Elucidating risk of neonicotinoid exposure to bees: understanding impacts on genes through to populations

Dr Richard Gill
Food Security: The Challenge of Feeding 9 Billion People

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ANALYSIS

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Solutions for a cultivated planet

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Figure 4 | Closing the diet gap. We estimate the potential to increase food supplies by closing the ‘diet gap’, shifting 16 major crops to 100% human food.
Insect pollination worth >€150bn pa globally

(Gallai et al. 2009 Ecological Economics)

Increased likelihood without pesticide
CHAPTER FOUR

Protecting an Ecosystem Service: Approaches to Understanding and Mitigating Threats to Wild Insect Pollinators


Gill et al. 2016
Advances in Ecological Research
“If we disappeared, the world would carry on, but if insects disappeared, the world would collapse ...”
David Attenborough

The Little Things That Run the World*
(The Importance and Conservation of Invertebrates)

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Are neonicotinoids killing bees?
Are pesticides (incl. neonicotinoids) harming bees?

figure taken from Vanbergen et al. 2013 *Frontiers in Ecology & Evolution*
Social bees - if ratio of ‘impaired bees’ : ‘healthy bees’ is too high colonies can show dynamics of collapse

Understanding what comprises induced stress and how we can reduce the risk is thus a good thing
Important considerations when addressing issue of insecticide effects (i.e. neonicotinoids) on bees

1. Hazard vs. risk

2. Do sub-lethal effects matter?

3. Does this scale up to effects at population level?

4. Causative vs. correlative studies: the issue with ‘realism’

5. Does it affect pollination service?

Majority of my focus will be on some studies that have shown negative effects, but there are studies having shown no effects
Key benefits of neonicotinoids
making them popular to use around the world

• Systemic – protect whole plant and for primary part of development

• No need for spraying as can treat seeds, or irrigation etc

• Far more toxic to insects than mammals, making them potentially safer to use

• However, for flowering crops / plants, neonicotinoids get into nectar & pollen
  – route of exposure to visiting pollinators
1. Hazard is not the same as risk

Neonicotinoids are an insecticide - not surprising they affect bees

Lab experiments provide controlled levels of exposure to observe (typically acute) effects

We understand very little about the rate of exposure & response in the wild

Concentration is not the same as dosage

image from website: http://www.gmo-safety.eu/database/1038.effects-maize-honeybees.html
Multiple Routes of Pesticide Exposure for Honey Bees Living Near Agricultural Fields
Christian H. Krupke, Greg J. Hunt, Brian D. Eitzer, Gladys Andino, Krispn Given

Population Ecology
Influence of Pesticide Residues on Honey Bee (Hymenoptera: Apidae) Colony Health in France
Marie-Pierre Chauvat, Patrice Carpentier, Anne-Claire Martel, Stéphanie Bougard, Nicolas Cougoul, Philippe Porta, Julie Lachaize, François Mace, Michel Aubert, and Jean-Paul Faucon

Pesticide Residues and Bees – A Risk Assessment
Francisco Sanchez-Bayo, Koichi Goka

Neonicotinoid Residues in Wildflowers, a Potential Route of Chronic Exposure for Bees
Cristina Botías, Arthur David, Julia Horwood, Alaa Abdul-Sada, Elizabeth Nicholls, Elizabeth Hill, and Dave Goulson

Contamination of wild plants near neonicotinoid seed-treated crops, and implications for non-target insects
Cristina Botías, Arthur David, Elizabeth M. Hill, Dave Goulson
A viewpoint held by some was that bees would actively avoid crops treated with insecticides

The Neonicotinoid Insecticide Imidacloprid Repels Pollinating Flies and Beetles at Field-Realistic Concentrations

Amy H. Easton, Dave Goulson

LETTER

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Bees prefer foods containing neonicotinoid pesticides

Sébastien C. Kessler1, Erin Jo Tiekeken2, Kerry L. Simcock1, Sophie Derveau1, Jessica Mitchell1, Samantha Softley1, Jane C. Stout2 & Geraldine A. Wright3

But, we need a clearer idea about what goes on under a complex field setting
Risk to foraging bees depends on landscape

Raine & Gill 2015 Nature
2. Do sub-lethal effects matter?

