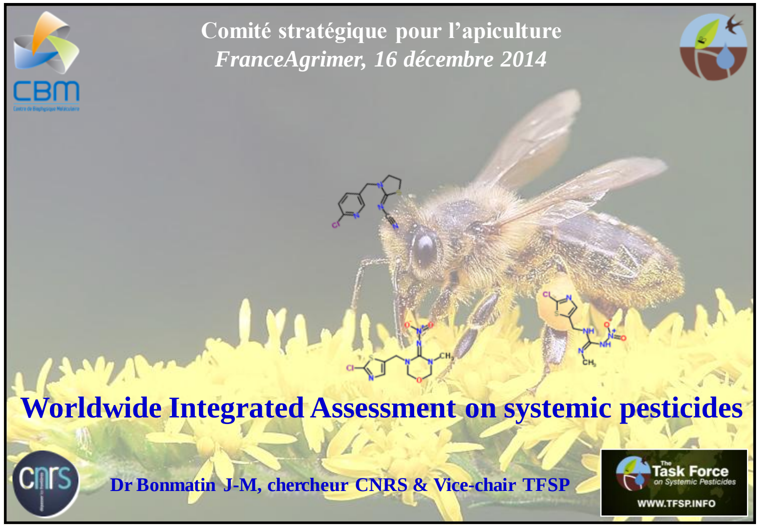
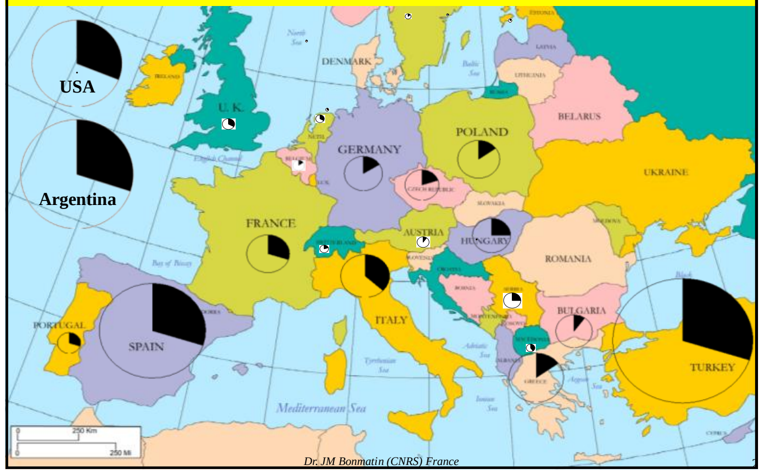
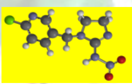


Pertes de ruches en 2008: *Colony Collapse Disorder (CCD)*



Affaiblissement et disparition de colonies : causes, seules ou combinées




- Pesticides (insecticides)
- Parasitisme (ex: *varroa jacobsoni*)
- Pathogènes (ex: virus, nosémose)
- Paysages (agriculture intensive)
- Perte de diversité (nectar et pollen)
- Prédateurs (ex: *Vespa velutina*)



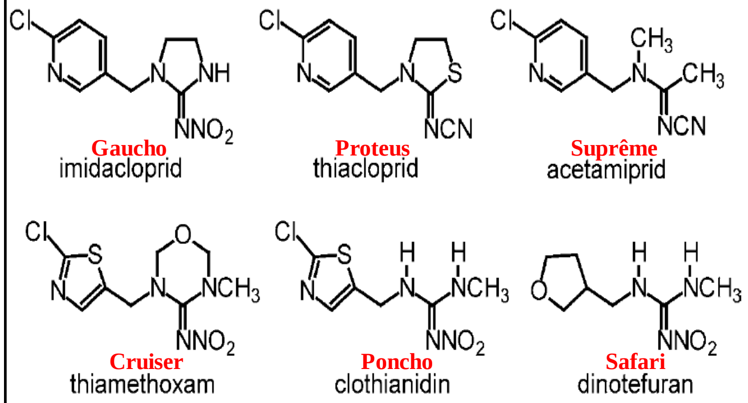
Insecticides : toxicité / abeilles (DL_{50} ng/ab)

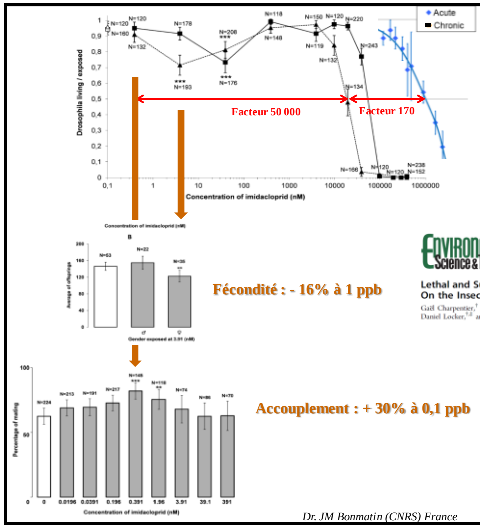
pesticide	®	Use	Dose g/ha	LD50 ng/ab	Tox/DDT
DDT	Dinocide	insecticide	200-600	27 000.0	1
thiaclopride	Proteus	insecticide	62,5	12 600.0	2.1
amitraze	Apivar	acaricide	-	12 000.0	2.3
acetamiprid	Supreme	insecticide	30-150	7 100.0	3.8
coumaphos	Perizin	acaricide	-	3 000.0	9
methiocarb	Mesurol	insecticide	150-2200	230.0	117
tau-fluvalinate	Apistan	acaricide	-	200.0	135
carbofuran	Curater	insecticide	600	160.0	169
λ-cyhalothrine	Karate	insecticide	150	38.0	711
thiaméthoxam	Cruiser	insecticide	69	5.0	5 400
fipronil	Regent	insecticide	50	4.2	6 475
imidaclopride	Gaucho	insecticide	75	3.7	7 297
clothianidine	Poncho	insecticide	50	2.5	10 800
deltaméthrine	Décis	insecticide	7,5	2.5	10 800

Néonicotinoïdes

- **Effets sur la drosophile**
- Expositions réelles (nectar)
- Impact sur les abeilles (revue)
- Evaluation mondiale des impacts
  - Invertébrés
  - Vertébrés
- Conclusions

Néonicotinoïdes





Environmental Science & Technology

Lethal and Sublethal Effects of Imidacloprid, After Chronic Exposure, On the Insect Model *Drosophila melanogaster*

Gaël Charpentier, Fanny Louat, Jean-Marc Bonmatin, Patrice A. Marchand, Fanny Vanier, Daniel Locker, and Martine Decoville

LOEC (0,1 ppb)

♂ acute LC50 / 3 300 000

♀ acute LC50 / 8 600 000

Néonicotinoïdes

- Effets sur la drosophile
- **Expositions réelles (nectar)**
- Impact sur les abeilles (revue)
- Evaluation mondiale des impacts
  - Invertébrés
  - Vertébrés
- Conclusions

Anal Bioanal Chem (2014) 406:621-633
DOI 10.1007/s00216-013-7483-z

RESEARCH PAPER

Sensitive analytical methods for 22 relevant insecticides of 3 chemical families in honey by GC-MS/MS and LC-MS/MS

Delphine Paradis · Géraldine Bérail · Jean-Marc Bonmatin · Luc P. Belzunces

Insecticide (MRL, ng/g of honey)	LOQ (ng/g of honey)
Acrinathrin (50)	0.5
Bifenthrin	0.5
Cypermethrin (50)	0.5
Deltamethrin (30)	0.5
Esfenvalerate	0.2
Fipronil (10)	0.5
Fipronil desulfinyl (10)	0.5
Fipronil sulfide (10)	0.5
Fipronil sulfone (10)	0.5
λ-cyhalothrin (20)	0.5
Permethrin	0.5
Pyraclofos	0.2
Resmethrin	0.5
Tebufenpyrad (50)	0.5
τ-fluvalinate (10)	0.2
Tolfenpyrad	0.5
Acetamiprid (50)	0.2
Clothianidin (10)	0.5
Ethiprole	0.5
Imidacloprid (50)	0.5
Thiacloprid (200)	0.2
Thiametoxam (10)	0.2

Exemple d'exposition réelle par le nectar (miel frais)

