Imperial College London

GCEE Grand Challenges

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

Dr Richard Gill

NERC SCIENCE OF THE ENVIRONMENT

Centre for Ecology & Evolution

THE ROYAL SOCIETY

BBSRC bioscience for the future

REVIEW

Food Security: The Challenge of Feeding 9 Billion People

H. Charles J. Godfray,[1]* John R. Beddington,[2] Ian R. Crute,[3] Lawrence Haddad,[4] David Lawrence,[5] James F. Muir,[6] Jules Pretty,[7] Sherman Robinson,[8] Sandy M. Thomas,[9] Camilla Toulmin[10]

ANALYSIS

doi:10.1038/nature10452

Solutions for a cultivated planet

Jonathan A. Foley[1], Navin Ramankutty[2], Kate A. Brauman[1], Emily S. Cassidy[1], James S. Gerber[1], Matt Johnston[1], Nathaniel D. Mueller[1], Christine O'Connell[1], Deepak K. Ray[1], Paul C. West[1], Christian Balzer[3], Elena M. Bennett[4], Stephen R. Carpenter[5], Jason Hill[1,6], Chad Monfreda[7], Stephen Polasky[1,8], Johan Rockström[9], John Sheehan[1], Stefan Siebert[10], David Tilman[1,11] & David P. M. Zaks[12]

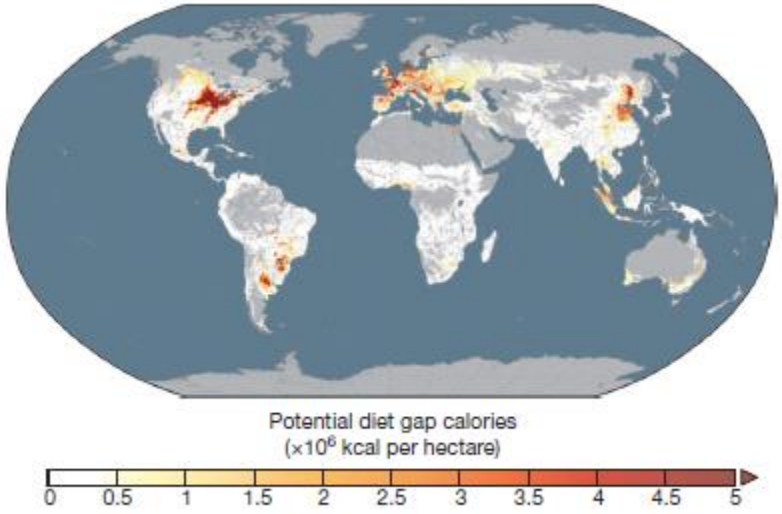
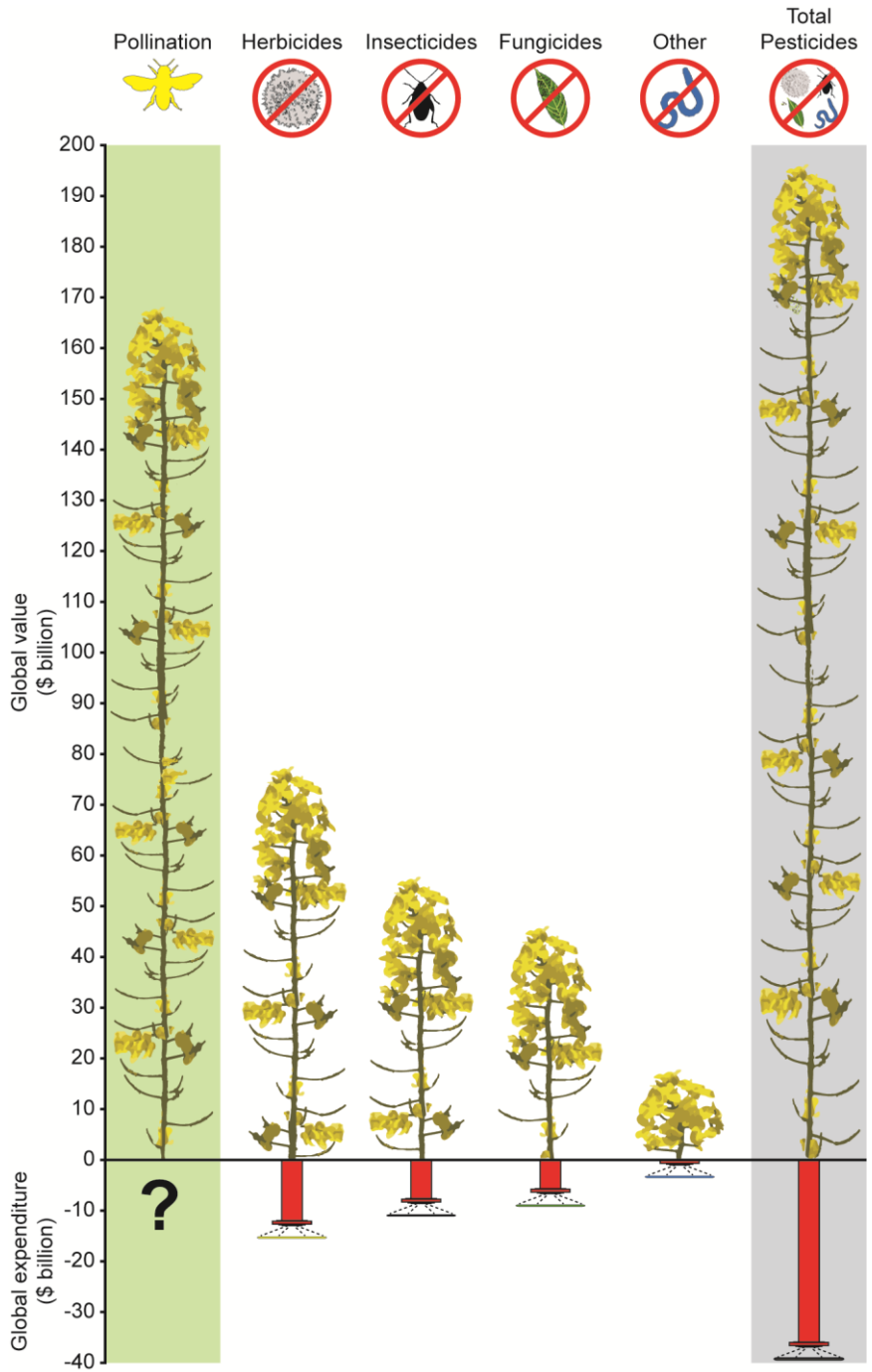