Exposure to field realistic concentrations is rarely acutely lethal to bees.
We know it targets receptors/cells underpinning behavioural responses

“Growing evidence ... deficits on neuronal Kenyon cells function in the mushroom bodies, which are major sites of learning and memory and multisensory integration”
RFID technology provides insights into neonicotinoid induced impairment to foraging behaviour

~3% of body mass
Neonicotinoid (imidacloprid) decreases pollen foraging performance

Gill et al. 2012
*Nature*

Gill & Raine 2014
*Functional Ecology*
Colony level effect

Gill et al. 2012 Nature

Whitehorn et al. 2012 Science
also found a decrease in number
of new queens (gynes) being
produced after Clothianidin
exposure

but also see:

A Four-Year Field Program Investigating Long-Term Effects of Repeated Exposure of Honey Bee Colonies to Flowering Crops Treated with Thiamethoxam

Edward Pilling¹, Peter Campbell²*, Mike Coulson², Natalie Ruddle², Ingo Tornier³
4. Population level effect?

- Very little data on wild bee abundance – no monitoring system in place (even after the EU restriction)

Honeybees have much better monitoring, but they are managed
Population level effect?

Impacts of neonicotinoid use on long-term population changes in wild bees in England

Ben A. Woodcock, Nicholas J.B. Isaac, James M. Bullock, David B. Roy, David G. Garthwaite, Andrew Crowe & Richard F. Pywell

“... exposure to neonicotinoids applied to commercial oilseed rape crops was correlated with population extinctions of wild bees ...”

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LETTER

Declines in insectivorous birds are associated with high neonicotinoid concentrations

Caspar A. Hallmann, Ruud P. B. Foppen, Chris A. M. van Turnhout, Hans de Kroon & Eelke Jongejans

• Based on distribution data, not population dynamic data (i.e. no abundance data)

• How standardised is the archival data?
5. Causative vs. correlative studies: the issue with realism

**Pros**
We can understand causative effects

**Cons**
Lab too artificial: enforces pesticide exposure

**Pros**
More realistic

**Cons**
So many environmental variables uncontrolled for that we can only understand correlative patterns

Ana Ramos Rodrigues
Fantastic piece of research, but there are limitations

Almost impossible to consider all environmental variables

‘Site’ is independent unit of replication, 8 sites per treatment = lack statistical power
Combining realism with control: neonicotinoid exposure study in field

1. Bumblebee colonies (*Bombus terrestris*)
2. 5 week experiment
3. Neonicotinoid, clothianidin

4. Provided what we deemed to be 1/2 of what a colony would collect

5. 10 control & 10 exposed to Clothianidin
Combining realism with control

Distinguishing between correlative and causative effects

Arce et al. 2016 in press *Journal of Applied Ecology*

LMER: model outputs
5. Does it affect pollination service
- does impairment to pollen foraging performance decrease pollination role?

My answer: currently not enough data
Found no significant effect on fruit set or number of seeds produced per apple compared to control.

Found dose dependent effect

* = significant difference
† = not significant
NS = not significant
My take home messages

Shouldn’t forget that currently neonicotinoids are an important part of crop protection, however we are responsible for understanding and lowering the risk(s) that neonicotinoids pose.

Problem is complex; typically no single factor is sole driver; different neonicotinoids act differently. Knee jerk reactions should be avoided, and pragmatic decisions taken.

Often not a black or white picture; should be careful of using loaded and/or misleading language.

“Strong evidence points to particular pesticides being to blame for killing them [bees]. But the environment minister recently refused to support a European vote to stop the pesticides being used.”

Not sure what this “strong” evidence is?