(Vendée printemps 2009 & 2010 : 2 ruchers x 3 ruches, prélèvements tous les 15 jours)

Insecticide	Niveau max (ng/g)	LMR (CE) (ng/g)
Acrinathrin	Not detected	50
Bifenthrin	Not detected	-
Cypermethrin	Not detected	50
Deltamethrin	**3.6**	**30**
Esfenvalerate	Not detected	-
~~Fipronil~~	Not detected	10
~~Fipronil desulfinyl~~	Not detected	10
~~Fipronil sulfide~~	Not detected	10
~~Fipronil sulfone~~	Not detected	10
λ-cyhalothrin	Not detected	20
Permethrin	Not detected	-
Pyraclofos	Not detected	-
Resmethrin	Not detected	-
Tebufenpyrad	Not detected	50
τ-fluvalinate	**69.2**	**10**
Tolfenpyrad	Not detected	-
Acetamiprid	**112.8**	**50**
~~Clothianidin~~	Not detected	10
Ethiprole	Not detected	-
~~Imidacloprid~~	Not detected	50
Thiacloprid	**11.6**	**200**
Thiamethoxam	**2.0**	**10**

Néonicotinoïdes

- Effets sur la drosophile
- Expositions réelles (nectar)
- **Impact sur les abeilles (revue)**
- Evaluation mondiale des impacts
  - Invertébrés
  - Vertébrés
- Conclusions

Sciencexpress Report

EMBARGOED UNTIL 2:00 PM US ET THURSDAY, 29 MARCH 2012

A Common Pesticide Decreases Foraging Success and Survival in Honey Bees

Mickaël Henry,[1,*] Maxime Beguin,[2] Fabrice Requier,[3,4] Orianne Rollin,[1,5] Jean-François Odoux,[4] Pierrick Aupinel,[4] Jean Aptel,[1] Sylvie Tchamitchian,[1] Axel Decourtye[5]

[1]INRA, UR406 Abeilles et Environnement, F-84914 Avignon, France. [2]Association pour le développement de l'apiculture provençale (ADAPI), F-13626 Aix-en-Provence, France. [3]Centre d'Etudes Biologiques de Chizé, CNRS (USC-INRA 1339), UPR1934, F-79360 Beauvoir-sur-Niort, France. [4]INRA, UE1255, UE Entomologie, F-17700 Surgères, France. [5]ACTA, UMT PrADE, UR 406 Abeilles et Environnement, F-84914 Avignon, France.

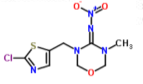
*To whom correspondance should be addressed. E-mail: mickael.henry@avignon.inra.fr

Non-lethal exposure of honey bees to thiamethoxam (neonicotinoid systemic pesticide) causes high mortality due to homing failure at levels that could put a colony at risk of collapse. Simulated exposure events on free-ranging foragers labeled with an RFID tag suggest that homing is impaired by thiamethoxam intoxication. These experiments offer new insights into the consequences of common neonicotinoid pesticides used worldwide.

authorization procedures now require running mortality surveys to ensure doses encountered in the field remain below lethal levels for honey bees.

However, a growing body of evidence shows that sublethal doses, i.e., doses that do not entail direct mortality, still have the potential to induce a variety of behavioral difficulties in foraging honey bees, such as memory and learning dysfunctions and alteration of navigational skills (9). Neonicotinoid pesticides used to protect crops against aphids and other sap-sucking insects are especially liable to provoke such behavioral troubles. They are highly potent and selective agonists of nicotinic acetylcholine receptors, which are important excitatory neurotransmitter receptors in insects (10, 11). Effects of sublethal neonicotinoid exposures in honey bees may include abnormal foraging activity (12–14), reduced olfactory memory and learning performance (15–17) and possibly impaired orienta-

Thiamethoxam



Neonicotinoid Pesticide Reduces Bumble Bee Colony Growth and Queen Production

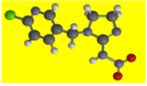
Penelope R. Whitehorn,[1] Stephanie O'Connor,[1] Felix L. Wackers,[2] Dave Goulson[1*]

Growing evidence for declines in bee populations has caused great concern because of the valuable ecosystem services they provide. Neonicotinoid insecticides have been implicated in these declines because they occur at trace levels in the nectar and pollen of crop plants. We exposed colonies of the bumble bee *Bombus terrestris* in the laboratory to field-realistic levels of the neonicotinoid imidacloprid, then allowed them to develop naturally under field conditions. Treated colonies had a significantly reduced growth rate and suffered an 85% reduction in production of new queens compared with control colonies. Given the scale of use of neonicotinoids, we suggest that they may be having a considerable negative impact on wild bumble bee populations across the developed world.

Bees in agroecosystems survive by feeding on wildflowers growing in field margins and patches of seminatural habitat, supplemented by the brief gluts of flowers provided by mass flowering crops such as oilseed rape and sunflower (*1*, *2*). Many crops are now routinely treated with neonicotinoid in- spreads to the nectar and pollen of flowering crops, typically at concentrations ranging from 0.7 to 10 μg kg^{-1}(*4*, *5*). Thus bee colonies in agroecosystems will be exposed to 2- to 4-week pulses of exposure to neonicotinoids during the flowering period of crops (*6*).

have shown some evidence that neonicotinoids reduced forager success under field conditions, no studies have examined their impacts on colonies foraging naturally in the field. Here, we present an experiment, using 75 *Bombus terrestris* colonies, designed to simulate the likely effect of exposure of a wild bumble bee colony to neonicotinoids present on the flowers of a nearby crop. The colonies were randomly allocated to one of three treatments. Control colonies received ad libitum (ad lib) pollen and sugar water over a period of 14 days in the laboratory. Over the same period, colonies in the "low" treatment were fed pollen and sugar water containing 6 μg kg^{-1} and 0.7 μg kg^{-1} imidacloprid, respectively, representing the levels found in seed-treated rape (*13*). The "high"-treatment colonies received double these doses, still close to the field-realistic range. After 2 weeks, all colonies were then placed in the field, where they were left to forage independently for a period of 6 weeks while their performance was monitored.

All colonies experienced initial weight gain followed by a decline as they switched from their growth phase to producing new reproductives. Colonies in both low and high treatments gained less weight over the course of



Imidacloprid

www.sciencemag.org SCIENCE VOL 336 20 APRIL 2012

PNAS PNAS PNAS

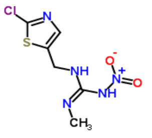
Neonicotinoid clothianidin adversely affects insect immunity and promotes replication of a viral pathogen in honey bees

Gennaro Di Prisco[a], Valeria Cavaliere[b], Desiderato Annoscia[c], Paola Varricchio[a], Emilio Caprio[a], Francesco Nazzi[c], Giuseppe Gargiulo[b], and Francesco Pennacchio[a,1]

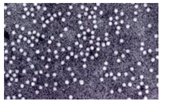
[a]Dipartimento di Agraria, Laboratorio di Entomologia E. Tremblay, Università degli Studi di Napoli Federico II, I-80055 Portici, Italy; [b]Dipartimento di Farmacia e Biotecnologie, Università di Bologna, I-40126 Bologna, Italy; and [c]Dipartimento di Scienze Agrarie e Ambientali, Università degli Studi di Udine, I-33100 Udine, Italy

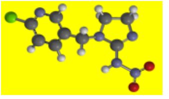
Edited by Gene E. Robinson, University of Illinois at Urbana–Champaign, Urbana, IL, and approved October 1, 2013 (received for review August 8, 2013)

Large-scale losses of honey bee colonies represent a poorly understood problem of global importance. Both biotic and abiotic factors are involved in this phenomenon that is often associated with high loads of parasites and pathogens. A stronger impact of pathogens in honey bees exposed to neonicotinoid insecticides has been reported, but the causal link between insecticide exposure and the possible immune alteration of honey bees remains elusive. Here, we demonstrate that the neonicotinoid insecticide clothianidin negatively modulates NF-κB immune signaling in insects and adversely affects honey bee antiviral defenses controlled by this transcription factor. We have identified in insects a negative modulator of NF-κB activation, which is a leucine-rich repeat protein. Exposure to clothianidin, by enhancing the transcription of the gene encoding this inhibitor, reduces immune defenses and promotes the replication of the deformed wing virus in honey bees bearing covert infections. This honey bee immunosuppression is similarly induced by a different neonicotinoid, imidacloprid, but not by the organophosphate chlorpyriphos, which does not affect NF-κB signaling. The occurrence at sublethal doses of this insecticide-induced viral proliferation suggests that the



