Neonicotinoid seed treatments and soybean (and corn) yields in the Midwest

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Insecticidal seed treatments = Neonicotinoids (NSTs)

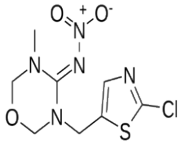
<u>Most large acreage crops are grown from treated seed (clothianidin or thiamethoxam):</u>

- *Virtually all corn* (95+ million acres)
- *75% of soybeans* (70+ million acres)
- *Canola, wheat, cotton, sorghum*

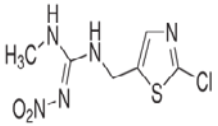
Rapid registration/adoption in last 10-14 years

Total of ca. 150-200 million acres annually

Neonicotinoids



Thiamethoxam



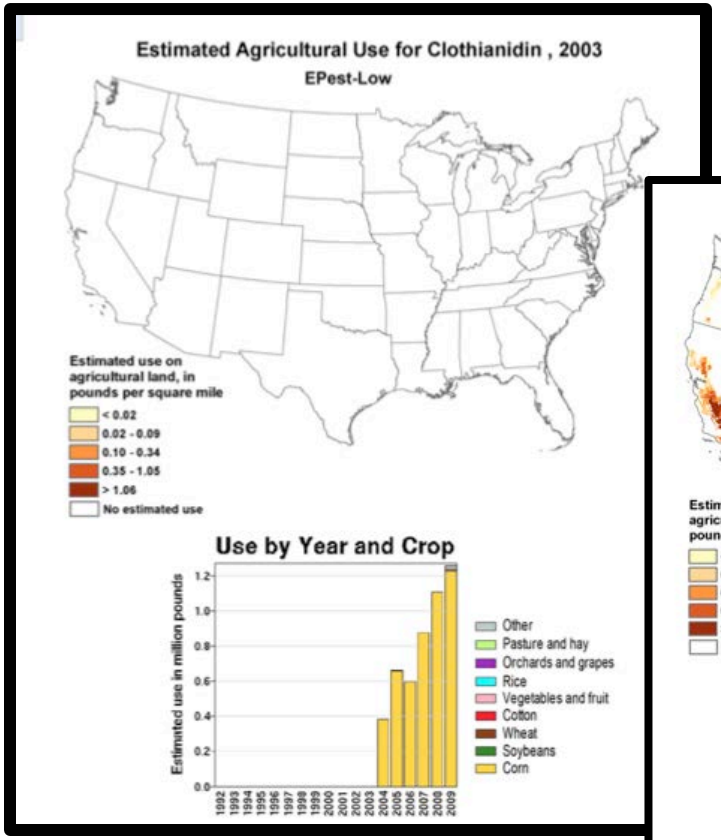
Clothianidin

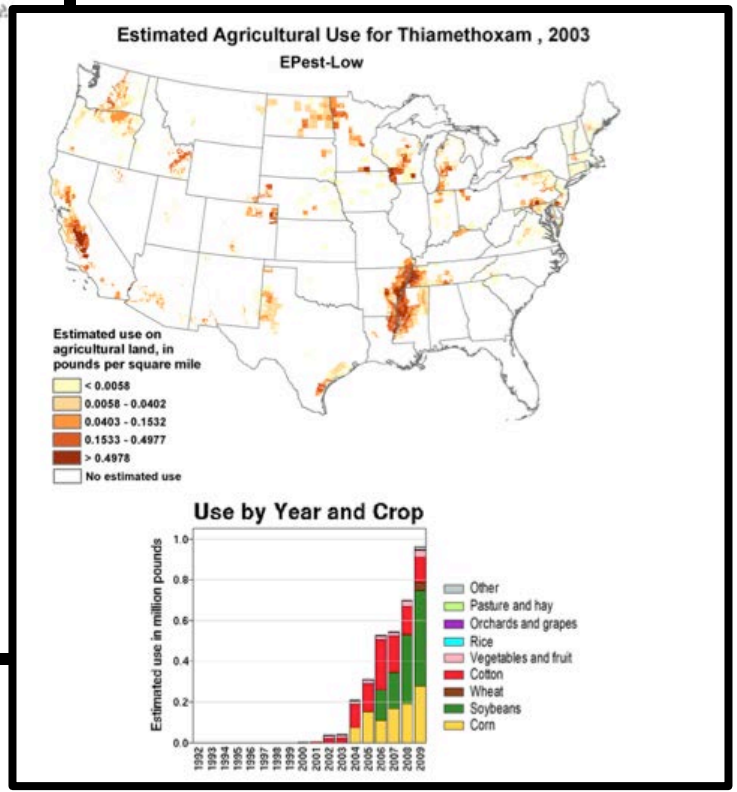
Synthetic derivatives of nicotine; potent neurotoxins that act on the nervous systems of insects

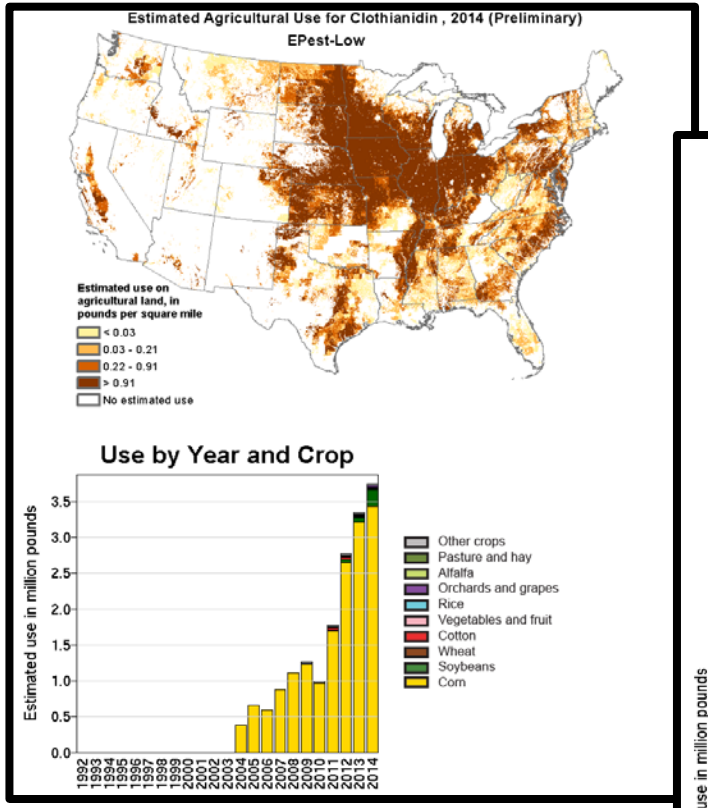
Effective against a broad range of insects, especially sucking insects

