



As regulators consider a ban on widely used insecticides, debate rages over the evidence.

NEONICS VS BEES

BY DANIEL CRESSEY

Maj Rundlöf remembers the moment she changed her mind about neonicotinoids. In December 2013, in her office at Lund University in Sweden, she and postdoc Georg Andersson were peering at data from their latest study. It was designed to test what would happen to bees if they fed on crops treated with neonicotinoids — the world's most widely used insecticides. "I didn't expect to see any effect at all, to be honest," says Rundlöf.

Hives of honeybees (*Apis mellifera*) weren't greatly affected by the chemicals in their pollen and nectar, the study suggested¹. But the data on bumblebees (*Bombus terrestris*) told a different story. Bumblebee colonies that hadn't fed on the treated crops looked normal: they were packing on weight to survive the winter. But in the colonies exposed to neonicotinoids, the growth chart was a flat line.

When the Swedish study was published in April 2015, it made headlines around the world. It was the first to show that neonicotinoid chemicals — known as neonics — could harm bees in a real-world farming situation.

Bee populations are declining in many parts of the globe, a worrying sign for the crops and wild plants that rely on these pollinators for their survival. Parasites, disease and shrinking food resources are all prime suspects. But a link to neonics has become a major flashpoint.

Even before Rundlöf's results were revealed, the European Union had placed heavy



Researchers have monitored the health of the red mason bee (*Osmia bicornis-rufa*), which nests in hollow cavities.

restrictions on the three most widely used neonics in flowering crops — plants that might be attractive to bees — amid rising concerns that the chemicals might harm pollinators. The restricted neonics were imidacloprid and clothianidin, made by agrochemical giant Bayer, and thiamethoxam, made by Syngenta. But farmers, the agrochemical industry and some scientists pointed out that the moratorium was precautionary and based on limited evidence, gathered mostly from lab tests.

Since Rundlöf's paper, studies showing real-world evidence of harm from pesticides in the field have been mounting — and environmental organizations have demanded wide-ranging bans. Regulatory agencies will soon decide what to do about neonics, which have a global market worth more than US\$1.5 billion per year. This month, the EU's European Food Safety Authority is due to complete a re-evaluation of evidence for restricting neonics; the EU will then need to decide what action to take. The US Environmental Protection Agency is expected to complete its own review of the insecticides next year. France's parliament has passed a law that would ban neonics in 2018, although some exemptions will be allowed.

But industry groups and some scientists say the evidence still isn't conclusive. The picture is complicated: some studies show harm to some bees in some circumstances, whereas others find no harm. The results seem to be affected by many factors, including the species of bee and the kinds of crops involved. Scientists working on the question say the subject has become toxic: any new study is instantly and furiously picked at by entrenched advocates on both sides. Even the results of the largest study on the matter, funded by the agrochemical industry, failed to produce a consensus. Published this year², it launched another round of recriminations — including complaints from funders who criticized the paper that they had paid for. Ultimately, it's likely that political or regulatory decisions will settle the matter before opposing parties agree, says Sainath Suryanarayanan, an entomologist and sociologist at the University of Wisconsin–Madison who has studied the bee-health issue. "It is a common pattern for highly contentious and polarized debates," he says.

THE WORLD'S FAVOURITE INSECTICIDE

In the early 1980s, scientists at Nihon Tokushu Noyaku Seizo in Tokyo, an arm of Bayer, started

LUCY HULMES/CEH



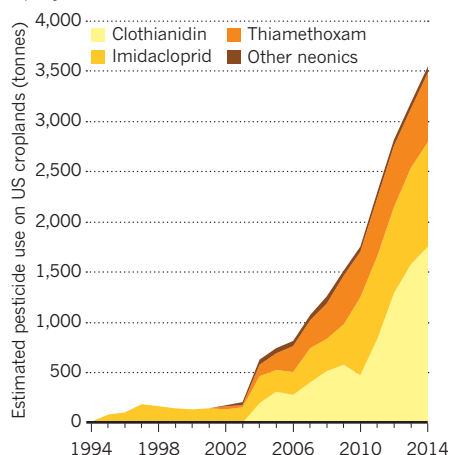
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to play around with nithiazine, an insecticide created in California a decade earlier. They discovered a new compound that was more than 100 times as effective at killing crop pests, such as aphids. Named imidacloprid, the chemical was launched onto the market in the 1990s, and it quickly became one of the most widely used insecticides in the world. By the mid-2000s, imidacloprid and similar compounds made up one-quarter of all insecticides (see 'Rising tide'). The compounds damage insects' nervous systems by causing the nerves to fire continually until they fail, eventually leading to death. Many neonicotinoids are applied directly to seeds, and are taken up by growing plants. If the plant flowers, the chemicals find their way into pollen and nectar.