Clothianidin + DWV





Imidacloprid + DWV

OPEN ACCESS Freely available online PLoS one

Exposure to Sublethal Doses of Fipronil and Thiacloprid Highly Increases Mortality of Honeybees Previously Infected by *Nosema ceranae*

Cyril Vidau[1,2], Marie Diogon[1,2], Julie Aufauvre[1,2], Régis Fontbonne[1,2], Bernard Viguès[1,2], Jean-Luc Brunet[3], Catherine Texier[2], David G. Biron[1,2], Nicolas Blot[1,2], Hicham El Alaoui[1,2], Luc P. Belzunces[3], Frédéric Delbac[1,2*]

1 Clermont Université, Université Blaise Pascal, Laboratoire Microorganismes: Génome et Environnement, BP 10448, Clermont-Ferrand, France, 2 CNRS, UMR 6023, LMGE, Aubière, France, 3 INRA, UMR 406 Abeilles & Environnement, Laboratoire de Toxicologie Environnementale, Site Agroparc, Avignon, France

Abstract

Background: The honeybee, *Apis mellifera*, is undergoing a worldwide decline whose origin is still in debate. Studies performed for twenty years suggest that this decline may involve both infectious diseases and exposure to pesticides. Joint action of pathogens and chemicals are known to threaten several organisms but the combined effects of these stressors were poorly investigated in honeybees. Our study was designed to explore the effect of *Nosema ceranae* infection on honeybee sensitivity to sublethal doses of the insecticides fipronil and thiacloprid.

Methodology/Finding: controls, (ii) infected wi infected with *N. cerana* 10 days p.i. to thiaclop content was evaluated infected honeybees we opposite effects on mic that *N. ceranae* infectio ethoxycoumarin-O-dee

Conclusions/Significan *ceranae*-infected honey mortality, however, did hypothesis that the co contribute to colony de

Citation: Vidau C, Diogon M, Au Honeybees Previously Infected b

Editor: Elizabeth Didier, Tulane

Received March 16, 2011; **Acc**

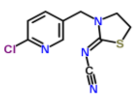
environmental microbiology sfam

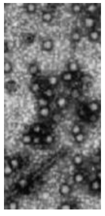
Environmental Microbiology (2014) doi:10.1111/1462-2920.12426

Bees under stress: sublethal doses of a neonicotinoid pesticide and pathogens interact to elevate honey bee mortality across the life cycle

Vincent Doublet,[1*†] Maureen Labarussias,[1] Joachim R. de Miranda,[2] Robin F. A. Moritz[1,3] and Robert J. Paxton[1,3,4]

Thiacloprid + nosema
Thiacloprid + BQCV





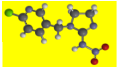
Bulletin of Insectology **67** (1): 125-130, 2014
ISSN 1721-8861

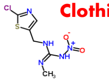
Sub-lethal exposure to neonicotinoids impaired honey bees winterization before proceeding to colony collapse disorder

Chensheng Lu[1], Kenneth M. Warchol[2], Richard A. Callahan[3]

[1]*Department of Environmental Health, Harvard School of Public Health, Landmark Center West, Boston, MA, USA*
[2]*Worcester County Beekeepers Association, Northbridge, MA, USA*
[3]*Worcester County Beekeepers Association, Holden, MA, USA*

Imidacloprid





Clothianidin

Abstract

Honey bee (*Apis mellifera* L.) colony collapse disorder (CCD) that appeared in 2005/2006 still lingers in many parts of the world. Here we show that sub-lethal exposure of neonicotinoids, imidacloprid or clothianidin, affected the winterization of healthy colonies that subsequently leads to CCD. We found honey bees in both control and neonicotinoid-treated groups progressed almost identically through the summer and fall seasons and observed no acute morbidity or mortality in either group until the end of winter. Bees from six of the twelve neonicotinoid-treated colonies had abandoned their hives, and were eventually dead with symptoms resembling CCD. However, we observed a complete opposite phenomenon in the control colonies in which instead of abandonment, they were re-populated quickly with new emerging bees. Only one of the six control colonies was lost due to *Nosema*-like infection. The observations from this study may help to elucidate the mechanisms by which sub-lethal neonicotinoids exposure caused honey bees to vanish from their hives.

Key words: colony collapse disorder, CCD, honey bee, neonicotinoids, imidacloprid, clothianidin.

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Four Common Pesticides, Their Mixtures and a Formulation Solvent in the Hive Environment Have High Oral Toxicity to Honey Bee Larvae

Wanyi Zhu[1]*, Daniel R. Schmehl[2], Christopher A. Mullin[1], James L. Frazier[1]

1 Department of Entomology, Center for Pollinator Research, The Pennsylvania State University, University Park, Pennsylvania, United States of America, 2 Honey Bee Research and Extension Laboratory, Department of Entomology and Nematology, University of Florida, Gainesville, Florida, United States of America

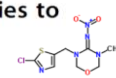
Abstract

Recently, the widespread distribution of pesticides detected in the hive has raised serious concerns about pesticide exposure on honey bee (*Apis mellifera* L.) health. A larval rearing method was adapted to assess the chronic oral toxicity to honey bee larvae of the four most common pesticides detected in pollen and wax - fluvalinate, coumaphos, chlorothalonil, and chloropyrifos - tested alone and in all combinations. All pesticides at hive-residue levels triggered a significant increase

Table S2. Pesticide detections in 329 wax and 496 pollen samples collected 2007-12 from North American honey bee colonies.

Total Pesticide*	CLASS#	Wax Samples with Detections (ppb)						Pollen Samples with Detections (ppb)						LOD¶
		%	Low	High	Mean	SEM§	95%tile	%	Low	High	Mean	SEM§	95%tile	
Fluvalinate	PYR	93	2	204000	6823	801	27440	72	1	2670	108	13	331	1
Coumaphos	OP	95	1	94131	3042	414	10847	59	1	5828	176	18	826	1
Chlorpyrifos	OP	58	1	890	17	4	37	44	0.1	830	42	4	189	0.1
Chlorothalonil	FUNG	42	1	53700	985	271	2024	50	1	98900	2318	439	15832	1
1-Methylpyrrolidinone (NMP)	INERT	9	1690	5420	3555	563	5234	0	---	---	---	---	---	500

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]

1 JSC International Limited, Harrogate, North Yorkshire, United Kingdom, 2 Syngenta Limited, Jealott's Hill Research Station, Bracknell, Berkshire, United Kingdom, 3 Eurofins Agroscience Services, EcoChem GmbH, Niefern-Öschelbronn, Germany

Abstract

Neonicotinoid residues in nectar and pollen from crop plants have been implicated as one of the potential factors causing the declines of honey bee populations. Median residues of thiamethoxam in pollen collected from honey bees after foraging on flowering seed treated maize were found to be between 1 and 7 µg/kg, median residues of the metabolite CGA322704 (clothianidin) in the pollen were between 1 and 4 µg/kg. In oilseed rape, median residues of thiamethoxam found in pollen collected from bees were between <1 and 3.5 µg/kg and in nectar from foraging bees were between 0.65 and 2.4 µg/kg. Median residues of CGA322704 in pollen and nectar in the oilseed rape trials were all below the limit of quantification (1 µg/kg). Residues in the hive were even lower in both the maize and oilseed rape trials, being at or below the level of detection of 1 µg/kg for bee bread in the hive and at or below the level of detection of 0.5 µg/kg for hive nectar, honey and royal jelly samples. The long-term risk to honey bee colonies in the field was also investigated, including the sensitive overwintering stage, from four years consecutive single treatment crop exposures to flowering maize and oilseed rape grown from thiamethoxam treated seeds at rates recommended for insect control. Throughout the study, mortality, foraging behavior, colony strength, colony weight, brood development and food storage levels were similar between treatment and control colonies. Detailed examination of brood development throughout the year demonstrated that colonies exposed to the treated crop were able to successfully overwinter and had a similar health status to the control colonies in the following spring. We conclude that these data demonstrate there is a low risk to honey bees from systemic residues in nectar and pollen following the use of thiamethoxam as a seed treatment on oilseed rape and maize.

