A Pesticide Success for Bees Pollinating Almond

Approximately 1.5 million honey bee colonies are currently used to pollinate ~950,000 acres of nut-producing almond trees in California. Since the estimated number of colonies in the United States is ~2.6 million according to the USDA National Agricultural Statistics Service, that means nearly 60% of the country's managed honey bees are flying around in California almond orchards each February.

So, if there was a time and place to ensure that bees were not exposed to harmful levels of pesticides, almond pollination in California would be high on the list. But is that the case? This is the topic for our eighteenth "Notes from the Lab," where we highlight **"*Combined toxicity of insecticides and fungicides applied to California almond orchards to honey bee larvae and adults*,"** written by Andrea Wade and colleagues and published in the journal ***Insects*** **[10:20 (2019)].**

Wade and colleagues' study was motivated by widespread beekeeper concern about potentially harmful pesticide exposure during almond pollination in 2014. Reportedly, upwards of 40% of colonies in almond orchards experienced adult honey bee deaths or dead and deformed brood, and 20% of colonies were completely dead. Data from the California Pesticide Information Portal indicated that several pesticides were applied during almond bloom, including the insecticides chlorantraniliprole, methoxyfenoxide, and difubenzuron, and the fungicides propiconazole, iprodione, boscalid, and pyraclostrobin.

The insecticides, which are applied during bloom to control the peach twig borer (*Anarsia lineatella*), work by targeting insect developmental processes and muscle function. In 2014, each insecticide was labeled for application in almonds during bloom due to low acute toxicity to honey bees. However, several studies have found sublethal impacts of these insecticides on honey bees, including impaired learning, reduced brood production, and reduced survival of adult workers and immature queens.

Fungicides are commonly applied to almond and nearly all other U.S. crops during bloom to control a wide variety of fungal plant pathogens. Due to their low acute toxicity to bees, fungicides are generally assumed to pose low risk. However, recent studies have found that several fungicides can synergize with insecticides and enhance their toxicity, especially when applied together via a tank-mix.

To test the potential impact of the insecticides and fungicide-insecticide combinations that bees could be exposed to while pollinating California almond, Wade and colleagues performed an elegant series of pesticide effects bioassays on honey bee larvae and adults. First, they dosed larval food with concentrations of each fungicide, insecticide, or fungicide-insecticide combination that could be expected given field application rates by growers (2% by volume). Larvae were allowed to develop until pupation and adult emergence was recorded. Second, a dose-response curve for adult worker bees was developed to assess when synergism between propiconazole and chlorantraniliprole occurred at various concentrations of chlorantraniliprole.

So, what did they find? Did any of the insecticides or fungicides impact larval mortality on their own? Yes. None of the fungicides impacted larval mortality on their own, nor did the insecticides chlorantraniliprole or methoxyfenozide. However, only 11% of larvae exposed to the insecticide diflubenzuron survived to adulthood, a nearly 4-fold reduction in survival compared to controls. While previous studies have found low acute toxicity of diflubenzuron to adult honey bees, this substantial impact on larvae mirrors previous field observations of reduced brood production following whole-colony exposures.

What about synergisms between fungicides and insecticides? While chlorantraniliprole was not very toxic to larvae on its own, the authors found that only 10% of larvae survived to adulthood when exposed to a combination of the fungicide propiconazole and chlorantraniliprole (a more than 5-fold reduction in survival), and only 40% survived when ex-