In France, where sunflower seeds coated with imidacloprid came on the market in 1994, beekeepers raised the alarm. They said that their honeybees were failing to make it home after foraging flights, and they pinned the blame on the sunflowers. The concerns triggered a 1999 French ban on imidacloprid-coated sunflower seeds, which continues to this day — although it was based on the precautionary principle, rather than formal proofs

RISING TIDE

Use of neonicotinoid insecticides has rapidly increased in the United States.



of harm, says Axel Decourtye, a researcher at the Institute for Bees in Avignon, France.

Scientists hurried to find those proofs — or evidence that the concern was overblown. Researchers quickly discovered that honeybees fed high doses of neonicotinoids died. And even sub-lethal doses triggered unusual behaviour:

exposed honeybees changed their dining habits, foraging less often but for longer periods³. Other research showed⁴ that neonicotinoids act on parts of a bee's brain associated with memory and learning. Honeybees trained to respond to particular scents by sticking out their tongues, for example, performed worse — or failed to learn the task at all — when dosed with a neonicotinoid.

At every stage, critics raised new queries about how realistic the experiments were, says Decourtye. "How do we know if the neonicotinoid doses are realistic? Does the effect on the individual have any effect on the colony?"

OUT IN THE FIELD

As work continued in the laboratory, researchers also began to turn to the fields. In 2012, Decourtye and his colleagues published a paper⁵ showing that what they called "thiamethoxam intoxication" seemed to interfere with the ability of honeybees to return to their hives after looking for food in a realistic, outdoor setting. Yet that study still dosed bees' food with neonicotinoids, rather than allowing them to feed on treated crops.

Around the same time, a UK team found⁶ that it was not just honeybees that could be at risk. They reported that colonies of bumblebees exposed to "field-realistic" levels of imidacloprid in the lab and then left to grow in field conditions grew slower than controls. They also produced 85% fewer new queens to carry on their line. That work was led by Dave Goulson, a bee researcher now at the University of Sussex in Brighton, UK. In 2006, Goulson had started a charity dedicated to conserving bumblebees, and people began telling him their concerns about neonicotinoids. "To start with, I was pretty dubious," he says. But by 2014, the Task Force on Systemic Pesticides (TFSP) — a group of 30 scientists, including Goulson — announced that it had analysed 800 peer-reviewed studies on neonicotinoids and bees, and found "clear evidence of harm sufficient to trigger regulatory action"⁸.

Rundlöf's study set out to be the most realistic yet. Her team sowed eight Swedish fields with oilseed-rape seeds coated in clothianidin, and eight with untreated seeds. They found¹ not only that bumblebee colonies in treated fields grew less well than the controls, but also that the numbers of wild bees in the treated fields fell. Industry spokespeople noted that honeybee colonies weren't affected, and also quibbled with the study — arguing, for example, that the researchers had only placed a small number of wild bees into fields, so findings might not be statistically robust. Rundlöf, however, points out that the researchers also surveyed wild bees flying around, and had the bumblebee-colony data to draw on. "I know we have robust evidence," she says.

In mid-2017, the largest field study yet — funded with some \$3 million from industry — reported its long-awaited results². Scientists from the Centre for Ecology and Hydrology (CEH) near Wallingford, UK, had

put honeybees, mason bees (*Osmia bicornis*) and bumblebees in 33 oilseed-rape fields in the United Kingdom, Germany and Hungary. This time, the seeds, sown in winter, had been coated with either clothianidin or thiamethoxam, or with a neonicotinoid-free pesticide treatment.

The researchers, led by CEH entomologist Ben Woodcock, found that bumblebees and mason bees fared less well the more neonics they were exposed to. The honeybee picture was more complicated: in some cases, neonics seemed to affect bee health, but in others, they didn't. In the United Kingdom and Hungary, neonic compounds seemed to reduce worker-bee numbers in honeybee hives; in Hungary, researchers also saw fewer egg cells in these hives, an indication of reduced reproductive success. In Germany, however, the honeybee hives exposed to neonics had more egg cells — a puzzling result. Overall, the CEH study concluded that neonicotinoids reduced bees' ability to establish new colonies after winter. The journal editor's summary of the paper came under the headline: "Damage confirmed".

The agrochemical firms that funded the study don't agree. At a press conference in June, when CEH scientists presented their results — without Woodcock, who was overseas — spokespeople from Syngenta and Bayer told reporters that both the study's analysis and its conclusions were questionable. They noted that Woodcock's team had analysed more than 200 pieces of information about honeybees; 9 showed a negative effect from neonicotinoids, whereas 7 were positive. "The one-line simplistic summary conclusion published does not reflect the data presented in this paper," argued Peter Campbell, an environmental specialist at Syngenta in Reading, UK, in a separate statement released to the media.