Funding: The authors have no external support or funding to report.

Competing Interests: Peter Campbell, Mike Coulson and Natalie Ruddle are employed by Syngenta Ltd., which developed and markets the neonicotinoid insecticide thiamethoxam. Ed Pilling is employed by the consultancy JSC International and was paid by Syngenta Ltd. to write the manuscript. Ed Pilling was also once an employee of Syngenta (joined JSC International in May 2011), and was directly involved in the study design and conduct. Ingo Tornier is employed by Eurofins Agroscience Services and was paid by Syngenta Ltd. to conduct the field trials. Syngenta Ltd. has numerous patents covering the active ingredient thiamethoxam and formulated products containing this active ingredient. This does not alter the authors' adherence to all the PLOS ONE policies on sharing data and materials.

* E-mail: peter.campbell@syngenta.com

Human and Ecological Risk Assessment, 20: 566–591, 2014
Published with license by Taylor & Francis
ISSN: 1080-7039 print / 1549-7860 online
DOI: 10.1080/10807039.2013.831263

WORKSHOP REPORT

A Causal Analysis of Observed Declines in Managed Honey Bees (*Apis mellifera*)

Jane P. Staveley,[1] Sheryl A. Law,[1] Anne Fairbrother,[2] and Charles A. Menzie[1]
[1]Exponent, Alexandria, VA, USA; [2]Exponent, Bellevue, WA, USA

ABSTRACT

The European honey bee (*Apis mellifera*) is a highly valuable, semi-free-ranging managed agricultural species. While the number of managed hives has been increasing, declines in overwinter surviv[...] in 2006, precipitated a large amount o[...] late the causative factors. A workshop v[...] introduced to a formal causal analysis[...] against specified criteria to evaluate t[...] survivability observed since 2006 of cor[...] industry. Candidate causes were categ[...] eral candidate causes were categorized[...] Due to time limitations, a full causal an[...] this article, examples are provided to il[...] findings, using three candidate causes. *Varroa* mites plus viruses were judged to be a "probable cause" of the reduced survival, while nutrient deficiency was judged to be a "possible cause." Neonicotinoid pesticides were judged to be "unlikely" as the sole cause of this reduced survival, although they could possibly be a contributing factor.

ACKNOWLEDGMENTS

We acknowledge the bee experts who attended the workshop: Troy Anderson, Tjeerd Blacquière, Jerry Bromenshenk, Diana Cox-Foster, James Cresswell, Chris Cutler, Galen Dively, Frank Drummond, David Epstein, Richard Fell, Gerald Hayes, Josephine Johnson, Christian Maus, Richard Rogers, Melinda Rostal, Cynthia Scott-Dupree, Thomas Steeger, Helen Thompson, and Geoffrey Williams. Special thanks to Glenn Suter, Susan Cormier, and Erica Fleishman for their expertise in causal analysis. Financial support for this workshop was provided by Bayer CropScience.

Key Words: honey bees, causal analysis, neonicotinoids, *Varroa*.

Risks of Neonicotinoid Insecticides to Honeybees

Anne Fairbrother,*† John Purdy,‡ Troy Anderson,§ and Richard Fell‖
†Exponent, Bellevue, Washington
‡Abacus Consulting Services, Campbellville, Ontario, Canada
§Department of Entomology and Fralin Life Science Institute, Vir
‖Department of Entomology, Virginia Tech, Blacksburg, Virginia,

Abstract—*The European honeybee,* Apis mellifera, *is an important pollinator of agricultural crops. Since 2006, when unexpectedly high colony losses were first reported, articles have proliferated in the popular press suggesting a range of possible causes and raising alarm over the general decline of bees. Suggested causes include pesticides, genetically modified crops, habitat fragmentation, and introduced diseases and parasites. Scientists have concluded that multiple factors in various combinations—including mites, fungi, viruses, and pesticides, as well as other factors such as reduction in forage, poor nutrition, and queen failure—are the most probable cause of elevated colony loss rates. Investigators and regulators continue to focus on the possible role that insecticides, particularly the neonicotinoids, may play in honeybee health. Neonicotinoid insecticides are insect neurotoxicants with desirable features such as broad-spectrum activity, low application rates, low mammalian toxicity, upward systemic movement in plants, and versatile application methods. Their distribution throughout the plant, including pollen, nectar, and guttation fluids, poses particular concern for exposure to pollinators. The authors describe how neonicotinoids interact with the nervous system of honeybees and affect individual honeybees in laboratory situations. Because honeybees are social insects, colony effects in semifield and field studies are discussed. The authors conclude with a review of current and proposed guidance in the United States and Europe for assessing the risks of pesticides to honeybees.* Environ Toxicol Chem 2014;33:719–731.

Keywords—Neonicotinoid; Honeybee; Risk assessment; Insecticide

new, emerging foreign-animal diseases. Public awareness and scientifically sound studies funded by governments and agricultural interests, including agricultural chemical companies, have identified the interaction of multiple stressors, including parasites (*Varroa* mites), pathogens (viruses, *Nosema* fungus), and nutrition (monofloral vs polyfloral pollen and nectar resources), as primary factors influencing honeybee health. Sublethal effects of pesticides on behavior, learning, and immunity are subtle and may not be measurable at realistic exposure concentrations. The more robust risk-assessment frameworks being proposed and recently adopted in Europe provide guidance for a better initial analysis of possible effects of pesticides, but higher-tier assessments must be implemented to determine the realistically probable consequences of chemical use under field conditions. Assessing risks only under worst-case conditions with individual honeybees, divorced from properties provided by colony interactions, serves only to understand potential mechanisms of action of different chemicals but not their aggregate risks. Because both pesticides and pollinators are critical to the continuing success of worldwide agriculture, it is imperative that we learn to accurately and honestly assess the benefits and risks of their interactions on commercial honeybees and other pollinators.

Acknowledgment

Funding for the development of this manuscript was provided by Bayer CropScience Ag Research Division.

Néonicotinoïdes

- Effets sur la drosophile
- Expositions réelles (nectar)
- Impact sur les abeilles
- **Evaluation mondiale des impacts**
  - **Invertébrés**
  - **Vertébrés**
- Conclusions

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Current Opinion in Environmental Sustainability

Neonicotinoids, bee disorders and the sustainability of pollinator services

Jeroen P van der Sluijs[1], Noa Simon-Delso[1], Dave Goulson[2], Laura Maxim[3], Jean-Marc Bonmatin[4] and Luc P Belzunces[5]

In less than 20 years, neonicotinoids have become the most widely used class of insecticides with a global market share of more than 25%. For pollinators, this has transformed the agrochemical landscape. These chemicals mimic the acetylcholine neurotransmitter and are highly neurotoxic to insects. Their systemic mode of action inside plants means phloemic and xylemic transport that results in translocation to pollen and nectar. Their wide application, persistence in soil and water and potential for uptake by succeeding crops and wild plants make neonicotinoids bioavailable to pollinators at sublethal concentrations for most of the year. This results in the frequent presence of neonicotinoids in honeybee hives. At field realistic doses, neonicotinoids cause a wide range of adverse sublethal effects in honeybee and bumblebee colonies, affecting colony performance through impairment of foraging success, brood and larval development, memory and learning, damage to the central nervous system, susceptibility to diseases, hive hygiene etc. Neonicotinoids exhibit a toxicity that can be amplified by various other agrochemicals and they synergistically reinforce infectious agents such as *Nosema ceranae* which together can produce colony collapse. The limited available data suggest that they are likely to exhibit similar toxicity to virtually all other wild insect pollinators. The worldwide production of neonicotinoids is still increasing. Therefore a transition to pollinator-friendly alternatives to neonicotinoids is urgently needed for the sake of the sustainability of pollinator ecosystem services.

Current Opinion in Environmental Sustainability 2013, 5:293–305
This review comes from a themed issue on **Open issue**
Edited by **Rik Leemans** and **William Solecki**
For a complete overview see the Issue and the Editorial
Available online 6th June 2013

http://dx.doi.org/10.1016/j.cosust.2013.05.007

Introduction

The introduction to the market in the early 1990s of imidacloprid and thiacloprid opened the neonicotinoid era of insect pest control [1]. Acting systemically, this new class of neurotoxic insecticides is taken up by plants, primarily through the roots, and translocates to all parts of the plant through xylemic and phloemic transport [2]. This systemic property combined with very high toxicity to insects enabled formulating neonicotinoids for soil treatment and seed coating with typical doses from 10 to 200 g ha^{-1} high enough to provide long lasting protection of the whole plant from pest insects.

