

# How Neonicotinoids Can Kill Bees

The Science Behind the Role These Insecticides Play in Harming Bees

Neonicotinoids are absorbed by the plant and transferred through the vascular system, making the plant itself toxic to insects.

Home and garden products may be applied to ornamental and landscape plants at rates many times higher than those approved for agricultural crops.

Bee safety of currently approved products should be reassessed and all conditional registrations immediately suspended.

Neonicotinoids have been adopted for use on an extensive variety of farm crops as well as ornamental landscape plants. They are the most widely used group of insecticides in the world, and have been for a decade. Developed as alternatives for organophosphate and carbamate insecticides, neonicotinoids are compounds that affect the nervous system of insects, humans, and other animals. Although less acutely toxic to mammals and other vertebrates than older insecticides, neonicotinoids are highly toxic in small quantities to many invertebrates, including beneficial insects such as bees.

The impact of this class of insecticides on pollinating insects such as honey bees and native bees is a cause for concern. Because they are systemic chemicals absorbed into the plant, neonicotinoids can be present in pollen and nectar, making them toxic to pollinators that feed on them. The potentially long-lasting presence of neonicotinoids in plants, although useful from a pest management standpoint, makes it possible for these chemicals to harm pollinators even when the initial application is made weeks before the bloom period. In addition, depending on the compound, rate, and method of application, neonicotinoids can persist in the soil and be continually taken in by plants for a very long periods of time.

Across Europe and North America, a possible link to honey bee die-offs has made neonicotinoids controversial. In December 2013, the European Union significantly limited the use of clothianidin, imidacloprid, and thiamethoxam on bee-attractive crops. In the United States, Canada, and elsewhere, local, state, and federal decision makers are also taking steps to protect pollinators from neonicotinoids. For example, the U.S. Fish and Wildlife Service phased out all uses of neonicotinoids on National Wildlife Refuges lands starting in January 2016.

This report reviews research on the impact of these pesticides on bees. For a research review on beneficial insects, including those important to biological control, see Hopwood et al. (2013). See Morrissey et al. (2015), Mineau et al. (2013), and Gibbons et al. (2015) for reviews on aquatic invertebrates, birds, and vertebrates, respectively.

The Xerces Society for Invertebrate Conservation also maintains an annotated bibliography of relevant research published since the writing of this report on its web site. That bibliography can be accessed at: [www.xerces.org/neonicotinoids-and-bees](http://www.xerces.org/neonicotinoids-and-bees).



A sleeping cluster of male sweat bees on apple blossom. Neonicotinoids can be applied to apple trees in backyards at rates between 12 and 120 times greater than allowed in commercial orchards. (Photo: Tom Potterfield/Flickr.com.)

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## Findings

The following findings are divided into three sections. In the first section, we present clearly documented information about neonicotinoid impacts on bees, i.e., facts that are supported by an extensive body of research. (Fully cited evidence for these is detailed in the main body of this report.) The second section covers what can be inferred from the available research. This includes possible effects for which there is currently only limited research or the evidence is not conclusive. In the third section, we identify knowledge gaps in our understanding of pollinator and neonicotinoid interactions. Filling these gaps will allow better-informed decisions about the future use and regulation of these chemicals.

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### Clearly Documented Facts

#### Exposure of Bees to Neonicotinoids

- ⇒ Neonicotinoid residues found in pollen and nectar are consumed by flower-visiting insects such as bees. Residue concentrations can reach levels that cause sublethal effects through a variety of application methods, including use of coated seed, and in some situations can reach lethal levels.
- ⇒ Neonicotinoids can persist in soil for months or years after a single application. Residues have been found in woody plants up to six years after soil drench application.
- ⇒ Untreated plants have been found to absorb the residues of some neonicotinoids that persisted in the soil from the previous year.
- ⇒ Neonicotinoids applied to crops, even as seed coatings, can contaminate adjacent vegetation, including bee-attractive wildflowers.
- ⇒ Products approved for home and garden use may be applied to plants at rates substantially higher than the maximum label rate approved for agricultural crops.
- ⇒ Direct contact from foliar applications of the most toxic neonicotinoids has caused bee kills; additionally, foliar residues on plant surfaces may remain lethal to bees for several days.
- ⇒ Bee kills have been caused by legal applications of neonicotinoids to *Tilia* (linden, basswood). Some of these applications, designed to be uptaken by the trees, occurred weeks to months prior to when bees visited the trees.

#### Effects on Honey Bees (*Apis mellifera*)

- ⇒ Clothianidin, dinotefuran, imidacloprid, and thiamethoxam are highly toxic to honey bees by contact and ingestion.
- ⇒ Thiacloprid and acetamiprid are moderately toxic to honey bees. (To understand how the EPA defines the levels of toxicity, see EPA Toxicity Classification Scale for Bees on right.)
- ⇒ Neonicotinoids absorbed by plants are metabolized over time. Some of the resulting breakdown products are also toxic to honey bees, and sometimes even more toxic than the original compound.
- ⇒ Honey bees exposed to sublethal levels of neonicotinoids can experience problems with flight and navigation, reduced taste sensitivity, and slower learning of new tasks, all of which impact foraging ability and hive productivity.
- ⇒ Larvae exposed to sublethal doses of imidacloprid in brood food had reduced survival and pupation, altered metabolism, and reduced olfactory response as adults.
- ⇒ Contaminated talc, abraded seed coating, or dust that becomes airborne during planting of neonicotinoid-coated seed is acutely toxic on contact to honey bees.