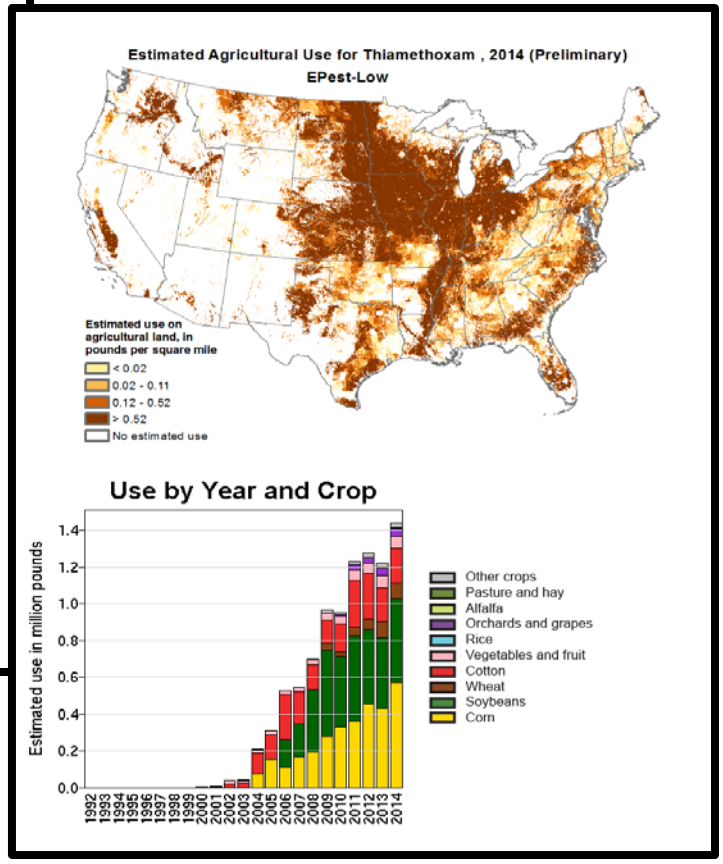
<u>Approved and used widely based on:</u>

- **Low vertebrate toxicity**
- **High water solubility** = allowing systemic action in plant tissues and movement through plant


Estimated Agricultural Use for Clothianidin , 2003
EPest-Low
Estimated use on agricultural land, in pounds per square mile
< 0.02
0.02 - 0.09
0.10 - 0.34
0.35 - 1.05
> 1.06
No estimated use
Use by Year and Crop
Estimated use in million pounds
Other
Pasture and hay
Orchards and grapes
Rice
Vegetables and fruit
Cotton
Wheat
Soybeans
Corn


Estimated Agricultural Use for Thiamethoxam , 2003
EPest-Low
Estimated use on agricultural land, in pounds per square mile
< 0.0058
0.0058 - 0.0402
0.0403 - 0.1532
0.1533 - 0.4977
> 0.4978
No estimated use
Use by Year and Crop
Estimated use in million pounds
Other
Pasture and hay
Orchards and grapes
Rice
Vegetables and fruit
Cotton
Wheat
Soybeans
Corn


Estimated Agricultural Use for Clothianidin , 2014 (Preliminary)
EPest-Low
Estimated use on agricultural land, in pounds per square mile
< 0.03
0.03 - 0.21
0.22 - 0.91
> 0.91
No estimated use
Use by Year and Crop
Estimated use in million pounds
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
Other crops
Pasture and hay
Alfalfa
Orchards and grapes
Rice
Vegetables and fruit
Cotton
Wheat
Soybeans
Corn


Estimated Agricultural Use for Thiamethoxam , 2014 (Preliminary)
EPest-Low
Estimated use on agricultural land, in pounds per square mile
< 0.02
0.02 - 0.11
0.12 - 0.52
> 0.52
No estimated use
Use by Year and Crop
Estimated use in million pounds
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
Other crops
Pasture and hay
Alfalfa
Orchards and grapes
Rice
Vegetables and fruit
Cotton
Wheat
Soybeans
Corn

We use NSTs on most soybeans… but does this practice pencil out?

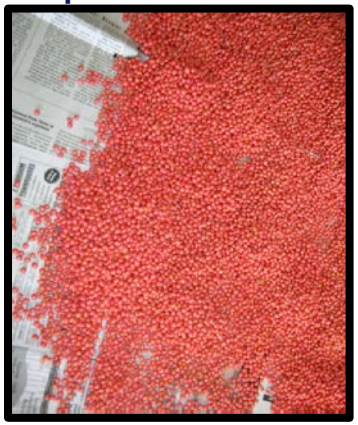
- Using NSTs under an IPM strategy is challenging due to unknowns about next year (i.e. order seed in fall, don't know what the next year will bring!)

- Consequently, the approach to NST use in North American annual crops since their introduction in the early 2000's has been a test of an 'insurance-based' approach to insect pest management ("If pest insects show up, we'll be ready for them")

- Let's look at the data!

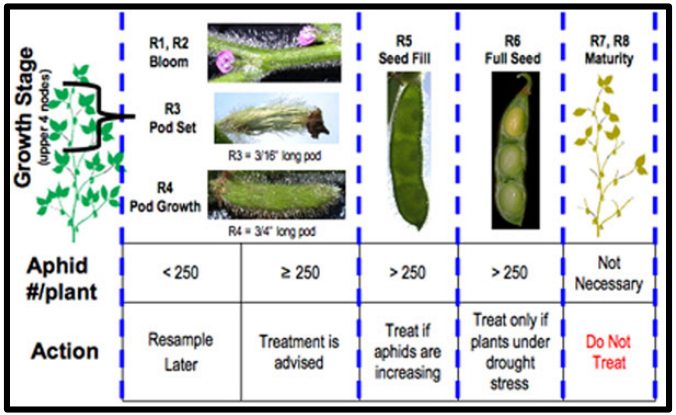
Insect pests of soybean? A short list!

- Soybean aphid remains the key insect pest
- Long-standing threshold is 250 aphids/plant, treat if exceeded
- How does this compare with seed treatment approach?