Neonicotinoids interact with the nicotinic acetylcholine receptors (nAChRs) of the insect central nervous system. They act mainly agonistically on nAChRs on the post-

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REVIEW
Journal of Environmental Immunology and Toxicology 1:1, 3-12; March/April 2013; © 2013 STM Publishing

Immune Suppression by Neonicotinoid Insecticides at the Root of Global Wildlife Declines

Rosemary Mason[1], Henk Tennekes[2], Francisco Sánchez-Bayo[3], Palle Uhd Jepsen[1]
[1]Hunters Hollow, Swansea, UK; [2]Experimental Toxicology Services (ETS) Nederland BV, The Netherlands;
[3]Centre for Ecotoxicology, University of Technology Sydney, Australia

Abstract
Outbreaks of infectious diseases in honey bees, fish, amphibians, bats and birds in the past two decades have coincided with the increasing use of systemic insecticides, notably the neonicotinoids and fipronil. A link between insecticides and such diseases is hypothesised. Firstly, the disease outbreaks started in countries and regions where systemic insecticides were used for the first time, and later they spread to other countries. Secondly, recent evidence of immune suppression in bees and fish caused by neonicotinoids has provided an important clue to understand the sub-lethal impact of these insecticides not only on these organisms, but probably on other wildlife affected by emerging infectious diseases. While this is occurring, environmental authorities in developed countries ignore the calls of apiarists (who are most affected) and do not target neonicotinoids in their regular monitoring schedules. Equally, scientists looking for answers to the problem are unaware of the new threat that systemic insecticides have introduced in terrestrial and aquatic ecosystems.

Journal of Environmental Immunology and Toxicology 2013; 1:3-12

Environ Sci Pollut Res
DOI 10.1007/s11356-014-3220-1
EDITORIAL

The Task Force on Systemic Pesticides
WWW.TFSP.INFO

Worldwide integrated assessment on systemic pesticides

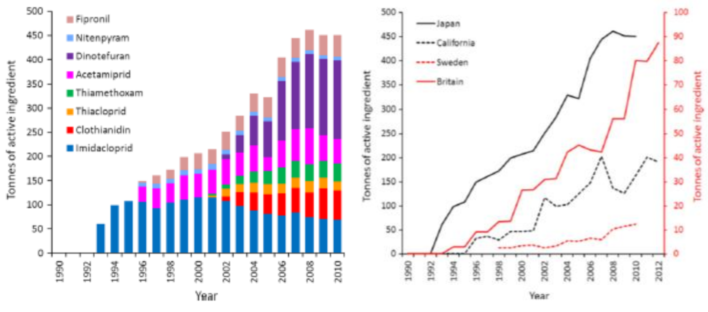
Global collapse of the entomofauna: exploring the role of systemic insecticides

Maarten Bijleveld van Lexmond • Jean-Marc Bonmatin • Dave Goulson • Dominique A. Noome

Evaluation mondiale intégrée (8 articles scientifiques)

- **Première méta-analyse des pesticides systémiques néo-nicotinoïdes et fipronil**
- **Intégrant plus de 800 publications et les données des fabricants**
- **29 scientifiques indépendants (auteurs)**
- **Publié dans *Environmental Science and Pollution Research*, 2014**

Croissance du marché mondial (1992-2010)



Utilisation préventive & massive + multiplicité des toxiques

Dr. JM Bonmatin (CNRS) France 25

Imidaclopride dans les pollens : de 1 à 39 ng/g en moyenne

Environ Sci Pollut Res

Table 4 Residues (neonicotinoids and fipronil) in pollen or in pollen-derived matrices (pollen/beebread)

Insecticide[a]	Detection rate[b] (%)	Range[c] (ng/g)	Mean[d] or magnitude[e,f] (ng/g)	Maximum[f] (ng/g)	Reference[g]
Imidacloprid	16.2	1–1,000	19.7	912	Sanchez-Bayo and Goka (2014)
		0.1–1,000	0.1 to 80.2+19.1[k]	101+27.5[k]	Dively and Kamel (2012)
	9.1	1–1,000	30.8	216	Rennich et al. (2012)
	2.9	1–1,000	39	206+554[l]+152[l]	Mullin et al. (2010)
	40.5	0.1–10	0.9	5.7	Chauzat et al. (2011)
		1–100	14	28	Stoner and Eitzer (2012)
	12.1	1–100	5.2+5.6[l]	70+5.6[l]	Stoner and Eitzer (2013)
		10–100	13	36	Laurent and Rathahao (2003)
	87.2	0.1–100	2.1	18	Bonmatin et al. (2005)
		1–100	9.39	10.2	Byrne et al. (2014)
		1–100	2.6	12	Wiest et al. (2011)
	83	0.1–100	3	11	Bonmatin et al. (2003)
		1–100			In EFSA (2013c):
			3-	15	See Stork (1999) (Germany 2005, DAR)
			3.45-	4.6	See Germany 2005 (DAR)
		1–10			In EFSA (2012a):
			1.56-	8.19	See Schmuck et al. (2001) (DAR)
				3.3	See Stork (1999) (Germany 2005, DAR)
		1–10	4.4-	7.6	Scott-Dupree and Spivak (2001)
	49.4	1–10	1.2		Chauzat et al. (2006)
		1–10	3.3-	3.9	Schmuck et al. (2001)
	0.8	1–10	1.35	<12	Lambert et al. (2013)
		0.1–1		<0.5	Thompson et al. (2013)

Dr. JM Bonmatin (CNRS) France 26

Imidaclopride dans les nectars : de 1 à 73 ng/g en moyenne

Environ Sci Pollut Res

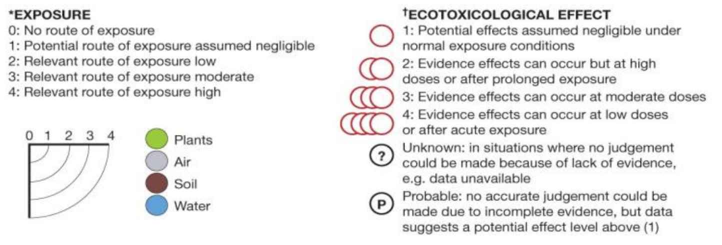
Table 5 Residues (neonicotinoids and fipronil) in nectar or in nectar-derived matrices (nectar/honey)

Insecticide[a]	Detection rate[b] (%)	Range[c] (ng/g)	Mean[d] or magnitude[e,f] (ng/g)	Maximum[f] (ng/g)	Reference[g]
Imidacloprid	21.4	1–100	6	72.8	Sanchez-Bayo and Goka (2014)
		10–100	13.37 to 72.81	95.2	Byrne et al. (2014)
		0.1–100	0.1 to 11.2+6.4[k]	13.7+9.4[k]	Dively and Kamel (2012)
	21.8	0.1–10	0.7	1.8	Chauzat et al. (2011)
		100–1,000		660[j]	Paine et al. (2011)
		100–1,000		171	Larson et al. (2013)
		1–100	6.6+1.1+0.2[l]	16+2.4+0.5[l]	Krischik et al. (2007)
		0.1–100	0.1 to 11.2+6.4[k]	13.7+9.4[k]	Dively and Kamel (2012)
		1–100	10.3	14	Stoner and Eitzer (2012)
		1–10			In EFSA (2012a):
			3.45-	4.6	See Stork (1999) (DAR)
			1.59-	8.35	See Germany (2005) (DAR)
	29.7	0.1–10	0.7+1.2[l]		Chauzat et al. (2009)
		0.1–10	1.9		Schmuck et al. (2001)
	21	0.1–10	0.6	2	Pohorecka et al. (2012)
		0.1–10	0.2[l]-	3.9[j]	Wiest et al. (2011)
	2.1	0.1–10	0.14[l]	<3.9[j]	Lambert et al. (2013)
		0.1–1	0.6-	0.8	Scott-Dupree and Spivak (2001)
		0.1–1	0.45	0.5	Thompson et al. (2013)