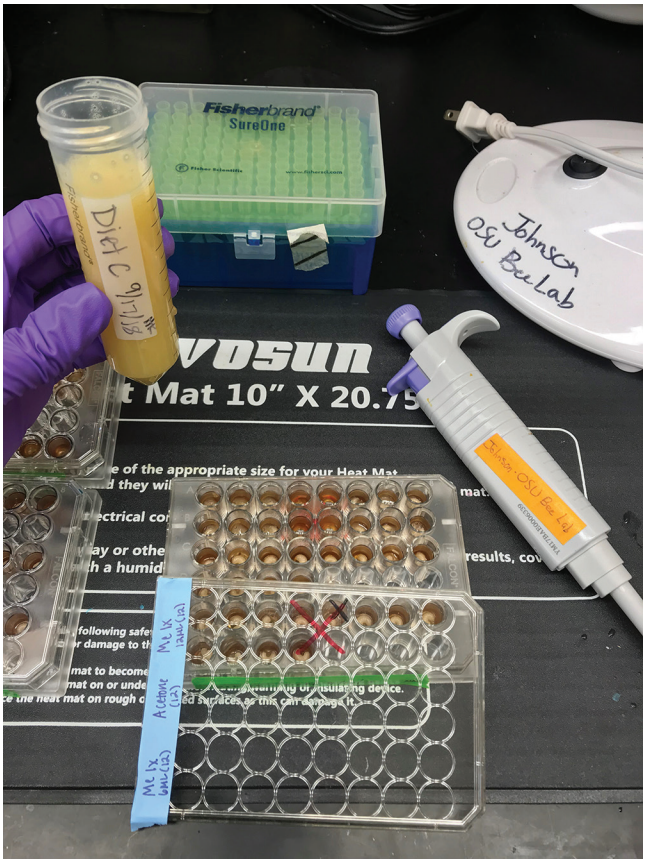

Fig. 1 *The set-up for larval feeding assays consisted of diets containing the various pesticides and pesticide combinations, which were fed to larvae in 48-well microplates (1 well for each larva).*

posed to the fungicide iprodione and chlorantraniliprole (a ~70% reduction in survival). The synergism between chlorantraniliprole and propiconazole was also found when adult workers were dosed. Thus, Wade and colleagues found evidence for risk of pesticide synergisms to larvae and adult honey bees pollinating California almond.

Well this doesn't seem good. Has anything changed since 2014? The reason the title of this article is *"A pesticide success for bees"* is because of the changes that have taken place since 2014. First, usage of chlorantraniliprole and methoxyfenozide had been steadily increasing between 2007-2014, but only half the amount of these insecticides was applied during bloom in 2015 compared to 2014. While usage of diflubenzuron had been decreasing somewhat since 2013, less than half of this insecticide was used in 2015 compared to 2014. In other words, even before Wade and colleagues' study was published this year, almond growers were reacting to beekeeper concerns about insecticide exposure.

Second, Wade and colleagues showed their preliminary findings to the California Almond Board in 2017, which resulted in the Board recommending to all California almond growers that no insecticides (including chlorantraniliprole, methoxyfenozide, and difubenzuron) be used during bloom. Furthermore, based on Wade and colleagues' results, the Board recommended that no tank-mixing of fungicides and insecticides should occur during bloom. These recommendations were summarized in the recent publication, "*Honey bee best management practices for California almonds*," which is freely available online: **http://www.almonds.com/pollination**.

If you're a beekeeper who conducts pollination of almond, be sure your grower is aware of the California Almond Board best management practices document. Furthermore, please feel free to share our recent "*Pesticide Decision-Making Guide to Protect Pollinators in Tree Fruit Orchards*" (Van Dyke et al., 2018), which summarizes all known information regarding risk to bees from insecticides, fungicides, and insecticide-fungicide synergisms.

Pollination is an important service that beekeepers provide to U.S. agriculture, and I've never met a grower who wants to harm bees. With better information and increased communication between beekeepers and growers, we can make pollination safer for bees. Wade and colleagues' research is a glowing example of this.

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

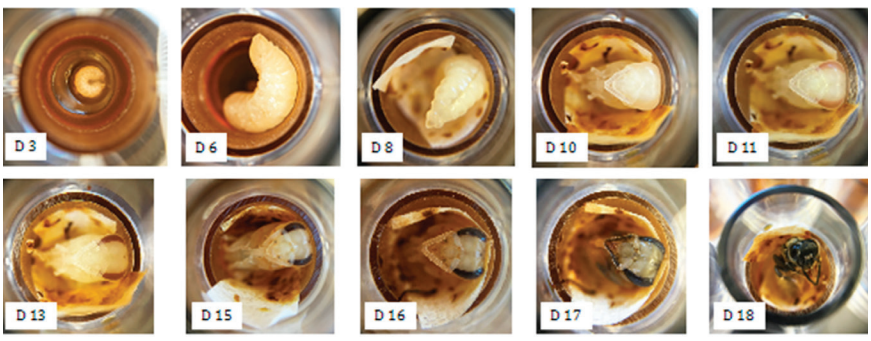

Fig. 2 *Larval development was monitored and successful adult emergence (D18) was recorded for each pesticide treatment.*

Reference:

Wade, A., C.-H. Lin, C. Kurkul, E. R. Regan and R. M. Johnson. 2019. Combined toxicity of insecticides and fungicides applied to California almond orchards to honey bee larvae and adults. *Insects* 10:20. **https://doi.org/10.3390/insects10010020**

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/**

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