



Notes

from the Lab:

The Latest Bee Science Distilled

by Scott McArt

Using fewer insecticides improves crop yield by increasing pollination by bees

The vast majority of farmers use chemical insecticides to protect their crops against potentially damaging insect pests. This should not be a foreign concept to beekeepers; the majority of beekeepers use miticides to protect their bees against the varroa mite.

But how farmers use insecticides varies greatly. Some farmers operate on a schedule, applying insecticides every month or so to prevent pest problems from occurring. When insecticides are cheap and pests are a consistent threat, this can be an effective strategy.*

Conversely, some farmers use Integrated Pest Management (IPM) to decide when to use insecticides. A cornerstone of IPM is monitoring for pests and only using insecticides when pest populations or damage from those pests reaches a predetermined economic threshold. In this way, insecticides are only used when necessary, which saves money and reduces unnecessary pesticide inputs

**While applying insecticides on a schedule can be an effective short-term strategy that controls insect pests, this strategy can lead to longer-term problems. A population of pest insects will evolve resistance against an insecticide more quickly if that insecticide is used frequently. This is why using multiple products in sequence (a pesticide rotation) or reducing application frequency via IPM is recommended.*

to the environment. To continue with the varroa analogy, if you monitor for varroa levels in your colonies and only treat with miticides when levels are above a predetermined threshold, you are practicing IPM.

When a crop relies on insects for pollination, another potentially important economic benefit of IPM exists. By using fewer insecticides, insect pollinators are less likely to be harmed, which could translate into better pollination, improved crop yield, and greater economic returns for a farmer.

This all sounds good in theory, but is there real-world evidence that practicing IPM and using fewer insecticides can improve yield in a pollination-dependent crop? If so, is increased yield due to greater numbers of bee pollinators? And what about a crop that doesn't rely on pollinators? Can farmers improve their bottom line by taking an IPM approach, or will they frequently surpass economic thresholds such that impacts on yield occur? These are the topics for our forty-ninth Notes from the Lab, where we summarize "IPM re-



Photo 1. One of the experimental watermelon plots used for the 3-year study. At each of five sites, one watermelon and one corn plot were conventionally managed (CM) with pesticides in the way that most farmers currently use them, while another set of watermelon and corn plots were managed using Integrated Pest Management (IPM). Pesticides were only used on the IPM plots when pest populations exceeded a predetermined economic threshold (see Figure 1).



Photo 2. Lead author Jacob Pecenka checking a honey bee colony at one of the experimental plots. Each CM and IPM plot received one supplemental honey bee and bumble bee colony.

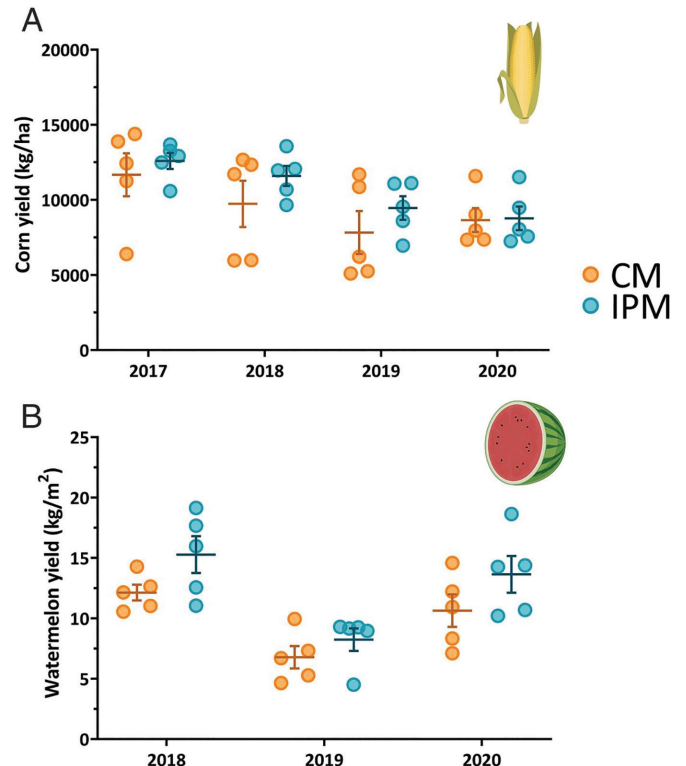
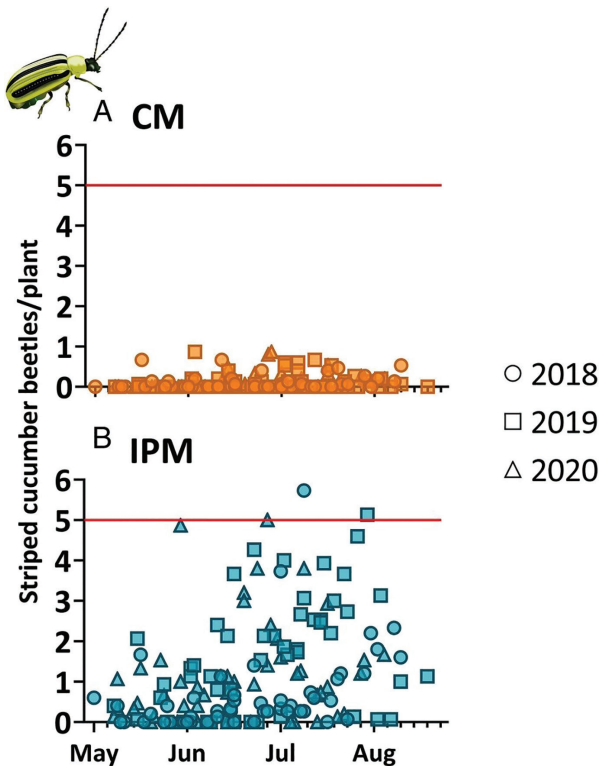
duces insecticide applications by 95% while maintaining or enhancing crop yields through wild pollinator conservation,” written by Jacob Pecenka and colleagues and published in the