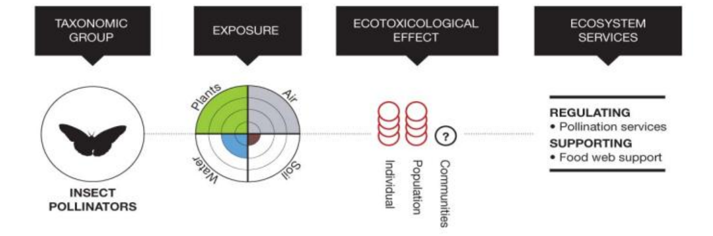
Dr. JM Bonmatin (CNRS) France 27

Dr. JM Bonmatin (CNRS) France 28

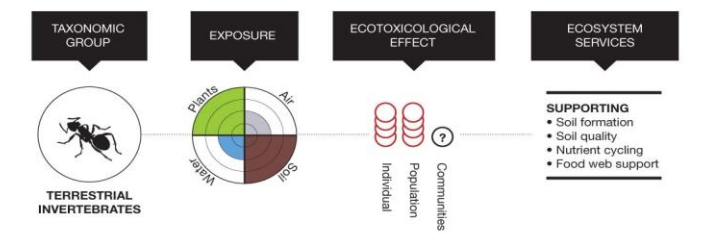
LEGENDE



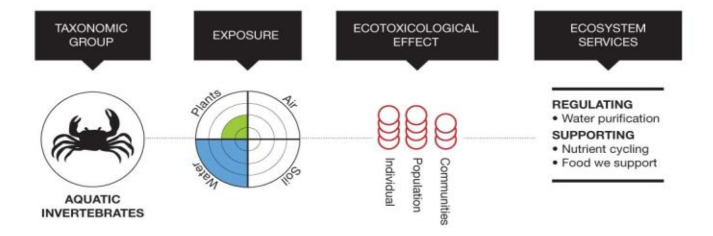
INSECTES



INVERTEBRES TERRESTRES



INVERTEBRES AQUATIQUES



Environ Sci Pollut Res
DOI 10.1007/s11356-014-3180-5

WORLDWIDE INTEGRATED ASSESSMENT OF THE IMPACT OF SYSTEMIC PESTICIDES ON BIODIVERSITY AND ECOSYSTEMS

A review of the direct and indirect effects of neonicotinoids and fipronil on vertebrate wildlife

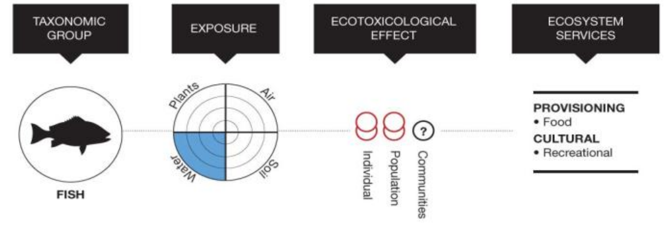
David Gibbons · Christy Morrissey · Pierre Mineau

Received: 7 April 2014 / Accepted: 6 June 2014

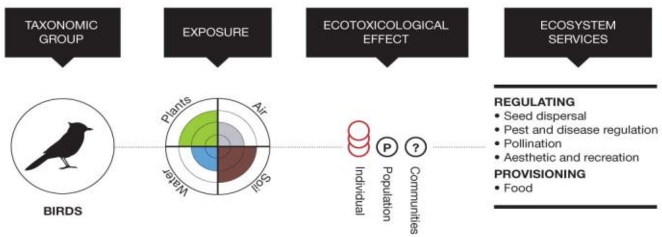
Abstract Concerns over the role of pesticides affecting vertebrate wildlife populations have recently focussed on systemic products which exert broad-spectrum toxicity. Given that the neonicotinoids have become the fastest-growing class of insecticides globally, we review here 150 studies of their direct (toxic) and indirect (e.g. food chain) effects on vertebrate wildlife—mammals, birds, fish, amphibians and reptiles. We focus on two neonicotinoids, imidacloprid and clothianidin, and a third insecticide, fipronil, which also acts in the same systemic manner. Imidacloprid and fipronil were found to be toxic to many birds and most fish, respectively. All three insecticides exert sub-lethal effects, ranging from genotoxic and cytotoxic effects, and impaired immune function, to reduced growth and reproductive success, often at concentrations well below those associated with mortality. Use of imidacloprid and clothianidin as seed treatments on some crops poses risks to small birds, and ingestion of even a few treated seeds could cause mortality or reproductive impairment to sensitive bird species. In contrast, environmental concentrations of imidacloprid and clothianidin appear to be at levels below those which will cause mortality to freshwater vertebrates, although sub-lethal effects may occur. Some recorded environmental concentrations of fipronil, however, may be sufficiently high to harm fish. Indirect effects are rarely considered in risk assessment processes and there is a paucity of data, despite the potential to exert population-level effects. Our research revealed two field case studies of indirect effects. In one, reductions in invertebrate prey from both imidacloprid and fipronil uses led to impaired growth in a fish species, and in another, reductions in populations in two lizard species were linked to effects of fipronil on termite prey. Evidence presented here suggests that the systemic insecticides, neonicotinoids and fipronil, are capable of exerting direct and indirect effects on terrestrial and aquatic vertebrate wildlife, thus warranting further review of their environmental safety.

Keywords Pesticide · Neonicotinoid · Imidacloprid · Clothianidin · Fipronil · Vertebrate · Wildlife · Mammals · Birds · Fish · Amphibians · Reptiles · Risk assessment

POISSONS



OISEAUX



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]

Recent studies have shown that neonicotinoid insecticides have adverse effects on non-target invertebrate species[1–6]. Invertebrates constitute a substantial part of the diet of many bird species during the breeding season and are indispensable for raising offspring[7]. We investigated the hypothesis that the most widely used neonicotinoid insecticide, imidacloprid, has a negative impact on insectivorous bird populations. Here we show that, in the Netherlands, local population trends were significantly more negative in areas with higher surface-water concentrations of imidacloprid. At imidacloprid concentrations of more than 20 nanograms per litre, bird populations tended to decline by 3.5 per cent on average annually. [...] this spatial pattern of decline app[...] of imidacloprid to the Netherland[...] show that the recent negative relat[...]

The present study takes advantage of two standardized, long-term, country-wide monitoring schemes in the Netherlands (see Methods)—the Dutch Common Breeding Bird Monitoring Scheme[17] and surface-water quality measurements[4]—to investigate the extent to which average concentrations of imidacloprid residues in the period 2003–2009 spatially correlate with bird population trends in the period 2003–2010. We selected 15 passerine species that are common in farmlands and depend on invertebrates during the breeding season (Extended Data Table 1 and Supplementary Methods). We interpolated concentrations of imidacloprid in surface water to bird monitoring plots (Extended Data Figs 1–3,

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Imidacloprid-treated seed ingestion has lethal effect on adult partridges and reduces both breeding investment and offspring immunity ☆

Ana Lopez-Antia[a,*], Manuel E. Ortiz-Santaliestra[a,b], François Mougeot[c], Rafael Mateo[a]

Slide 37

- Conclusions on soils as ecosystem services
- Freshwater ecosystem functions
  - Nutrient cycling and water quality
  - Aquatic food chain effects
  - Conclusions on freshwater ecosystem functions
- Fisheries and aquaculture
  - Threats to cultured fish stocks
  - Shellfish aquaculture
  - Neonicotinoids in fish-rice ecosystems
  - Conclusion on risks to cultured fisheries
- Biological pest control
  - Predators as natural pest control
- Pollination
  - Pollination as an ecosystem service
  - Pollination of crops
  - Pollination of wild plants
  - Conclusions on ecosystem services from pollinators and other beneficial insects
- Food security
  - Pollinator-dependent crops
  - The economic value of pollination
  - Food supply and food quality
  - Seed security and seed treatments
  - Insecticide resistance
  - Conclusions on food security
- Conclusions
- References

Environ Sci Pollut Res
DOI 10.1007/s11356-014-3277-x

WORLDWIDE INTEGRATED ASSESSMENT OF THE IMPACT OF SYSTEMIC PESTICIDES ON BIODIVERSITY AND ECOSYSTEMS

Risks of large-scale use of systemic insecticides to ecosystem functioning and services