NST

VS



IPM

Neonicotinoid-treated seed for soybean aphid control

- Determining the pest-killing window: newest unifoliates and trifoliates collected throughout season, thiamethoxam (Cruiser) concentrations measured in leaf tissues
- Goal: determine overlap of insecticide concentrations with damaging soybean aphid populations

Stage	Days post planting	Untreated	Thiamethoxam
VE*	8	31.4 (3.6)	6509.3 (1204.3)
VC*	11	13.7 (8.2)	9075.0(4550.6)
V1*	14	8.0 (2.7)	1366.1 (405.7)
V1/V2*	18	39.3 (26.4)	151.3 (67.4)

LC/MS-MS concentrations (ppb) of thiamethoxam from foliage samples (n=88).

*** = significant differences detected using ANOVA, *F*=20.03; df=1,120; *P*<0.001.**

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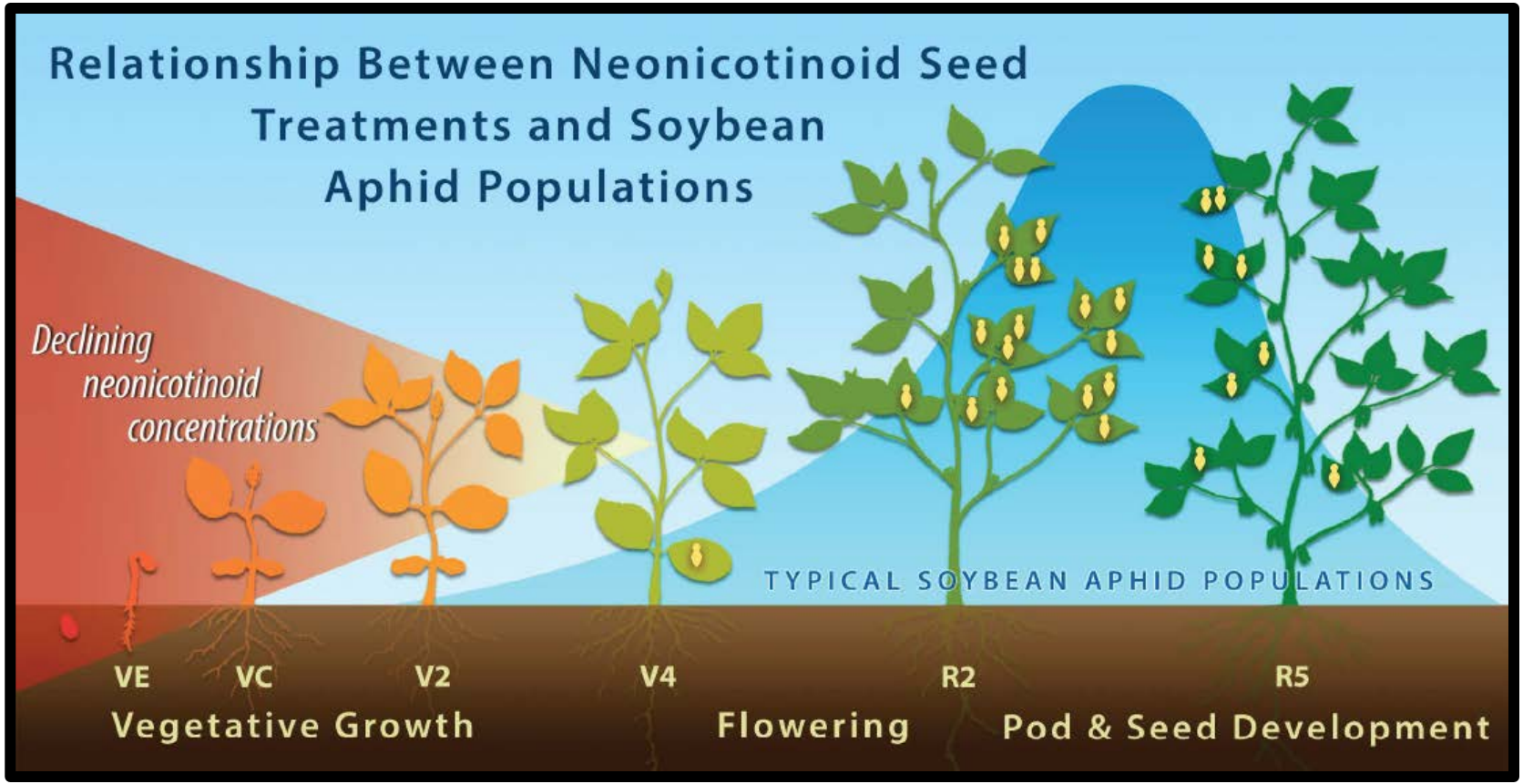
V1*	14	8.0 (2.7)	1366.1 (405.7)
V1/V2*	18	39.3 (26.4)	151.3 (67.4)
V2	20	0.2 (0.1)	10.0 (4.3)
V2/V3	23	0.7 (1.3)	1.0 (0.3)
V3	26	2.3 (3.1)	6.7 (4.1)
V5	29	0.1 (0.1)	0.5 (0.08)
V6	32	2.0 (3.8)	0.7 (0.2)
R1	35	0.02 (0.01)	0.1 (0.07)
R1	38	0.08 (0.1)	0.08 (0.003)

Typical soybean aphid arrival in Indiana is R2/R3 (earlier in WI?)

No differences for most of growing season

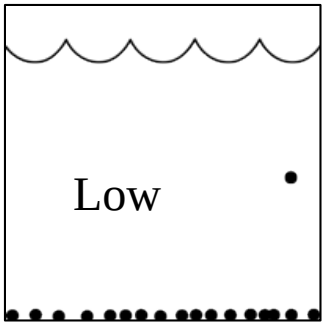
2017 study: IPM vs. seed treatments
Break-even probabilities

- Two year, seven state field study (IN, IA, KS, ND, SD, WI, MN), include all input costs vs. yield
- 2012 = no locations over soybean aphid threshold, IPM option had higher break-even probability (13.71% for IPM vs. 4.77% for NST/Cruiser)
- 2013 = soybean aphids over threshold in some locations, IPM option had higher break-even probability (98.13% IPM vs. 59.86% NST/Cruiser)
- Overall, net return of $121.07/ha (IPM) vs. $6.97/ha (Cruiser-treated seed)

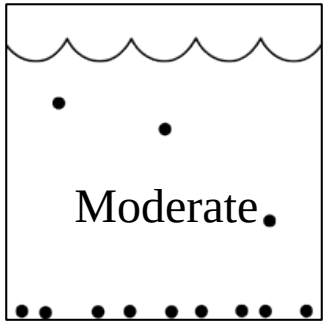

Relationship Between Neonicotinoid Seed Treatments and Soybean Aphid Populations
Declining neonicotinoid concentrations
TYPICAL SOYBEAN APHID POPULATIONS
VE
VC
V2
V4
R2
R5
Vegetative Growth
Flowering
Pod & Seed Development

Why so little neonicotinoid in our target plants? Physics!