Proceedings of the National Academy of Sciences [2021].

For their study, Pecenka and colleagues focused on one pollination-dependent crop (watermelon) and

one crop that doesn’t require insect pollination (corn). They wanted their study to mimic what a farmer would experience in the field, so they set up large field-scale plots of watermelon and corn at five sites across Indiana (Photo 1). The sites were positioned along a latitudinal gradient with at least 100 km separating one another, ensuring a diversity of climatic conditions, soil types, and local pest pressures.

At each site, one watermelon and one corn plot were conventionally managed (CM), and an identical set of plots were managed using Integrated Pest Management (IPM). Farmer surveys were conducted before the experiment and the CM plots were managed in the way that most farmers currently manage their fields. For watermelon, this included a soil drench of the neonicotinoid insecticide imidacloprid (Wrangler at 814.09 mL/ha) and four sprays of the pyrethroid insecticide lambda-cyhalothrin (Warrior II at 140.3 mL/ha) at 4, 6, 8, and 10 weeks post-transplant. For corn, seed was treated with the neonicotinoid thiamethoxam (Cruiser 5FS at



(L) Figure 1. Striped cucumber beetles (SCBs) were higher in IPM watermelon fields, but infrequently reached levels associated with economic loss. Watermelon fields within both CM (A) and IPM (B) systems were scouted weekly, and each point represents a 15-plant average of SCBs from seedling transplant until fruit harvest. Red lines in each graph indicate the five-beetle/plant economic threshold, while circles (2018), squares (2019), and triangles (2020) differentiate experiment years. In IPM fields, in each instance in which beetle levels reached the economic threshold, insecticide was applied <2 d following the survey. **(R) Figure 2.** Corn yield was unaffected by CM vs. IPM management (A), but watermelon yield was significantly higher when grown under an IPM system (B). Each point within a cluster (n = 5) represents the yield from a site during that field season. Whiskers within the plot show the mean ± SEM of all sites within each cluster.

1.25 mg a.i. per seed). Conversely, the IPM watermelon and corn plots only used insecticides when pests reached a predetermined economic threshold, which rarely occurred (Figure 1).

All plots were supplemented with a honey bee and bumble bee colony (Photo 2) and bee visitation at watermelon flowers was recorded weekly during bloom. At the watermelon plots, plants were surveyed for pests for a 10-week period that extended into harvest, at which time mature fruits from each plot were counted, weighed, and inspected for marketability using USDA grading standards. At the corn plots, early- and late-season crop damage were assessed, and yield was determined by subsampling the plots. Finally, pesticide residues in soils, crop leaves, and crop pollen were measured using liquid chromatography and mass spectrometry (HPLC-MS/MS).

