# Notes from the Lab:

## The Latest Bee Science Distilled

by Scott McArt and Travis Grout

### *Neonicotinoid insecticides: When there's risk to bees, when there are economic benefits to users, and when there are viable replacements*

Neonicotinoid insecticides. If you're like many people who we interact with, you just read those two words and already have an opinion. Perhaps such a strong opinion that there's little point to us writing more.

But for those brave souls who are willing to wade into the science on neonicotinoids (neonics, for short), here's your chance. We just published a 432-page report in which we comprehensively synthesized all literature on risk to pollinators (>400 peer-reviewed studies regarding exposure to and effects from neonics) and economic benefits to farmers/applicators (>5,000 paired neonic/control field trials) for each context in which neonics are used. In addition, we summarized all application contexts in which neonicotinoid insecticides could be reliably replaced by alternative chemical insecticides or non-chemical pest control technologies or techniques.

So, for our thirty-third Notes from the Lab, we're going to summarize the main take-home messages from **"Neonicotinoid insecticides in New York: Economic benefits and risk to pollinators,"** written by us and freely available for download at: https://pollinator.cals.cornell.edu/pollinator-research-cornell/neonicotinoid-report/.

**Why did we write this report?** Two reasons. First, like many of you, we've been surprised by the lack of a comprehensive synthesis on this topic that's relevant to policy makers. A synthesis that quantifies risk to pollinators ***and*** benefits to farmers/applicators for each context in which neonics are used. There is potentially risk to pollinators from every chemical insecticide, and there are potentially economic benefits to users for every chemical insecticide. But how much risk is there from neonics? And how large are the benefits?

Second, here in New York, we have a governor and state agencies that are committed to ensuring our Pollinator Protection Plan (PPP) is more than just a list of guidelines. In addition to surveying wild pollinators, improving habitat, working with beekeepers to improve management practices, and many other actions, there is real money being put toward research on poorly understood or controversial topics, including pesticides. Since the state's PPP was initiated in 2016, New York has allocated $1.2 million to applied research so we can improve our understanding of factors shaping pollinator health. And that includes neonicotinoids.

**Why is this report unique?** The scope of the report is limited to direct economic benefits to users and risk to pollinators. Thus, it is intended to complement existing studies and risk assessments, particularly the comprehensive reviews of neonicotinoid active ingredients conducted by the U.S. Environmental Protection Agency (USEPA). At the same time, the report is unique (and hopefully useful for policy makers!) since it summarizes new analyses and quantifies benefits to users and risk to pollinators in a side-by-side manner for the five major application contexts in which neonics are used: field crops (corn, soybean, wheat); fruit crops (e.g., apple, strawberry, blueberry); vegetable crops (e.g., squash, pumpkin); ornamentals, turf, & landscape management (e.g., golf courses, ornamental plant nurseries); and conservation & forestry (e.g., control of hemlock woolly adelgid in forests).

**OK, let's get to it. What did we find regarding risk to pollinators?** For risk, lots of exposure data exist for field crops, while less is known regarding neonicotinoid exposures in tree fruits, vegetables, and turfgrass & ornamentals settings. And no exposure data exist that are relevant to pollinators in conservation & forestry settings. This means we have better insight about risk in field crops compared to all other settings.

Taking an LOEC approach to quantifying risk (i.e., using Lowest Observable Effects Concentrations from the peer-reviewed literature for neonic impacts on honey bees to set the bar for what's defined as risk), the 4-panel figure in Figure 1 shows when risk occurs in each setting. All the blue data points above the red line indicate risk, while all the data below the red line indicate no risk. In and near corn and