Figure 4 | Closing the diet gap. We estimate the potential to increase food

Insect pollination worth >€150bn pa globally

(Gallai *et al.* 2009 *Ecological Economics*)



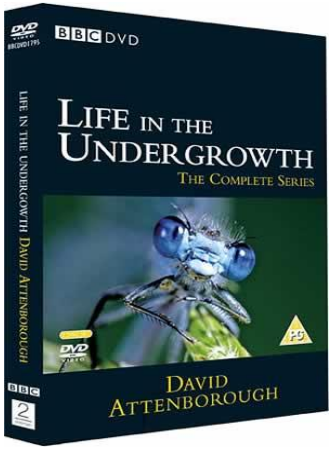
CHAPTER FOUR

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

Richard J. Gill*,1, Katherine C.R. Baldock†, Mark J.F. Brown‡, James E. Cresswell§, Lynn V. Dicks¶, Michelle T. Fountain‖, Michael P.D. Garratt#, Leonie A. Gough*, Matt S. Heard**

Gill *et al.* 2016

Advances in Ecological Research



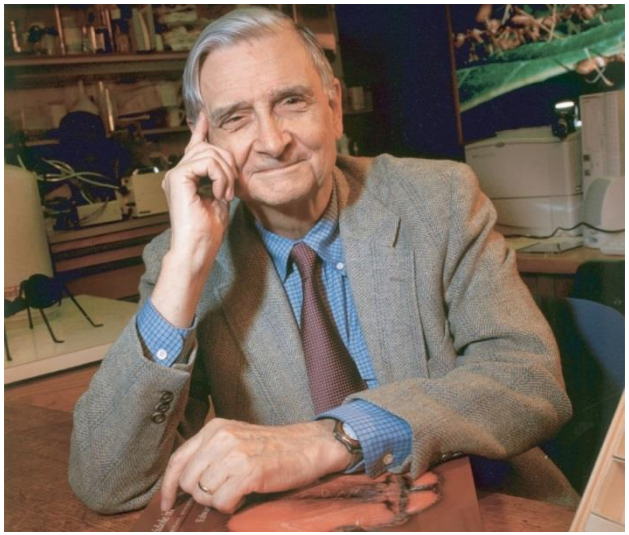
"If we disappeared, the world would carry on, but if insects disappeared, the world would collapse …"

David Attenborough

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

EDWARD O. WILSON

Museum of Comparative Zoology
Harvard University
Cambridge, Massachusetts, 02138–2902



~~Are neonicotinoids killing bees?~~

Are pesticides (incl. neonicotinoids) harming bees?

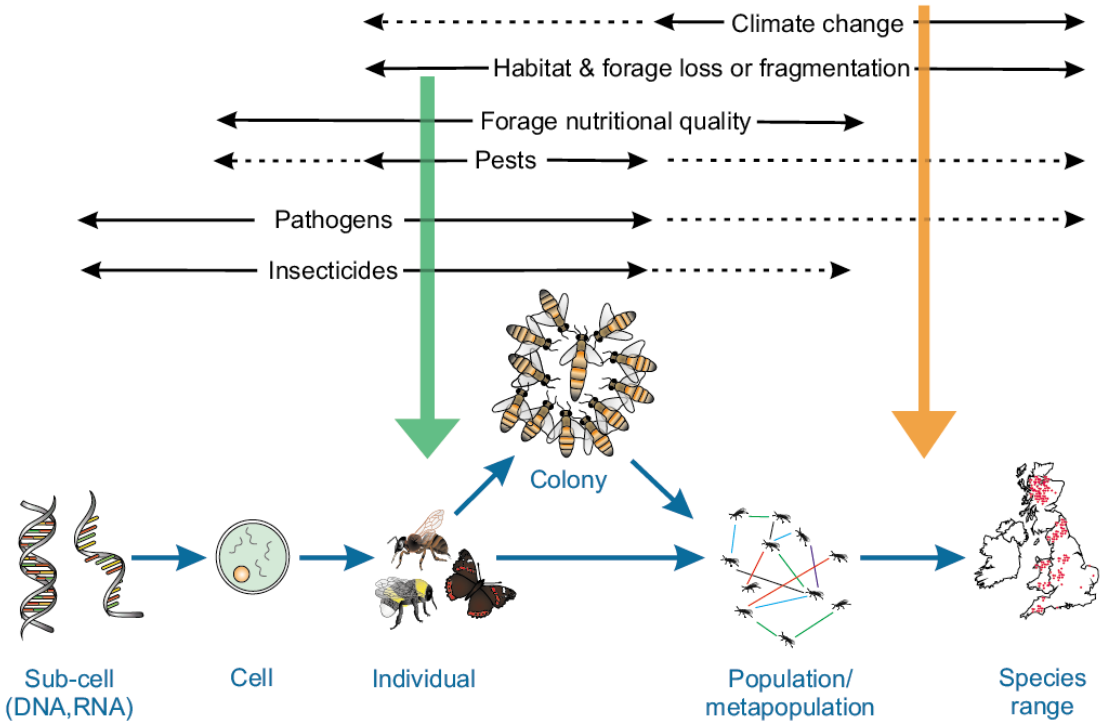


figure taken from Vanbergen *et al.* 2013 *Frontiers in Ecology & Evolution*

ECOLOGY LETTERS

Ecology Letters, (2013) **16**: 1463–1469 doi: 10.1111/ele.12188

LETTER

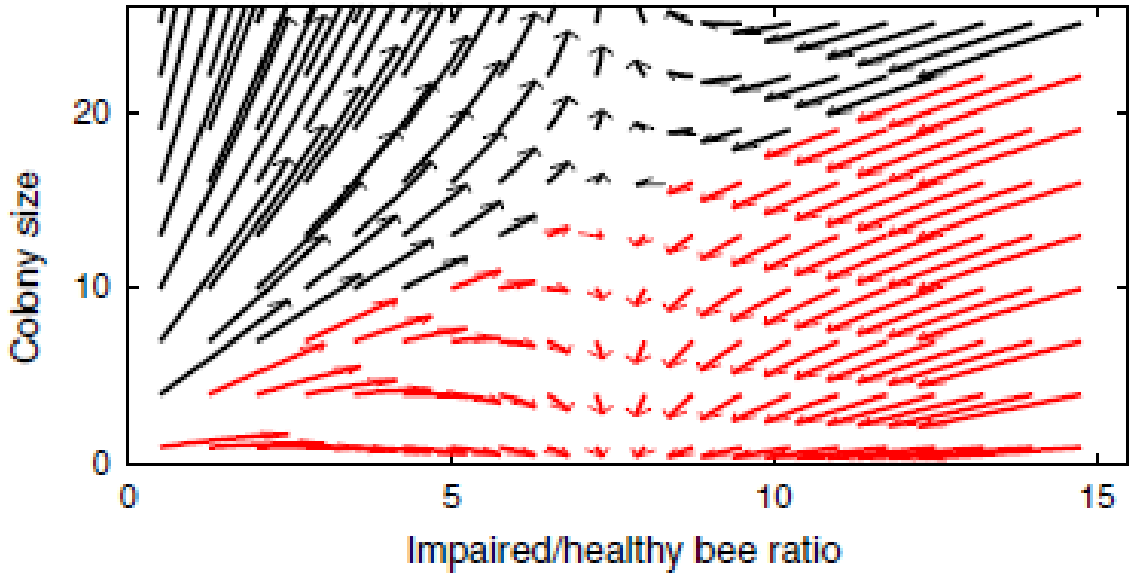
Chronic sublethal stress causes bee colony failure