Water solubility comparisons



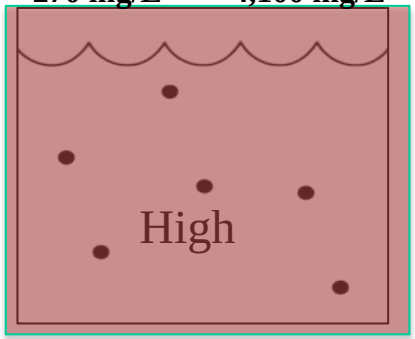
Lambda-cyhalothrin (Warrior, pyrethroid insecticide) 0.005 mg/L



Atrazine (triazine herbicide) 0.03 mg/L

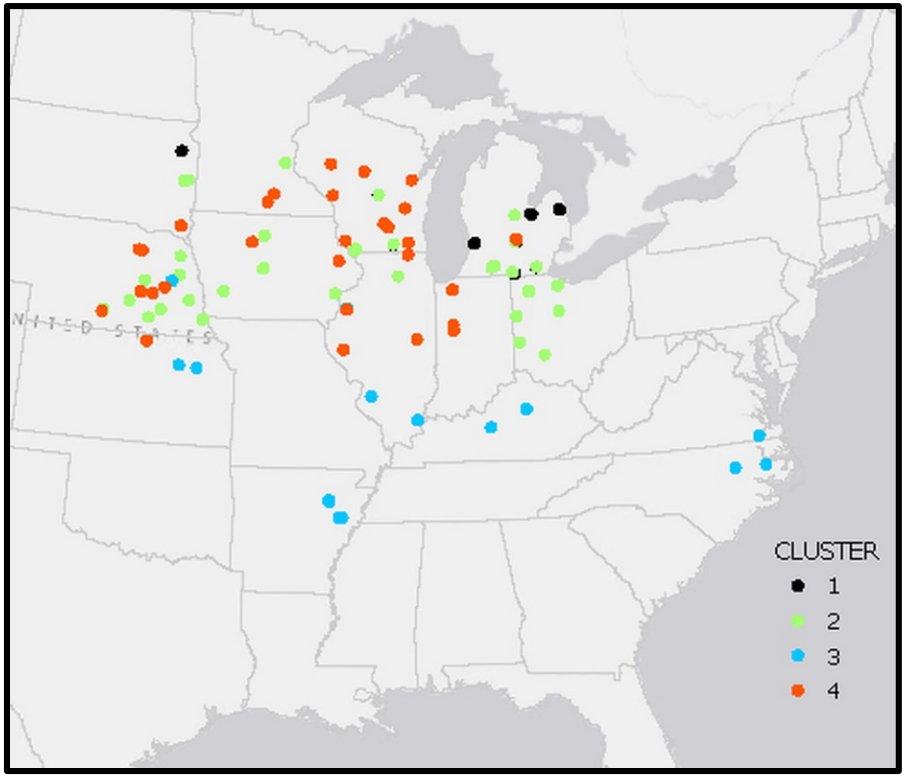
Clothianidin (Poncho) = 270 mg/L

Thiamethoxam (Cruiser ST) = 4,100 mg/L



Region-wide study: Methods

- Soybean yield data were aggregated from 194 replicated field experiments established from 2006 to 2017, within 14 states
- Total of 11,146 plot-specific yields



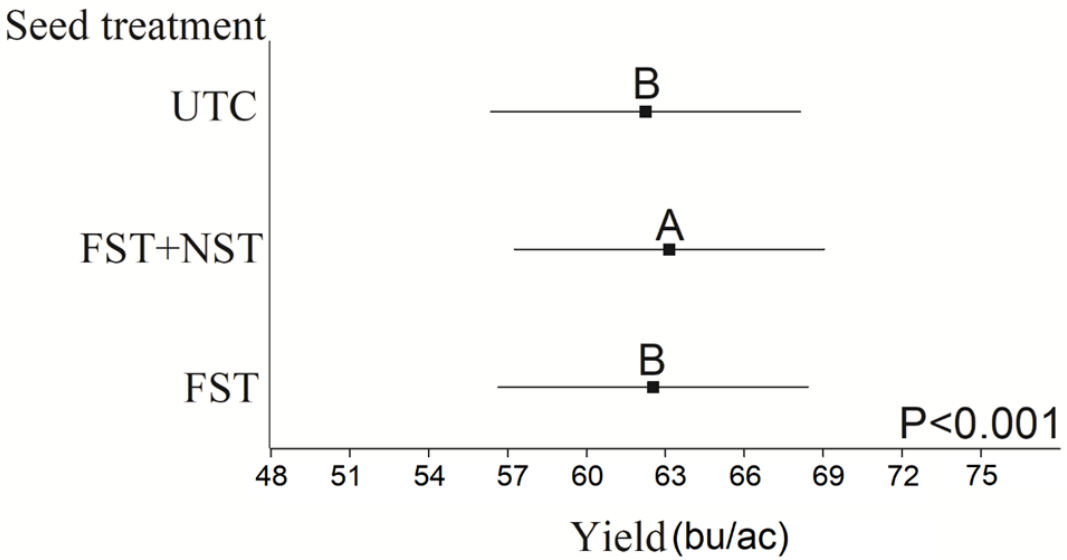
Methods *cont.*

- FST (Fungicide only), FST+NST (fungicide + insecticide), and untreated controls (UTC) were applied in all locations

- **Partial economic analysis**: yield in every trial with seeding rate of 100,000, 140,000, or 180,000 seeds/ac were converted to profit for five soybean price scenarios: 8, 11, 14, 17, and 20 $/bu.

- The profit for each scenario (seeding rate × seed treatment (FST, FST+NST, UTC) × soybean price) was used as dependent variable in mixed model analysis.

