Notes from the Lab: The Latest Bee Science Distilled

by Scott McArt

Harmful pesticide exposures during crop pollination come from beyond the farm

As I write this, it's currently pollination season throughout the northern U.S., which means lots of beekeepers are bringing lots of bees to lots of farms. In New York, pollination is worth ~$400 million per year to the state's fruit and vegetable farmers. In other words, this annual early-summer movement of pollinators isn't just a curiosity, it's vital to the economy. And that means it's in everyone's best interest to make sure that bees, our main agricultural pollinators, aren't exposed to harmful pesticides while performing their pollination services.

Kelsey Graham

Photo 1 *A honey bee visits a cluster of blueberry flowers during blueberry pollination season in southwestern Michigan.*

We know that bees are almost always exposed to pesticides during crop pollination. For example, a recent analysis of bee-collected pollen during Michigan blueberry pollination season found that honey bee colonies are simultaneously exposed to 35 pesticides, on average (Graham et al. 2021). Managed bumble bees fare a bit better and are exposed to 19 pesticides, on average. That's still quite a few pesticides!

The important question is this: Are pesticide exposures during crop pollination dangerous, or are they simply trace amounts of contaminants that are unlikely to impact bee health? Perhaps more importantly, if some harmful exposures do occur, where do they come from? If we understand the sources of high-risk exposures, we can work to reduce exposures from those sources in the future. These are the topics for the fifty-fifth Notes from the Lab, where I summarize ***"Pesticide risk to managed bees during blueberry pollination is primarily driven by off-farm exposures,"*** written by Kelsey Graham and colleagues and published in the journal *Scientific Reports* [2022]. Full disclosure: I am a co-author on this study.

For their study, Graham and colleagues focused on two species of bees used for commercial blueberry pollination (Photo 1) in Michigan and elsewhere, the Western honey bee (*Apis mellifera*) and the common Eastern bumble bee (*Bombus impatiens*). To measure the magnitude and sources of pesticide risk, the authors first sampled bee-collected pollen from multiple honey bee and bumble bee colonies at highbush blueberry farms during peak bloom. Pollen from honey bees was sampled in each of two years from 21 fields that were managed using conventional pest management, organic pest management, or no chemical pest management at any time of the year. Pollen from bumble bees was sampled at 15 fields in the second year of the study at conventional or unsprayed farms (Photo 2). Blueberry flowers, foraging honey bees and bumble bees, and wax from honey bee colonies were also collected at each of the fields.

All samples were immediately frozen and shipped to my lab at Cornell University. At the lab, we extracted the samples, then used liquid chromatography with tandem mass spectrometry (LC-MS/MS) to screen for and quantify 261 potential pesticides via our multi-residue analysis (Photo 3). Note: we've opened this analysis to the public (details here: **https://blogs.cornell.edu/ccecf/**) — please feel free to get in touch and send us samples from your hives if you think you have reason to be concerned about pesticides.

Once the pesticides were quantified from the flowers, bees, wax, and bee-collected pollen, the authors assessed

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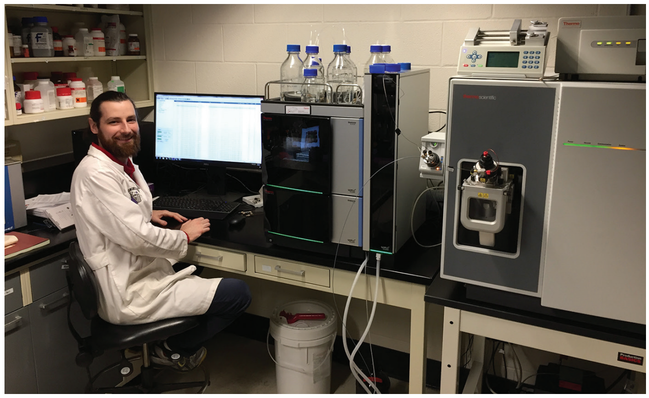

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(L) Photo 2 *Jessica Greer, field technician at MSU, samples pollen from common Eastern bumble bee workers as they return to their colonies at a blueberry farm.* **(R) Photo 3** *Co-author Nico Baert quantifies pesticide residues in pollen samples via our LC-MS/MS. Author's note: This machine is worth more than my house.*

whether there were potentially harmful exposures via the Risk Quotient, or RQ. This metric is used by researchers and regulatory agencies (e.g., the U.S. Environmental Protection Agency) to determine pesticide risk to bees. The metric is a simple combination of exposure (e.g., quantity of a pesticide in pollen, measured in parts per billion) and toxicity (measured as LD_{50}, or lethal dose of that pesticide which kills 50% of honey bees tested). The RQ for each sample is calculated as the sum of risk from pesticides detected in the sample. In other words, for a pollen sample that contains 35 pesticides, the RQ is the sum of risk from all of the 35 individual pesticides.

Finally, Graham and colleagues determined which pesticides were registered for use in blueberry fields in Michigan. For pesticide detections not registered for use in blueberry fields, the authors looked into other crops where those pesticides were registered for use.