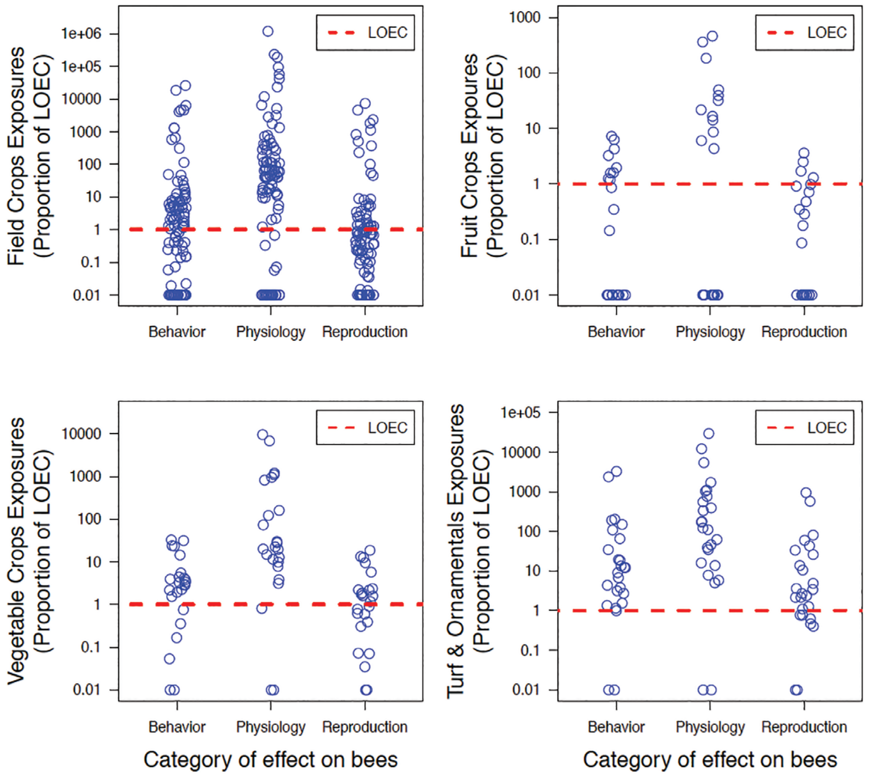


**Fig. 1** *Quantitative neonicotinoid exposures to bees in field crops, fruit crops, vegetable crops, and turf & ornamentals settings expressed as a proportion of the lowest observed effect concentrations (LOECs) for adverse impacts on honey bee behavior, physiology, and reproduction. Dashed line (at y = 1) indicates the LOEC for each response. Thus, all data points above the dashed line are above the LOEC and indicate risk, while all data below the dashed line are below the LOEC and indicate no risk. Mean values for each individual study and setting are represented by open blue circles; each mean value includes all neonicotinoid exposure data (including zero values) from each study. Note that because the log of zero is undefined, all zero values (i.e., when no neonicotinoids were found) were set to 0.1 in this figure. Data points are jittered in each effects category to improve visualization.*

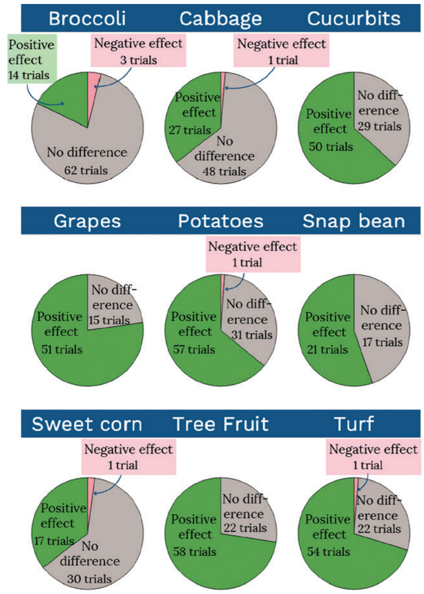


**Fig. 2** *Number of North American field trials reporting significantly better performance (green), significantly worse performance (red), or no significant difference (gray) in terms of yield, crop damage, or pest control for neonicotinoid-treated plots compared to no-insecticide controls.*

soybean fields that are planted with neonicotinoid-treated seeds, 74% of exposures are likely to impact honey bee physiology (cellular respiration), 58% of exposures are likely to impact honey bee behavior (worker memory and foraging efficiency), and 37% of exposures are likely to impact honey bee reproduction (egg laying and survival of new queens). With 96 exposure assessments, we have high confidence in these results; risk from neonics is often high in field crops settings.

Risk can also be high in other settings, but less data exist (i.e., there are fewer blue data points compared to field crops in Figure 1). Therefore, we have less confidence about conclusions regarding risk in these settings. This is an important conclusion in and of itself; we actually don't know much about risk to pollinators from neonicotinoid insecticides in most application contexts because few studies have quantified exposure in these contexts. In other words, while there are literally hundreds of studies that have assessed hazard from neonics (i.e., studies that dose bees with neonics and assess how those doses impact mortality, reproduction, behavior or physiology), surprisingly few studies have assessed exposure to bees in the settings where neonics are used. Since risk is the product of hazard and exposure, we're therefore often limited in what we can say about risk without knowing more about exposure.

That said, there are three additional take-home messages regarding risk. First, risk from neonicotinoids used on cucurbits (e.g., squash, pumpkin) result in exposures that are likely to impact honey bee reproduction in 85% of cases. The USEPA has recently recognized the high risk of neonicotinoids in cucurbits, issuing a recommendation to prohibit use of imidacloprid-, clothianidin-, and thiamethoxam-based products on cucurbits between vining and harvest to protect pollinators. Our analysis extends this window before the vining stage, since applications before or during planting (i.e., treatments applied to soils before seeding or at the time of transplanting) result in exposures known to impact honey bee reproduction.

Second, exposures in ornamentals (i.e., flowering plants in nurseries) are likely to impact honey bee reproduction in 70% of cases. While this conclusion is based on only 18 exposure assessments, the results are likely indicative of broader patterns given the widespread use of neonicotinoids on ornamental plants at nurseries.

