The impacts of multiple stressors on managed bees:

Novel insights from the PoshBee project

AUTHORS*

Brown M.J.F., Albrecht M., De la Rúa P., Hellström S., Klein A-M., Michez D., Nazzi F., Paxton R.J., Straw E.A., Wintermantel D. & Potts S.G.

POLICY RECOMMENDATIONS

In order to properly understand the risks to managed bees in a real-world context, risk assessments and new research should:

- Implement a systems-based risk assessment approach;
- Develop and apply a post-approval monitoring system to track real impacts of use;
- Consider a greater variety of representative species and sub-species, life history stages, sexes and castes;
- Include field realistic exposure to a wide range of chemical, disease and nutritional stressors, both individually and in combination, and assess a wide range of commonly used and emerging pesticides;
- Routinely adopt more semi-field and field assessments in addition to laboratory studies, including a wide range of forage crops;
- Investigate a broader set of sublethal impacts (measured end-points), ranging from molecular to individual, colony and population effects.

EU and Member State policies aiming to protect and enhance managed bees and wild pollinator health should fully take account of multiple stressors:

- European Food Safety Authority: Risk assessments should use a systems approach, and incorporate post-approval monitoring.
- Common Agricultural Policy Strategic Plans: Specific measures to protect pollinators, and wider biodiversity, should be further developed to mitigate risks from pesticides exposure, such as providing flower-rich habitats.
- Implementation of Pesticides Directive National Action Plans: The risks posed by multiple interacting agrochemicals and the interactions between agrochemicals and other stressors should be recognised and embedded in national plans.
- Biodiversity policies: (Nature Restoration Law, Biodiversity Strategy, EU Pollinators Initiative) should ensure that habitat creation/restoration actions provide a diversity of high quality floral resources throughout the pollinator flight season.
- National Beekeeping Policies: Support should be provided for training beekeepers in improved husbandry to identify and deal with threats from pathogens interacting with pesticide and/or nutritional stress, and also enhanced monitoring for a range of established and emerging pests and diseases.

* Multiple additional authors contributed to the underpinning science and details can be found in the relevant Deliverables.

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KEY TERMS FOR BEES AND STRESSORS

Bee species:

Honey bees: western honey bee, *Apis mellifera*
Bumblebees: managed *Bombus terrestris*
Solitary bees: refers to mason bees, e.g. *Osmia bicornis* or *Osmia cornuta*

Agrochemicals*:

Sulfoxaflor and Flupyradifurone are insecticides
Azoxystrobin and Boscalid are fungicides
Glyphosate is a herbicide
Coumaphos is an acaricide

Causes of diseases:

Crithidia bombi and *C. mellificae* are trypanosomatids gut pathogens of bumblebees and honey bees respectively
Varroa destructor is a parasitic mite found in honey bee hives
Paenibacillus larvae is a bacterial pathogen of honey bees
Nosema ceranae is a microsporidium pathogen of honey bees

* Chemical treatments were sometimes commercial formulations, and thus these treatments will have included co-formulants; for instance, some evidence suggests that a co-formulant may explain azoxystrobin-based formulation impacts. Details are available in the relevant Deliverables.

KEY MESSAGES

Managed bees and other pollinators are exposed to a wide variety of stressors and these often act in combination. Historically, most risk assessments and research have focused on the impacts of individual stressors on honey bees. However, there is broad scientific consensus that there is a need for a systems-based risk assessment approach and a post-approval monitoring system. This should consider: multiple interacting stressors; a variety of pollinator species (including different subspecies, sexes, castes and life history stages); field studies as well as laboratory studies; and a diversity of end-points (molecular, physiological, behavioural, developmental, reproductive and colony health).

The PoshBee project has made a significant step change in our understanding of how the interactions between agrochemicals, pathogens and nutrition impact bees, including:

- The impacts of combined stressors sometimes, but not always, exceed the sum of the stressors' impact when they are considered in isolation.
- There are often differences in the way that species and sub-species sexes, castes, and life stages within a species, respond to the same set of stressors.
- Laboratory studies and semi-field experiments do not always reach the same conclusions, for a given combination of stressors and target species.

NOVEL INSIGHTS PROVIDED BY POSHBEE INCLUDE:

Chemical x nutrition interactions:

High quality and diverse floral resources can reduce the negative effects of pesticides (e.g. sulfoxaflor and azoxystrobin) on honey bees and bumblebees in both laboratory and field experiments. Negative pesticide impacts on solitary bees were not mitigated by increased pollen diversity during development, but increased nutritional quality of forage improved solitary bee survival and performance in the semi-field.

Chemical x pathogen interactions:

There is no synergistic effect of pesticides (sulfoxaflor, glyphosate, azoxystrobin or flupyradifurone) and a gut pathogen (*Crithidia*) on bumblebees or solitary bees. Similarly for honey bee health, there are no interactions between these pesticides and pathogens, though there are a few exceptions (e.g. azoxystrobin with *Paenibacillus* bacteria, and sulfoxaflor in combination with *Nosema ceranae*).

Chemical x chemical interactions:

Laboratory exposure to some individual chemicals (e.g. sulfoxaflor, boscalid, glyphosate) can reduce bumblebee foraging/feeding performance, but there is no synergistic effect of exposure to these specific pairs of pesticides. In semi-field experiments, there are no synergistic impacts of sulfoxaflor in combination with azoxystrobin on bumblebees, solitary bees or honey bees. In a field study, multiple pesticides are associated with reduced bumblebee colony performance.

