GARDENERS BEWARE

2014

Bee-Toxic Pesticides Found in "Bee-Friendly" Plants sold at Garden Centers Across the U.S. and Canada

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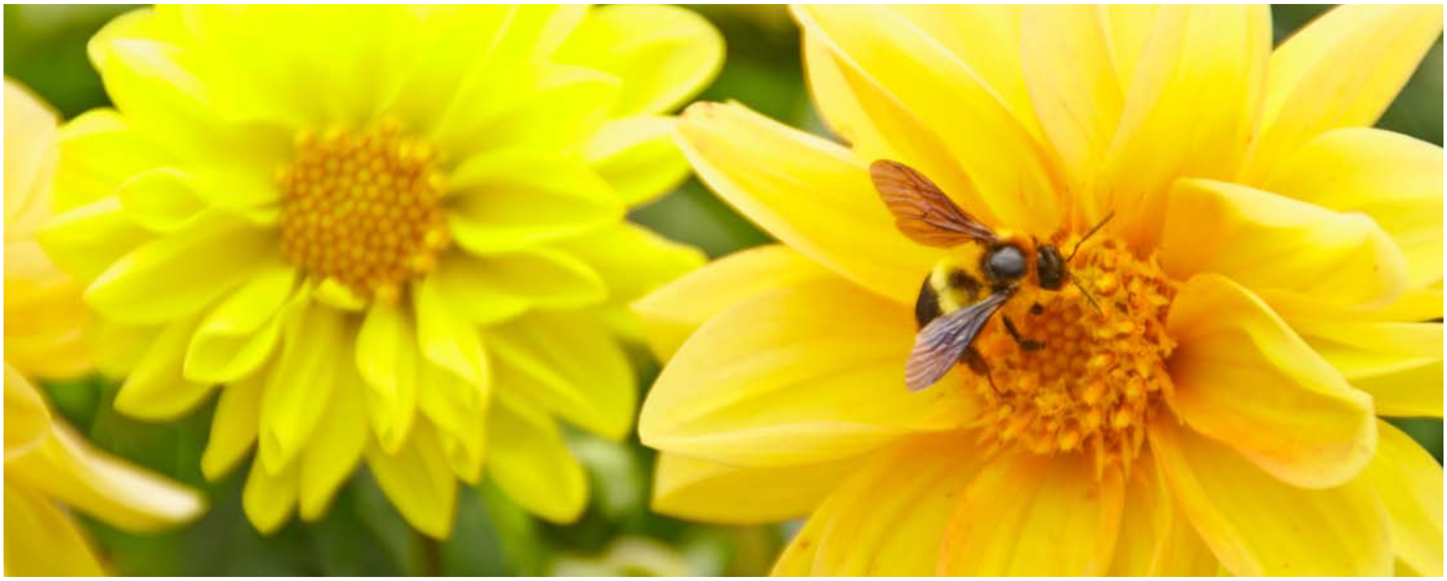

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About Friends of the Earth:

Friends of the Earth U.S., founded by David Brower in 1969, is the U.S. voice of the world's largest federation of grassroots environmental groups, with a presence in 74 countries. Friends of the Earth works to defend the environment and champion a more healthy and just world. Through our 45-year history, we have provided crucial leadership in campaigns resulting in landmark environmental laws, precedent-setting legal victories and groundbreaking reforms of domestic and international regulatory, corporate and financial institution policies. **www.FoE.org**

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Executive Summary

In 2013, Friends of the Earth U.S. and the Pesticide Research Institute released *Gardeners Beware: Bee-Toxic Pesticides Found In "Bee-Friendly Garden Plants Sold Nationwide*, a report documenting a first-of-its-kind pilot study on the prevalence of neonicotinoid pesticides in bee-attractive plants commonly purchased by home gardeners. For the spring 2014 planting season, we expanded the scope of the study to include 18 locations in the U.S. and Canada and analyzed neonicotinoid concentrations in flowers separately from the greenery (stems and leaves). The results of our new study show that the use of neonicotinoid insecticides in nursery plants is still widespread, and these plants remain a source of exposure for bees and other pollinators.

Two-thirds of the food crops humans eat every day require bees and other pollinators to successfully produce a crop. However, the health and productivity of honey bees, bumble bees, and other pollinators are in great peril, and populations are dwindling worldwide. Concerned citizens have responded by planting "bee-friendly" gardens to provide urban foraging grounds. Unfortunately, as our new study shows, many of the nurseries that provide bee-attractive plants sold at top retailers in the U.S. and Canada continue to use persistent, systemic neonicotinoid insecticides that have been shown to impair the health and survival of bees and other vulnerable pollinators.

Although managed honey bee losses have been linked to multiple factors—including *Varroa* mite infestations, pathogens, malnutrition and habitat degradation—a strong and growing body of scientific evidence suggests that neonicotinoid pesticides are a major contributing factor. Neonicotinoids, manufactured primarily by Bayer CropScience, Syngenta, and Dow AgroSciences, are used extensively in agricultural and urban/suburban areas. The neonicotinoid imidacloprid—introduced in 1994—is among the most widely used insecticides in the world. Neonicotinoids are used as seed treatments on more than 140 crops, with virtually all corn, and a large percentage of soy, wheat, and canola seeds planted in the U.S. being pretreated with neonicotinoids.

Neonicotinoids are systemic pesticides that are taken up through roots and leaves and distributed throughout the entire plant, including pollen and nectar. These pesticides can poison bees directly, but even low-level exposure can lead to sublethal effects such as altered learning, impaired foraging and immune suppression, which exacerbates the lethality of pathogen infections and mite infestations. Unfortunately, home gardeners have no idea they may actually be poisoning pollinators through their efforts to plant bee-friendly gardens.

The plants included in this new study were purchased from major nursery outlets and garden centers, including Home Depot, Lowe's and Walmart in 18 cities throughout all four official geographic regions of the U.S., as well as three provinces of Canada. The collected plant samples were submitted to an independent accredited analytical laboratory to identify specific neonicotinoids and quantify their concentrations in the flowers alone versus the stems and leaves.

Findings include:

- Neonicotinoid residues were detected in 36 out of 71 (51 percent) of commercial nursery plant samples. In the samples with detections, the combined concentrations of bee-toxic neonicotinoids ranged from 2 to 748 micrograms per kilogram (μg/kg) in flowers and 2 to 1,945 μg/kg in stems and leaves.
- In approximately half of samples with detections, the neonicotinoid residues were distributed evenly between flowers and stems/leaves or were localized primarily in the flowers. This result suggests that bees are being exposed to neonicotinoids through contact with contaminated flowers and ingestion of pollen and nectar within the flower.
- Since 51 percent of the plants that were tested contained neonicotinoid residues, the chance of purchasing a plant contaminated with neonicotinoids is high. Therefore, many home gardens have likely become a source of exposure for bees.
- For the samples with positive detections, adverse effects on bees and other pollinators consuming nectar and pollen from these plants are possible, ranging from sublethal effects on navigation, fertility, and immune function to pollinator death.

The bulk of available scientific literature suggests that neonicotinoids are a key contributing factor to the decline of pollinator populations. As a result of this growing body of evidence, the European Commission suspended the use of three neonicotinoids (clothianidin, imidacloprid, and thiamethoxam) on flowering plants attractive to bees in European Union countries, effective December 1, 2013. Unfortunately, U.S. EPA has been slow to adequately address the threats to pollinators posed by neonicotinoids, delaying any substantive action until 2016–2019 when the Registration Review process for these chemicals is completed.

At the local and state levels in the U.S. and in the marketplace, there are signs of progress.

The "Saving America's Pollinators Act" H.R. 2692 would suspend seed treatment, soil application, or foliar uses of certain neonicotinoid insecticides on bee-attractive plants until U.S. EPA reviews all of the scientific evidence, and field studies can be done to evaluate both short- and long-term effects of these pesticides on pollinators. The bill is bipartisan and currently has sixty-eight co-sponsors.

Since 51 percent of the plants that were tested contained neonicotinoid residues, the chance of purchasing a plant contaminated with neonicotinoids is high. Many home gardens have likely become a source of exposure for bees

In addition to federal legislation, state and local governments have been active in working to address neonicotinoids. In February 2014, Oregon passed the "Save Oregon's Pollinators Act" HB4139-A. The city of Eugene, OR became the first city in the country to ban the use of neonicotinoids on city property. In May, the Minnesota legislature passed two bills: one prohibiting retailers from labeling plants treated with pollinator-lethal insecticides (e.g., neonicotinoids) as bee-friendly and another to compensate beekeepers for bee losses. Additional measures to protect bees from exposure to bee-toxic pesticides have been introduced in Minnesota and the following states: California, Maine, Maryland, New Jersey, New York, Alaska and Vermont.

In Canada, the Province of Ontario introduced a Beekeepers Financial Assistance Program to compensate for losses of more than 40 percent of registered active hives. Prince Edward County in Ontario temporarily suspended the use of neonicotinoids on municipal lands, effective immediately.

Retailers, from small local nurseries to national chains like BJ's Wholesale Clubs, Inc., are also making progress on this issue by committing to phase out their use of neonicotinoids in garden plants and removing neonicotinoid pesticide products from their shelves.

Although U.S. EPA and Health Canada's Pesticide Management Regulatory Agency (PMRA) have not yet taken action, there is still much that can be done to protect bees. Friends of the Earth U.S. and allies are asking consumers, retailers, suppliers, institutional purchasers and local, county, state and federal regulators and policymakers to take action to avoid neonicotinoid pesticides to help protect bees and other pollinators.

Recommendations for Garden Retailers:

- Do not sell off-the-shelf neonicotinoid insecticides for home garden use.
- Require neonicotinoid-free vegetable and bedding plants from suppliers and do not sell plants or plant starter mixes pre-treated with these insecticides.
- Offer third-party certified organic starts and plants.
- Educate your customers on why your company has made the decision to protect bees and other pollinators.