So, what did they find? Did pesticides need to be used in the IPM watermelon or corn plots? As seen in Figure 1, pest pressure was greater in IPM vs. CM watermelon plots in all three years. However, the economic threshold of five striped cucumber beetles per plant (red lines in Figure 1) was only observed four times in the IPM plots. As a result, insecticide sprays were only used in the IPM plots on those four occasions, compared to 77 applications in the CM plots over the same period. In other words, 95% fewer insecticide applications were used in the IPM plots compared to CM plots.

Pest pressure on corn was effectively absent during the first three years of the study, with <1% of sampled plants showing any direct evidence of feeding by western corn rootworm, the primary insect pest in the region. In the fourth and final year of the study, damage was more prevalent, with 33% of IPM corn roots showing evidence of rootworm feeding. However, these damage levels were still below the economic threshold and therefore no insecticides were used in the IPM corn plots throughout the 4-year study.

How did reduced insecticide usage via IPM impact bee visitation and crop yield? The number of bees visiting watermelon flowers was 99% greater in IPM vs. CM plots, and the number of transition visits (i.e., visits that a bee made from a male to a female flower) was 305% greater in IPM vs. CM plots. Interestingly, this increase in bee visitation was driven

almost entirely by wild bees, especially sweat bees (Photo 3); honey bee and bumble bee abundance did not differ between the IPM vs. CM plots.

Given the difference in bee visitation to watermelon flowers, it's not a surprise that yield in this pollination-dependent crop was 26% greater in IPM vs. CM plots (Figure 2). Greater yield in IPM plots was mostly attributed to a greater number of fruits, though there was also a trend for increased fruit weight. There were more IPM watermelons with rind damage and insect feeding damage, but this represented <5% loss and is taken into account in the yield assessment.

Because corn is wind-pollinated, it doesn't benefit from bee visitation. The authors' results show that corn also doesn't benefit from insecticide seed treatments. There was no statistical difference in corn yields between IPM (mean = 10,602 kg/ha) compared to CM (mean = 9,471 kg/ha) fields, and this was true in all four years of the study (Figure 2).

Wait a minute, so does this mean most farmers are actually losing money by using more pesticides than they need to use? Yes. And this is an important result. In watermelon, the average cost of using insecticides in CM plots was \$94.33 per hectare per year, while the small number of insecticide applications in IPM plots cost \$3.35 per hectare per year. The CM approach never recovered the cost of insecticides throughout the 4-year study; instead, the data show that watermelon farmers who switch from CM to IPM will increase profits by >\$90 per hectare.

In corn, the economic results are similar. The cost of using neonicotinoid seed treatments at the rate used in this study was \$57.79 per hectare. This cost was never recovered at any of the sites or in any year of the study. In other words, the data show that corn farmers will always increase profits by foregoing neonicotinoid seed treatments. This result is in line with several recent large-scale studies and meta-analyses on this topic (Grout et al. 2020, Labrie et al. 2020, Smith et al. 2020). Even though neonicotinoids are used on 80-100% of field corn seeds in the United States, these insecticides are rarely needed and can result in an economic loss for farmers.

Economics often drives decisions by humans, and the study by Pecenka and colleagues shows very nicely that economics can encourage more sustainable farming practices regard-



Photo 3. A sample of bees that were visiting IPM watermelon flowers. Note the large number of black and green sweat bees (family Halictidae) in the sample. Bee visits to watermelon were 99% greater in IPM vs. CM plots.

ing pesticide usage. Using chemical insecticides always results in environmental contamination that has the potential to harm non-target organisms. Indeed, the levels of pesticides found in soils and crop pollen were up to 100x greater in CM vs. IPM plots, sometimes at levels that could acutely kill bees. This is very likely why fewer ground-nesting wild bees (e.g., some of the sweat bees shown in Photo 3) were found visiting watermelon at the CM vs. IPM plots, which translated to less pollination and reduced yield.

But the good news is that bees increased very quickly (i.e., the first year of this study) following adoption of IPM. This means farmers can quickly improve crop yields if they reduce pesticide inputs. This is especially important for insect-pollinated crops, many of which we know are currently limited by pollinators (Reilly et al. 2020), and it's also probably important for wind-pollinated crops such as corn. Even though the authors didn't measure

them, I bet there were other insects such as predators, parasitoids, and soil-dwelling nutrient cyclers that increased in the IPM plots. All of those organisms can reduce crop pest populations and/or increase yield. And they're also pretty cool. Not as cool as bees, of course, but that's a topic for another day.

Until next time, bee well and do good work.

Scott McArt

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