Results



SCIENTIFIC REPORTS

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Neonicotinoid seed treatments of soybean provide negligible benefits to US farmers

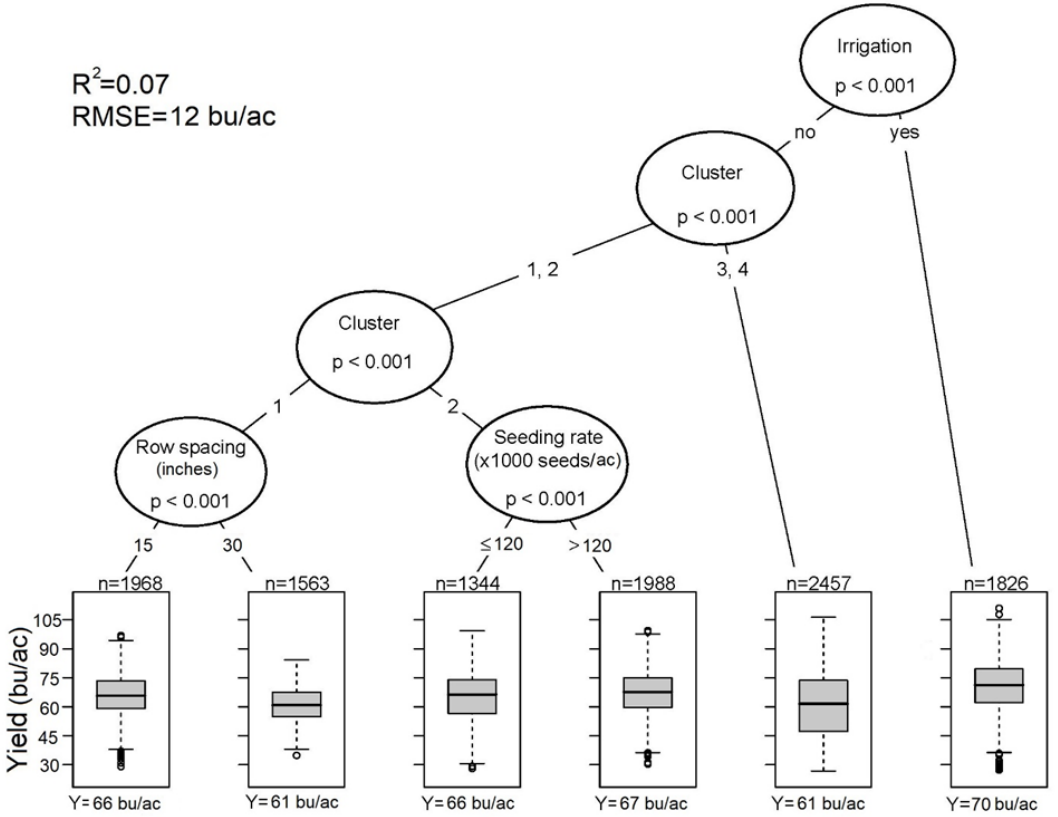
Spyridon Mourtzinis, Christian H. Krupke, Paul D. Esker, Adam Varenhorst, Nicholas J. Arneson, Carl A. Bradley, Adam M. Byrne, Martin I. Chilvers, Loren J. Giesler, Ames Herbert, Yuba R. Kandel, Maciej J. Kazula, Catherine Hunt, Laura E. Lindsey, Sean Malone, Daren S. Mueller, Seth Naeve, Emerson Nafziger, Dominic D. Reisig, William J. Ross, Devon R. Rossman, Sally Taylor & Shawn P. Conley

Scientific Reports **9**, Article number: 11207 (2019) | Cite this article

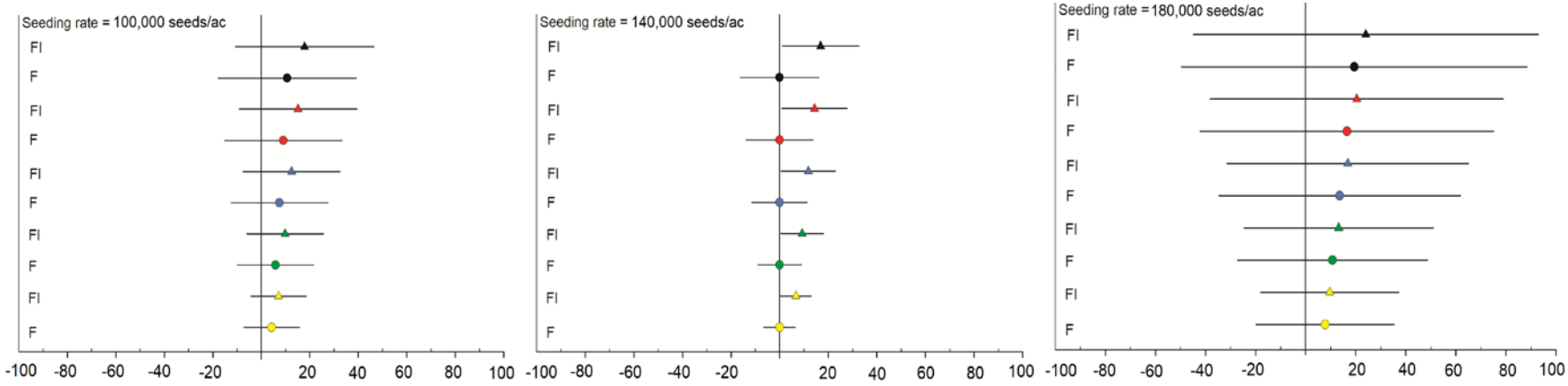
Soybean yield due to applied seed treatments across the entire region. The black rectangles show the mean yield and the lines extend to the lower and upper 95% confidence limits

Results *cont.*

Management practices had a greater influence than seed treatments



Results *cont.*



Breakeven cost of fungicide only (F - circles), fungicide + insecticide (FI - triangles) seeds compared to untreated (line at 0 $/a) for 8 $/bu (yellow), 11 $/bu (green), 14 $/bu (blue), 17 $/bu (red), and 20 $/bu (black) soybean price scenarios. The lines extend to the lower and upper 95% confidence limits of each income difference (FST-UTC and FST+NST-UTC)

What about corn?