Recommendations for Wholesale Nursery Operations Supplying Retailers:

- Use only untreated seeds for plants grown from seed.
- Do not use neonicotinoid insecticides as soil drenches, granules, or foliar treatments when growing vegetable and bedding plants.
- Offer neonicotinoid-free and organic vegetable and bedding plants to your customers and label them as such.
- Educate your customers about why your nursery operation made the choice to limit the use of neonicotinoid pesticides.
- If quarantine regulations require use of systemic insecticides on certain plants that are hosts for invasive pests, treat only those plants, minimize the number of treatments and label treated plants accordingly. Do not use neonicotinoids if less toxic systemic pesticides are approved for use on the target pest. Use pest exclusion systems wherever possible to avoid having to treat plants with pesticides.

Recommendations for Home Gardeners and Institutional Purchasers (such as schools, universities, private companies, hospitals, and others):

- Stop using all neonicotinoid insecticides on your property and facilities (e.g. landscaping around parking lots, grounds and gardens) and only plant neonicotinoid-free plants.
- Specify in contracts with landscaping companies that service your grounds and trees not to use neonicotinoid insecticides and not to install plants pretreated with neonicotinoids.
- Provide critical habitat for pollinators by planting pollinator friendly trees and flowers.

Recommendations for Cities, Counties and U.S. States:

- Suspend the use of neonicotinoids and other insecticides for cosmetic purposes on ornamental and landscape plants, like the ban now in force in Ontario, Canada.
- Pass resolutions to ensure that neonicotinoids are not used on city- and county-owned property, including schools, parks and gardens.
- Require that bee-toxic insecticides be prominently labeled as such in displays of these chemicals at garden centers, hardware stores and nurseries.
- Provide critical habitat for pollinators by planting pollinator-friendly trees and flowers.

Recommendations for the U.S. EPA:

- Suspend the registrations of neonicotinoids for agricultural as well as cosmetic and other unnecessary uses pending the results of pesticide re-evaluation.
- Require a bee hazard statement on the label of all products containing systemic insecticides toxic to pollinators, including soil drenches and foliar use products.
- Prioritize the systemic insecticides for Registration Review starting in 2014, and ensure inclusion of independent, peer-reviewed research on the acute and chronic effects of systemic insecticides on bees.
- Expedite the development and implementation of valid test guidelines for sublethal effects of pesticides on pollinators and require data from these studies for all currently registered and any new pesticides.

Recommendations for the U.S. Congress:

- Support and pass H.R. 2692, the Saving America's Pollinators Act, introduced by Representatives John Conyers (D, Mich.) and Earl Blumenauer (D, Ore.). This legislation will suspend seed treatment, soil application, or foliar uses of certain neonicotinoid pesticides on bee-attractive plants until:
    - all of the scientific evidence is reviewed by the U.S. EPA, and
    - field studies can be done to evaluate both short- and long-term effects of these pesticides on pollinators.

Recommendations for Health Canada's Pesticide Management Regulatory Agency (PMRA):

- Suspend the registrations and temporary registrations of neonicotinoid pesticides in both agriculture and minor use pending the results of the PMRA re-evaluation.

Recommendations for Canadian Provinces:

- Enact an immediate moratorium on the sale of neonicotinoid-treated seeds on field crops as well as for minor use in horticulture in each respective province, pending the results of the PMRA re-evaluation of neonicotinoids.

Recommendations for Consumers:

- **Take Action U.S.:** Join the Friends of the Earth U.S. Bee Action campaign at www.BeeAction.org and sign our petition to garden retailers asking that they stop selling neonicotinoid treated plants and products that contain neonicotinoids. You can also contact your member of Congress and encourage them to support the Saving America's Pollinators Act. You can find action, and bee-friendly gardening tips at www.BeeAction.org.
- **Take Action Canada:** Join the Friends of the Earth Canada campaign – take part in The Bee Cause work (www.BeeCauseCanada.org) and sign the petition to influence garden centres in Canada to stop selling neonicotinoid treated plants.
- **Raise Your Voice Locally:** Let your local nursery manager know that you will only purchase plants free of neonicotinoids and ask the manager to communicate your request to their corporate headquarters and suppliers who grow the plants they sell.

Find a sample letter for U.S. companies and more ideas for action at www.BeeAction.org. For a sample letter for Candian companies, visit the FOE Canada website at http://foecanada.org/en/files/2014/03/Model_Letter_on_Neonics_to_Garden_Centres.pdf.

- **Grow Bee-Safe:** Avoid buying neonicotinoid-treated seeds and seedlings. Purchase organic plant starts or grow your plants from untreated seeds in organic potting soil for your home vegetable and flower gardens.
- **Practice Bee-Safe Pest Control:** Avoid the use of systemic bee-toxic pesticides in your garden (see Appendix A) and use alternative approaches such as providing habitat to attract beneficial insects that prey on pest insects in your garden. If pest pressure is too high, use insecticidal soaps or oils and other eco-friendly pest control products. For more tips and links to more resources for pollinator and eco-friendly gardening, visit www.BeeAction.org and www.garden4bees.com.
- **Do not buy products that contain neonicotinoids:** Read the label and avoid using off-the-shelf neonicotinoid insecticides in your garden. These products may contain acetamiprid, clothianidin, imidacloprid, thiamethoxam and dinotefuran as active ingredients. See Appendix A at the end of this report for a list of common consumer products containing neonicotinoids.
- **Do a clean sweep:** See if you have these products at home, dispose of them as municipal hazardous waste or take them back to the store where you bought them.

I. Introduction and Background

In 2013, Friends of the Earth U.S. and the Pesticide Research Institute released *Gardeners Beware: Bee-Toxic Pesticides Found in "Bee-Friendly" Garden Plants Sold Nationwide,*[1] a report documenting our first-of-its-kind, pilot study on the prevalence of neonicotinoid pesticides in bee-attractive plants commonly purchased by home gardeners in three U.S. cities. For the spring 2014 planting season, we expanded the scope of our pilot study to include 18 locations in the U.S. and Canada and analyzed neonicotinoid concentrations in flowers separately from stems and leaves. The results of our new study show that the use of neonicotinoid insecticides in nursery plants is still widespread, and these plants continue to represent a source of exposure for bees and other pollinators.

Bees in Trouble

Bees are essential to the production of one out of every three bites of food we eat.[2, 3] In fact, 71 of the 100 crops that provide 90 percent of the world's food—from almonds to strawberries—are pollinated by bees.[4] Honey bees and other pollinators contribute nearly $20 billion to the U.S. economy[5] and $217 billion to the global economy.[6, 7] Yet evidence is mounting that the health and productivity of these critical pollinators, along with many wild pollinators, is declining rapidly.

In the mid 1990s, beekeepers in France, then in the U.S. and elsewhere experienced high colony losses, both overwintering losses and colony collapse during the spring and summer, when colonies should be thriving. Overwintering losses in the U.S. reached critical levels (i.e., colony losses in excess of 30 percent) during the 2006–2007 season.[8] In locations throughout the U.S., beekeepers noticed their colonies mysteriously collapsing, with adult bees disappearing and leaving the queen, honey and developing larvae in the nearly empty hives. This phenomenon has been dubbed "Colony Collapse Disorder" or CCD.[9, 10]

Since the 2006–2007 season, when massive losses were first observed throughout Europe and North America, the colony loss statistics have varied among different geographical regions. U.S. beekeepers reported winter 2013–2014 hive losses of 23 percent of their hives, with an average over the last eight years of almost 30 percent.[11] In contrast, Italy, which banned the use of neonicotinoids as seed treatment for corn in 2008 due to combined spring and winter colony losses of approximately 30 percent, has witnessed a significant decrease in overwintering colony mortality, with a loss rate of 5.3 percent for the 2012–2013 winter season.[12] Many other European nations, including Belgium, the United Kingdom and Sweden, suffered colony losses as high as 33 percent during the same period.

Meanwhile colony losses and acute bee kill incidents continue to intensify in North America. In July 2013, 37 million bees were reported dead across a single farm in Ontario.[13] Approximately 80,000 commercial honey bee colonies died or were damaged during almond pollination in the early spring of 2014 in the San Joaquin Valley of California.[14] Many beekeepers point to pesticide use as the culprit, although neonicotinoids are not directly implicated in this bee kill incident.[15] Some farmers are facing shortages of bees necessary to pollinate their crops, and the cost to farmers of renting bees for pollination services has increased by up to 20 percent in some cases.[16] Bumble bees, as well as many other wild pollinators have also recently experienced dramatic declines.[17]

The impacts of colony loss and pollinator decline transcend the fate of these individual pollinator species and beekeeping industries that rely upon them. With more than 85 percent of all flowering plants reliant on pollinators for reproduction,[18] the disappearance of bees could contribute to losses of many native plant species. For humanity at large, fewer pollinators also mean a more expensive diet with less variety and reduced nutritional value.

Systemic pesticides play a role in pollinator declines

A number of factors—including parasites,[19] diseases, loss of forage and habitat[20] and changing climate[21]—have been identified as possible contributors to pollinator declines. However, a growing body of evidence points to exposure to systemic pesticides, particularly neonicotinoid insecticides and some fungicides, as primary drivers of the observed decline in pollinator populations.

Other systemic insecticides as well as systemic fungicides and herbicides are commonly used, but neonicotinoids have received the most study in terms of their effects on bees and are among the most widely used systemic pesticides. Preliminary results from the bee-kill incident in California almonds point to tank mixes containing insect growth regulators as the main culprit, but also indicate the presence of systemic fungicides (e.g., boscalid and pyraclostrobin, azoxystrobin, cyprodinil) in high concentrations. Although systemic fungicides typically have low acute toxicity to honey bees, studies have demonstrated the ability of certain systemic fungicides to magnify the toxic effects of neonicotinoids acetamiprid and thiacloprid.[22, 23] Results from another study suggest that systemic fungicides may compromise immune function.[24] Additional work is needed to determine the sublethal and chronic effects of systemic fungicides on pollinators, both alone and in combination with other types of pesticides.

