THE PRODUCER-POLLINATOR DILEMMA: NEONICOTINOIDS AND HONEYBEE COLONY COLLAPSE

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Abstract

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Neonicotinoid insecticides are the most important new insecticide class introduced in the past 40 years. They are the number one selling insecticide in the world, and are used on over 90% of the corn produced in the U.S. However, neonicotinoids could very likely be causing widespread and severe impairment to bee colonies, and possibly contributing to Colony Collapse Disorder (CCD). This is problematic since bees, and honey bees in particular, are the single most important pollinator for global agriculture. Pollination services contribute to one of every three mouthfuls of food consumed (Xerces Society, 2011). Direct pollination services were recently valued in a Cornell University Study to be worth 16 billion dollars a year in U.S. Farm income (Calderone, 2012). As more is learned about the nature of systemic neonicotinoids and their adverse effects on beneficial pollinators, a potential conflict between crop protection and pollinator conservation becomes clear, posing a dilemma between food production required to feed a growing global population and the risk of widespread colony collapses.

The scientific community has been examining the phenomenon of CCD, and anecdotal links between the bee losses and the application of neonicotinoid insecticides, since it was first noticed by French beekeepers in 1994 and then in the U.S. in 2006. While previous studies failed to demonstrate links to CCD, a new generation of field-realistic studies has chronicled the synergistic and sublethal effects of neonicotinoids on individual bees and colonies over longer-term exposure using real-world foraging conditions. Recent studies strongly support the link between neonicotinoids and CCD (Henry et al., 2012; Whitehorn et al., 2012; Gill et al., 2012; Lu et al., 2012; Tapparo et al., 2012; Krupke et al., 2012). However, independent researchers such as James Cresswell, Jim Frazier, and USDA scientist Jeffrey Pettis (Cresswell, 2011; Cresswell, Desneux, and vanEngelsdorp, 2012; Frazier et al., 2011; Frazier 2012; Grist.org) along with farming and crop protection interests, and the producers of the neonicotinoid products all caution that there is not yet enough evidence to draw definitive conclusions, and that there are a variety of causal factors behind CCD. Can these pesticides continue to be used safely in the U.S. or do their risks to pollinators outweigh their benefits to humans and animals?

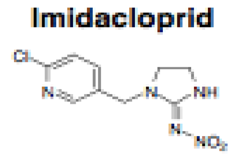
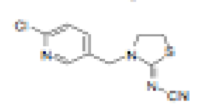
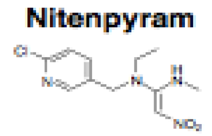
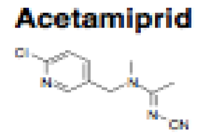
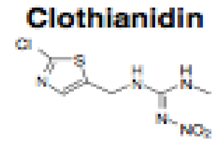
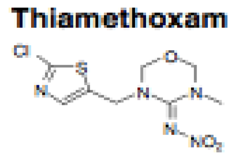
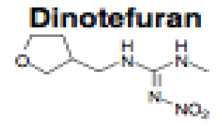
Native Bees Poster (Pollinator Partnership, http://www.pollinator.org/NativeBees.htm)

Introduction

Neonicotinoid pesticides have been shown, in multiple independent studies conducted in the U.S. and Europe, to have negative impacts on both wild bees and managed honey bees (Henry et al., 2012; Whitehorn et al., 2012; Gill et al., 2012; Lu et al., 2012; Tapparo et al., 2012; Krupke et al., 2012). France has banned such systemic pesticides based upon the precautionary principle, while in the U.S. neonicotinoids are used on over 90 percent of the U.S. corn crop (Bayer Crop Science). The debate over continued approval of this potentially harmful class of pesticides has reached the U.S. EPA, where petitions for review have been raised by an alliance of beekeepers, concerned lawmakers, and environmental defense groups. Proponents of neonicotinoids, those in both agricultural and chemical industries, insist that these chemicals are safe for controlled use in the field and that recent studies used flawed assumptions on actual field dosage and faulty bee-colony-reproduction statistics. Despite the claims to the contrary, there does seem to be converging evidence that Neonicotinoids, the number one selling class of insecticide in the world, are indeed detrimental to bees, but the question is--at what concentration, and are these realistic exposure rates in nature?

