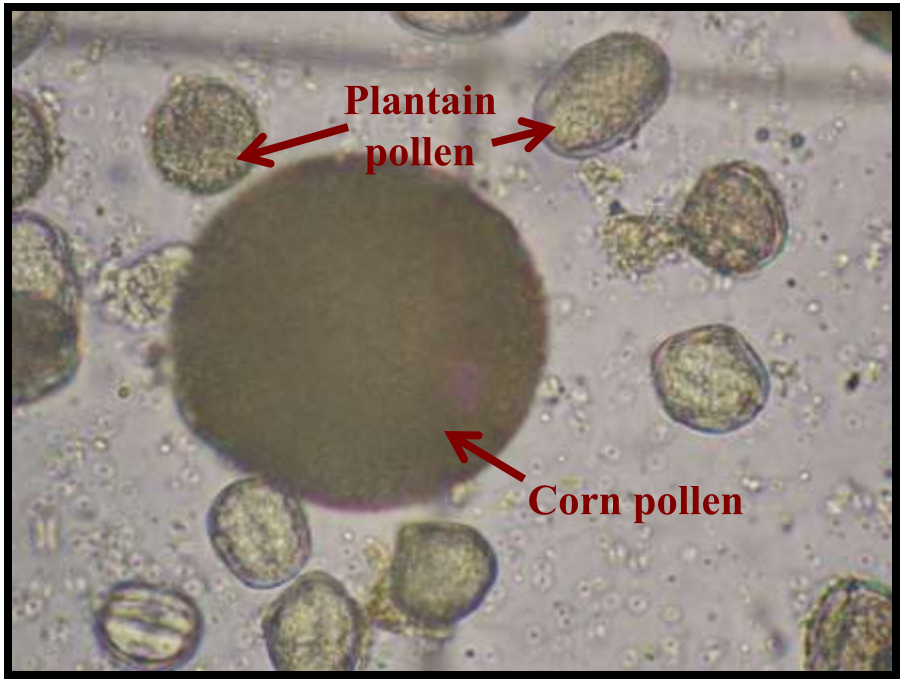
- Neonicotinoids are persistent+systemic: pollen from treated seed expresses low levels of neonicotinoids in other crops (canola)

- Honeybees that consume water droplets from plants grown from treated corn seed will die in lab

- No published studies of corn pollen foraging or effects

Pollen analyses

- Hives placed in/near corn fields with pollen traps installed
- Quantified levels of pesticides in collected pollen and determined fraction of corn pollen collected by bees
- Focused upon period of peak pollen shed



Pollen samples: Treated vs. untreated corn

- Collected pollen from 100 plants in field, grown from treated and untreated seed
- Low levels of neonicotinoids and fungicides detected in pollen grown from treated seeds
- But will bees collect corn pollen?