John Bryden,[1]* Richard J. Gill,[1,2]
Robert A. A. Mitton,[1]
Nigel E. Raine[1] and
Vincent A. A. Jansen[1]

Abstract

Current bee population declines and colony failures are well documented yet poorly understood and no single factor has been identified as a leading cause. The evidence is equivocal and puzzling: for instance, many pathogens and parasites can be found in both failing and surviving colonies and field pesticide exposure is typically sublethal. Here, we investigate how these results can be due to sublethal stress impairing colony

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

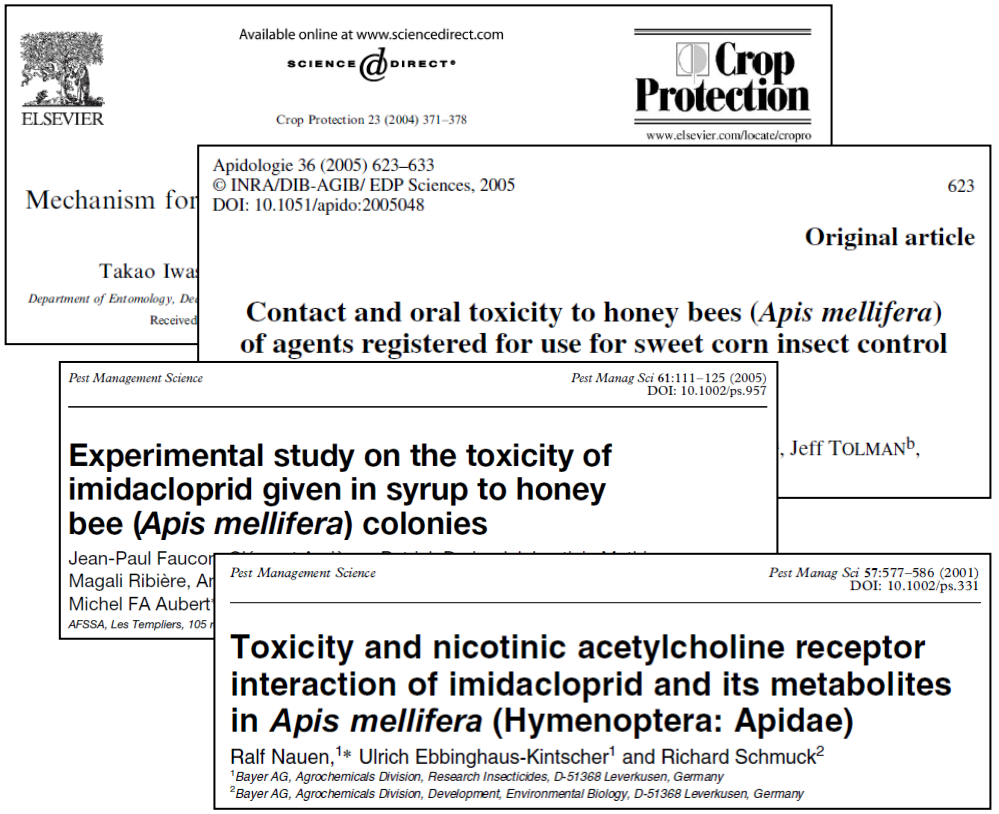
- Systemic – protect whole plant and for primary part of development
- No need for spraying as can treat seeds, or irrigation etc
- Far more toxic to insects than mammals, making them potentially safer to use
- However, for flowering crops / plants, neonicotinoids get into nectar & pollen
  - route of exposure to visiting pollinators

seeds treated with neonicotinoid coating

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



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Crop Protection 23 (2004) 371–378
Crop Protection
www.elsevier.com/locate/cropro

Mechanism for

Takao Iwa

Department of Entomology, De

Received

Apidologie 36 (2005) 623–633
© INRA/DIB-AGIB/ EDP Sciences, 2005
DOI: 10.1051/apido:2005048

623

Original article

Contact and oral toxicity to honey bees (*Apis mellifera*) of agents registered for use for sweet corn insect control

Pest Management Science

Pest Manag Sci 61:111–125 (2005)
DOI: 10.1002/ps.957

Experimental study on the toxicity of imidacloprid given in syrup to honey bee (*Apis mellifera*) colonies

, Jeff TOLMAN[b],

Jean-Paul Faucon
Magali Ribière, Ar
Michel FA Aubert
AFSSA, Les Templiers, 105 r

Pest Management Science

Pest Manag Sci 57:577–586 (2001)
DOI: 10.1002/ps.331

Toxicity and nicotinic acetylcholine receptor interaction of imidacloprid and its metabolites in *Apis mellifera* (Hymenoptera: Apidae)

Ralf Nauen,[1]* Ulrich Ebbinghaus-Kintscher[1] and Richard Schmuck[2]
[1]Bayer AG, Agrochemicals Division, Research Insecticides, D-51368 Leverkusen, Germany
[2]Bayer AG, Agrochemicals Division, Development, Environmental Biology, D-51368 Leverkusen, Germany

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

Concentration is not the same as dosage

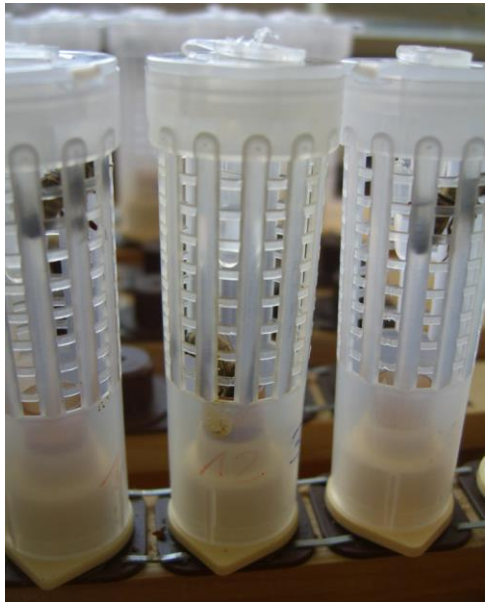


image from website: http://www.gmo-safety.eu/database/1038.effects-maize-honeybees.html