Neonicotinoids are not only capable of killing bees outright by attacking their nervous systems, but low levels of exposure can impair foraging abilities and navigation; disrupt learning, communication and memory; reduce fecundity and queen production; and suppress the immune systems of bees, making them more vulnerable to disease and pests

This study focuses on the neonicotinoid insecticides and their occurrence in nursery plants. First introduced in the mid-1990s, neonicotinoids are a class of neurotoxic pesticides having high acute bee toxicity and associated with numerous sublethal effects. Exposure to neonicotinoids is a common thread that has been shown to increase pollinator vulnerability and decrease natural resilience to external stressors such as pests and pathogens.[24, 25, 26, 27] (See Section V). These chemicals also persist in the environment and occur in the pollen and nectar of a wide variety of crops over many acres in the U.S. and Canada. Analysis of pollen and wax in beehives confirms widespread pollinator exposure.[28] The combination of high toxicity and frequent exposure suggests that neonicotinoids are playing a key role in colony losses and the decline of bees and other essential pollinators.

Neonicotinoids are among the most widely used insecticides and are manufactured primarily by Bayer CropScience and Syngenta. Indeed, neonicotinoids are used as seed treatments on more than 140 crops,[29] with virtually all corn and a majority of soy, wheat, cotton, canola and sunflower seeds planted in the U.S. being pretreated with neonicotinoids, despite research finding that this application does not necessarily increase crop yields or benefit farmers.[30] These insecticides have a variety of uses beyond agriculture, from lawn maintenance and landscaping, to termite and flea control. They are systemic pesticides that are taken up through the roots and leaves of the plant and distributed throughout the entire plant.

The recent mass death of bumble bees in Oregon—the largest-ever reported incident of bumble bee death in the U.S.—illustrates the problem of neonicotinoids. In June 2013, more than 50,000 bumble bees, representing roughly 300 colonies, were found dead or dying in a Target store parking lot in Wilsonville, OR. The culprit was a neonicotinoid pesticide, dinotefuran, applied to nearby linden trees at the manufacturer recommended application rate.[40] The pesticide was applied to prevent honeydew secreted by aphids from dripping onto parked cars.

Throughout the summer of 2013, three other bee kills linked to dinotefuran and another neonicotinoid, imidacloprid, were reported to the Oregon Deparment of Agriculture. In the wake of these incidents, the Department restricted the use of 18 insecticide products containing dinotefuran until December 24, 2013, while it completed an investigation into these poisonings.[41] The Department announced prohibited application of dinotefuran and imidacloprid products for application to Tilia species (i.e., Linden trees).[42]

While most insecticides are toxic to pollinators, the neonicotinoid family of insecticides stands apart from the rest, posing both immediate and long-term risks to bees and other pollinators. New research shows that neonicotinoids are not only capable of killing bees outright by attacking their nervous systems, but low levels of exposure can impair foraging abilities and navigation;[26] disrupt learning, communication and memory;[25] reduce fecundity and queen production;[27] and suppress the immune systems of bees,[31] making them more vulnerable to disease and pests. Neonicotinoids are persistent, lasting for years in the soil, as well as systemic, permeating the entire plant and later released in pollen, nectar and other plant fluids.[32] See Section V for a full discussion of laboratory and field studies showing effects of neonicotinoid exposure on bees.

Neonicotinoids aren't just harming honey bees. These pesticides have also been shown to kill other helpful insects critical to sustainable food production and components of healthy ecosystems, such as wild bees,[27] dragonflies, lacewings, and ladybugs.[33, 34, 35] Further, this class of pesticides may also be severely impacting bird populations[36] as well as earthworms,[33] amphibians, and aquatic insects.[37, 38] 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, specifically several neonicotinoids, with research suggesting a cause and effect link.[39]

II. Bee-Toxic Pesticides Hiding in "Bee-Friendly" Gardens

Many home gardeners, "urban homesteaders" and beekeepers have responded to the global bee and pollinator crisis by planting bee-friendly gardens, creating habitat and forage for wild pollinators and domesticated honey bees alike.[43] Due to their efforts, many urban gardens have become havens for wild pollinators and honeybees.

However, the data presented in this report indicates that gardeners may be unwittingly planting bee-attractive seedlings and plants purchased from major retailers for their bee-friendly gardens, only to poison pollinators in the process.

Neonicotinoids sold to consumers as plant treatments and in pre-treated nursery plants

Neonicotinoids are widely used in commercial agriculture, but are also commonly found in systemic insecticide treatments for flowers, trees and a variety of other plants attractive to bees and other pollinators. These insecticides are sold in garden centers and nurseries under a variety of trade names including Bayer Advanced systemic insect control products. Consumers should read the active ingredients section on the product label to determine whether the insecticide contains on or more of the following neonicotinoids: acetamiprid, clothianidin, dinotefuran, imidacloprid, thiamethoxam and thiacloprid. A list of commercially available products containing neonicotinoid insecticides is provided in Appendix A).[44]

In addition, many of the seedlings and plants sold in nurseries and garden stores across the U.S. are being treated with neonicotinoids at much higher doses than are used on farms, where levels of neonicotinoid use are already raising concerns among beekeepers and researchers studying the decline of pollinator populations.

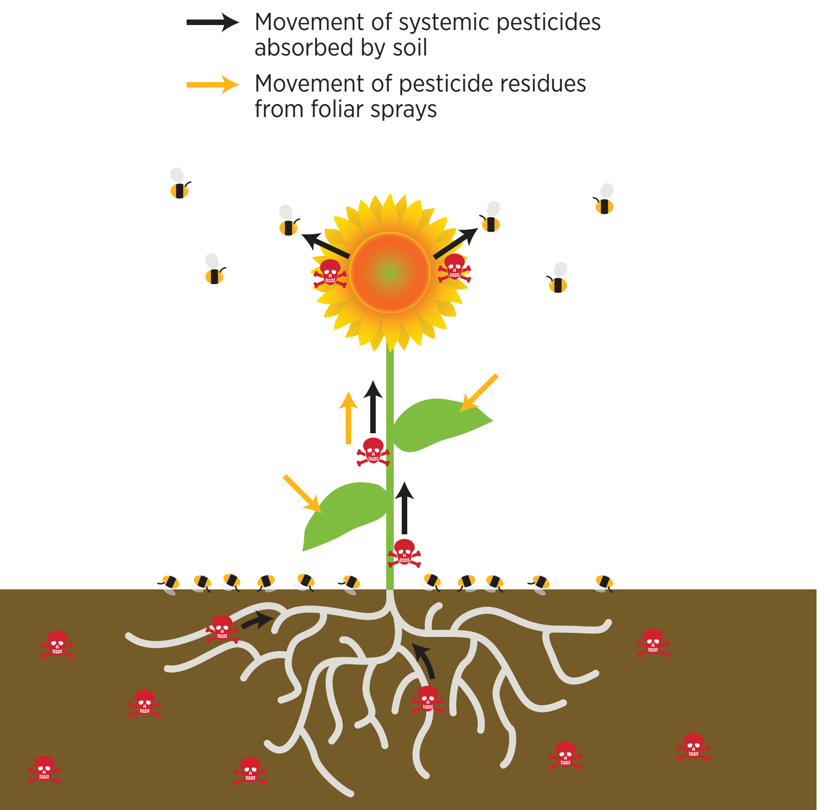
In certain extreme cases, such as an infestation of disease-carrying invasive insects, federal and state laws mandate the treatment of nursery plants with neonicotinoids and other insecticides to prevent the spread of pests capable of disabling an entire crop sector. For example, the California Department of Food and Agriculture (CDFA) and U.S. Department of Agriculture (USDA) have implemented quarantine requirements to reduce the role that retail sales of citrus and other host plants play in the spread of the Asian citrus psyllid (ACP), which carries a disease lethal to citrus trees known as Huanglongbing disease (HLB).[45, 46] Any host plants within or moving into a CDFA-established quarantine zone must receive a combination insecticide treatment consisting of a foliar pyrethroid and a soil drench containing a systemic insecticide in the form of a neonicotinoid insecticide.[47]

Notwithstanding this requirement, the results of our study show that many nursery bedding and vegetable plants *not* listed as hosts for ACP or other regulated pests are still being treated with one or more neonicotinoids prior to sale – with no disclosure to people who are purchasing the plants.

Systemic Pesticides Are Distributed Throughout Plants

Nurseries commonly apply systemic pesticides as soil injections, granular or liquid soil treatments, foliar sprays (applied to leaves), and seed treatments. Water-soluble pesticides are readily absorbed by plant roots and transported systemically in the plant's vascular system to other portions of the plant, including roots, pollen and nectar, leaves, stems, and fruit.[48] This systemic action results in the exposure of beneficial, non-target insects such as bees to potentially lethal doses of these pesticides.

Residue levels in plant tissues vary widely depending on the application rate, time since treatment, plant variety, soil composition, and water solubility of the particular pesticides.[49] In past laboratory studies, the highest concentrations of imidacloprid (a relatively water-soluble member of the neonicotinoid class of insecticides) from seed and soil treatments were observed in the leaves of younger plants, with lower concentrations found in older plants, roots, apex leaves, fruit, and flowers.[50, 51] Neonicotinoids also have the potential to be transported with irrigation water horizontally through soil and into neighboring plants.[52]



SYSTEMIC PESTICIDES ARE ABSORBED FROM THE SOIL BY THE ROOTS AND TRANSPORTED TO OTHER PARTS OF THE PLANT

The method of pesticide application also affects the amount of residue taken up by the plant, with soil drenches at recommended application rates resulting in higher concentrations than seed treatments.[50] One study indicates that foliar applications of neonicotinoids are absorbed through the leaves into the internal plant tissue and tend to remain localized in the treated area,[53] however, other foliar-applied systemic pesticides (e.g., most herbicides) are translocated throughout the plant. Soil applications of systemic insecticides are well known to result in distribution and concentration of residues in various tissues of the plant following treatment.[54] In general, the movement of systemic pesticides is much slower in woody ornamentals, compared to soft-stemmed ornamentals.