Finally, it's important to note that each neonicotinoid insecticide is not created equal. Specifically, acetamiprid (a cyanoamidine neonicotinoid) is three orders of magnitude less toxic to bees than clothianidin, imidacloprid and thiamethoxam (nitroguanidine neonicotinoids). Thus, even though acetamiprid is a neonicotinoid to which bees are often exposed, it poses little risk compared to the nitroguanidine neonicotinoids and other chemical insecticides that are much more toxic.

**What about economic benefits of neonics?** To assess benefits, we tapped into data from >5,000 paired neonic/control field trials that have assessed impacts on pest populations, crop damage or yield. For many application contexts, there are clear benefits from using neonics. As shown in Figure 2, the majority of trials that have been conducted on fruits, vegetables and turfgrass (e.g., on golf courses) find that using neonicotinoids reduces pest populations, limits crop damage, or improves yield compared to untreated control plots. And this often results in direct economic benefits to users since the benefits overcome the cost of neonics. For a handful of important pests, including root-form phylloxera (grape), root weevils (berries), boxwood leafminer (ornamentals), and thrips and Swede midge (cabbage), there are few or no effective chemical alternatives available. In addition, removal of any one insecticide (including neonics) from a rotation increases the risk of developing insecticide-resistant pest populations and increasing long-term pest management costs to farmers.

But benefits aren't always observed when neonicotinoids are used. That fact is particularly clear in field crops settings. As seen in the figure for field corn (Figure 3), neonicotinoid-treated corn seeds rarely provide yield benefits to farmers. Specifically, 83-97% of field trials find no significant increase (or a decrease) in corn yield when neonicotinoid-treated seeds are used compared to chemical alternatives or untreated controls. Even when compared to plots using no insecticides, 87% of field trials observe no increase in corn yield when neonicotinoid-treated seeds are used. The results for corn are similar to those from soybean (Figure 4). Specifically, 82-95% of field trials find no increase (or a decrease) in soybean yield when neonicotinoid-treated seeds are used compared to chemical alternatives or untreated controls.

As should be expected, the unfavorable results for yield in corn and soybean translate to infrequent economic benefits for farmers who use neonicotinoid-treated seeds. Nevertheless, neonicotinoid-treated seeds are used by nearly all conventional field corn farmers and the majority of soybean producers. In part, this is due to the insurance value of neonicotinoid-treated seeds. Even if routine use of neonicotinoid-treated seeds does not increase net income, such preventative pest control products protect growers against unpredictable, potentially severe, losses from early-season pests. We suggest that incentives and policies to reduce usage of neonicotinoid-treated seeds should address those products' value as inexpensive crop insurance as well as pest management tools.

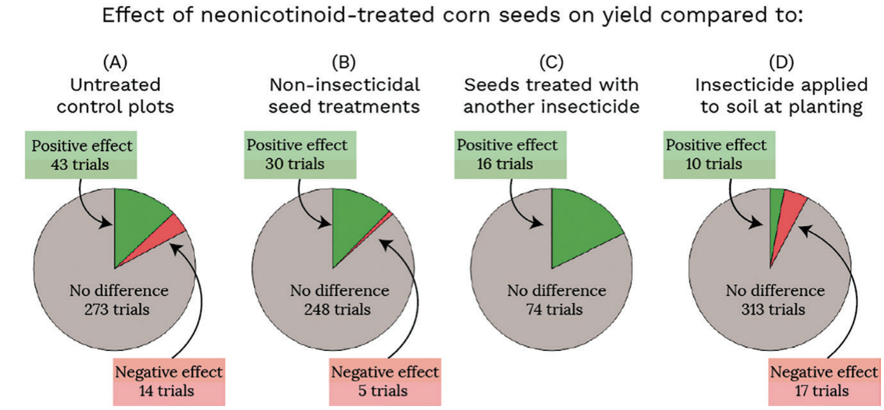


**Fig. 3** *Number of corn field trials reporting significantly higher (green), significantly lower (red), or no difference (gray) in yields in plots using neonicotinoid-treated seeds compared to plots using a non-neonicotinoid treatment or untreated control. Non-insecticidal seed treatments are seeds treated with fungicides, bactericides and/or nematicides. Alternative insecticides include a pyrethroid (tefluthrin), anthranilic diamides (chlorantraniliprole and cyantraniliprole), organophosphates (chlorethoxyfos, terbufos), and a phenylpyrazole (fipronil).*

**If neonicotinoids will be replaced, what should replace them?** No chemical insecticide is risk-free, and the potential chemical insecticide replacements for neonicotinoids possess risks of their own. Thus, throughout the report, we make note of contexts in which IPM approaches, non-synthetic chemical insecticides (e.g., biocontrols, biopesticides, or RNA-based approaches), and other pest control technologies are likely to be effective.

