Notes from the Lab:

The Latest Bee Science Distilled

by Scott McArt

Imagine a world where the effects of drinking a beer never wear off because the human body can't break down the alcohol and eliminate it. As a person drinks more beer, the alcohol in their blood builds up to higher and higher levels – it bioaccumulates. In this world, even occasional beers could kill.

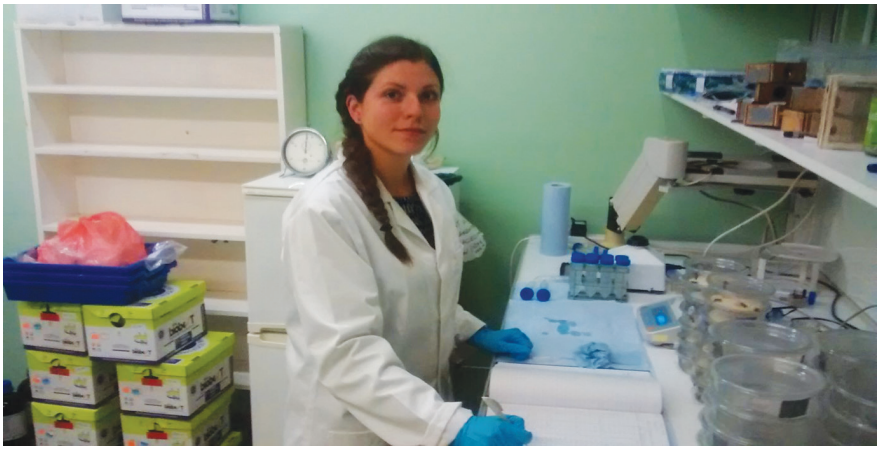
What does this have to do with bees? It turns out that some insecticides can also bioaccumulate, which can greatly increase the duration of their toxicity to bees, thereby increasing their risk. This is the topic for our sixteenth "Notes from the Lab," where we highlight **"Fipronil pesticide as a suspect in historical mass mortalities of honey bees,"** written by Philippa Holder and colleagues and published in the journal ***Proceedings of the National Academy of Sciences of the United States*** **[115:13033-13038 (2018)].**

Holder and colleagues' study was inspired by two main observations. First, between 1994 and 1998, there were several instances of mass honey bee colony deaths near agricultural areas in France. Second, French farmers (especially sunflower growers) started to use two new insecticides at this time. Fipronil, a phenylpyrazole insecticide, was introduced in 1993, and imidacloprid, a neonicotinoid insecticide, was introduced in 1994. Both fipronil and imidacloprid are systemic insecticides, meaning they can be taken up by any plant and incorporated into pollen and nectar. Thus, there's substantial risk of exposure to pollinators, including honey bees.

As most readers of this column will know, there's been a large body of work over the past decade or so on risk to bees from neonicotinoid insecticides, including imidacloprid. This work includes speculation that imidacloprid was the culprit for acute losses of honey bee colonies in France in the mid-1990s. However, most exposure data show that imidacloprid levels in pollen, nectar and honey are generally quite low – on the order of a few parts per billion. These low-level exposures are not good for bees, of course, but there's little evidence they're sufficient to cause acute mass die-offs of colonies.

On the other hand, there is reason to suspect that fipronil can potentially cause colonies to fail at similar low-level exposures. Why? While honey bees can rapidly metabolize and detoxify parts per billion levels of imidacloprid, they may have less ability to do so with fipronil. This could explain why the 10-day LD_{50} of honey bees for imidacloprid is 123 nanograms per bee (ng/bee), but the 10-day LD_{50} for fipronil is only 3 ng/bee. With these data in mind, Holder and colleagues set out to test whether fipronil could in fact bioaccumulate in bees, how this impacts its toxicity compared to imidacloprid, and how the viability of full honey bee colonies might be affected.