## Effects on Bumble Bees (*Bombus* spp.)

- ⇒ Imidacloprid, clothianidin, dinotefuran, and thiamethoxam are highly toxic to bumble bees.
- ⇒ Exposure to sublethal amounts of neonicotinoids can result in reductions in food consumption, reproduction, worker survival rates, colony survival, and foraging activity.
- ⇒ Queen production is significantly reduced by sublethal amounts of neonicotinoids, which may lower bumble bee populations because fewer colonies are established the following year.

## Effects on Solitary Bees

- ⇒ Clothianidin and imidacloprid are highly toxic to blue orchard bees (*Osmia lignaria*) and alfalfa leafcutter bees (*Megachile rotundata*).
- ⇒ Imidacloprid residues on alfalfa foliage increase rates of mortality of alfalfa leafcutter bees and alkali bees (*Nomia melanderi*).
- ⇒ Blue orchard bee larvae required more time to mature after consuming sublethal levels of imidacloprid in pollen.
- ⇒ Sublethal amounts of neonicotinoids can have harmful effects on the reproduction of red mason bees (*Osmia bicornis*).

## Presence in the Environment

- ⇒ Tens of millions of acres of neonicotinoid-coated seed is planted annually in the United States and Canada. When applied systemically and taken up by the plant, imidacloprid, thiamethoxam, and clothianidin can have residual activity within plants for months to years.
- ⇒ Imidacloprid, thiamethoxam, and clothianidin are persistent in soil, with residues present for months to years.
- ⇒ Neonicotinoids can move into water and have been found in a range of water bodies, where they may persist. Clothianidin has been found in rivers and streams, wetlands, groundwater, and puddles. Imidacloprid has been found in surface water, groundwater, and puddles. Thiamethoxam has been found in waterways, wetlands, groundwater, and puddles, and has also been detected in irrigation water pulled from ground wells. Acetamiprid and dinotefuran have been found in waterways.

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## Inferences from Research Results

### Exposure of Bees to Neonicotinoids

- ⇒ Application as a seed coating can result in low levels of residues in pollen and nectar that have been linked with sublethal effects in solitary bees.
- ⇒ Application methods such as foliar sprays, soil drenches, and trunk injections apply a higher dosage per plant than seed coatings and may result in much higher—even lethal—levels of neonicotinoid residues in pollen and nectar.
- ⇒ Application of neonicotinoids before and during bloom may result in residue levels in pollen and nectar that cause sublethal effects or even mortality.
- ⇒ Application by soil drench or trunk injection to woody ornamental species may result in residue levels in blossoms that cause lethal and sublethal effects for more than a year after treatment.
- ⇒ Foliar applications may have shorter residual toxicity in comparison to other application methods such as trunk injection and soil drench.
- ⇒ Pesticide residues, including from planting coated seeds, have been found in honey bee hives.

## Effects on Pollinators

- ⇒ There is no direct link demonstrated between neonicotinoids and the honey bee syndrome known as colony collapse disorder (CCD). However, recent research suggests that pesticides, including neonicotinoids, may make honey bees more susceptible to parasites and viruses, including the intestinal parasite *Nosema*, which has been implicated as one causative factor in CCD.
- ⇒ Neonicotinoids may synergistically interact with demethylase inhibitor (DMI) fungicides. DMI fungicides have significantly increased the toxicity of neonicotinoids to honey bees in some laboratory tests. The synergistic effects of these mixtures in field settings using formulated pesticides in water appear to be less dramatic in comparison with the laboratory research.
- ⇒ Bumble bees and solitary bees can be affected by neonicotinoids at lower concentrations than are honey bees. Currently, evaluation of other pollinators beyond honey bees is extremely limited in EPA's pesticide registration process.

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## Knowledge Gaps

### Exposure of Bees to Neonicotinoids

- ⇒ What are the conditions under which residue levels both in the plant and soil increase in concentration over time with repeated applications?
- ⇒ What is the risk posed by neonicotinoid contamination of nontarget plants growing near treated plants?
- ⇒ What is the risk posed by bees from forage cover crops absorbing neonicotinoids when planted in a rotation with a neonicotinoid-treated row crop?
- ⇒ How do these chemicals move through the plant? For example, how soon after product application do neonicotinoid residues appear in pollen and nectar, how fast is it metabolized in the plant, and how do levels vary with application method, crop, and specific compound? Do they move in phloem tissue in addition to xylem?
- ⇒ Is the combined presence of neonicotinoids and their break-down products in pollen or nectar as toxic or more toxic to bees than the individual chemicals?
- ⇒ Does the movement of neonicotinoids within a plant vary with the type of plant (e.g., herbaceous vs. woody), or by functional group (e.g., forbs vs. legumes vs. grasses)?
- ⇒ How do residue levels vary in plants grown under differing field conditions (e.g., drought), soil types (e.g., sandy vs. loam), or under variable nutrient levels?

### Effects on Pollinators

- ⇒ What are the acute and chronic contact and ingestion effects of neonicotinoids to bees other than honey bees?
- ⇒ What is the full extent of the sublethal effects of neonicotinoids on adult bees?
- ⇒ What is the full extent of effects of neonicotinoids on larval bees?
- ⇒ Do honey bees experience delayed effects of neonicotinoids during adverse weather conditions (e.g., winter or drought) when stored foods are consumed?
- ⇒ What is the full extent of effects that soil residues have on ground-nesting bees (which represent approximately 70% of bee species)?
- ⇒ What effects, if any, do neonicotinoid contaminated plant tissues and mud have on bees that construct nests from these materials?
- ⇒ How do neonicotinoids affect other pollinators such as butterflies, moths, beetles, flies, and wasps?

To download the full report and read policy recommendations, go to  
[www.xerces.org/neonicotinoids-and-bees](http://www.xerces.org/neonicotinoids-and-bees).