Pesticide affects social behavior of bees

Neonicotinoid exposure impairs the social dynamics of bumblebees inside the nest

By Nigel E. Raine

Bees are critically important to agricultural crop production and to the reproduction of most flowering plant species on the planet (1). Yet, these essential ecosystem service providers are in decline around the world (1, 2). Widespread pesticide use associated with increasingly intensive agriculture is one of several, likely interacting, factors that contribute to these concerning pollinator declines (2). Although insecticide applications are targeted at controlling pests, their use can have unintended impacts on beneficial insects, including bees. As the most widely used class of insecticides in the world, neonicotinoids have come under considerable scrutiny following concerns around their nontarget impacts on bees (3). On page 683 of this issue, Crall et al. (4) identify how exposure to these neurotoxic insecticides can adversely affect individual bumblebees and social dynamics within their colony.

Using an innovative automated, robotic platform, Crall et al. continuously monitored the behavior of all workers inside multiple bumblebee colonies, each housed in a specially constructed nest box attached to a foraging chamber (see the figure). They found that environmentally realistic exposure to the neonicotinoid imidacloprid, dissolved in artificial nectar collected from the foraging chamber, resulted in measurable behavioral changes in workers inside the nest: They were less active, less likely to feed and care for larvae (act as nurses), and more likely to be found toward the periphery of the nest, compared to workers in control colonies. Furthermore, these changes were stronger at night, potentially relating to daily patterns in pesticide consumption or detoxification; this requires further investigation.

In spring, bumblebee queens emerge from hibernation and seek nest sites. Once a site has been chosen, each queen tries to establish her colony. She secretes wax to form the nest structure, including pots to store nectar and pollen. The queen then lays eggs that will become workers. Until these hatch, the queen is a single mother performing all the foraging, incubation of eggs, larval feeding, and nest construction and cleaning. When adult workers emerge, they take over most of these tasks. Larger workers typically undertake foraging and other tasks outside the colony, whereas smaller workers nurse their sister larvae and perform other roles inside the nest. Although the sight of bees foraging on flowers is more familiar to us, these roles inside the nest are equally important to colony success.

Environmentally realistic exposure to neonicotinoids (imidacloprid and thiamethoxam) has been shown to affect multiple aspects of worker foraging behavior, including their flower choices, foraging trip duration, and ability to collect pollen (5, 6). Such impacts on foraging performance can delay or reduce colony growth by limiting the quantity of pollen entering the nest to support larval growth (7). However, studies exposing bumblebee colonies to the neonicotinoid clothianidin, or an alternative systemic insecticide (sulfoxaflor), report impacts on colony development (8, 9) and reproductive output (9), without observing any significant impacts on pollen foraging performance. A potential alternative mechanism for these results is provided by the observations of Crall et al., suggesting that recording behavioral dynamics and interactions inside the nest could be an important component of future assessments of pesticide exposure on bumblebees. It will be interesting to see whether the automated monitoring system they developed can operate under less controlled conditions.

Impacts of neonicotinoid exposure on nursing behavior might also limit the flow of nutrients to some or all larvae, functionally acting on colony growth in the same way as limiting pollen flow into the nest through forager impairment. If this is the case, it might be possible to detect greater differentials in pollen storage between treated and control colonies, assuming pollen is coming into all colonies at similar rates but being fed to larvae less quickly in those exposed to insecticide. Differences in the spatial position of both larvae and workers within the nest also have important consequences for bumblebee colony dynamics. Larvae found further from the...
center of the nest receive less food from workers, so they develop into smaller adults (10). If neonicotinoid-exposed workers move further away from the center of the nest and are less likely to engage in nursing behavior, this might substantially affect food intake rates of peripheral larvae. Future experiments could examine whether this leads to higher mortality of these larvae, or changes the body size distribution of workers, which can already vary 10-fold within a single colony that is not exposed to pesticides (10).

Rates of larval development and survival might be further affected by impaired thermoregulation in response to neonicotinoid exposure (4). This would likely have the greatest impact in early spring, when temperatures are lowest and thermoregulation relies on the queen and, if present, a few workers. Queens exposed to neonicotinoids under laboratory conditions have significantly lower rates of colony establishment (11); such impacts would likely be exacerbated if thermoregulation was affected under less benign conditions in the field.

The approach of Crall et al. offers exciting future opportunities to examine impacts of pesticide exposure on the earliest, and potentially most vulnerable, phase of the bumblebee life cycle—by monitoring the queen’s behavior during nest establishment and as the colony grows. Understanding the impacts of pesticide exposure on bumblebee queens might be particularly important if this could bridge concerns around differences in chemical sensitivity between social and solitary bee species (12). Current ecotoxicology risk assessments for pesticide regulation use the highly social honey bee (Apis mellifera) to represent potential impacts for all insect pollinators. However, the highly social honey bee lifestyle is atypical as the majority of bee species are solitary, with a small number of bumblebee species (~250 worldwide) being social for part of their annual life cycle.

When considering relatively subtle behavioral impacts of long-term, chronic exposure to pesticides, the dynamics of large (honey bee) or small (bumblebee) colonies might act to buffer and conceal the appearance of adverse effects. However, females from solitary bee species, like early spring bumblebee queens, are overworked single mothers, making it more likely that a small behavioral change as a result of pesticide exposure might have a measurable impact on their ability to produce as many high-quality offspring. The work by Crall et al. also offers important potential avenues to improve risk assessments of impacts on bees for any pesticide.

REFERENCES AND NOTES


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Assessing behavior inside the colony

A computer-controlled, robotic observation platform with a mobile camera array enables automated periodic video monitoring of all bumblebees individually marked with BEEtags within 12 colonies. Schematic not to scale.

BIOCHEMISTRY

Recruiting more proteins to the RNA world

A primordial but still essential ribozyme co-opt protein as it evolves

By William G. Scott and Kiyoshi Nagai

Ribonuclease P (RNase P) recognizes precursor transfer RNA (pre-tRNA) and processes it to generate mature tRNAs that are used for assembling proteins. Unlike almost all other enzymes, RNase P is a ribozyme, an enzyme with an active site that is composed of RNA, and it is present in every living organism. RNase P is among the most ancient of enzymes, a living molecular fossil from an “RNA world” in which life is thought to have originated. On page 657 of this issue, Lan et al. (1) present structures of the yeast RNase P enzyme by itself and bound to its pre-tRNA substrate. Additionally, the structure of the human form, by itself and bound to its tRNA product, is reported by Wu et al. (2). These reveal the detailed mechanism by which RNase P hydrolyzes pre-tRNA to produce the required 5′-phosphorylated tRNA of exactly the correct length. These structures unambiguously reveal how an assortment of proteins conspire to form a measuring device that ensures that the pre-tRNA substrate is correctly processed by the catalytic RNA subunit of this universal and essential enzyme.

RNase P was discovered by Robertson, Altman, and Smith in 1972 (3), who described an enzyme in the bacterium Escherichia coli that precisely removes the 5′end of pre-tRNAs to produce mature tRNA products,
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