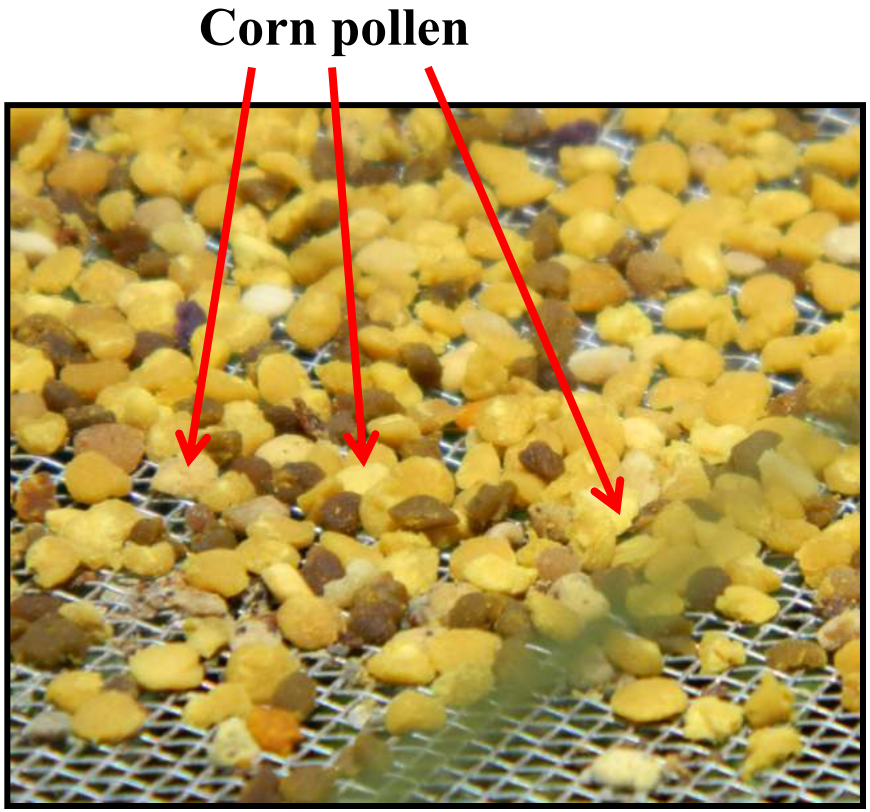
Corn Plant Type	Thiamethoxam (Cruiser)	Clothianidin (Poncho)	Metalaxyl (Apron)
Treated seed	2.1 ppb	2.6 ppb*	3.7 ppb
Untreated seed	ND	ND	ND

* Equivalent to 2.6 ng/gram, the oral LD50 for clothianidin is 2.8 ng of clothianidin/bee

Results:
Bee-collected pollen analysis

- Bees collected surprisingly high levels of corn pollen when available
- Many samples left to analyze…

HIVE ID	Range: % corn pollen (mean±SE)
Untreated 1	16 - 82 (58±12)
Untreated 2	9 - 73 (48±11)
Treated 1	18 - 76 (48±12)
Treated 2	3 - 43 (24±7)
Means/totals	44.5 (± 5.7)



Bee-collected pollen analysis: Pesticides

- Half of the pollen samples analyzed to date contained thiamethoxam, clothianidin or both
- All contained fungicides, applied aerially during pollen shed
- Fungicides in this family synergize neonicotinoid toxicity in honeybees

	Mean concentrations (SE), ppb (# samples with detection)			
HIVE ID	**Thiamethoxam (Cruiser)**	**Clothianidin (Poncho)**	**Propiconazole (Tilt)**	**Azoxystrobin (Quadris)**
Untreated 1	ND	4.0 (1/5)	17.5 (±6.0) (5/5)	29.2 (±13.5) (5/5)
Untreated 2	ND	4.9 (±2.3) (4/5)	10.8 (±1.9)(5/5)	15.6 (±4.2) (5/5)
Treated 1	ND	ND	9.7 (±3.6) (5/5)	19.7 (±11.6) (5/5)
Treated 2	2.18 (3/5)	27.8 (±15.4) (4/5)	7.5 (±1.2) (5/5)	12.1 (±4.7) (5/5)