Guttation Drops Bee (Reetz et al., 2011)

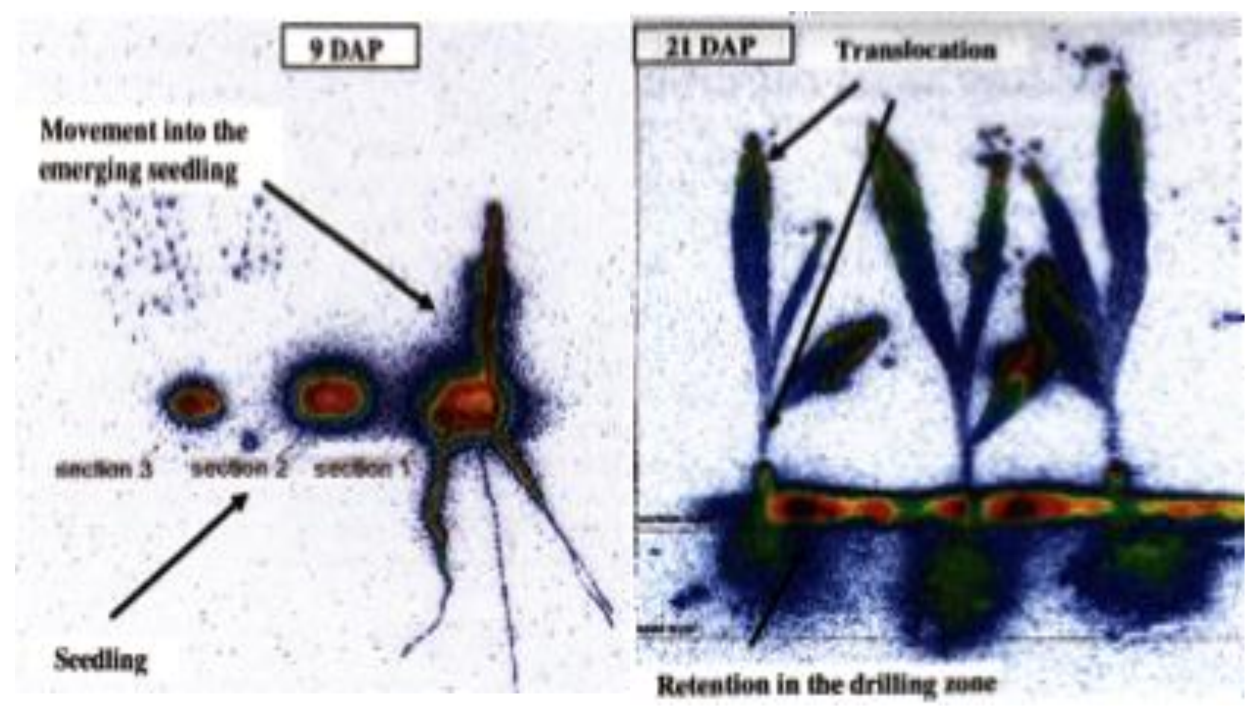
Corn Pollen Bee (Frazier et al., 2011)

Neonicotinoid	Product Names	Patent Info	Commercial Use
Imidacloprid 	Gaucho, Admire, Hachikusan, Earth Garden, Merit, Imicide Provado Macho Malice, Sepresto Widow, Wrangler, Numerous Bayer Products, DIY Tree Care Products Multi-Insect Killer, Ferti-lome 2-N-1 Systemic, Hi-Yield Systemic Insect Spray, Hunter, Knockout Ready-To-Use Grub Killer Lesco Bandit, Marathon, Monterey Once a Year Insect Control II, Ortho Bug B Gon Year-Long Tree/Shrub Insect Control, Orhto MAX Tree/Shrub Insect Control, Surrender, GrubZ Out	Bayer 1985, commercial introduction 1991 Japan 1993 U.K. 1994 U.S	Seed dressing, soil drench, granules, injection, or spray to a wide range of field and tree crops, as well as ornamental plants, trees, and turf. Also, topical use on pets for flea control and application to buildings for termite control.
Thiacloprid 	Winbarlard, Eco-one Froable, Calypso	Bayer 1985, commercial introduction 1999 Brazil	Foliar spray to cotton and pome fruit crops
Nitenpyram 	Bestguard, Pedan Best, Capstar	Sumitomo Chem. Co. 1988, commercial introduction 1995	*Not Commonly used on Plants in U.S. Topical use on pets and livestock for flea control. Used in Japan/China on rice, fruit.
Acetamiprid 	Mospilan, Matsu green, Kadan, Yielder SG, Assail, Tristar, Ortho Flower, Fruit and Vegetable Insect Killer, Ortho Rose and Flower Insect Killer	Nippon Soda 1989, commercial introduction 1995 Japan	Foliar spray for leafy vegetables, fruiting vegetables, cole crops, citrus fruits, pome fruits, grapes, cotton,ornamental plants and flowers.
Clothianidin 	Poncho, Dantotsu, Full Swing, Moriate, Hustler, Takelock, Arena, Clutch, Belay, Aloft, Bayer Advanced All-in-One Rose & Flower Care granules, Green Light Grub Control with Arena	Sumitomo Chem. Co. & Bayer 1989, commercial introduction 2002 Japan 2003 U.S	Seed treatment, foliar spray or soil drench for a variety of field and tree crops, also for turf and a variety of ornamental trees and flowers.
Thiamethoxam 	Actara, Cruiser FS30, Actara, Adage, Centric, Platinum, Flagship Maxide Dual Action Insect Killer, Meridian	Syngenta 1992, commercial introduction 1997 N. Zealand	Seed dressing, soil drench, injection, granules, foliar spray to a wide range of field crops, as well as ornamental plants and turf.
Dinotefuran 	Starkle, Albarin, Bonfram, Venom Scorpion, Green Light Tree & Shrub Insect Control with Safari 2 G, Safari, Transect, Zylam 20SG Systemic Turf Insecticide	Mitsui Chemicals 1994, commercial introduction 2002 Japan	Soil drench or foliar spray to leafy and fruiting vegetables, turf, and ornamental plants. Also used as bait or granules for cockroach control.