Nursery Plants Are Treated at Higher Application Rates than Agricultural Crops

Across the U.S. approximately 90 million acres of corn and 74 million acres of soybeans are planted from neonicotinoid-treated seeds. Bees can be exposed through dust during planting, as well as pollen and nectar in mature plants. Although there are more acres of neonicotinoid-treated agricultural crops, nursery plants are treated at much higher application rates and represent a potentially more potent source of exposure. A single corn plant grown from an imidacloprid-treated seed will have access to 1.34 milligrams (mg) of imidacloprid from the soil in which it is grown.[55] In contrast, the recommended label application rate for a perennial nursery plant in a three-gallon pot is 300 mg of imidacloprid, an amount that is 220 times more imidacloprid per plant. See the Xerces report for a comprehensive comparison of neonicotinoid use in agricultural and landscape settings.[56]

Environmental monitoring studies provide evidence that neonicotinoids used in residential landscapes can be translocated throughout the plant, accumulating in the blossoms at high concentrations. USDA researchers found that imidacloprid trunk injections in maple and horse chestnut trees 10–12 months prior to bloom led to residues levels in flowers ranging from 30–130 µg/kg.[57] Imidacloprid residues were detected at high levels in the flowers of dogwood trees (1,038–2,816 µg/kg, 17 months post application),[58] rhododendrons [27–850 µg/kg (6 months post application) and up to 19 µg/kg (three to six years post application)],[59, 60] and serviceberry (66–4,560 µg/kg, 17 months post application).[61] Further, nectar concentrations of 600 µg/kg were observed in eucalyptus trees treated with imidacloprid via soil drench five month before the bloom period.[62] See Table 4 and the associated text in Section IV below for a review of neonicotinoid concentrations in nectar, pollen, fruit and plant tissues of garden plants.

Neonicotinoids Persist from One Season to the Next

Neonicotinoids applied to soil and as seed treatments are found in soils, plant tissues, pollen, nectar, and even surface water long after the application. Plants treated with neonicotinoids continue exuding these pesticides in pollen and nectar for months to years after initial treatment. This persistence is a common property of neonicotinoids and is characterized by a measurement called "half-life," which is the time required for half of the pesticide to degrade.

A good general guideline is that the time required for more than 95 percent of a compound to degrade will take five half-lives. For example, imidacloprid, a neonicotinoid and one of the most widely used insecticides worldwide, has a reported soil half-life of 48 to more than 365 days, depending on the soil type, exposure to sunlight, and the amount of vegetation present.[63, 64] Soil half-lives of 148 to 1,155 days have been observed for clothianidin, a related neonicotinoid.[65] With these degradation rates, it could take well over five years for imidacloprid and 15 years for clothianidin to degrade after application. Neonicotinoids also break down to highly persistent, bee-toxic degradates and metabolites (e.g., thiamethoxam breaks down to form clothianidin),[66] so the effects of neonicotinoid residues may persist longer than anticipated based on the half-life of the applied substance.

Imidacloprid and other neonicotinoids released from seed treatments are likely to persist in the soil near the treated seed and become incorporated into later generations of plants. One study found imidacloprid in soils up to 82 days after planting,[67] while another study reported 23 percent of the original imidacloprid being present in the growing soil after 97 days.[68] Further, many of the degradation products are themselves toxic to pollinators and also persistent in the environment. A recent study demonstrated that imidacloprid and two of its bee-toxic metabolites persist in the nectar of citrus trees treated with imidacloprid via drip irrigation at comparable concentrations, whether applied two or eight months prior to sampling.[69]

How Pollinators Are Exposed to Neonicotinoids

Contaminated pollen, nectar, water and dust, as well as direct sprays are all sources of pollinator exposure to harmful insecticides. Bees may consume water exuded from young corn plants grown from treated seeds that have neonicotinoid concentrations up to 1,000 times greater than those found in nectar.[70, 71] Neonicotinoids can also leach throughout soils[52] and runoff to ground and surface waters,[38] thereby increasing pollinator exposure to these bee-toxic pesticides through their sources of drinking water. Worker honey bees foraging on contaminated plants and drinking from contaminated water sources ultimately carry these harmful insecticide residues back to the hive. These contaminated materials are then used as food for the colony, delivering a potentially lethal dose of toxic insecticides to other worker bees, drones, the queen, and sensitive larvae.

III. Neonicotinoid Regulation and Market Shift

Europe acts to protect bees

Action of EU Member States: The evidence that neonicotinoids are a key factor in pollinator decline is compelling, which is why these insecticides have been restricted in several European countries. Restrictions in the EU began in 1999 with the suspension of imidacloprid use in sunflower seed dressing in France[72] and now also prohibit the use of three neonicotinoids (clothianidin, imidacloprid and thiamethoxam) on corn seed dressings in France, Germany[73] and Italy.[72] Since these restrictions went into effect, overwinter colony losses have dropped from approximately 30 percent to 13.6 and 14.1 percent in France and Germany, and reached a low of 5.3 percent for Italy during the 2012–2013 winter season.[12]

In May 2014, France banned the spraying bee-toxic pesticides during daylight hours from March to October after analyzing research by the French Agency for Food, Environmental and Occupational Health and Safety (ANSES), which found that honey bees forage for pollen, nectar and water primarily during the daytime.[74] The French agriculture ministry is in the process of drafting a document outlining the details of the ban for publication in its official journal. The ban will be fully implemented in three to four months with no exceptions.[74]

Continent-Wide Actions: Recent European risk assessments echo many of the concerns highlighted in the open literature on neonicotinoids. In January, 2013, the European Food Safety Authority (EFSA) published a scientific review[75] stating that neonicotinoids pose an unacceptably high risk to bees, and the industry-sponsored science upon which regulatory agencies' claims of safety have relied is inadequate for assessing the potential impacts on pollinators.[76] EFSA recommended that the three most widely used pesticides—imidacloprid, clothianidin, and thiamethoxam—should not be used on crops attractive to bees.[75]

In January, 2013, the European Food Safety Authority (EFSA) published a scientific review stating that neonicotinoids pose an unacceptably high risk to bees, and the industry-sponsored science upon which regulatory agencies' claims of safety have relied is inadequate for assessing the potential impacts on pollinators

As a result of EFSA's recommendation, the European Commission voted to enforce a continent-wide two-year suspension on the use of neonicotinoids imidacloprid, clothianidin, and thiamethoxam on flowering plants, effective December 1, 2013.[77] This regulatory action represents the first and only wide-reaching restriction on these pesticides based on scientific concerns of toxicity toward honey bees and other pollinator populations.

Following an analysis of the published human toxicology literature, EFSA scientists[78] concluded that neonicotinoids may affect human health, particularly that of developing infants and children, stating that "acetamiprid and imidacloprid may adversely affect the development of neurons and brain structures associated with functions such as learning and memory." As a result, EFSA recommended that maximum allowable exposure levels be lowered until additional research is completed.[78]

The United States continues to stall

Federal Policy: Meanwhile, the United States Environmental Protection Agency (EPA) has yet to take substantial action on the threats to pollinators posed by neonicotinoids.[79] While some neonicotinoids are fully registered, others were allowed to enter the market under a "conditional registration." The conditional registration loophole has allowed hundreds of pesticides—more than 60 percent of those used in the U.S.—to be used commercially without adequate safety data.[80, 81] In some cases, these temporary approvals were implemented in the face of objections by EPA's own scientists.[82]

In August 2013, EPA notified all of their registrants they would need to amend their product labels for outdoor foliar use products that contain certain neonicotinoids (clothianidin, dinotefuran, imidacloprid and thiamethoxam) by the end of September to include a "Pollinator Protection Box," "Bee Icon" and language to address pollinators in the Directions for Use section of each label.[83] Unfortunately, the labels only focus on foliar sprays, ignoring the widest application of neonicotinoid pesticides: seed and soil treatments that enable the uptake of pesticides into the plant and later into the pollen and nectar, which are gathered and eaten by bees and other key pollinators. U.S. EPA has not yet incorporated the bee hazard warning label for the most common application methods. Further, it is fundamentally impossible for label language to address the inherent problems with neonicotinoids—these insecticides are systemic and persistent, meaning that bees are likely exposed regardless of the method or timing of application. The proposed labels therefore fall short of addressing the problem of bee declines.

The public comments and recommendations submitted to EPA concerning neonicotinoids —including proposed actions to protect pollinators and critiques of the new label—have not been adequately addressed. Despite mounting scientific evidence linking these pesticides to bee declines, and more than a million public comments urging swift action on neonicotinoids to protect bees,[84] the EPA has delayed action until its review of these pesticides is complete in 2016–2019. As a result, these chemicals remain on the market in the U.S.

Spurred by current events surrounding bee kills and pollinator decline, in July 2013 Representatives John Conyers (D, Mich.) and Earl Blumenauer (D, Ore.) introduced "Saving America's Pollinators Act" H.R. 2692. This legislation would suspend seed treatment, soil application, and foliar uses of certain neonicotinoid insecticides on bee-attractive plants until U.S. EPA reviews all of the scientific evidence and field studies can be done to evaluate both short- and long-term effects of these pesticides on pollinators.[85] The bill is bipartisan and currently has sixty-eight co-sponsors in the U.S. House of Representatives.[86]

In June 2014, President Obama issued a memorandum directing U.S. government agencies to take additional measures to protect pollinators by establishing a new Pollinator Health Task Force, to be co-chaired by the Secretary of Agriculture and the Administrator of the EPA.[87] This task force will develop a National Pollinator Health Strategy within 180 days, including an action plan to conduct research focused on "understanding, preventing, and recovering from pollinator losses."Specific tasks include identifying ways to improve habitat creating a public education campaign to teach people ways they can help pollinators and fostering public-private partnerships.[88] The federal strategy also calls on EPA to assess the impacts of pesticides, including neonicotinoids.

To coincide with the White House memorandum, the EPA released a new guidance document for assessing pesticide risks to bees. Developed in cooperation with the California Department of Pesticide Regulation (DPR) and Health Canada's Pest Management Regulatory Agency (PMRA), the new document provides guidance to risk assessors evaluating the potential risks of pesticides, including systemic pesticides, to honey bees and other bee species.[89] The agency also posted its Residual Time to 25% Bee Mortality (RT25) Data online. This data, compiled from registrant-submitted studies, can be used to "determine the length of time over which field weathered foliar residues remain toxic to honey bees" or other insects following foliar application of products to plants.[90] Only a limited number of crop-pesticide combinations are currently available, and commonly-used soil applications are not considered.