OPEN ACCESS Freely available online PLoS one

Multiple Routes of Pesticide Exposure for Honey Bees Living Near Agricultural Fields

Christian H. Krupke[1]*, Greg J. Hunt[1], Brian D. Eitzer[2], Gladys Andino[1], Krispn Given[1]

OPEN ACCESS Freely available online PLoS one

High Levels of Miticides and Agrochemicals in North American Apiaries: Implications for Honey Bee Health

Christopher A. Mullin[1]*, Maryann Frazier[1], James L. Frazier[1], Sara Ashcraft[1], Roger Simonds[2], Dennis vanEngelsdorp[3], Jeffery S. Pettis[4]

Population Ecology

Influence of Pesticide Residues on Honey Bee (Hymenoptera: Apidae) Colony Health in France

MARIE-PIERRE CHAUZAT,[1,2] PATRICE CARPENTIER,[3] ANNE-CLAIRE MARTEL,[1] STÉPHANIE BOUGEARD,[4] NICOLAS COUGOULE,[1] PHILIPPE PORTA,[1] JULIE LACHAIZE,[1] FRANÇOIS MADEC,[4] MICHEL AUBERT,[1] AND JEAN-PAUL FAUCON[1]

OPEN ACCESS Freely available online PLOS ONE

Pesticide Residues and Bees – A Risk Assessment

Francisco Sanchez-Bayo[1]*, Koichi Goka[2]