So, what did they find? Were the bees ever exposed to harmful levels of pesticides during pollination? Yes. As shown in Figure 1, there was a great deal of variation in risk from pesticides among sample types (flowers, bees, wax, bee-collected pollen) and among farms. Most samples were below RQ thresholds set by the EPA and European Food Safety Authority (EFSA); the horizontal green dashed line in Figure 1 represents the EFSA level of concern (LOC) for 10-day chronic oral exposure, the blue dashed line is the EFSA LOC for acute contact exposure, and the red dashed line is the EPA LOC for acute contact exposure. All data points *below* those dashed lines indicate harmful exposures are unlikely, while all data *above* the thresholds indicate harmful exposures are likely, as defined by the EPA and EFSA.

No flower, bee, or wax samples were above the EPA or EFSA LOCs for contact exposure, while 3.4% of honey bees and 3.5% of wax samples were above the EFSA 10-day chronic oral exposure LOC (RQ > 0.03; Figure 1). The story was very different for pollen, however. Overall, 72.4% of honey bee-collected pollen samples in 2018 and 45.4% in 2019 were above the 10-day EFSA chronic oral exposure LOC, while 46.7% of bumble bee pollen samples exceeded this level. Because managed bees typically conduct pollination for at least 10 days, the 10-day chronic exposure LOC is relevant. This said, only 1.0% of honey bee pollen samples from 2019 were above the EPA acute contact exposure LOC (RQ > 0.4) and 5.2% were above the EFSA acute contact exposure LOC (RQ > 0.2; Figure 1).

What were the pesticides that contributed most to risk? For honey bee- and bumble bee-collected pollen, the insecticides chlorpyrifos, clothianidin, and carbaryl contributed most to RQ from contact exposure and the insecticides clothianidin, imidacloprid, and chlorpyrifos contributed most to RQ from oral exposure.

Risk was lower for all other sample types (flowers, bees, and wax). The fungicide fenbuconazole contributed most to RQ from flowers, the insecticide carbaryl and fungicides carbendazim and fenbuconazole contributed most to RQ in bees, and the insecticide chlorpyrifos contributed most to RQ from wax.

Did the high-risk exposures come from blueberry fields or elsewhere? Mostly elsewhere. As shown in Figure 2, the vast majority of the RQ came from pesticides not registered for use at any time on blueberries.

For honey bee-collected pollen from 2018, 69% of the RQ from contact exposure and 63% of the RQ from oral exposure came from pesticides not registered for use on blueberries (Figure 2). In 2019, 93% of the RQ from contact exposure and 82% of the RQ from oral exposure came from pesticides not registered for use on blueberries. For bumble bee-collected pollen in 2019, 65% of the RQ from contact exposure and 87% of the RQ from oral exposure came from pesticides not registered for use on blueberries.

Well, that's troubling. So where did the high-risk exposures come from? That's the million-dollar question, and unfortunately it's impossible to say for sure. At some point, I would love to use unique isotopically-labeled pesticides on all farms within the flight radius of a honey bee colony to assess this question. But that would be very expensive, of course! In the meantime, let's use the data in hand and evaluate the three highest-risk pesticides in pollen: clothianidin, imidacloprid, and chlorpyrifos.

The neonicotinoid insecticides clothianidin and imidacloprid are used to control various sucking and chewing insects in a variety of crops, most commonly as seed treatments in corn and soybeans, which are grown in the landscape surrounding the blueberry fields evaluated in this study. Clothianidin is not registered for use on blueberries and imidacloprid is used at some conventional blueberry farms in the region, but not at organic or no-spray farms, where several pollen exposures occurred. Thus, it seems likely that at least some of the clothianidin and imidacloprid exposures came from corn and soybean fields, perhaps via contaminated weedy flowers surrounding the fields.

The organophosphate insecticide chlorpyrifos is not registered for use in blueberry but was found in 89% of pollen samples. Chlorpyrifos is registered for trunk applications to control insects in vineyards and orchards, as well as in corn and other field crops in the study region. This breadth of use makes it a bit harder to speculate on specific crop origin(s). However, chlorpyrifos was recently banned by the EPA, mostly due to the fact that it's been linked to neurological problems in human children. Given the prevalence of chlorpyrifos in bee-collected pollen, this ban could provide substantial reductions in risk for pollinators if exposures are primarily from current applications and not legacy residues in the environment.