MAIN FINDINGS OF THE POSHBEE PROJECT

Chemical x Nutrition interactions:

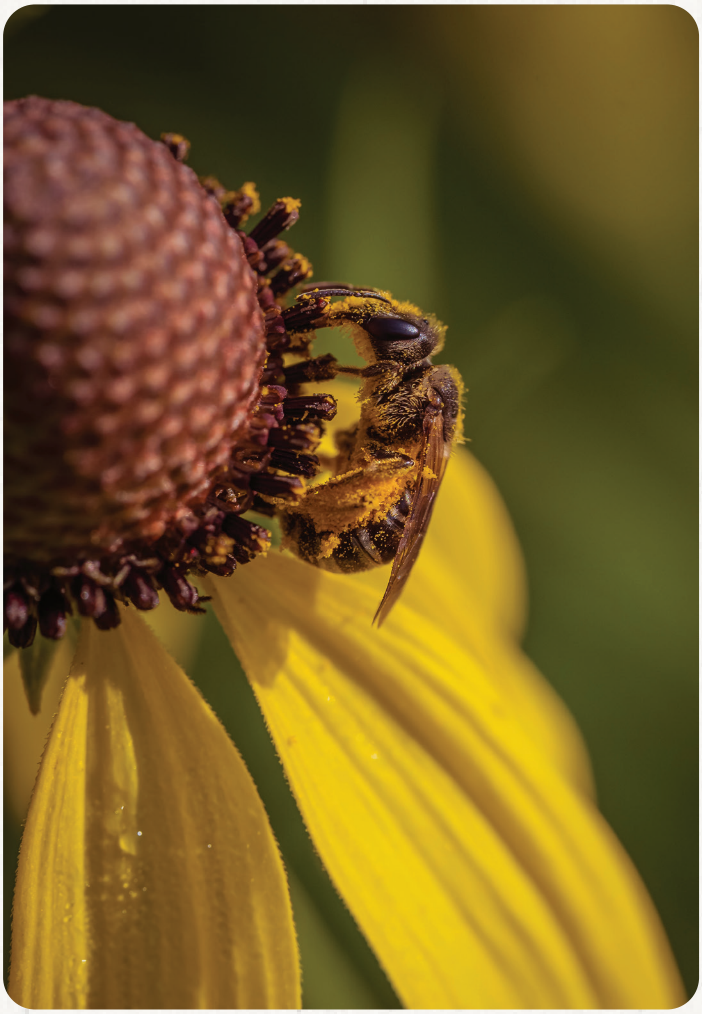
- In laboratory studies of bumblebee workers, the interaction between nutritional and chemical stress was variable. Azoxystrobin and glyphosate had no impact on development and pollen intake. In contrast, sulfoxaflor negatively affected both development and pollen collection, but a high-quality pollen diet reduced the negative effects of sulfoxaflor exposure. More information here.
- Sulfoxaflor reduced survival, cocoon weight, and pollen consumption, and increased development time of solitary bee larvae in the laboratory. When larvae were fed more diverse pollen diets, these negative effects were not mitigated. More information here.
- In laboratory studies, a high-quality pollen diet fed to honey bee workers reduced the toxic effects of field realistic concentrations of azoxystrobin and sulfoxaflor. More information here.
- Preliminary results of field experiments in Germany (vineyards) and Spain (almond orchards) did not indicate negative impacts of glyphosate on a wide range of reproductive parameters of honey bees, bumblebees and solitary bees in fields with both high and low floral nectar resources. More information here.
- In semi-field experiments, there are negative synergistic impacts of flupyradifurone and food stress on offspring production and foraging behaviours of solitary bees, but no effect on bumblebees or honey bees. Azoxystrobin reduced colony growth of bumblebees when they were exposed to low quality floral forage. More information here.

Chemical x Pathogen interactions

- Under laboratory conditions, the bumblebee pathogen, *Crithidia bombi*, did not interact with sulfoxaflor, glyphosate or azoxystrobin, and there were no effects on survival or parasite loads of workers and males, learning in workers, or hibernation and colony foundation in queens. Further, colonies exposed to sulfoxaflor and *C. bombi* showed no difference in foraging behaviour or pollination of field beans in semi-field conditions. More information here and here.
- In solitary bees, neither flupyradifurone nor glyphosate caused an increase in *Crithidia mellificae*, or increased mortality, in the laboratory. In the semi-field condition, there were negative effects of the pathogen on survival, but no interaction between chemical and pathogen in terms of foraging and nesting behaviour, and reproductive success. More information here.
- In the laboratory, the combined impacts of chemicals and pathogens on honey bees was dependent upon the particular stressor and endpoint considered.
    - *Varroa* mites in combination with azoxystrobin, sulfoxaflor or coumaphos had no effect on honey bee larvae and adults. However, sulfoxaflor and coumaphos together did have significant negative impacts on both larval and adult mortality. More information here.
    - *Paenibacillus larvae* in combination with azoxystrobin had a negative effect on larval mortality, but no effect in combination with sulfoxaflor or glyphosate. More information here.
    - *Nosema ceranae* in combination with azoxystrobin, sulfoxaflor or glyphosate had no impact on food intake or the expression of immune and detoxification genes in worker honey bees, or on queen or drone survival. More information here.

Chemical x Chemical interactions

- In the laboratory, bumblebee workers exposed to boscalid consumed less nectar, but there was no effect of glyphosate, and no synergistic effect of exposure to both pesticides together. More information here.
- For solitary bees, nectar consumption was reduced when they were exposed to sulfoxaflor, but there was no effect of azoxystrobin. There was no synergistic interaction between the two pesticides; the interaction was antagonistic. More information here.
- In semi-field experiments, sulfoxaflor or azoxystrobin on their own reduced bumblebee foraging performance; but neither had impacts on honey bees or solitary bees. There was no synergistic interactive impact of the two chemicals on any bee species. More information here.
- In a European field study, multiple pesticides found in bumblebee-collected pollen are associated with reduced colony performance, especially in simplified landscapes with intensive agricultural practices. More information here.



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