Neonicotinoid Chart (AGROW Online, JEPA Online, Xerces Society Online, Iwasa et al., 2004; Jeschke et al., 2011; Tomizawa and Casida, 2005; Wakita et al., 2003; Tomlin, 2009)

The Versatility and Spread of Neonicotinoids

- Neonicotinoids have made a major impact on pests since 1991
- Imidacloprid is the number one selling insecticide in the world
- Presently in the U.S. there are over 400 neonicotinoid products on the market for a wide range of residential, construction, backyard gardening, agriculture, and veterinary uses and these products come in many forms, including liquids, granules, dusts, and packages that dissolve in water
- Neonicotinoid pesticides are used in over 120 countries (Jeschke et al., 2011) and on crops such as vegetables, pomes, nuts, citrus, rice, cotton, maize, potatoes, sugar beets, rapes and soybeans (Agrowpages Online Resource)
- Neonicotinoids have an endless range of uses because their unique physiochemical properties and translocation rates (see figure below), combined with residual activity, make them highly effective against sucking and chewing species, including aphids, whiteflies, leafhoppers, planthoppers, and the Colorado potato beetle (Jeschke et al., 2011)
- "Seed dressing, film coating, pelleting, and multilayer coating allow an environmentally safe and perfect protection of young plants against insect attacks. With this method, application of the active ingredient is practically independent of the weather and can be applied directly at the site of action. Application amounts (g of active ingredient per hectare) used per unit area are thereby reduced remarkably" (Jeschke et al., 2011)



Systemic Translocation of Neonicotinoid seed treatment through emerging sapling
9 and 21 days after planting (Yamamoto and Casida, 1999, pgs. 199, 200)