Madeleine Chagnon · David Kreutzweiser · Edward A.D. Mitchell · Christy A. Morrissey · Dominique A. Noome · Jeroen P. Van der Sluijs

Received: 29 April 2014 / Accepted: 1 July 2014

Abstract Large-scale use of the persistent and potent neonicotinoid and fipronil insecticides has raised concerns about risks to ecosystem functions provided by a wide range of species and environments affected by these insecticides. The concept of ecosystem services is widely used in decision making in the context of valuing the service potentials, benefits, and use values that well-functioning ecosystems provide to humans and the biosphere and, as an endpoint (value to be protected), in ecological risk assessment of chemicals. Neonicotinoid insecticides are frequently detected in soil and water and are also found in air, as dust particles during sowing of crops and aerosols during spraying. These environmental media provide essential resources to support biodiversity, but are known to be threatened by long-term or repeated contamination by neonicotinoids and fipronil. We review the state of knowledge regarding the potential impacts of these insecticides on ecosystem functioning and services provided by terrestrial and aquatic ecosystems including soil and freshwater functions, fisheries, biological pest control, and pollination services. Empirical studies examining the specific impacts of neonicotinoids and fipronil to ecosystem services have focused largely on the negative impacts to beneficial insect species (honeybees) and the impact on pollination service of food crops. However, here we document broader evidence of the effects on ecosystem functions regulating soil and water quality, pest control, pollination, ecosystem resilience, and community diversity. In particular, microbes, invertebrates, and fish play critical roles as decomposers, pollinators, consumers, and predators, which collectively maintain healthy communities and ecosystem integrity. Several examples in this review demonstrate evidence of the negative impacts of systemic insecticides on decomposition, nutrient cycling, soil respiration, and

Responsible editor: Philippe Garrigues

M. Chagnon (✉)
Département des sciences biologiques, Université du Québec à Montréal, Case Postale 8888, Succursale Centre-Ville, Montréal, Québec H3C 3P8, Canada
e-mail: chagnon.madeleine@uqam.ca

D. A. Noome
Task Force on Systemic Pesticides, 46, Pertuis-du-Sault, 2000 Neuchâtel, Switzerland

Slide 38

- Alternatives to neonicotinoid insecticides for pest control: case studies in agriculture and forestry
  - Abstract
  - Introduction
  - Case studies of alternative pest management in maize
    - Controlling wireworms (Agriotes spp.)
      - Accurate wireworm population monitoring and damage prediction
      - Agronomic strategies for controlling wireworm populations
      - Applying biological tools for controlling wireworm populations
      - Applying chemical insecticides for controlling wireworm populations
    - Controlling Western corn rootworm (Diabrotica virgifera virgifera)
      - Accurate WCR population monitoring and damage prediction
      - Agronomic strategies for controlling WCR populations
      - Applying biological tools for controlling WCR populations
      - Applying chemical insecticides for controlling WCR populations
    - Controlling black cutworm (Agrotis ipsilon)
  - Case study of alternative pest management in Canadian forests
    - Exotic parasitic insects
    - Native parasitic insects
    - Native fungal pathogens
    - An alternative, non-persistent systemic insecticide
  - Conclusions
  - References

Environ Sci Pollut Res
DOI 10.1007/s11356-014-3628-7

WORLDWIDE INTEGRATED ASSESSMENT OF THE IMPACT OF SYSTEMIC PESTICIDES ON BIODIVERSITY AND ECOSYSTEMS

Alternatives to neonicotinoid insecticides for pest control: case studies in agriculture and forestry

Lorenzo Furlan · David Kreutzweiser

Received: 14 April 2014 / Accepted: 16 September 2014

Abstract Neonicotinoid insecticides are widely used for control of insect pests around the world and are especially pervasive in agricultural pest management. There is a growing body of evidence indicating that the broad-scale and prophylactic uses of neonicotinoids pose serious risks of harm to beneficial organisms and their ecological function. This provides the impetus for exploring alternatives to neonicotinoid insecticides for controlling insect pests. We draw from examples of alternative pest control options in Italian maize production and Canadian forestry to illustrate the principles of applying alternatives to neonicotinoids under an integrated pest management (IPM) strategy. An IPM approach considers all relevant and available information to make informed management decisions, providing pest control options based on actual need. We explore the benefits and challenges of several options for management of three insect pests in maize crops and an invasive insect pest in forests, including diversifying crop rotations, altering the timing of planting, tillage and irrigation, using less sensitive crops in infested areas, applying biological control agents, and turning to alternative reduced risk insecticides. Continued research into alternatives is warranted, but equally pressing is the need for information transfer and

Introduction

Systemic neonicotinoid insecticides are used to protect a wide variety of crops. Based on their efficacy to control many insect pests and their systemic activity, they are used extensively in agriculture so that by 2008, neonicotinoids accounted for one quarter of the global insecticide market (Jeschke et al. 2011), and this rate is increasing (Simon-Delso et al. 2014). The extensive use of neonicotinoids in agriculture has undoubtedly met technical and commercial goals, i.e. simplification of agricultural systems and large pesticide applications for pest prevention to maximize efficiencies and profits. However, increasing evidence indicates that this large-scale use results in high broad-spectrum insecticidal activity of the neonicotinoids even at very low dosages, and this has led to serious risk of environmental impact (Henry et al. 2012; Goulson 2013; van der Sluijs et al. 2013, 2014; Whitehorn et al. 2012). The large-scale, often prophylactic use (Goulson 2013) of neonicotinoid insecticides contrasts with the main principle of an integrated pest management (IPM) approach which includes an assessment of economically important pest populations in order to determine if an insecticide treatment is

Slide 39

EPA Pesticide Program Updates

From EPA's Office of Pesticide Programs

www.epa.gov/pesticides

October 16, 2014

In This Update:

EPA Finds Neonicotinoid Seed Treatments of Little or No Benefit to U.S. Soybean Production

Today, the U.S. Environmental Protection Agency (EPA) released an analysis of the benefits of neonicotinoid seed treatments for insect control in soybeans. A Federal Register notice inviting the public to comment on the analysis will publish in the near future.

"We have made the review of neonicotinoid pesticides a high priority. During the review, we found that many scientific publications claim that treating soybean seeds has little value," said Jim Jones, Assistant Administrator for the Office of Chemical Safety and Pollution Prevention. "This propelled the agency to evaluate the economic benefits of this use. "We found that the benefits to U.S. soybean farmers on a national scale were just not there."

The EPA assessment examined the effectiveness of these seed treatments for pest control and estimated the impacts on crop yields and quality, as well as financial losses and gains.

The analysis concluded that:

- There is no increase in soybean yield using most neonicotinoid seed treatments when compared to using no pest control at all.
- Alternative insecticides applied as sprays are available and effective;
- All major alternatives are comparable in cost; and;
- Neonicotinoid seed treatment could provide an insurance benefit against sporadic and unpredictable insect pests, but this potential benefit is not likely to be large or widespread throughout the United States.

This analysis is an important part of the science EPA will use to move forward with the assessment of the risks and benefits under registration review for the neonicotinoid pesticides. Registration review, the periodic re-evaluation of pesticides to determine if they continue to meet the safety standard, can result in EPA discontinuing certain uses, placing limits on the pesticide registration,

Ontario

Recherche de nouvelles

Salle de presse

Réduire l'utilisation de pesticides et protéger la santé des pollinisateurs

L'Ontario se fixe l'objectif de réduire l'utilisation de néonicotinoïdes de 80 p. cent

25 novembre 2014 10h00 | Ministère de l'Environnement

L'Ontario adopte des mesures pour renforcer la santé des oiseaux, des abeilles, des papillons et des autres pollinisateurs afin de garantir des écosystèmes en santé, un secteur agricole productif et une économie forte.

Les pollinisateurs jouent un rôle important dans la productivité agricole de l'Ontario. Des cultures comme les pommes, les cerises, les pêches, les prunes, les concombres, les asperges, les courges, les citrouilles et les melons ont besoin des pollinisateurs afin de pousser.