State and Local Policy: In addition to federal legislation, state and local governments have been active in working to address neonicotinoids. In 2005, Long Island, New York, restricted use of Imidacloprid. It is not sold at garden centers to consumers and only trained applicators can use imidacloprid on landscapes.[91] New York state also restricted use of clothianidin, dinotefuran and thiamethoxam, on urban landscapes or agriculture.[92, 93, 94] In February 2014, Oregon passed the "Save Oregon's Pollinators Act" HB4139-A.[95] The city of Eugene, OR became the first city in the country to ban neonicotinoids by passing the Council Resolution, "Enhancing Current Integrated Pest Management in Parks".[96] In May, the Minnesota legislature passed two bills: labeling legislation HF 2798,[97] which prohibits retailers from labeling plants treated with pollinator lethal insecticides (e.g., neonicotinoids) as bee-friendly, and beekeeper compensation legislation to compensate beekeepers for pesticide-related losses as part of the omnibus supplemental appropriations bill (HF 3172).[98]

Additional measures to protect bees have been introduced in Minnesota and the following states: California, Maine, Maryland, New Jersey, New York, Alaska and Vermont. See Appendix D for additional information.

State of Play in Canada

Federal Policy: Following massive honey bee die-offs in spring 2012 and 2013, Health Canada determined that approximately 75 percent of dead bees tested positive for neonicotinoids, primarily from dust from the planting of treated seeds.[99] They determined in September 2013 that "current agricultural practices related to the use of neonicotinoid-treated corn and soybean seed are not sustainable due to their impact on bees and other pollinators."

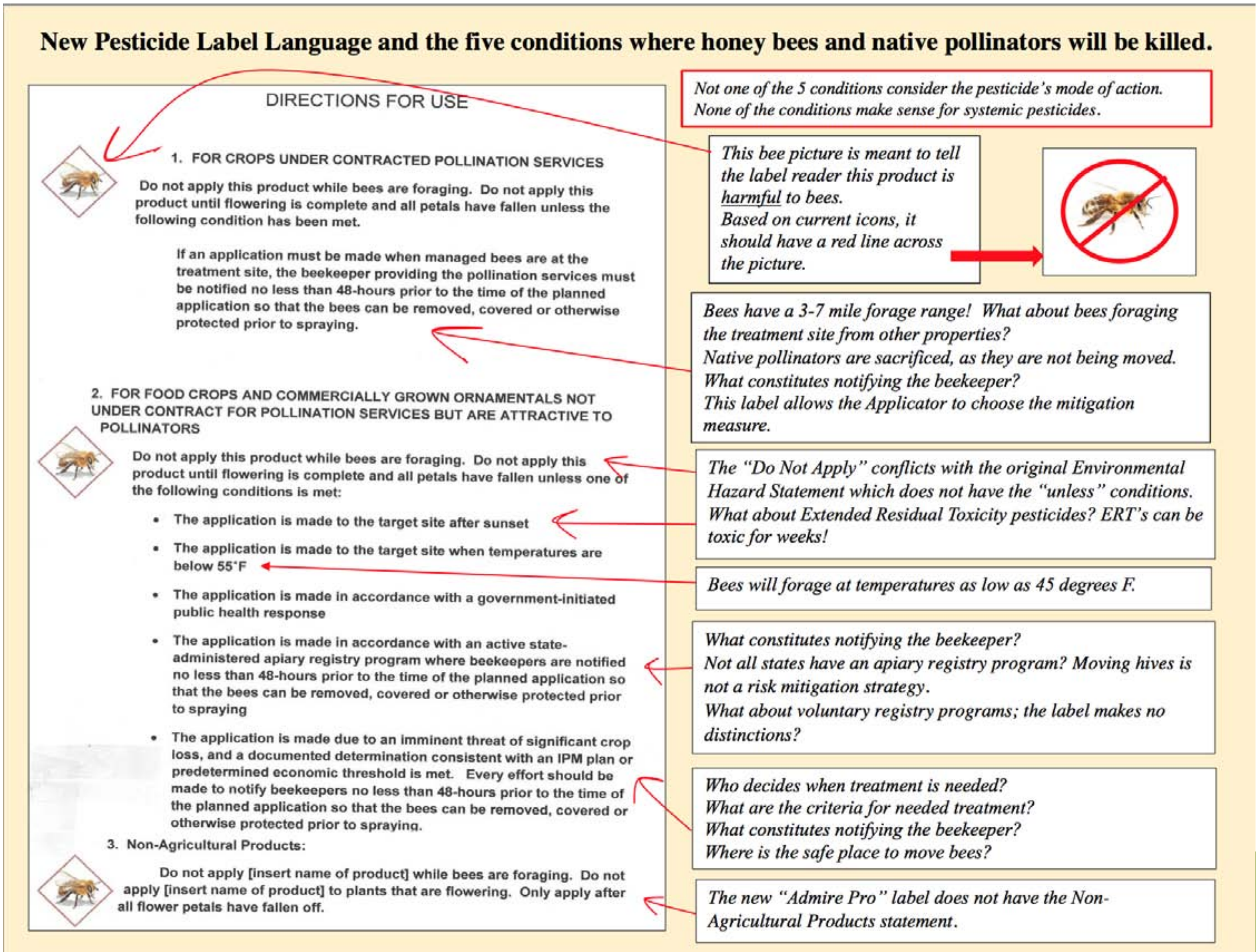
Health Canada decided to address dust containing neonicotinoid residues during the spring planting by producing best practices guidelines for farmers, effective spring 2014.[100] The inadequacy of these measures is underscored with research showing the importance of other exposure pathways (i.e., pollen, nectar and surface water) and the discovery of additional species potentially impacted by environmental contamination with

NEONICOTINOID TREATED SEEDS PRODUCE DUST THAT CAN POISON POLLINATORS.

neonicotinoids. Overall, it seems clear that the impacts of neonicotinoid-coated seeds persist well beyond planting season, extending to contamination of water, soil and subsequent crops planted in treated areas for years following the treatment.

Despite widespread calls for Canada to replicate the European Union's moratorium on neonicotinoid use, Health Canada's Pest Management Regulatory Agency (PMRA)—charged with regulating pesticides in Canada—has only agreed to expedite work previously announced in 2012 in light of international policy updates surrounding neonicotinoids. Working with U.S. EPA and the California Department of Pesticide Regulation, PMRA is now conducting an interim assessment of pollinator risk scheduled for completion in 2015 using currently available data pertaining to clothianidin, imidacloprid and thiamethoxam.[101] The PMRA assessment will be used to determine whether the risks associated with pollinator exposure to these three neonicotinoids warrants regulatory action.

In addition, Canada's Standing Senate Committee on Agriculture and Forestry



THE DIRECTIONS FOR USE ON THE NEW LABEL FOR FOLIAR-USE PRODUCTS HAVE BEEN WIDELY CRITICIZED BY BEEKEEPERS AS IN CONFLICT WITH OTHER PARTS OF THE LABEL, UNENFORCEABLE AND UNWORKABLE FOR BEEKEEPERS. HOWEVER, THE MOST COMMON METHOD OF APPLYING NEONICOTINOID PRODUCTS ARE TO SEEDS, TO THE SOIL, OR IN IRRIGATION SYSTEMS. THESE PRODUCTS WILL LACK THE BEE HAZARD WARNING LABEL. SOURCE: POLLINATOR STEWARDSHIP COUNCIL.

commenced its hearings on the importance of bees and bee health in the production of honey, food and seed in Canada. The Senate's report is expected to address strategies for governments, producers and industry to safeguard bee health.

Provincial Policy: Six of Canada's ten provinces (Alberta, Ontario, Quebec, Nova Scotia, New Brunswick, Prince Edward Island) and nearly 200 municipalities now have some type of lawn and landscape (i.e., cosmetic) pesticide restriction in place. A seventh province, Manitoba, will be establishing restrictions effective in 2015. Prince Edward County in Ontario became the first Canadian municipality to temporarily suspend the use of neonicotinoids on municipal lands, effective June 1, 2014.[102] However, in most cases these restrictions do not extend to nursery use of neonicotinoids that arrive in Canadians' gardens, yards and landscapes via bedding plants and garden starts. Indeed, Health Canada's Pesticide Management Regulatory Agency (PMRA) permits the use of neonicotinoids under "Minor Use Pesticides" for horticulture. Garden Centers and nurseries are not required to notify customers regarding their use of neonicotinoids in plant offerings.

While the federal agency, PMRA, is responsible for registering pesticides, provinces in Canada can control usage but show no likelihood of acting in advance of the federal re-evaluation of neonicotinoids. Two provinces, Ontario and Quebec, monitor for neonicotinoids in water including puddles, wells, rivers and streams after planting. Quebec authorities have detected the presence of neonicotinoids in all 16 rivers tested as well as 60 percent of wells tested for the past ten years in potato growing areas.[103]

Ontario's Bee Health Working Group reported on its findings with no support for a moratorium, instead choosing to focus on best management practices including dust suppression measures.[104]

90 percent of households think managing residential and public lawns and gardens in an environmentally friendly way is important

Interestingly, Ontario's Ministry of Agriculture and Food Crop Specialists are now calling attention to the prophylactic use of neonicotinoids and questioning the benefits of their use on any more than 10 to 20 percent of corn and soy acreage. Almost 100 percent of Ontario's corn and canola acres, 95 percent of dry beans and 65 percent of soybeans are currently treated with neonicotinoids.[105]

To help cope with the massive honey bee losses during the 2014 planting season, the Province of Ontario has introduced a Beekeepers Financial Assistance Program that will compensate for losses of more than 40 percent of registered active hives.[106] Beekeepers are eligible to receive $105 for each hive that is lost or severely damaged between January 1 and October 31, 2014.