But we also realize that, at least in the short term, alternative chemical insecticides are the most likely replacements for neonics. To that end, it's worth reiterating that alternative chemical insecticides exist for nearly all relevant target pests. However, switching from neonicotinoids usually entails a direct or indirect cost to users. Farmers and pesticide applicators choose products with care. When they use a neonicotinoid insecticide, it is typically because that product is the best option when considering price, efficacy, safety, insecticide rotation pattern, and other factors.

In field crops settings, the most promising alternative chemical insecticides are pyrethroids (e.g., tefluthrin) and anthranilic diamides

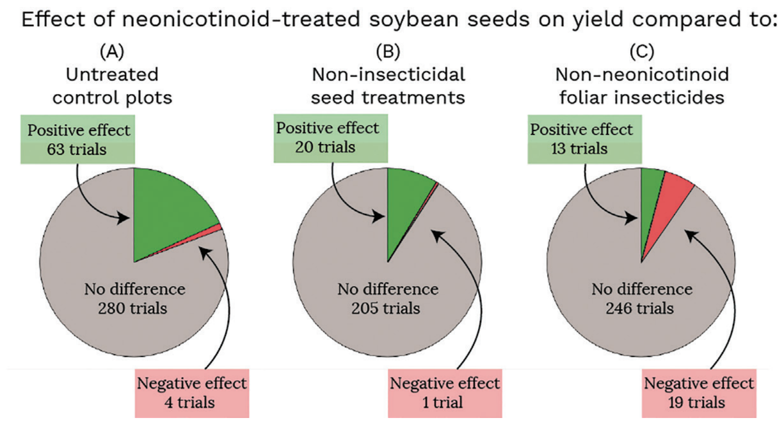


**Fig. 4** *Number of soybean field trials reporting significantly higher (green), significantly lower (red), or no difference (gray) in yields in plots using neonicotinoid-treated seeds compared to plots using a non-neonicotinoid treatment or untreated control. Non-insecticidal seed treatments are seeds treated with fungicides, bactericides and/or nematicides. Alternative insecticides include foliar sprays based on pyrethroids (beta-cyfluthrin, bifenthrin, cyfluthrin, deltamethrin, esfenvalerate, gammacyhalothrin, lambda-cyhalothrin, zeta-cypermethrin), organophosphates (acephate, chlorpyrifos, dimethoate), carbamates (carbaryl), tetronic acids (spirotetramat), butenolides (flupyradifurone), flonicamid (flonicamid), avermectins (abamectin), pyridine azomethine derivatives (pymetrozine, pyrifluquinazon), sulfoximines (sulfoxaflor), and pyropenes (afidopyropen).*

*Some alternatives to neonics bring their own risks.*

(chlorantraniliprole and cyantraniliprole). Because pyrethroids are not systemic and are less environmentally persistent, they likely pose less risk to pollinators compared to neonicotinoid-treated seeds. But at the same time, they likely pose more risk to pesticide applicators due to greater toxicity to vertebrates (including humans) compared to neonics.

Anthranilic diamides are systemic insecticides, but they're much less toxic to pollinators compared to neonicotinoids. Chlorantraniliprole and cyantraniliprole show promise as alternative systemic insecticide seed treatments for corn and soybean, respectively, though they are currently more expensive than neonics.

Finally, a main reason why preventative seed treatments are used so extensively in field crops is due to the unpredictable nature of early-season pest outbreaks. Further work to improve the predictability of such outbreaks via degree-day modeling that includes site-specific characteristics clearly has potential to increase the sustainability and security of field crops production in the United States and beyond.

Alternative chemical insecticides in other application contexts are numerous, and we encourage readers to dive into the full report if interested. But in the interest of space, we will only highlight one additional example here. As noted above, acetamiprid is three orders of magnitude less toxic to bees than the nitroguanidine neonicotinoids clothianidin, imidacloprid and thiamethoxam. Thus, acetamiprid poses little risk to bees in each application context in which it's used, while it often results in economic benefits to users. This is important since some people are currently pushing for a full ban on neonicotinoids. If such a ban occurred, it is likely the replacement chemical insecticides for acetamiprid would pose greater risk to bees in most application contexts.

This project was made possible by the NYS Environmental Protection Fund via New York's Pollinator Protection Plan. We hope the report is useful to researchers, extension folks, policy makers and other stakeholders within and beyond New York.

Until next time, bee well and do good work.

Scott McArt

**Reference:**

**Grout, T. A., P. A. Koenig, J. K. Kapuvari and S. H. McArt. 2020.** Neonicotinoid insecticides in New York: Economic benefits and risk to pollinators. 432 pp. **https://pollinator.cals.cornell.edu/pollinator-research-cornell/neonicotinoid-report/**

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