Woodcock was incensed by the criticism. In an interview with environmental group Greenpeace, he said that industry had accused him of being a liar. Now, he says, he regrets that choice of words, but he still thinks industry took a blinkered view of the results. "I do feel that the sentiment of what I implied, while inappropriate, was not an unreasonable reaction," he says. The negative effects were in key areas related to bee health, he says, adding that for industrial firms to deny that neonics are having an effect on bees is "probably naive".

Many of the academics *Nature* talked to agree. "I think the majority of researchers highlight that the weakening of bee populations caused by neonicotinoids is proved," says Decourtye. But not everyone is so certain. "The question of whether the damage to bees is translated to an effect in fields on whole populations of bees is much harder to show," says Linda Field, head of the department of Biointeractions and Crop Protection at Rothamsted Research in Harpenden, UK. Mature colonies may survive even if individual bees are impaired, because other worker bees compensate, notes Nigel Raine, a biologist at the University of Guelph in

Canada. But solitary bees, such as wild bees and queen bumblebees emerging from hibernation, might be at greater risk.

Campbell thinks that many academics are "neutral" on the matter, but are not vocal about it. Studies showing harm to bees tend to garner media attention, and are published in widely read journals, whereas those showing no impact are relegated to less highly cited publications, he says. But Goulson and Woodcock say some of the studies that industry cites as

"A LOT OF FARMERS DO FUNDAMENTALLY RELY ON NEONICOTINIDS."

showing no harm are statistically dubious, and more flawed than the headline-garnering trials that show harm.

Christian Maus, global lead scientist for bee care at Bayer in Monheim am Rhein, Germany, picks his words carefully. "I think it is clear and undebated that neonicotinoids do have some intrinsic toxicity to bees," he says. "But under realistic conditions, as prevailing in the field and agricultural practice, we have not seen any evidence that they would be harming honeybee colonies, for instance, when they are correctly applied."

COMBINATORIAL EFFECTS

Researchers are looking beyond simple relationships between a single pesticide and bee harm. In a 2012 paper⁸, Raine and his colleagues showed that exposing bumblebees to a neonicotinoid in combination with a pesticide called a pyrethroid hampered their ability to collect pollen. Colonies exposed to both compounds experienced higher losses of worker bees than did controls, or colonies dosed with only one. The study was the first to show combinatorial effects, Raine says — which is important, because bees will be exposed to multiple compounds in the wild. And this year, in a paper⁹ published alongside Woodcock's, a Canadian team studying honeybee colonies near maize (corn) plants found that the presence of the fungicide boscalid halved the dose of neonics needed to cause death.

That work also suggested that neonic chemicals can migrate away from the plants that they are supposed to protect: by identifying the sources of pollen grains in the hives, the researchers showed that bees were exposed

to neonics mainly through pollen from untreated plants. Neonicotinoids are water-soluble — which is how they move from seeds into growing plant tissues. "But that also means they can be washed off the seed, into the soil, and maybe into other plants," says Christian Krupke, an entomologist at Purdue University in West Lafayette, Indiana.

THE B WORD

Regulators in some countries will soon decide whether to take further action to restrict neonics — and here, researchers are split. Some campaign groups, such as Greenpeace and the Pesticide Action Network, have argued for a ban on the use of neonics on all outdoor crops, not just those that might be attractive to bees, such as the bright-yellow flowers of oilseed rape.

"A lot of farmers do fundamentally rely on neonicotinoids," says Woodcock. And clamping down severely on one chemical might mean that greater amounts of other damaging substances are used. "If people can't use neonicotinoids and they go to other insecticides, is that any better? There are lots of knock-on effects," says Field.

That concern points to wider doubts about the regulatory systems that allowed agrichemicals such as neonics onto the market in the first place, says Goulson. Many researchers are hesitant to advocate outright bans. Some, such as Rundlöf, say it isn't their job to make policy recommendations. But Goulson says his view has changed as the evidence has mounted. In 2014 — at the time of the TFSP's first synthesis report — he thought that there might be certain situations in which neonics were the best option. But since then, he says, there's been even stronger evidence of collapsing insect populations — and it is hard to regulate partial bans. "I think now I'd vote for a complete ban," he says.

Whatever regulators do, Goulson says, he is growing increasingly downbeat about the chances of any consensus forming between industry and academia on the issue. "I'm starting to come to the conclusion there will never be a game-changer," he says. "There is nothing I think any scientist could do at this point to make people all sit down and have any answer." ■

Daniel Cressey reported for *Nature* from London. He is now deputy editor at *Research.

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