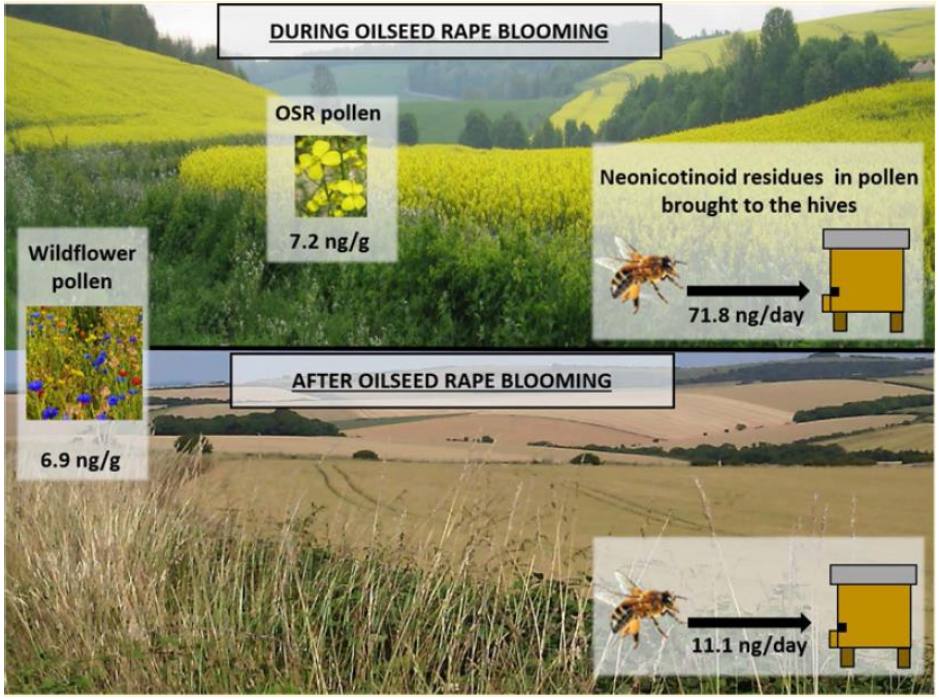
Environmental Science & Technology

Article

pubs.acs.org/est

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



ELSEVIER

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

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

OPEN ACCESS Freely available online

PLOS ONE

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

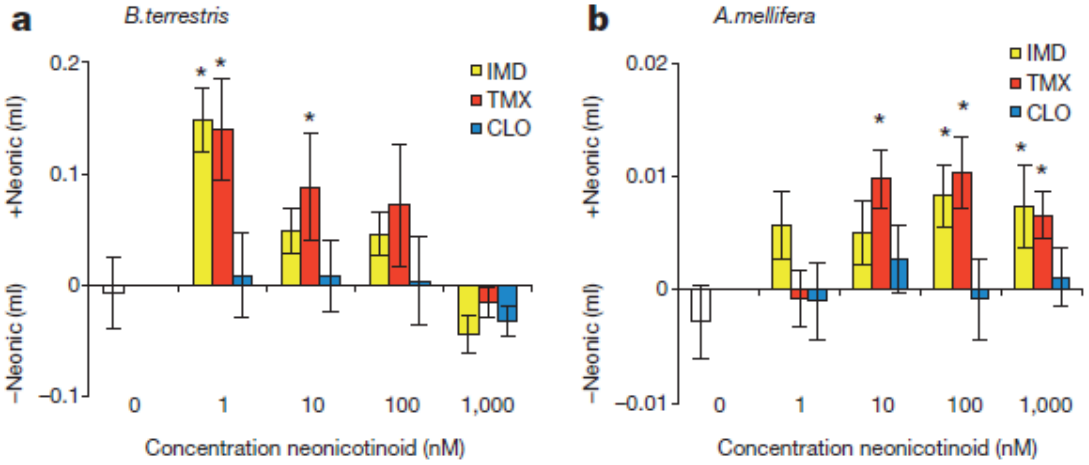
Amy H. Easton, Dave Goulson*

LETTER

doi:10.1038/nature14414

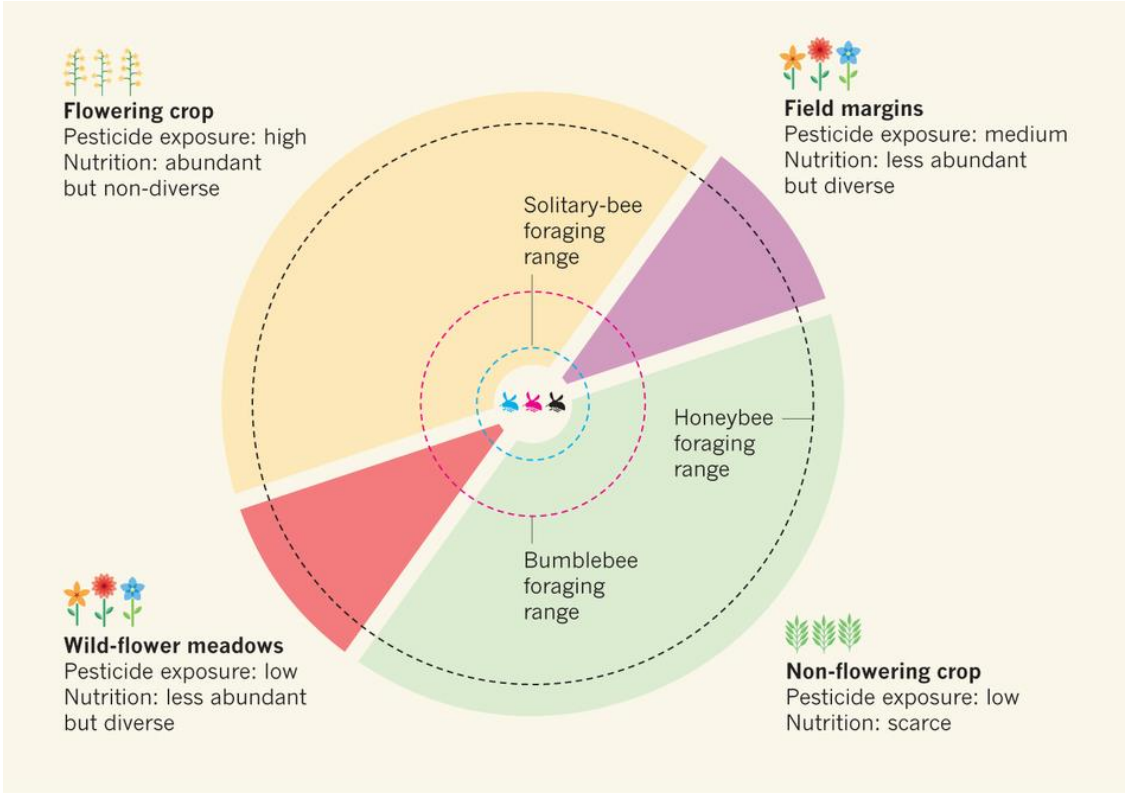
Bees prefer foods containing neonicotinoid pesticides

Sébastien C. Kessler[1]*, Erin Jo Tiedeken[2]*, Kerry L. Simcock[1], Sophie Derveau[3], Jessica Mitchell[4], Samantha Softley[1], Jane C. Stout[2] & Geraldine A. Wright[1]



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

The Sublethal Effects of Pesticides on Beneficial Arthropods

Nicolas Desneux,[1] Axel Decourtye,[2] and Jean-Marie Delpuech[3]

Annu. Rev. Entomol. 2007. 52:81–106

Neurotoxins are likely to affect behaviour

We know it targets receptors/cells underpinning behavioural responses

ARTICLE

Received 8 Oct 2012 | Accepted 25 Feb 2013 | Published 27 Mar 2013

DOI: 10.1038/ncomms2648 OPEN

Cholinergic pesticides cause mushroom body neuronal inactivation in honeybees

Mary J. Palmer[1], Christopher Moffat[1], Nastja Saranzewa[1], Jenni Harvey[1], Geraldine A. Wright[2] & Christopher N. Connolly[1]

"Growing evidence … deficits on neuronal Kenyon cells function in the mushroom bodies, which are major sites of learning and memory and multisensory integration"

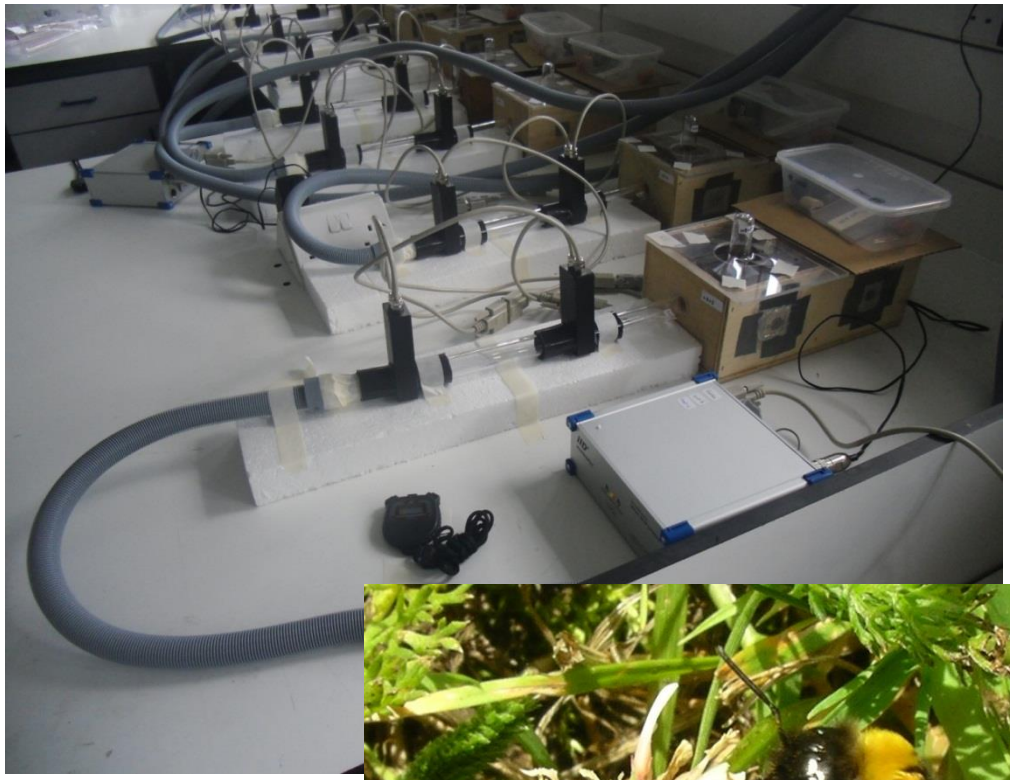
OPEN

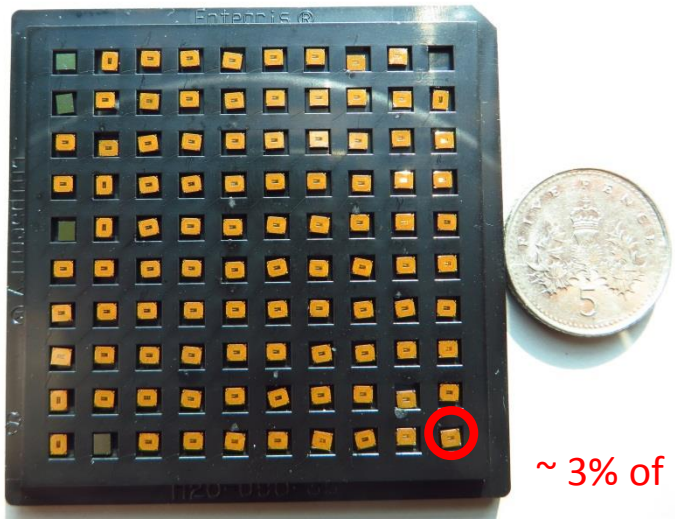
Neonicotinoids target distinct nicotinic acetylcholine receptors and neurons, leading to differential risks to bumblebees