Seed treatments are labeled for control of many pests…

Corn rootworm

Seedcorn maggot

Wireworm

Black cutworm

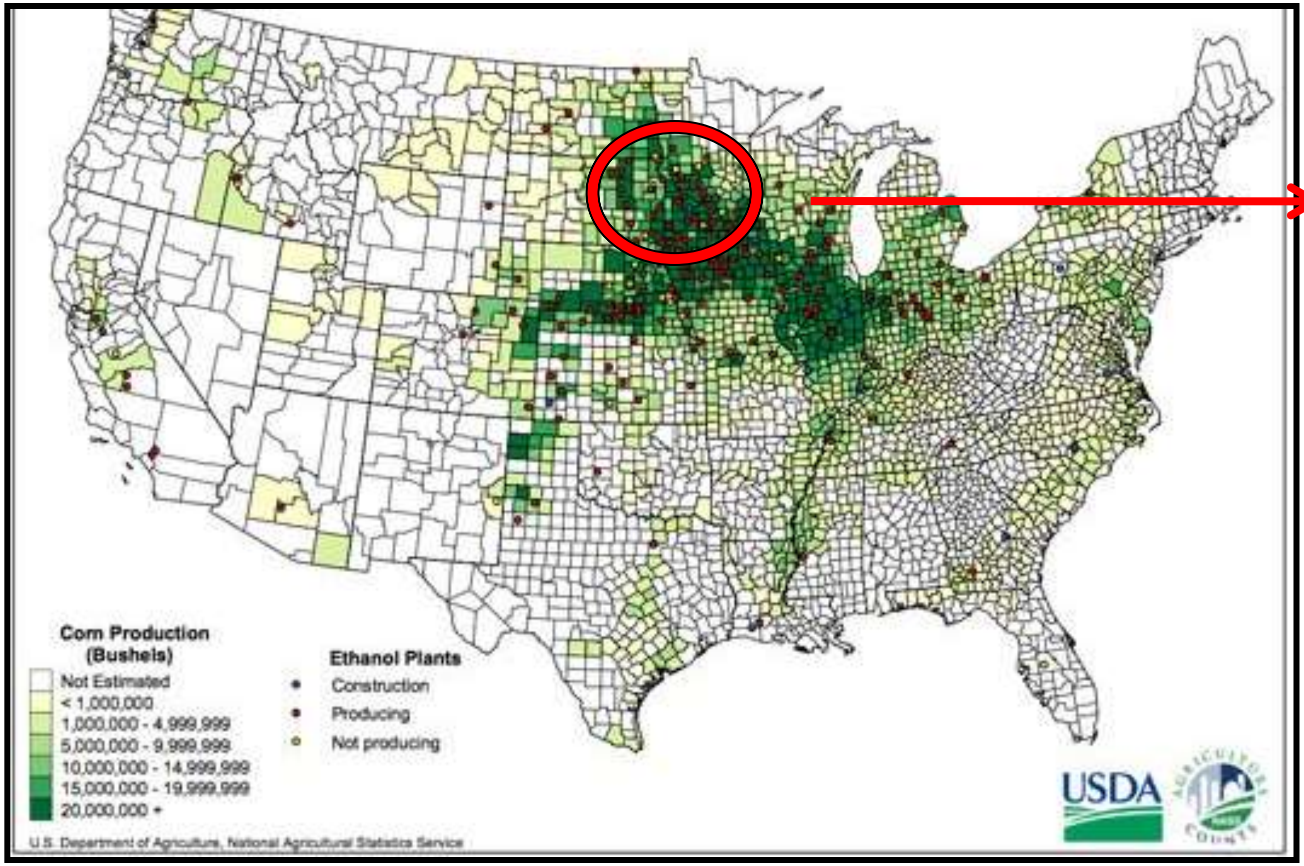
White grub

And many, many more!

Benefits of neonicotinoid-treated seed?

- Labeled for a variety of early-season pests, mainly soil insects
- Efficacy is highly variable, very few independent efficacy studies
- Do we need seed treatment on all annual crops? What are the costs vs. benefits?
- IPM? Applications of seed treatments are not based on any monitoring/thresholds etc.

Where/when do bees and corn overlap?



Most managed pollinators in the US spend May through October in upper Midwest

Summary

- Honey bees living near fields where treated seeds are planted have multiple routes of exposure to seed treatment insecticides throughout spring and summer
- Exposure may be by contact (dust, soil), by ingestion (corn and other pollen), and is likely a combination
- Talc exhaust is highly toxic, mobile and the most obvious target for mitigation

Next steps

Now:

- **Determine how to limit movement of dust off of planting equipment and away from planting area**

Later:

- **Examine when/where seed treatments are necessary in crop production**

  This limits non-target exposure, increases durability of insecticides (avoid resistance), maximizes producer return on investment

Questions?