Exports to Japan: In the first widely reported trade incident, Japan rejected two containers of buckwheat from Manitoba farmers raising concerns about future shipments.[107] The buckwheat exceeded Japan's maximum residue limit for thiamethoxam applied to canola, corn and soybean seeds planted in Western Canada. Japan uses buckwheat to make soba noodles. Scientists point to the persistence of neonicotinoids used to grow crops prior to buckwheat as the potential source of the contamination.

Marketplace shift

Due to a successful campaign by Friends of the Earth England, Wales, Northern Ireland (EWNI) and allies, a majority of the UK's largest home improvement retailers—including Homebase, B&Q and Wickes—have made public commitments to eliminate sales of products containing pesticides linked to declining bee populations. In 2013, Friends of the Earth U.S. and allies launched a campaign calling on U.S. retailers to take similar actions in absence of meaningful action by the EPA.

The 2013 *Gardeners Beware* study found neonicotinoid residues detected in 54 percent (seven out of thirteen samples from a total of 28 plants) of commercial nursery plants from Lowe's, Home Depot and Orchard Supply Hardware in Washington, DC; Minneapolis, MN and the San Francisco Bay Area, CA.[1] Since that time, the market has shifted significantly. Consumer trends for 2014 show demand for organic products has increased by double digit rates, with 80 percent of Americans concerned about protecting their health, environment and the society around them.[108] This shift in buying practices extends to lawn and garden products, which accounts for $58 billion dollars annually in sales and therefore ranks third in how Americans spend their money.[108]

According to a recent National Gardening Association survey, nearly 90 percent of households think managing residential and public lawns and gardens in an environmentally friendly way is important. A growing number of consumers are choosing eco-friendly products over those with toxic chemicals.[109] There is clearly a growing demand for safe, Earth-conscious alternatives and for organic growing methods that are benign to human health and the environment.

Many regional and local nurseries and landscaping companies are responding to increased consumer demand for truly Earth- and bee-friendly garden supplies and nursery plants, as well as the growing body of science indicating systemic neonicotinoid pesticides are a key contributing factor to pollinator declines. Table 1 outlines various commitments retailers across the U.S. and Canada have made to reduce their use and sale of neonicotinoids in garden plants and products to date.

Table 1. Retailer Commitments Regarding Neonicotinoid Use

Retailer	Contact Information	Number and location of Stores	Policy Statement
Bachman's	Bachman's flagship store and corporate office 6010 Lyndale Ave. S Minneapolis, MN 55419 866-222-4642 www.bachmans.com customerservice@bachmans.com	21 locations throughout Minnesota	Eliminated the use of neonicotinoids for their own nursery stock and outdoor plants. Removed products containing neonicotinoids from their store shelves and provide recommendations for alternatives to customers.[110] The store is contacting its garden plant suppliers as well, to encourage them to discontinue the use of neonicotinoids. Moving forward, Bachman's is focusing on raising awareness about pollinator preservation, providing education and training about plant issues, expanding pollinator natural habitat on their property and encouraging others to do the same. Read policy statement here: http://bachmanswholesale.com/pollinators-and-neocicotinoids/
The Behnke Nurseries Co.	Corporate Office 11300 Baltimore Avenue PO Box 290 Beltsville, MD 20705 301-937-1100 www.behnkes.com behnkes@behnkes.net	3 locations in Maryland	Pledge to: 1) Never apply neonicotinoid pesticides to plants on the Behnke property, either in ground or in pots; 2) Recommend use of least-toxic effective remedies; and 3) discontinue sales of all neonicotinoid-containing products. Read policy statement here: http://behnkes.com/website/about-us/pesticide-policy.html
Berkeley Horticultural Nursery	1310 McGee Avenue Berkeley, California 94703 510-526-4704 www.berkeleyhort.com mail@berkeleyhort.com	1 location in California	Eliminated neonicotinoids from the store. All of its California Certified Organic plants are neonic-free, including any plants from its vegetable and herb tables. It does not sell any treatments that contain neonicotinoids, although other plants may contain these chemicals. Read policy statement here: http://www.berkeleyhort.com/gardening-suggestions/14-0102/

Table 1. (continued).

Retailer	Contact Information	Number and location of Stores	Policy Statement
BJ's Wholesale Clubs, Inc.	BJ's Wholesale Clubs, Inc. Corporate Office Headquarters HQ 25 Research Dr. Westborough, MA 01581 Corporate Phone Number: 1-508-651-7400 Fax Number: 1-508-651-6114 Customer Service Phone Number: 1-800-257-2582 www.bjs.com	200+ locations in 15 states	Requires all vendors to disclose the use of any neonicotinoids in nursery or plant-able products (i.e. blueberry bushes, tulip bulbs). Requires any vendors using neonicotinoids in nursery or bedding plants to submit plan/ process used to protect bees when using neonicotinoids (i.e. timing, segregation, etc.) Asks all vendors to be out of neoticotinoid plants by the end of this year and/or will include a label that states "treated with neonicotinoids, use caution around pollinators." Read policy statement here: http://libcloud.s3.amazonaws.com/93/ba/5/4725/BJs_neonic_commitment.pdf
Cavano's Perennials Inc.	6845 Sunshine Avenue Kingsville, MD 21087 410-592-8077 sales@cavanos.com	2 locations in Maryland	Discontinued use of all neonicotinoid pesticides on growing operations. Read policy statement here: http://www.cavanos.com/Neonicotinoid.pdf
Ecoscape Environmental Design, LLC	6595 Odell Place, Suite I Boulder, CO 80301 303-447-2282 Ecoscapedesign.com	1 location in Colorado	Does not use neonicotinoids in any of its garden practices and has pledged to never use them.
Gertens Greenhousees and Garden Center	5500 Blaine Ave Inver Grove Heights, MN 55076 651-450-1501 www.gertens.com info@gertens.com	2 locations in Minnesota	Does not use neonicotinoids on any bedding plants or on seeds for plants the store grows. The store does apply neonicotinoids to larger plants and hanging baskets and does not guarantee starter plugs or cutters being supplied from other locations have not been pre-treated with neonicotiniods.[111] Read policy statement here: http://www.gertens.com/atGertens/neonics.html

Table 1. (continued).

Retailer	Contact Information	Number and location of Stores	Policy Statement
Harlequin's Gardens	4795 North 26th St Boulder, Colorado 80301 303-939-9403 www.harlequinsgardens.com	1 location in Colorado	Will never use neonicotinoids on plants or sell any neonic pesticides in any form. Will make every effort to buy plants from wholesalers who do not use neonics. Read policy statement here: http://www.harlequinsgardens.com/about-2/policy-on-pesticides-including-neonicotinoids/
Produce Denver	Sustainability Park 2500 Lawrence St. Denver, CO 80205 303-579-6228 www.producedenver.com info@producedenver.com	1 location in Colorado	Only uses organic methods for pest control and tries their best to not buy treated plants because they are an edible landscaping company.
Suncrest Nurseries Inc.	400 Casserly Rd Watsonville, CA 95076 831-728-2595 www.suncrestnurseries.com	Supply to California retail nurseries and garden centers	Will stop using neonicotinoids altogether as of July 1, 2014. Read policy statement here: http://grownatives.cnps.org/2014/06/17/an-announcement-about-neonicotinoids-from-suncrest-nurseries/
Timberline Gardens, Inc.	11700 W. 58th Ave Arvada, CO 80002 303-420-4060 www.timberlinegardens.com	1 location in Colorado	Does not use neonicotinoids in any of its garden practices and has pledged to never use them. Read policy statement here: http://www.timberlinegardens.com/blog/timberline-a-non-neonicotinoid-garden-center/
Urban Farm Company of Colorado	info@urbanfarmcolorado.com 970-658-0667 www.urbanfarmcolorado.com	1 location in Colorado	Will never use neonicotinoids on plants and will make every effort to buy plants from wholesalers who do not use neonicotinoids. Read policy statement here: http://libcloud.s3.amazonaws.com/93/38/e/4726/Urban_Farm_Co_neonic_commitment.pdf

1 Bachman's Wholesale Nursery and Hardscapes. Bachman's Public Pollinator Preservation Statement. March, 2014. http://bachmanswholesale.com/pollinators-and-neocicotinoids/ [accessed 5/12/2014].
2 Gertens. As Growers We Know and We Want You to Know. 2014. http://www.gertens.com/atGertens/neonics.html.

IV. Bee-Toxic Pesticides Continue To Be Used in Bee-Friendly Nursery Plants

The widespread agricultural use of neonicotinoids is a common exposure pathway for bees; however, cosmetic use of these pesticides in gardens, lawns, and landscapes may be an important factor in declining bee and wild pollinator health. Nursery plants are typically treated with systemic insecticides, either by foliar or soil treatments or by use of treated seeds to kill pest insects that feed on the plant. Systemic pesticides are absorbed through the roots or leaves of the plant and transported to various plant tissues. While this phenomenon is well established, limited quantitative information is available on the levels of neonicotinoids found in consumer nursery plants sold at garden retailers and how these levels in the environment might affect pollinator health. Unfortunately, pollinator-friendly nursery plants sold to unsuspecting consumers carry neither a list of pesticides used, nor do they carry a warning that these pesticides could harm pollinators.

As a follow-up to the 2013 Gardeners Beware pilot study,[1] Friends of the Earth U.S. and the Pesticide Research Institute conducted this expanded study to examine the scope and magnitude of neonicotinoid contamination of common nursery plants, as well as the distribution of these insecticides within the plants.[1] In addition, the results of this updated study provide a clear comparison to the recent continent-wide survey of nursery plants sold in the European Union, which showed that more than 98 percent of plant samples were contaminated with conventional pesticides.[112]

Within this report, we outline sampling results that provide insight into the level of contamination found in the flowers versus leaves and stems of representative nursery plants. We also summarize neonicotinoid insecticide contamination of various plant materials (stems, leaves, pollen and nectar), the damaging effects of this contamination on the health of bees and other pollinators, and suggest actions various stakeholders can take to help protect the welfare of these critically important insects.