Received: 22 January 2016
Accepted: 30 March 2016
Published: 28 April 2016

Christopher Moffat[1], Stephen T. Buckland[2], Andrew J. Samson[1], Robin McArthur[1], Victor Chamosa Pino[1], Karen A. Bollan[1], Jeffrey T.-J. Huang[3] & Christopher N. Connolly[1]

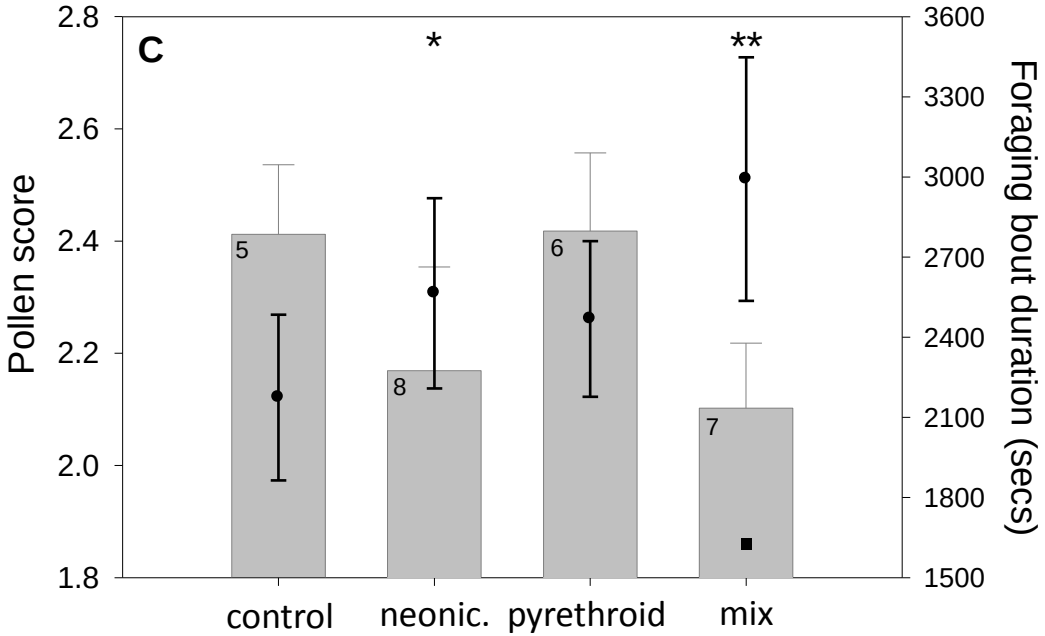
RFID technology provides insights into neonicotinoid induced impairment to foraging behaviour





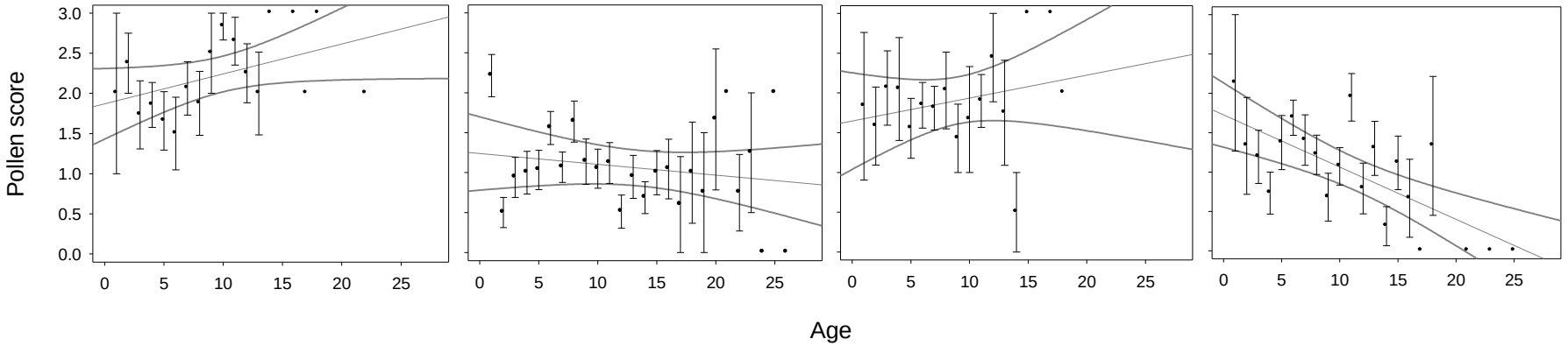
~ 3% of body mass

Neonicotinoid (imidacloprid) decreases pollen foraging performance

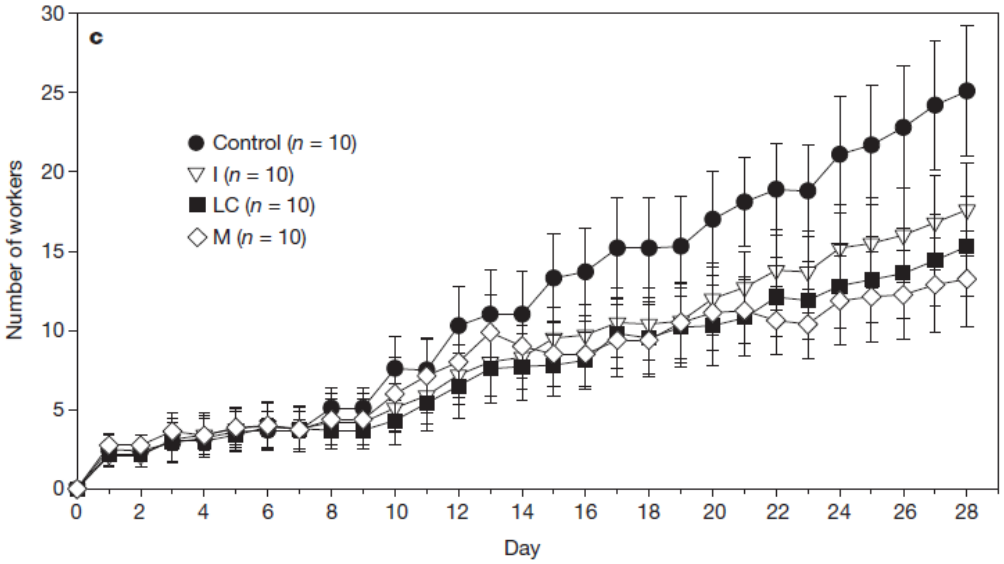


Gill *et al.* 2012
Nature

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:

OPEN ACCESS Freely available online

PLOS ONE

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

Edward Pilling[1], Peter Campbell[2]*, Mike Coulson[2], Natalie Ruddle[2], Ingo Tornier[3]

4. Population level effect?

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

CHAPTER FOUR

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

Richard J. Gill*,[1], Katherine C.R. Baldock[†], Mark J.F. Brown[‡]
James E. Cresswell[§], Lynn V. Dicks[¶], Michelle T. Fountain[‖],
Michael P.D. Garratt[#], Leonie A. Gough*, Matt S. Heard**

Advances in Ecological Research, Volume 54
ISSN 0065-2504
http://dx.doi.org/10.1016/bs.aecr.2015.10.007

Department for Environment Food & Rural Affairs

www.gov.uk

The National Pollinator Strategy: for bees and other pollinators in England
November 2014

European Red List of Bees

Ana Nieto, Stuart P.M. Roberts, James Kemp, Pierre Rasmont, Michael Kuhlmann, Mariana García Criado, Jacobus C. Biesmeijer, Petr Bogusch, Holger H. Dathe, Pilar De la Rúa, Thibaut De Meulemeester, Manuel Dehon, Alexandre Dewulf, Francisco Javier Ortiz-Sánchez, Patrick Lhomme, Alain Pauly, Simon G. Potts, Christophe Praz, Marino Quaranta, Vladimir G. Radchenko, Erwin Scheuchl, Jan Smit, Jakub Straka, Michael Terzo, Bogdan Tomozii, Jemma Window and Denis Michez

Honeybees have much better monitoring, but they are managed

Population level effect?

ARTICLE

Received 7 Aug 2015 | Accepted 5 Jul 2016 | Published 16 Aug 2016

DOI: 10.1038/ncomms12459 OPEN

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

Ben A. Woodcock[1,*], Nicholas J.B. Isaac[1,*], James M. Bullock[1], David B. Roy[1], David G. Garthwaite[2], Andrew Crowe[2] & Richard F. Pywell[1]

"… exposure to neonicotinoids applied to commercial oilseed rape crops was **correlated** with population extinctions of wild bees …"

- Based on distribution data, not population dynamic data (i.e. no abundance data)
- How standardised is the archival data?

LETTER

doi:10.1038/nature13531

Declines in insectivorous birds are associated with high neonicotinoid concentrations

Caspar A. Hallmann[1,2], Ruud P. B. Foppen[2,3], Chris A. M. van Turnhout[2], Hans de Kroon[1] & Eelke Jongejans[1]

5. Causative *vs.* correlative studies: the issue with realism

lab

field

Pros

We can understand causative effects

Cons

Lab too artificial: enforces pesticide exposure

Pros

More realistic

Cons

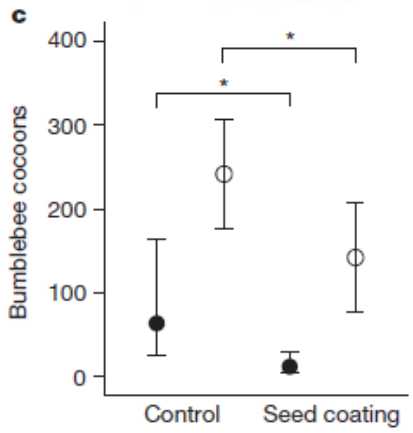
So many environmental variables uncontrolled for that we can only understand correlative patterns

LETTER

doi:10.1038/nature14420

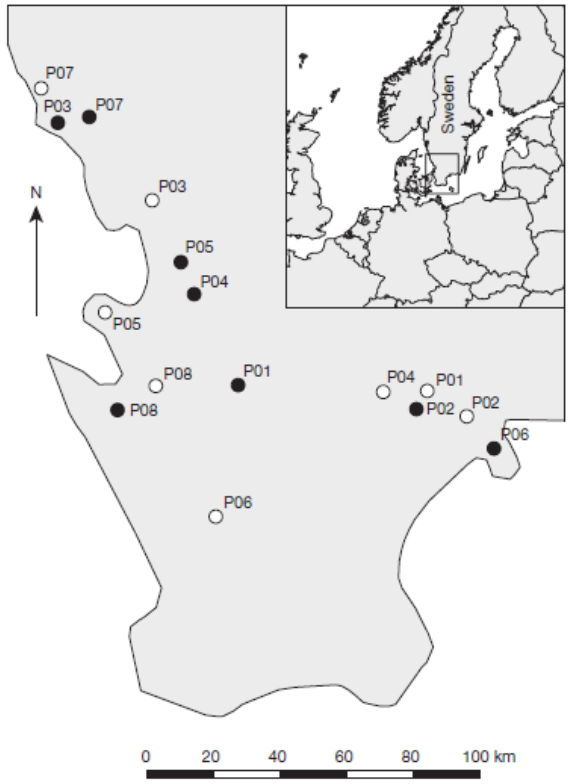
Seed coating with a neonicotinoid insecticide negatively affects wild bees

Maj Rundlöf[1], Georg K. S. Andersson[1,2], Riccardo Bommarco[3], Ingemar Fries[3], Veronica Hederström[1], Lina Herbertsson[2], Ove Jonsson[4,5], Björn K. Klatt[2], Thorsten R. Pedersen[6], Johanna Yourstone[1] & Henrik G. Smith[1,2]