L'Agence de réglementation de la lutte antiparasitaire fédérale a conclu à l'existence d'un lien entre la plantation de semences de maïs et de soya traitées aux néonicotinoïdes - un insecticide agricole -- et la mortalité d'abeilles en Ontario. L'approche de la province aidera à garder les cultures en santé et à améliorer l'environnement grâce aux moyens suivants :

- poursuivre l'objectif de réduire de 80 p.cent le nombre d'acres plantés avec des semences de maïs et de soya traitées aux néonicotinoïdes d'ici 2017;
- réduire le taux de mortalité des abeilles durant l'hiver à 15 p. cent d'ici 2020;
- établir un Plan d'action pour la santé des pollinisateurs exhaustif.

La province tiendra une consultation sur une proposition visant à réduire l'utilisation de semences de maïs et de soya traitées aux néonicotinoïdes. Si elles sont approuvées, de nouvelles règles sur l'utilisation des néonicotinoïdes seront en place d'ici le 1er juillet 2015, à temps pour la saison de plantation agricole 2016.

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Environ Sci Pollut Res
DOI 10.1007/s11356-014-3229-5

EDITORIAL

Conclusions of the Worldwide Integrated Assessment on the risks of neonicotinoids and fipronil to biodiversity and ecosystem functioning

J. P. van der Sluijs · V. Amaral-Rogers · L. P. Belzunces · M. F. I. J. Bijleveld van Lexmond · J-M. Bonmatin · M. Chagnon · C. A. Downs · L. Furlan · D. W. Gibbons · C. Giorio · V. Girolami · D. Goulson · D. P. Kreutzweiser · C. Krupke · M. Liess · E. Long · M. McField · P. Mineau · E. A. D. Mitchell · C. A. Morrissey · D. A. Noome · L. Pisa · J. Settele · N. Simon-Delso · J. D. Stark · A. Tapparo · H. Van Dyck · J. van Praagh · P. R. Whitehorn · M. Wiemers

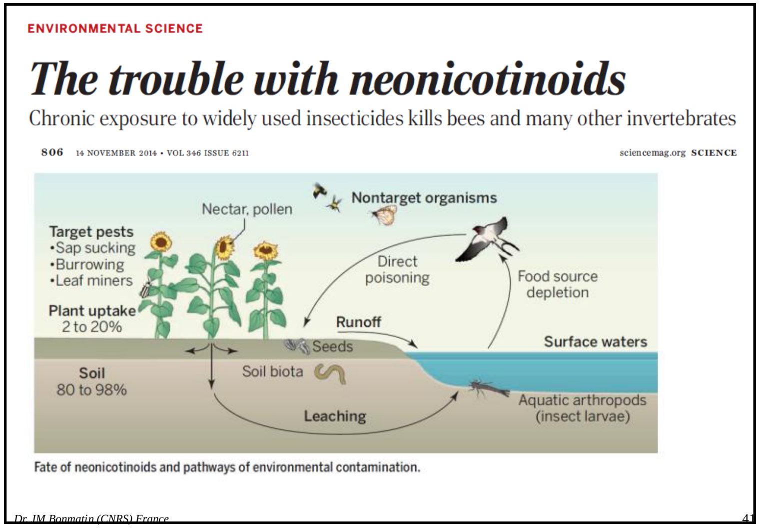
- ➢ Utilisation préventive et massive
- ➢ Très haute toxicité sur les invertébrés
- ➢ haute toxicité sur les vertébrés
- ➢ longue persistance dans les sols
- ➢ forte contamination des eaux (surface & profonde)

➡

- ✓ Disparition des pollinisateurs
- ✓ Menace sur la stabilité de l'écosystème
- ✓ Menace sur la sécurité alimentaire (quantité & qualité)

⬇

L'utilisation présente des néonicotinoïdes n'est pas durable
=> réduire/suspendre => gestion intégrée des ravageurs (IPM)



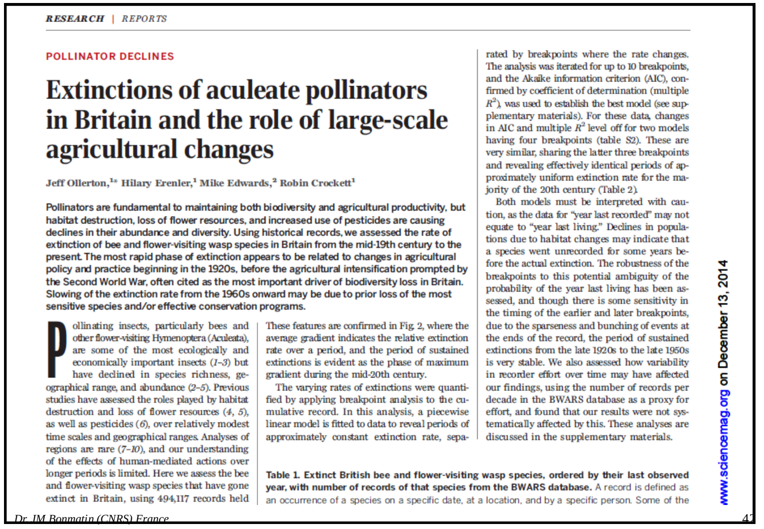
ENVIRONMENTAL SCIENCE

The trouble with neonicotinoids

Chronic exposure to widely used insecticides kills bees and many other invertebrates

806 14 NOVEMBER 2014 • VOL 346 ISSUE 6211 sciencemag.org SCIENCE

Fate of neonicotinoids and pathways of environmental contamination.



POLLINATOR DECLINES

Extinctions of aculeate pollinators in Britain and the role of large-scale agricultural changes

Jeff Ollerton,[1*] Hilary Erenler,[1] Mike Edwards,[2] Robin Crockett[1]

Pollinators are fundamental to maintaining both biodiversity and agricultural productivity, but habitat destruction, loss of flower resources, and increased use of pesticides are causing declines in their abundance and diversity. Using historical records, we assessed the rate of extinction of bee and flower-visiting wasp species in Britain from the mid-19th century to the present. The most rapid phase of extinction appears to be related to changes in agricultural policy and practice beginning in the 1920s, before the agricultural intensification prompted by the Second World War, often cited as the most important driver of biodiversity loss in Britain. Slowing of the extinction rate from the 1960s onward may be due to prior loss of the most sensitive species and/or effective conservation programs.

Pollinating insects, particularly bees and other flower-visiting Hymenoptera (Aculeata), are some of the most ecologically and economically important insects (*1–3*) but have declined in species richness, geographical range, and abundance (*2–5*). Previous studies have assessed the roles played by habitat destruction and loss of flower resources (*4*, *5*), as well as pesticides (*6*), over relatively modest time scales and geographical ranges. Analyses of regions are rare (*7–10*), and our understanding of the effects of human-mediated actions over longer periods is limited. Here we assess the bee and flower-visiting wasp species that have gone extinct in Britain, using 494,117 records held

These features are confirmed in Fig. 2, where the average gradient indicates the relative extinction rate over a period, and the period of sustained extinctions is evident as the phase of maximum gradient during the mid-20th century.

The varying rates of extinctions were quantified by applying breakpoint analysis to the cumulative record. In this analysis, a piecewise linear model is fitted to data to reveal periods of approximately constant extinction rate, separated by breakpoints where the rate changes. The analysis was iterated for up to 10 breakpoints, and the Akaike information criterion (AIC), confirmed by coefficient of determination (multiple R^2), was used to establish the best model (see supplementary materials). For these data, changes in AIC and multiple R^2 level off for two models having four breakpoints (table S2). These are very similar, sharing the latter three breakpoints and revealing effectively identical periods of approximately uniform extinction rate for the majority of the 20th century (Table 2).

Both models must be interpreted with caution, as the data for "year last recorded" may not equate to "year last living." Declines in populations due to habitat changes may indicate that a species went unrecorded for some years before the actual extinction. The robustness of the breakpoints to this potential ambiguity of the probability of the year last living has been assessed, and though there is some sensitivity in the timing of the earlier and later breakpoints, due to the sparseness and bunching of events at the ends of the record, the period of sustained extinctions from the late 1920s to the late 1950s is very stable. We also assessed how variability in recorder effort over time may have affected our findings, using the number of records per decade in the BWARS database as a proxy for effort, and found that our results were not systematically affected by this. These analyses are discussed in the supplementary materials.

Table 1. Extinct British bee and flower-visiting wasp species, ordered by their last observed year, with number of records of that species from the BWARS database. A record is defined as an occurrence of a species on a specific date, at a location, and by a specific person. Some of the