Sampling and Analysis

In 2013, Friends of the Earth U.S. and Pesticide Research Institute conducted a pilot study to determine the extent of neonicotinoid contamination in the nursery plants purchased from major retail outlets (Home Depot, Lowe's and Orchard Supply Hardware) in three areas of the U.S. (San Francisco Bay Area, CA; Minneapolis, MN Area; Washington, DC Area). Please see the 2013 report, *Gardeners Beware*,[1] for details regarding plant sampling and analysis for the previous pilot study.

The current study expands on the pilot project by including 18 different locations across North America and providing an analysis of neonicotinoid residues in flowers separately from the bulk plant material (stems and leaves). The plants used in this study were purchased from major retail outlets (Home Depot, Lowe's and Walmart) in all four official U.S. Census regions (15 cities) and three provinces of Canada:

1. U.S. West – Eugene, OR; San Francisco Bay Area, CA (CA); Sacramento, CA (SAC); Boulder, CO
2. U.S. Midwest – Minneapolis, MN; Ann Arbor, MI
3. U.S. Northeast – Portland Area, ME; Boston, MA; New York, NY
4. U.S. South – Baltimore Area, MD; Washington, DC; Raleigh, NC; Atlanta, GA; St. Augustine, FL; Austin, TX
5. Canada – Vancouver, BC; London, ON; Montreal, QC

In each location, pollinator-friendly flowering plants were purchased for neonicotinoid residue analysis. Only soft-stemmed (non-woody) flowering plants known to attract both pollinators and pest insects (aphids, etc.) were selected for this study.

FLOWERS WERE TRIMMED FIRST, FOLLOWED BY THE STEMS AND LEAVES. SAMPLERS CLEANED THEIR SCISSORS AND CHANGED GLOVES AND SURFACE PROTECTORS BETWEEN SAMPLES TO MINIMIZE CROSS-CONTAMINATION.

Within one week of purchase, the plants were prepared for neonicotinoid analysis, employing a rigorous protocol to avoid cross-contamination between samples. All flowers and emerging buds were cut at the base of the flower head (where the flower joins the stem) and packaged together for neonicotinoid residue analysis in flowers. Likewise, the remaining plant material was cut at the base of the stem, above the roots and level of soil, and packaged together for residue analysis in the stems and leaves. Materials from multiple potted plants of the same kind were combined in bags for flowers or greenery to provide sufficient material for the analysis of a single sample. As a result, 190 individual plants were analyzed as part of 71 whole plant samples (divided into flower and stems & leaves sub-samples) submitted for analysis.

Samples from different locations were submitted for analysis beginning in late March and ending in late May of 2014. The timing of sample submission varied according to the availability of bee-attractive plants in retail nursery outlets. Flower sub-samples were analyzed for every whole plant sample included in the study. For the flowers with positive detections, the corresponding sub-samples consisting of stems and leaves were also analyzed. In addition, we analyzed a subset of the stem and leaf sub-samples from plants without detectible neonicotinoid residues in the flowers.

An accredited analytical laboratory performed the sample extractions and subsequent neonicotinoid residue analysis using AOAC method 2007.01. Prepared samples were analyzed for neonicotinoid active ingredients (acetamiprid, clothianidin, dinotefuran, flonicamid, imidacloprid, thiacloprid and thiamethoxam) and degradation products (6-chloronicotinic acid, clothianidin MNG, clothianidin TMG, clothianidin TZMU, clothianidin TZNG, 5-hydroxy imidacloprid, imidacloprid des nitro HCl, imidacloprid olefin, imidacloprid olefin des nitro and imidacloprid urea) with detection limits ranging from 1–50 μg/kg. For more details on the experimental procedures, see Appendix B.

FLOWER AND GREENERY SUB-SAMPLES FOR EACH PLANT SAMPLE WERE INDIVIDUALLY PACKAGED BEFORE SHIPPING TO THE LAB.

40 percent of the positive samples tested positive for two or more neonics

Results

Based on the analysis of flowers, stems and leaves, 36 out of 71 (or 51 percent) of the whole plant samples in the study tested positive for one or more neonicotinoid insecticides. The analytical lab detected the following pesticides and breakdown products in these plant samples: acetamiprid, clothianidin, clothianidin TZMU (lower toxicity degradate), dinotefuran, flonicamid, imidacloprid, 5-hydroxy imidacloprid (toxic degradate), imidacloprid des nitro (lower toxicity degradate), imidacloprid olefin (toxic degradate), imidacloprid olefin des nitro (lower toxicity degradate) and thiamethoxam. Imidacloprid and its metabolites were found most frequently, with residues of the parent imidacloprid detected in 28 of the 36 (77 percent) plant samples that tested positive for neonicotinoids. See Appendix C for additional information on the concentrations of individual pesticides in the flower and stem and leaf compartments of each plant sample.

While more than half of the samples (60 percent) contained only one neonicotinoid or combination of one neonicotinoid and its breakdown products, an almost equivalent number of samples (40 percent) tested positive for two or more neonicotinoids. African daisies from North Carolina and Georgia showed measurable levels of four different neonicotinoids. This result provides insight into how nurseries use these insecticides. There are very few insecticide products that contain multiple neonicotinoids as active ingredients and none that contain three to four different neonicotinoids, so these plants were likely treated multiple times during their short lifespans. In addition, clothianidin, a breakdown product of thiamethoxam, is frequently observed in thiamethoxam-treated plant samples (Appendix C).[37]

In order to capture the cumulative toxicity of the plants with multiple neonicotinoids, we developed a method to express all toxicity in units of imidacloprid equivalents. The neonicotinoids all have moderate to high acute toxicity to bees, and all act by the same mechanism of action that interferes with the proper functioning of the nervous system. Clothianidin is the most acutely toxic and acetamiprid the least (see Table 2). To assess cumulative toxicity, we created Relative Potency Factors (RPFs) for each pesticide using the oral LD_{50} values (the dose of neonicotinoid at which 50 percent mortality of test bees is observed following oral exposure), where the RPF is equal to the ratio of the oral honey bee LD_{50} of each insecticide relative to the LD_{50} of imidacloprid. Using this method, we obtained a cumulative neonicotinoid concentration for each plant sample in terms of imidacloprid equivalents. Only neonicotinoids of moderate to high acute bee toxicity, according to U.S. EPA ecotoxicity categories for non-target insects,[113] were factored into the calculation of the imidacloprid equivalent concentration for each sample. For details regarding the RPF approach, please see Appendix B.

Table 2. Relative Acute Toxicity of Neonicotinoid Insecticides and Degradation Products to Honey Bees

Pesticide	Oral LD_{50} (μg/bee)	Oral LC_{50} (μg/L)	Relative Potency Factor
Acetamiprid	14.53	558,846	0.0003
Clothianidin	0.0037	142	1.06
Dinotefuran	0.023	885	0.17
Imidacloprid	0.0039	150	1.00
5-Hydroxy Imidacloprid	0.159	6,115	0.025
Imidacloprid Olefin	0.023	885	0.17
Thiamethoxam	0.005	192	0.78

We evaluate neonicotinoid breakdown products observed in this sampling study based on acute toxicity to honey bees. It is widely established in the literature that imidacloprid breaks down in the environment or is metabolized into numerous degradation products.[114, 115, 116] Four of these potential degradates were detected in the samples; however, only two (5-hydroxy imidacloprid and imidacloprid olefin) are moderately to highly acutely toxic to honey bees.[117, 118, 119] Clothianidin is both an active ingredient and a high toxicity degradate of thiamethoxam. Although some breakdown products of clothianidin are highly toxic, the one observed in this study (clothianidin TZMU) is not acutely toxic to bees (LD_{50} > 113 μg/bee).[120] Likewise, flonicamid is of low acute honey bee toxicity (LD_{50} = 53.3 mg/bee).[121]

Active ingredients and degradates of low acute toxicity were excluded from the calculation of imidacloprid equivalent concentrations to provide a conservative estimate of potential plant toxicity due to neonicotinoid contamination. Despite their omission, it remains uncertain whether these chemicals of low acute toxicity become more toxic following chronic exposure, potentially leading to sub-lethal effects and/or synergizing the toxicity of other contaminants found in the environment. The exclusion of lower toxicity degradation products means that the calculated imidacloprid equivalent concentration is the lower limit of the total pollinator toxicity for these plant samples. See Section V below for a review of adverse effects on honey bees, bumble bees and solitary bees related to neonicotinoid exposure at varying doses.

A summary of the residue data for each location in terms of imidacloprid equivalents is shown in Table 3 and Figure 1. Neonicotinoid residues were observed in plants sampled from all but two of the 18 locations (Eugene, OR and Sacramento, CA). It should be noted that the absence of residues in these samples does not necessarily mean that contaminated plants are not being sold in these locations. Daisies (African, English, Gerbera and Shasta), *Salvia*, *Scabiosa* and *Coreopsis* appear to be the most heavily contaminated types of plants in this study.

Table 3. Results summary for nursery plant sampling in the U.S. and Canada

Location	Proportion of Samples with Detections[a]	Plant Types Testing Positive for Neonicotinoids	Bee-Toxic Residue Level in Flowers (µg/kg)[b]	Bee-Toxic Residue Level in Stems & Leaves (µg/kg)[b]
BC[c]	2/4	Salvia, Lavender	21.2	14.5
CA[d]	3/4	African Daisy, Gerbera Daisy, Lavender	34.1–175.1	44.3–1,775
CO	2/4	Salvia, African Daisy	2.7–12.3	2.9–19.1
DC	3/4	Scabiosa, Coreopsis, Salvia	2.2–4.4	9.3
FL	1/4	Gaillardia	ND	40.3
GA	3/4	African Marigold, African Daisy, Salvia	18.5–747.6	59.3–1,711
MA	3/4	English Daisy, Marigold, Primrose	3.2–410.3	3.6–1,945
MD	1/4	Scabiosa	198.6	250.8
ME	3/4	Scabiosa, English Daisy, Coreopsis	3.2–428.1	3.2–557.6
MI	2/4	Phlox, Gerbera Daisy	3.7–122.6	4.3–263.1
MN[e]	3/4	Salvia, Scabiosa, African Daisy	ND	3.4–5.6
NC	2/4	Gerbera Daisy, African Daisy	2–29.8	11.7–27.9
NY	1/4	African Daisy	ND	5
ON	4/4	Gerbera Daisy, Calibrachoa, Shasta Daisy, Zonal Geranium	7.7–22.9	NA
OR	0/4	– –	ND	NA
QC	2/4	African Daisy, Salvia, Alyssum	3.7–51.8	NA
SAC[d]	0/4	– –	ND	ND
TX	1/3	Shasta Daisy	43	10.2

ND = No Detections
NA = Not Analyzed

[a] Number of whole plant samples (composites of multiple plants) submitted for analysis and testing positive for any neonicotinoid pesticide in the flower and/or stems and leaves sub-samples. Samplers in all but one location submitted four (4) whole plant samples (combination of flower and stem and leaf sub-samples) to the lab for analysis. Only three (3) samples were submitted for Texas.