Seed treatments are labeled for control of…

Corn rootworm

Seedcorn maggot

Wireworm

Black cutworm

White grub

And many more…

Seed treatments and pest management: 2012 and 2013 efficacy study at 3 sites

Hybrid: DKC 62-61 RR2

Treatments:

1. Naked seed
2. Treated with Poncho 250 (0.25 mg clothianidin/seed) + fungicide
3. Treated with Poncho 1250 (1.25 mg clothianidin/seed) + fungicide

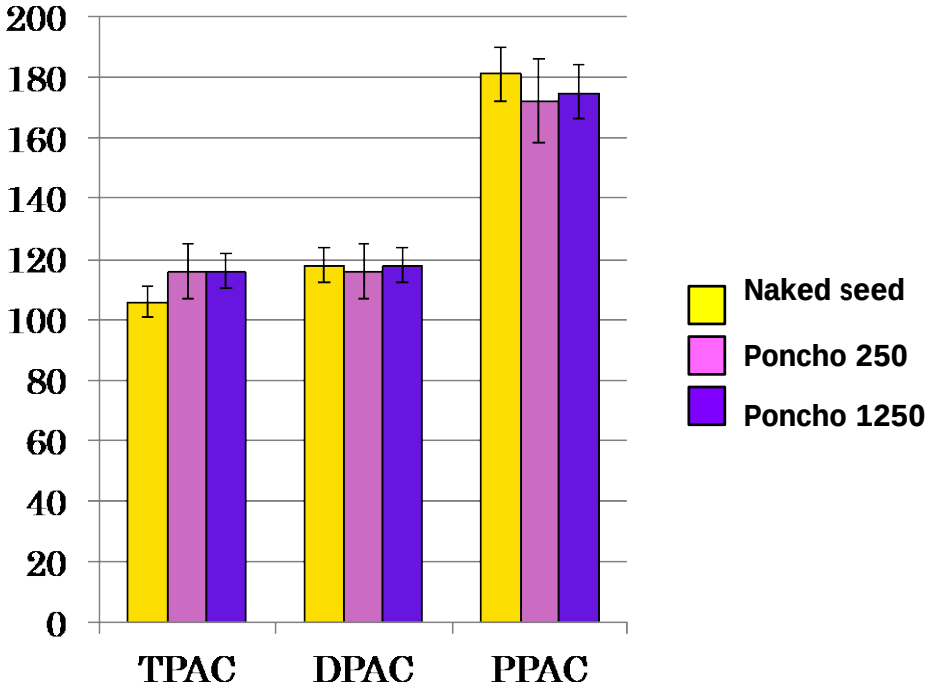
Data collected:

- Stand counts, plant heights
- Root injury
- Yield

Treated seed efficacy: Yield (bu/acre) 2012

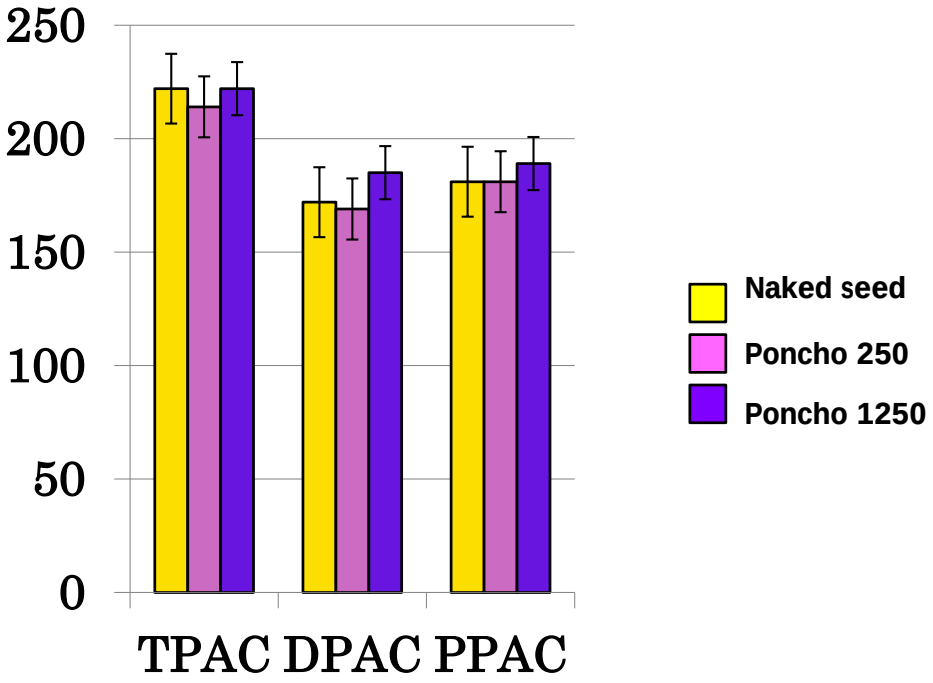
No statistical differences found

<u>Harvest dates</u>:
TPAC: 11/8/12
PPAC: 11/11/12
DPAC: 11/16/12



Treated seed efficacy: Yield (bu/acre) 2013

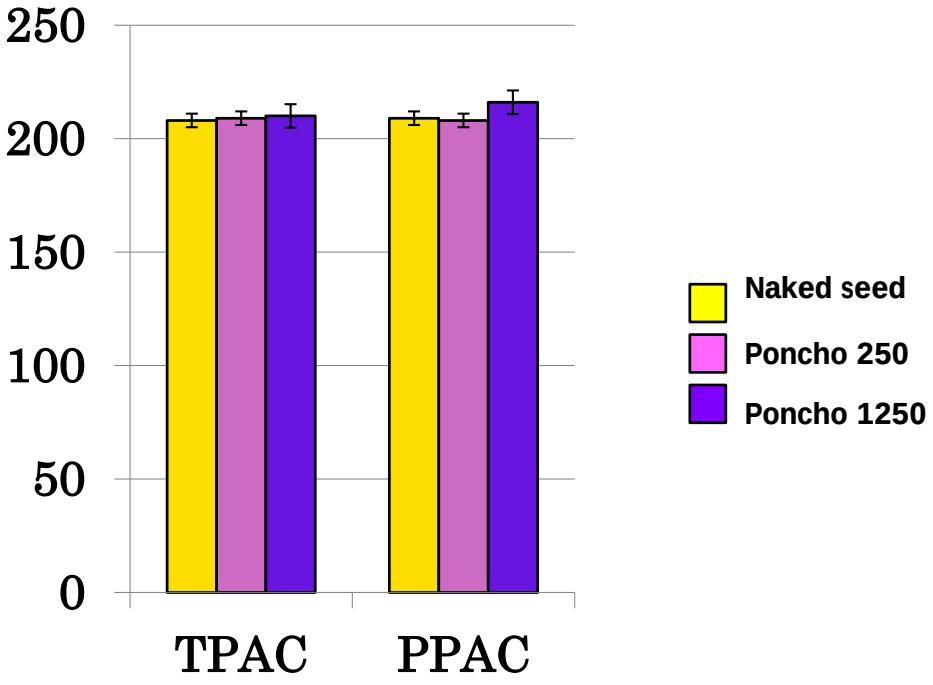
No statistical differences found



Harvest dates:
TPAC: 11/14/13
PPAC: 11/15/13
DPAC: 10/25/13

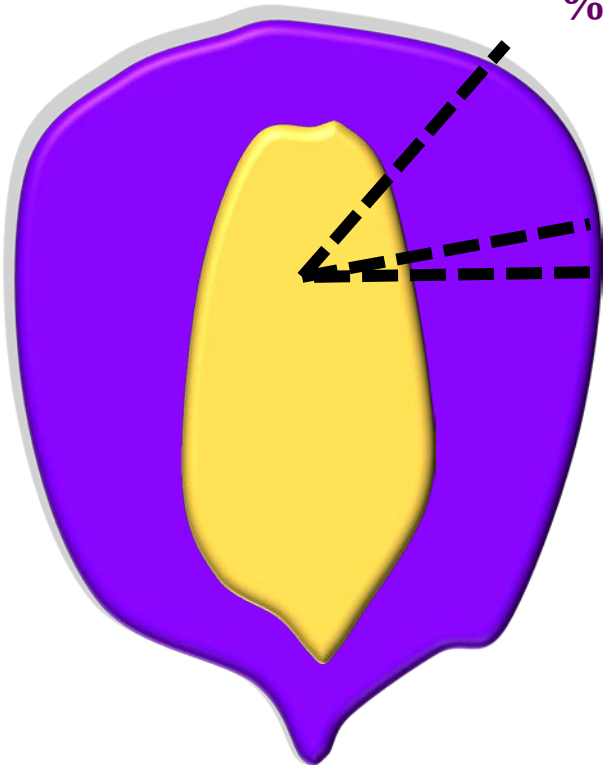
Treated seed efficacy: Yield (bu/acre) 2014

No statistical differences found



Harvest dates:
TPAC: 11/12/14
PPAC: 10/28/14

Fate of neonicotinoids applied to corn seeds?



% taken up by plant?

5-10% lost as dust at planting

Insecticidal seed treatments:

Defining the “pest management window”

Hybrid: DKC 62-61 RR2

Treatments:

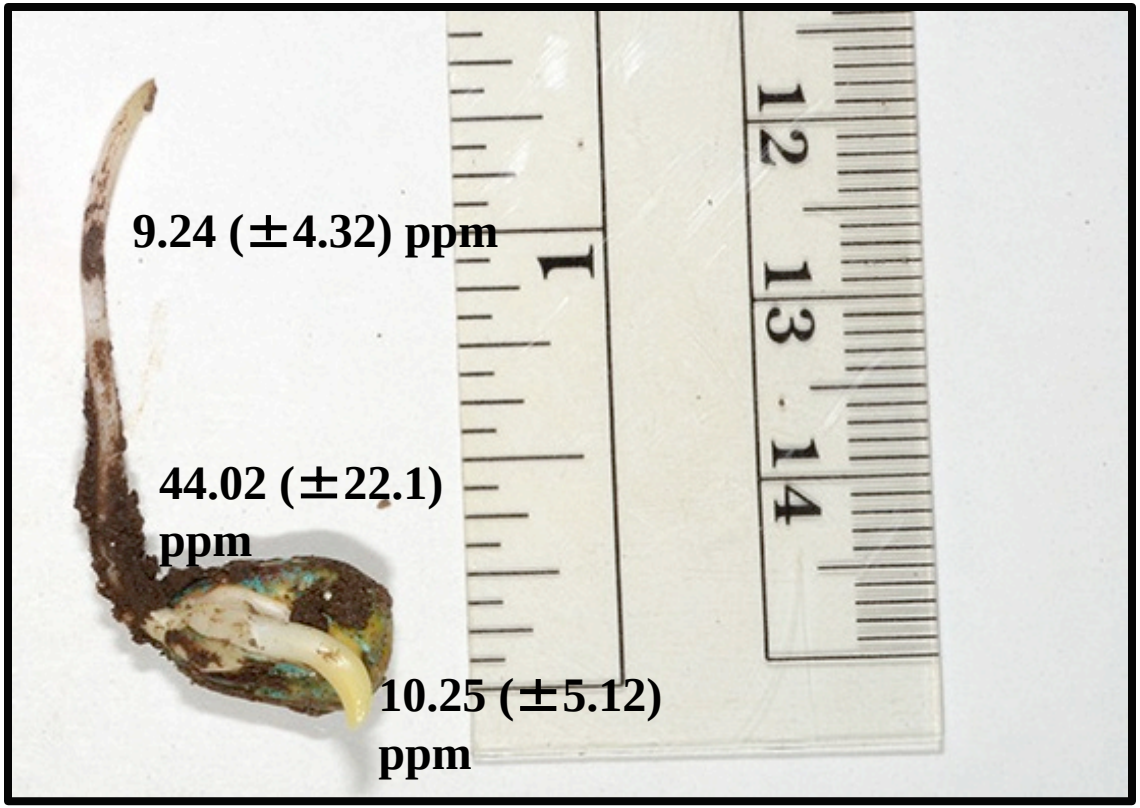
1. Naked seed*
2. Fungicide only*
3. Low rate: Poncho 250 (0.25 mg clothianidin/seed) + fungicide
4. High rate (“Rootworm rate”): Poncho 1250 (1.25 mg clothianidin/seed) + fungicide

Data collected:

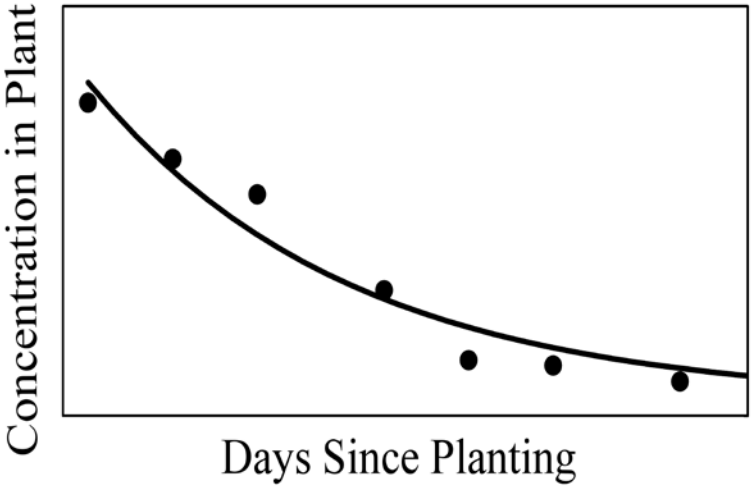
- 10 plants removed/photographed, 3X/week
- Presence of pests/damage documented
- Root, shoot and seed homogenized and neonicotinoid content measured