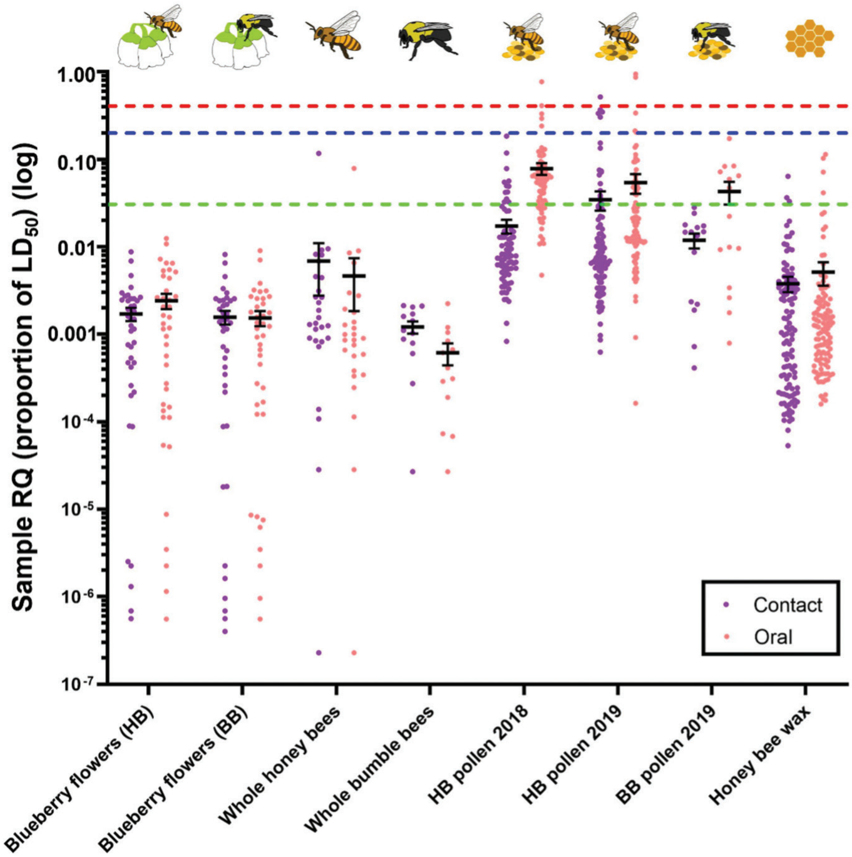

Figure 1. *Average sample risk quotients by sample type. Risk quotient (RQ) calculated with contact (purple) and oral (pink) toxicity (LD_{50}) values and data are presented as proportion of LD_{50}. Toxicity data for* Apis mellifera *or* Bombus terrestris *were used, depending on the sample type. Individual sample RQs are represented by the dots, horizontal black lines are the mean, and the error bars represent standard error of the mean. RQ is displayed in relation to the EPA and EFSA levels of concern; green dashed line is the EFSA level of concern for 10-day chronic oral exposure, blue dashed line is the EFSA level of concern for acute contact exposure, and red dashed line is the EPA level of concern for acute contact exposure.*

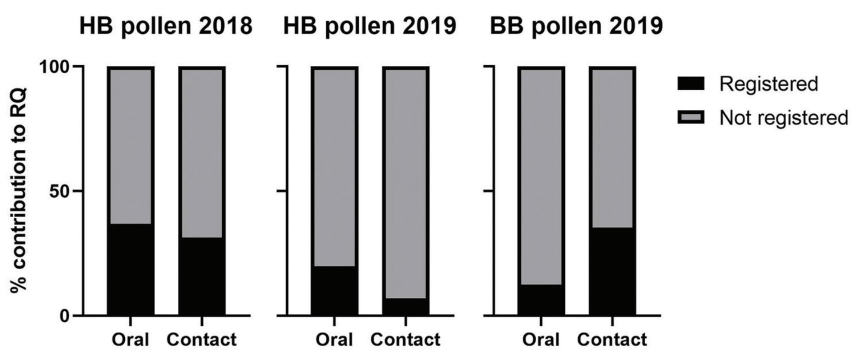

Figure 2. *Contribution of pesticide active ingredients to pollen risk quotient (RQ) values based on whether they are registered for use on blueberries, or not. A product was considered registered for use on blueberries if the label indicated it's permitted to be applied to blueberry bushes at any time of the year. RQs were calculated with contact LD_{50} values and oral LD_{50} values for* Apis mellifera *or* Bombus terrestris*, depending on which species collected the pollen (HB-honey bees,* Apis mellifera*; BB-bumble bees,* Bombus impatiens*).*

Overall, the study by Graham and colleagues highlights that pesticide risk to bees is a landscape-scale issue in mixed agricultural landscapes. High-risk pesticide exposures can occur when some crops are in bloom and others have completed bloom, thereby allowing higher-risk insecticide applications. To me, this means practicing Integrated Pest Management (IPM) is by far the clearest way to reduce high-risk exposures while growing the food we all need to eat. Yet surprisingly few farmers (or beekeepers, by the way) practice IPM to the level needed for significant reductions in pesticide risk. Instead, pesticides are often applied on a calendar-based schedule with little or no knowledge of pest levels. If we're going to improve the sustainability of U.S. agriculture, this has to change.

Until next time, bee well and do good work.

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References:

Graham, K. K., M. O. Milbrath, Y. Zhang, A. Soehnlen, N. Baert, S. H. McArt and R. Isaacs. 2021. Identities, concentrations, and sources of pesticide exposure in pollen collected by managed bees during crop pollination. *Scientific Reports* 11:16857 **https://doi.org/10.1038/s41598-021-96249-z**

Graham, K. K., M. O. Milbrath, Y. Zhang, N. Baert, S. H. McArt & R. Isaacs. 2022. Pesticide risk to managed bees during blueberry pollination is primarily driven by off-farm exposures. *Scientific Reports* 12:7189. **https://doi.org/10.1038/s41598-022-11156-1**

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