- 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

Andres Arce

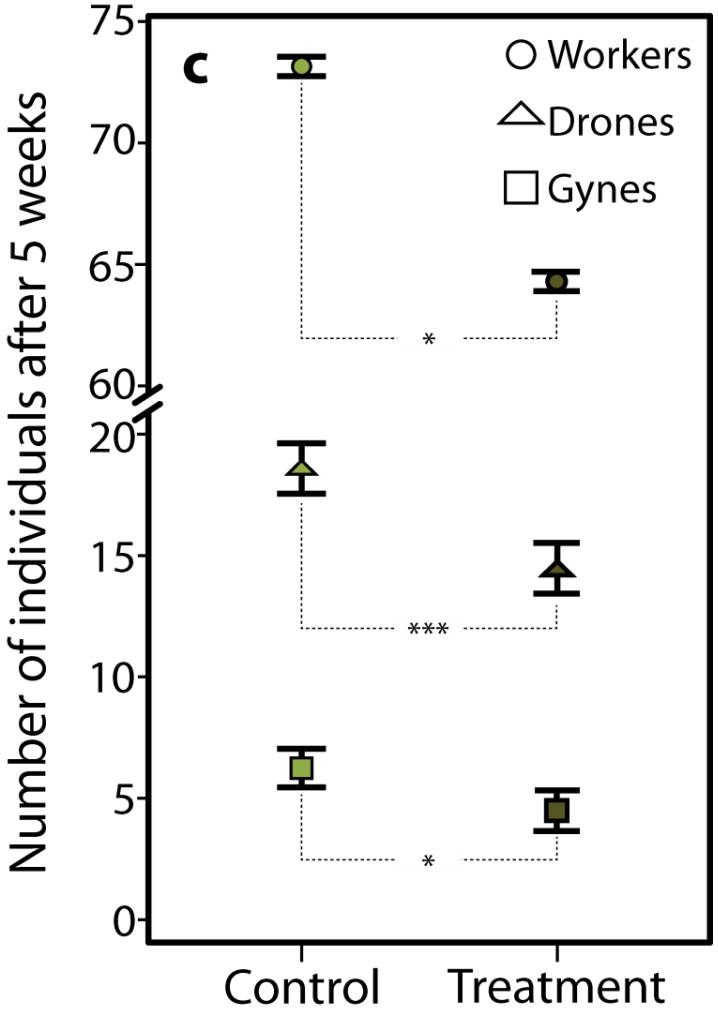
1. Bumblebee colonies (*Bombus terrestris*)
2. 5 week experiment
3. Neonicotinoid, clothianidin
4. Provided what we deemed to be 1/2 of what a colony would collect
5. 10 control & 10 exposed to Clothianidin

Combining realism with control

Distinguishing between correlative and causative effects

Dr Andres Arce

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



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?

Ecotoxicology
DOI 10.1007/s10646-014-1189-7

Field realistic doses of pesticide imidacloprid reduce bumblebee pollen foraging efficiency

Hannah Feltham · Kirsty Park · Dave Goulson

Journal of Applied Ecology
British Ecological Society
Journal of Applied Ecology 2016 doi: 10.1111/1365-2664.12689

Investigating the impacts of field-realistic exposure to a neonicotinoid pesticide on bumblebee foraging, homing ability and colony growth

Dara A. Stanley[1,2*], Avery L. Russell[3], Sarah J. Morrison[4], Catherine Rogers[1] and Nigel E. Raine[1,5]

Functional Ecology
British Ecological Society
Functional Ecology 2014 doi: 10.1111/1365-2435.12292

Chronic impairment of bumblebee natural foraging behaviour induced by sublethal pesticide exposure

Richard J. Gill*† and Nigel E. Raine*‡

My answer: currently not enough data

LETTER

doi:10.1038/nature16167

* = significant difference

† = not significant

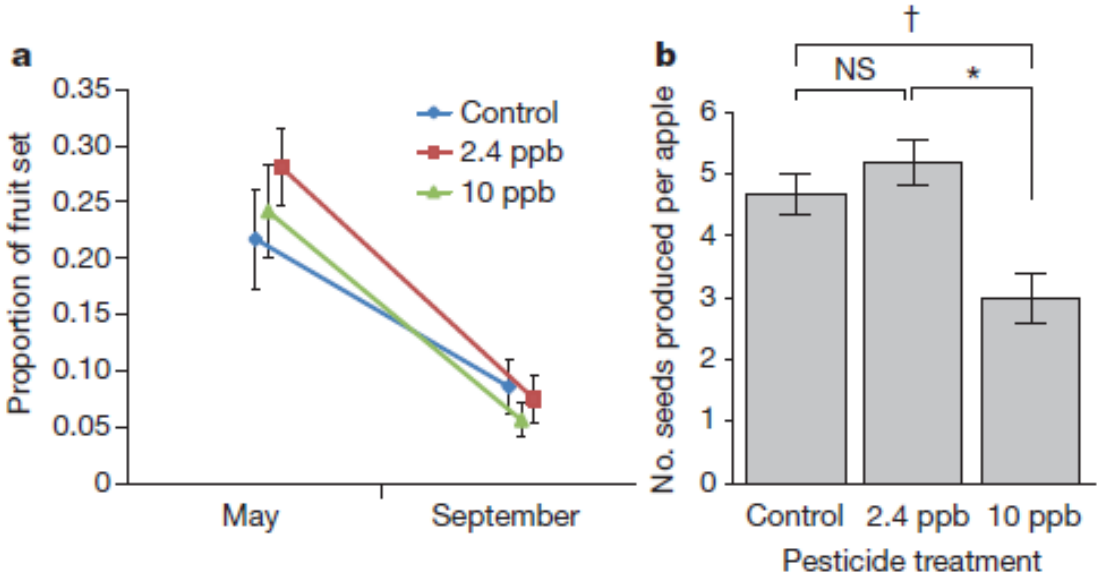
NS = not significant

Neonicotinoid pesticide exposure impairs crop pollination services provided by bumblebees

Dara A. Stanley[1], Michael P. D. Garratt[2], Jennifer B. Wickens[2], Victoria J. Wickens[2], Simon G. Potts[2] & Nigel E. Raine[1,3]

Found no significant effect on fruit set or number of seeds produced per apple compared to control

Found dose dependent effect



but also see:

SCIENTIFIC REPORTS

OPEN

Evidence for pollinator cost and farming benefits of neonicotinoid seed coatings on oilseed rape

Received: 20 February 2015
Accepted: 25 June 2015
Published: 13 August 2015

G. E. Budge[1], D. Garthwaite[1], A. Crowe[1], N. D. Boatman[1], K. S. Delaplane[2], M. A. Brown[3], H. H. Thygesen[1] & S. Pietravalle[1]

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

38 DEGREES
people. power. change.

"Strong evidence points to particul… being to blame for killing them [bees]. But th… ent minister recently refused to support a … to stop the pesticides being used"

Not sure what this "strong" evidence is?