doi:10.1038/nature11637

ECOLOGY

Bumblebees and pesticides

A study showing the effects of two pesticides on bumblebees highlights the need for risk assessments to consider multiple species and the complex chain of factors that determines insect exposure to chemicals.

JULIET L. OSBORNE

Bee and pollination science is blooming. Research efforts around the world are seeking to explain bee colony losses, which could threaten both wild and agricultural plant systems owing to the crucial role of bees in pollination. The impact of pesticides on bees is one factor that has caught the attention of scientists and the public alike: more than 100 papers and reports have been published on this topic so far this year, including research[1–3], scientific reviews[4–6] and reports on regulatory risk-assessment procedures[7–9]. In a paper published on *Nature*'s website today[10], Gill *et al.* strike at the heart of this debate, providing a thorough data set that examines bumblebee responses to two pesticides.

Gill and colleagues investigated the effects of two insecticides (imidacloprid and λ-cyhalothrin) on the development and growth of bumblebee colonies, and on the foraging activity of individual bees, by tagging them with microchips. The researchers placed feeders of sugar syrup that had been spiked with imidacloprid, and/or filter paper treated with λ-cyhalothrin, in the path of bumblebees leaving their nest boxes. Significantly, the bees were not restricted to visiting the treated material — they could bypass the filter paper and the feeder, and they were able to forage in the surrounding landscape for pollen and nectar.

The authors report that fewer adult worker bees emerged from pupae in the colonies exposed to imidacloprid, which resonates with a previous study[2] that found reduced production of queen bees in imidacloprid-treated colonies. Gill and colleagues also found that bees from such colonies exhibited increased foraging activity, and that a higher proportion of foragers did not return to the colony. In colonies exposed to λ-cyhalothrin, they observed higher mortality of worker bees in the nest. Finally, they report that colonies exposed to both pesticides showed additive effects predictable from the individual treatment results.

This paper is important for three reasons. First, whereas most studies on bees and pesticides, and most risk-assessment models, focus on honeybees, Gill *et al.* studied bumblebees, which have a different biology and ecology and may be more vulnerable to pesticides[2]. Honeybees are smaller than bumblebees, so individual insects may be more susceptible to acute effects of chemicals, but their colonies contain tens of thousands of workers, and colony-level effects may be buffered by this sheer size. By contrast, a bumblebee colony has only a few dozen workers, so it is likely to be less resilient to the loss of individuals. The smaller colony size also makes it more difficult to monitor the survival of wild bumblebee colonies. European regulatory authorities are urgently considering how to incorporate data on bumblebees into pesticide risk assessments[3,6], and Gill and colleagues' findings provide useful input to this discussion.

Second, and unusually, the authors measured effects of pesticides on both individual bees and the whole colony. This dual evaluation stems from the concept that, if a bee acquires an acute lethal dose in the field, it will not return to the colony; however, if it ingests a sublethal dose, it might bring the material back to the colony, feed it to the brood and potentially affect the development and survival of nest-mates (an effect that would have greater impact in small colonies). Gill and colleagues' study is a helpful step towards considering this complex combination of sublethal dosage, acute and chronic mortality, and overall colony impacts, but these processes need further attention.

Examining the effects of a combination of chemicals is the third strength of this study, particularly because current regulatory requirements do not take into account the fact that insects will be exposed to multiple products[5–7]. Gill *et al.* chose chemical doses to approximate those to which a bee might be exposed in the field, although there will almost certainly be debate about whether these doses (and methods of exposure) were realistic. The chosen concentrations match label guidelines for application, but these may not reflect what farmers actually use in best or common practice.

And herein lies the catch. There are simply not sufficient field data available on the variable spatial and temporal distribution of pesticides on or in plant material, nor on bee foraging choices, to make useful comparisons between field and experimental exposure[6]. Insects probably experience a complex 'pesticide-exposure landscape' comprising multiple chemicals from several manufacturers, in one or multiple locations, applied at different doses