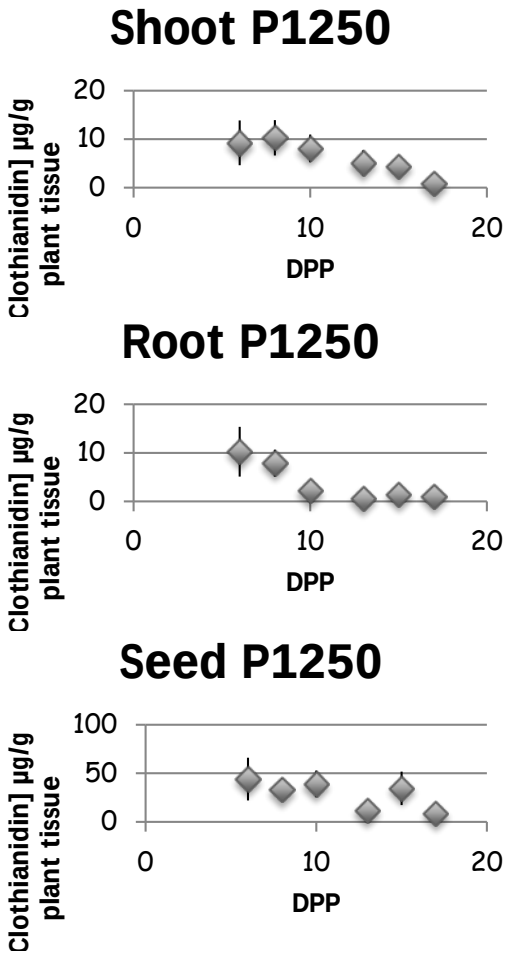
Clothianidin concentrations: May 12 (6 days after planting)

P1250 = 1.25 mg clothianidin/kernel

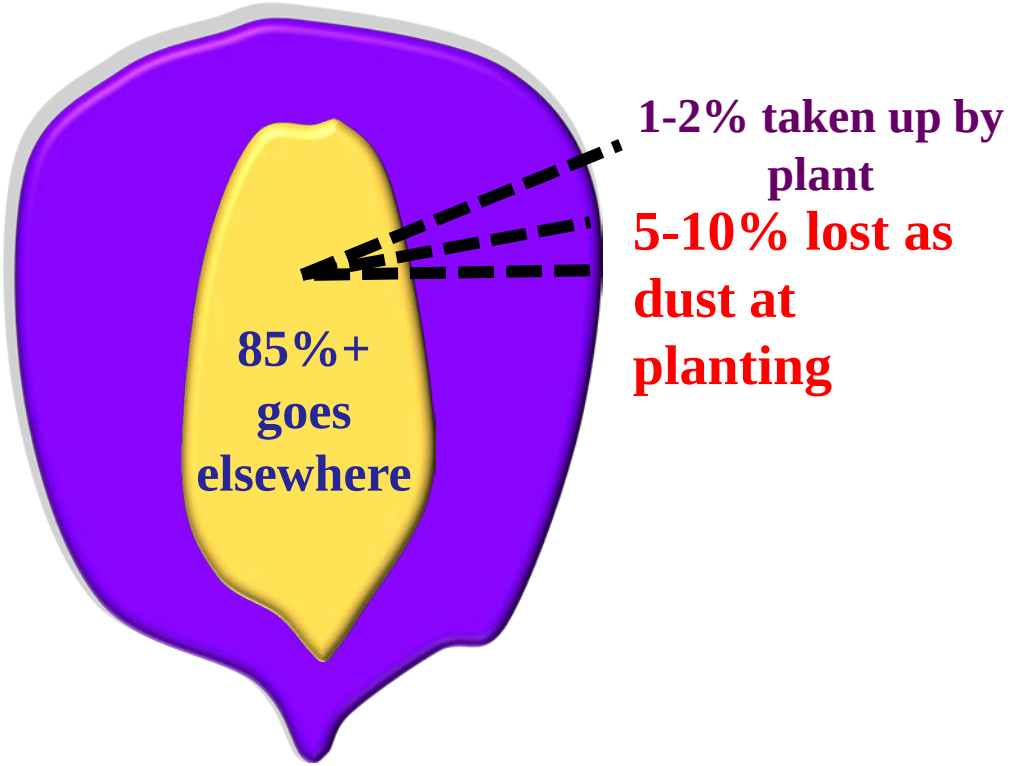


Neonicotinoid concentrations in plant *rapidly* decline after planting

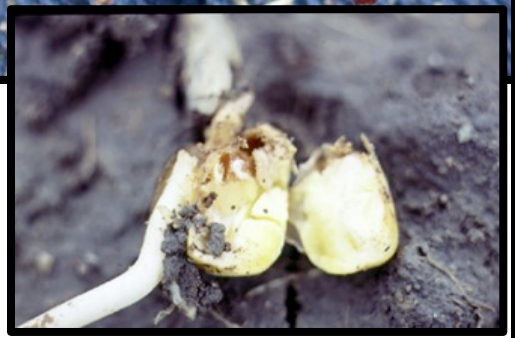




Fate of neonicotinoids applied to corn seeds



Seed/Seedling Feeders/Damage Observed?



Seed/Seedling Feeders/Damage Observed?

None

Conclusions: soybeans

- The lack of consistent economic yield benefits in both single pest studies (soybean aphid) and across the region (multi pest) highlight that NSTs usually won't pay off for soybean farmers
- Few pests + a short window of activity = low chance of economic benefit
- Adjusting other soybean management practices, such as planting date, row spacing and seeding rate, appear to have a greater potential to increase yields across the entire examined region compared to neonicotinoid use

Conclusions: corn

- Fewer studies due to lack of untreated corn seeds for research. So far, no indications that NSTs pay off for corn farmers
- Few pests + a short window of activity = low chance of economic benefit
- Corn seed is not widely available without NSTs. Less opportunity to save $ here, but recommend the lowest/cheapest rate of NST if Bt hybrids planted


The End