So, what did they find? Did fipronil bioaccumulate in bees? In the laboratory, Holder and colleagues found that nearly all of the highly toxic sulfone metabolite of fipronil persisted in bees for at least 6 days. In contrast, >90% of imidacloprid is typically excreted from honey bees within 48 hours – just about the same rate as humans eliminate blood alco-



Dr. Philippa Holder working on pesticide dosing experiments in the lab

Dr. James Cresswell collecting adult honey bees for the experiments

hol. The authors also found that the ability of fipronil's toxic metabolite to bioaccumulate was the main reason for its potency, which was much greater ounce-for-ounce than that of imidacloprid. Each tiny unit of fipronil remained inside the bee's body doing harm, day after day, which meant that the bee didn't need to eat much to be killed once time had passed. For imidacloprid, each tiny unit was eliminated by the bee's body relatively quickly and had little opportunity to cause harm. This meant that bees only died once they consumed a relatively large amount of imidacloprid, much greater than is typically encountered in nectar and pollen.

How did the ability of fipronil to bioaccumulate impact colony mortality? Holder and colleagues constructed a simulation model to assess what the mortality rates of environmentally realistic[1] doses might mean for full-size honey bee colonies. These types of models are a powerful tool and are often used in pesticide risk assessments. Their results were striking. While colonies continued to grow with field-realistic exposure to imidacloprid, they failed rapidly (typically in less than a month) in response to realistic fipronil exposure. This rapid failure is similar to what was observed in France in the mid-1990s.

Well this seems scary. What's the chance that my bees run into fipronil? Fipronil is currently banned in the European Union due to its potential to impact non-target organisms such as bees. In the U.S., fipronil is still used on some fruits and vegetables, primarily via the product Regent®, and on Christmas trees via the product PTM™. Fipronil is also used in pet products and in ant/roach baits and termiticides. Usage has declined steadily since 2001 in the U.S., but still occurs.

Interestingly, despite fipronil being banned in Europe, occasional acute bee kills further support the risk posed from this insecticide. For example, in 2014, 172 hives across 23 apiaries died suddenly in Bern, Switzerland. Fipronil residues were found to have been accidentally present in a tank used to apply fungicides to fruit trees that were in bloom.

Can anything be done to reduce the likelihood of my bees encountering fipronil or other pesticides that bioaccumulate? Because fipronil is a systemic and environmentally persistent insecticide, applications prior to bloom have the potential to accumulate in pollen and nectar. Thus, if you pollinate crops with your bees, we recommend you speak with your grower to understand their usage of fipronil and other pesticides. During this discussion, we suggest passing along our new extension booklet, titled *A Pesticide Decision-Making Guide to Protect Pollinators in Tree Fruit Orchards* (Van Dyke et al., 2018). This guide is free and downloadable from our website via the link below.

Second, perhaps we can catch high-risk bioaccumulating pesticides via improved regulatory efforts. Currently, there are no specific risk assessment protocols in place at either the United States Environmental Protection Agency (US EPA) or the European Food Safety Authority (EFSA) to identify pesticides such as fipronil that increase in toxicity via bioaccumulation. Holder and colleagues suggest that such methods could be introduced with only slight modifications of the current "first tier" tests that occur at the US EPA and EFSA. Since these modifications may require minimal additional effort, they could be a useful addition for currently registered pesticides, and especially new pesticides that will be considered in the future.

Until next time, bee well and do good work,
Scott McArt

1. The researchers manipulated several doses across a range of exposures (concentrations that were below, similar to, and above concentrations found previously in pollen, nectar and honey). From these data, a conservatively derived parameter based on previous exposure data was then incorporated into their simulation model. This method of parameter acquisition is common methodology for risk assessment models.

Reference:

Holder, P. J., A. Jones, C. R. Tyler and J. E. Cresswell. 2018. Fipronil pesticide as a suspect in historical mass mortalities of honey bees. *Proceedings of the National Academy of Sciences of the United States* 115:13033-13038. **https://doi.org/10.1073/pnas.1804934115**

Van Dyke, M., E. Mullen, D. Wixted and S. H. McArt. 2018. A Pesticide Decision-Making Guide to Protect Pollinators in Tree Fruit Orchards. *Available for free download at:* **https://pollinator.cals.cornell.edu/resources/grower-resources/**

Scott McArt, an Assistant Professor of Pollinator Health, helps run the Dyce Lab for Honey Bee Studies at Cornell University in Ithaca, New York. He is particularly interested in scientific research that can inform management decisions by beekeepers, growers and the public.

Email: shm33@cornell.edu
Lab website: blogs.cornell.edu/mcartlab
Pollinator Network: pollinator.cals.cornell.edu
Facebook: facebook.com/dycelab