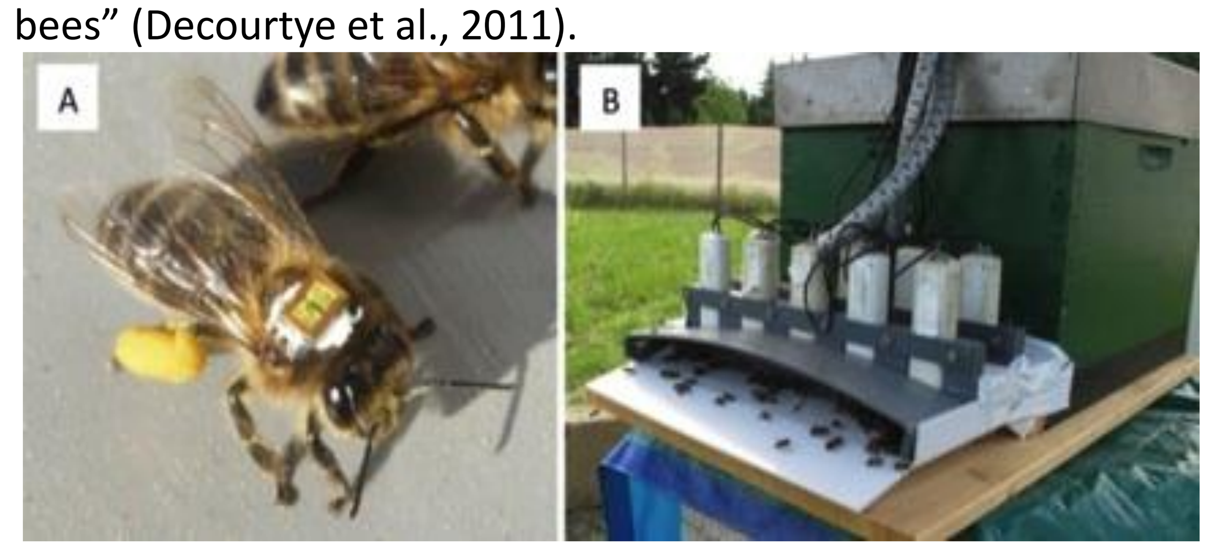
Unique Physiochemical Properties

Neonicotinoids are highly potent and considered a "low-rate technology." They possess good water solubility, and are readily absorbed and translocated by root systems and leaves alike, making these compounds highly systemic, particularly when used as a seed dressing (Yamamoto and Casida, 1999)(see figure above). This property makes neonicotinoids highly complimentary to Bt seeds and crops, which take between 3-6 weeks to buildup sufficient Bt levels in emerging seedlings to deter pests, whereas neonicotinoid seed coatings provide immediate efficacy against devastating early-growth-stage pests such as corn rootworm species (Benbrook Interview).

Due to the systemic penetration into all parts of the plant, some neonicotinoids have demonstrated "strong preventative effects on some plant virus transmissions" (Maienfisch et al., 2001; Jeschke et al., 2011). Less pest resistance to neonicotinoids exists because they possess a new mode of action by binding at a specific site, the postsynaptic nicotinic acetylcholine receptor (NaChR), making them important for management of insecticide resistance (Agrow online resource). The major strength of neonicotinoids results from their low mammalian toxicity and favorable safety profile (Yamamoto and Casida, 1999).

Realistic Field Studies

A new era of research is now yielding data that enable researchers to track individual bees with radio frequency identification tags (RFID) as they enter and exit the hive to forage. A greater level of understanding is possible when the aggregated behavior patterns of individual bees can be studied and compared to the overall hive's performance and well-being. This unique methodology for bee research began in early 2011 with experiments conducted by Decourtye et al. which "aim to show how the RFID device can be used to study the effects of pesticides on both the behavioral traits and the lifespan of bees" (Decourtye et al., 2011).



Honey bee RFID monitoring equipment. (A) A pollen-forager honey bee fitted with a 3-mg RFID tag. (B) A hive entrance equipped with RFID readers for detecting returning marked foragers (Henry et al., 2012)

Conclusions: Weighing Evidence and Measuring Risks

There would seem to be a convergence of evidence through 2012, as a new generation of studies has been published, and the increased focus on bee losses around the world have led to a greater call for neonicotinoid bans. Brazil, Japan, and Britain are currently considering bans, and the U.S. is currently reviewing neonicotinoids. **What multiple researchers are confirming is that sub-lethal doses of neonicotinoid insecticides, through cumulative and multiple routes of exposure, are hindering bees' cognitive abilities (such as memory, navigation of mazes, foraging, communication skills), causing chronic mortality, and *possibly* weakening individual and colony immunity and ability to fight disease. Many of these effects were reported at very low levels of dosage, far below the LD 50, and lower than the recommended application rates (in some cases at rates which would have been undetectable using most equipment had those bees not been part of the control group). Furthermore, the chronic effects of the neonicotinoids very often take longer than 48 hours to create observable effects, more often requiring weeks of sublethal exposure before a tipping point is reached within individual bees which then impacts, and possibly collapses, the entire hive.** There is little dispute that the neonicotinoid class of insecticides is highly toxic to bees--a fact reported by the manufacturers throughout the testing process. The key issue for the agrochemical companies, which have invested countless R&D hours combined with massive monetary resources in creating a new and safer pesticide, is their assertion that the neonicotinoids are safe to bees for field use *at the prescribed* rates. As a person well versed in the neonicotinoids discourse and the competing studies, Dr. James Frazier, Professor of Entomology at Pennsylvania State University states regarding the EPA conditional registration of clothianidin for use in the US: **"For me this raises real concerns that the neonicotinoids that are currently being used in the market place were registered by a risk assessment process that was seriously flawed in its capacity to evaluate systemic pesticides" (Frazier Critic Letter, 2012).**