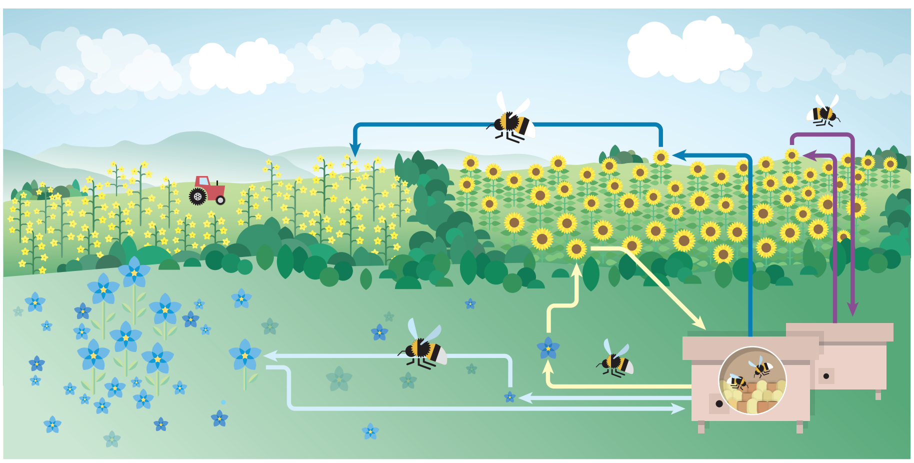

Figure 1 | A complex exposure landscape. In a typical agricultural setting, different crops may be sprayed with different pesticides at different times and doses. Bees will obtain food both from these crops and from wild plants, which makes it difficult to estimate their overall exposure to chemicals. Furthermore, bees returning to the colony after foraging may pass on the pesticides as they feed larvae. In an attempt to partially mimic this exposure complexity, Gill *et al.*[10] placed pesticide-laden feeders and filter paper (not shown) at the entrance to boxed colonies of bumblebees, which could also access flowers on crops and wild plants in the wider landscape. The researchers measured the effect of these added pesticides at both the individual-bee and colony level.

and different times by several farmers[5] (Fig. 1). Regardless of whether the doses used by Gill and colleagues closely match field doses, their study should stimulate further exploration of the exposure landscape for bees and other non-target organisms.

The UK government and other regulatory agencies around the world are currently considering updating guidelines for pesticide registration and use. To what extent should single studies such as this one influence these decisions? Although Gill and colleagues' experimental design does not fit the normal three-tiered approach to risk assessment (which incorporates laboratory, semi-field and field experiments[7,8]), it does expose areas where the current assessment system provides insufficient evidence. Indeed, the authors' recommendations — the need for evaluations of effects on bumblebees, at individual and colony levels, and of the effects of combinations of chemicals — closely match recent recommendations from European agencies[7,8]. However, the requirement for standardization and repeatability of protocols inevitably makes for slow implementation of such recommendations. So the question remains: should policy-makers make decisions on the strength of current evidence, or should they wait for more?

Furthermore, this debate is complicated by the impact of multiple other factors on bees. For example, we have as yet no convincing demonstration of the relative effects of pesticides on bee colonies compared to the effects of parasites, pathogens and foraging resources. It is not experimentally feasible to study all possible combinations of factors in all landscapes, but modelling colony dynamics, foraging patterns and external influences is a practical and time-efficient way to make progress. Such models should be built using robust data sets and possess enough detail on life-cycle dynamics to be considered realistic[11]. The part played by mass-flowering crops, such as oilseed rape and sunflowers, also needs to be evaluated more clearly. These crops may have both positive and negative impacts on bees: they can enhance bee colony growth and pollinator-species diversity in otherwise flower-poor environments, but they are typically treated with pesticides. So the net effect on pollinator populations of growing thousands of hectares of these crops has yet to be established.

And finally, the balance between protecting crops from pest damage and protecting pollinators needs further consideration. What alternative pest-management strategies would farmers adopt, for example, if a particular class of agrochemical were removed from their toolkit? The debate on pesticide use would be enhanced by a sound framework in which to represent the relevant socioeconomic and environmental trade-offs.

In summary, this single study does not provide a full explanation for bee declines, nor a definitive answer to questions about how to change pesticide regulations. But its convincing and detailed data set highlights the appropriateness of including bumblebees in agrochemical risk assessments and, more broadly, the need for a better understanding of pesticide-exposure landscapes. ■

Juliet L. Osborne *is at the Environment and Sustainability Institute, University of Exeter, Penryn, Cornwall TR10 9EZ, UK.*
e-mail: j.l.osborne@exeter.ac.uk

1. Henry, M. *et al. Science* **336,** 348–350 (2012).
2. Whitehorn, P. R., O'Connor, S., Wackers, F. L. & Goulson, D. *Science* **336,** 351–352 (2012).
3. Department for Environment, Food and Rural Affairs *Neonicotinoid Insecticides and Bees: The State of the Science and the Regulatory Response* (DEFRA, 2012).
4. Blacquière, T., Smagghe, G., van Gestel, C. A. M. & Mommaerts, V. *Ecotoxicology* **21,** 973–992 (2012).
5. Thompson, H. M. *Interaction Between Pesticides and Other Factors in Effects on Bees* EFSA Supporting Publs 2012:EN-340 (2012).
6. European Food Safety Authority *EFSA J.* **10,** 2752 (2012).
7. EFSA Panel on Plant Protection Products and Their Residues *EFSA J.* **10,** 2668 (2012).
8. Fischer, D. & Moriarty, T. *Pesticide Risk Assessment for Pollinators: Summary of a SETAC Pellston Workshop* Pensacola, Florida (Soc. Environ. Toxicol. Chem., 2011).
9. Oliver, R. *Am. Bee J.* **152,** 805–810 (2012).
10. Gill, R. J., Ramos-Rodriguez, O. & Raine, N. E. *Nature* http://dx.doi.org/10.1038/nature11585 (2012).
11. Henry, M. *et al. Science* **337,** 1453 (2012).

The author declares competing financial interests. J.L.O. has a research project partly funded by Syngenta.