[b] Total concentration of moderately to highly acutely bee-toxic neonicotinoids (acetamiprid, clothianidin, dinotefuran, imidacloprid, 5-hydroxy imidacloprid (degradate), imidacloprid olefin (degradate), and thiamethoxam) in imidacloprid equivalents.

[c] *Salvia* contained a moderately to highly acutely bee-toxic pesticide (imidacloprid), lavender contained a pesticide of lower acute bee toxicity (flonicamid).

[d] CA = San Francisco Bay Area, CA; SAC = Sacramento, CA.

[e] *Salvia* and *Scabiosa* contained a moderately to highly acutely bee-toxic pesticide (dinotefuran), African Daisy contained a pesticide of lower acute bee toxicity (flonicamid).

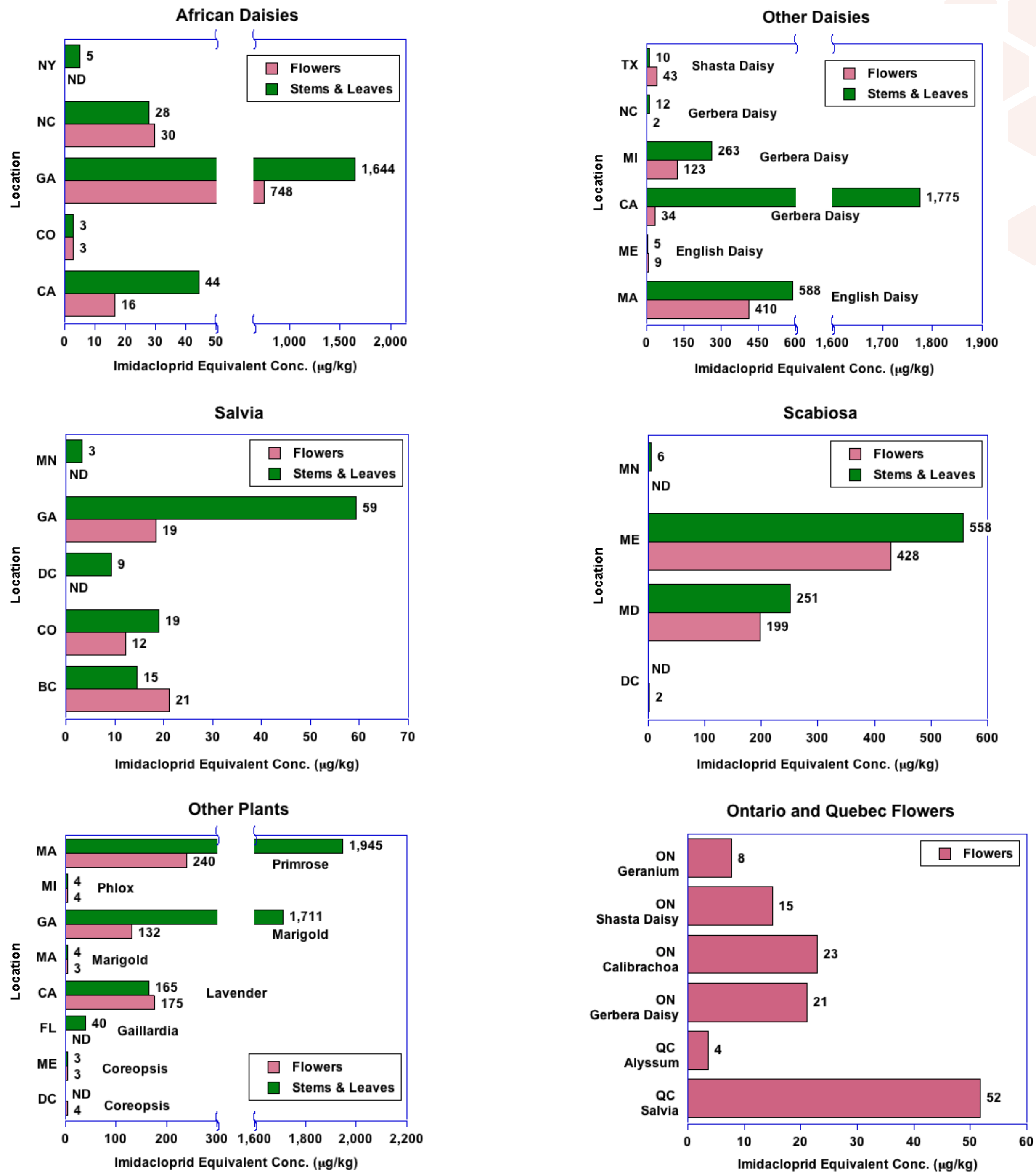


Figure 1: Tests reveal that 36 out of 71 samples of nursery plants available at retail outlets in North America contained detectable levels of neonicotinoid insecticides, and 34 of these samples had residue levels ranging from 2 to 1,945 µg/kg in imidacloprid equivalents. Toxicity is expressed in units of imidacloprid equivalents to account for the cumulative bee toxicity of plants containing multiple insecticides (see Appendix C). Several of the sample residues concentrations either exceed or approach the LC_{50} of imidacloprid (150 µg/kg; the concentration of imidacloprid in nectar at which 50 percent of test bees died after one feeding). Higher neonicotinoid concentrations were generally observed in the stems and leaves; however, several samples showed comparable or higher levels in the flower component compared to the stems and leaves. See text for further explanation.

A review of the comparison charts for flower versus stem and leaf sub-samples suggests that higher levels of contamination with neonicotinoids is somewhat more likely in the stems and leaves. However, 11 of the 28 pairs in these figures show approximately even distribution of the residues between flowers versus stems and leaves, while another three show substantially higher residues in the flower compartments (see Figure 2).

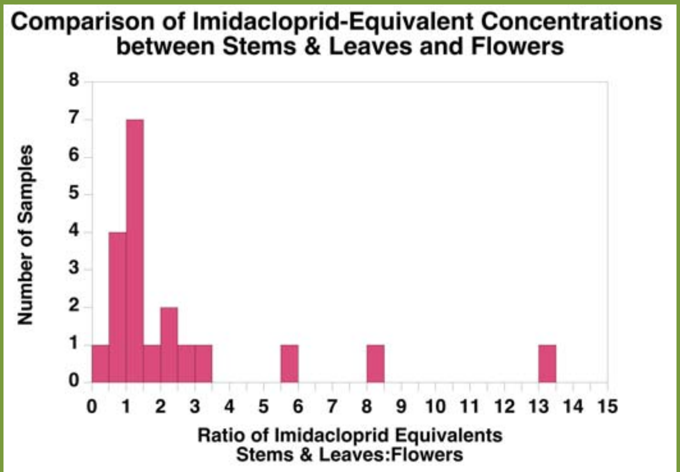


Figure 2: Most samples had similar concentrations of neonicotinoid pesticides in flowers compared to stems and leaves. This plot excludes two samples (Coreopsis and Scabiosa from DC) with residues only detected in the flowers. We also excluded one outlier sample, a Gerbera daisy from California with the concentration of neonicotinoids in stems/leaves 52 times higher than that in the flowers. The two other Gerbera daisy samples do not show the same skewed distribution of residues.

The analysis of several additional plant samples provides insights into the persistence of neonicotinoids in potted plants purchased from garden centers and the status of labeled "bee-friendly" flowers.

1) Lavender from the San Francisco Bay area of California was sampled immediately following purchase from Home Depot (results in Table 3 and Appendix C) and then again seven weeks after the initial sampling (results in Appendix C). Between sampling events, the plant was flood watered daily. The sampling results show significant decreases in the concentrations of clothianidin (to 13.2 μg/kg from 100–110 μg/kg), thiamethoxam (to 7.9 μg/kg from 38.7–74.1 μg/kg) and imidacloprid (to <1 μg/kg from 11.3 μg/kg). This result suggests that flushing contaminated plants with water over an extended period of time may help remove neonicotinoid residues from potted plants; however, if plants are in the ground, this strategy may have only limited success. In addition, this method may lead to contamination of nearby soil, surface water and plants with the released neonicotinoid residues due to runoff.

2) Also analyzed were flowers of a salvia plant from Blooms Nursery with a bee-friendly label indicating that the plant was not treated with neonicotinoids. The labeling for this plant appears to be accurate, with no neonicotinoid residues detected for this sample (CA Salvia Flowers, Appendix C).

Comparison of Measured Residues in Nursery Plants to Other Studies

The levels of neonicotinoids found in the both the flower and stem/leaf nursery samples are comparable to those found in other studies of treated plants (see Table 4). Overall, concentrations depend on the type and age of the plant, the part of the plant analyzed, the soil type, the length of time between treatment of the plant and measurement of insecticide concentrations, and the treatment method (soil, foliar, or seed treatment). For the nursery plant samples tested, we do not know how or when the plants were treated. Concentrations in plants are likely to change over time, either increasing if more pesticide is available from the soil or decreasing as the plant grows. Thus, these data provide a snapshot of neonicotinoid residue levels in the flowers and greenery (stems and leaves) of plants available in retail nurseries.

Data from a representative sample of available published studies are presented in Table 4, providing a comparison of concentrations of imidacloprid and/or thiamethoxam in various plants treated under different conditions. Concentrations of soil-applied imidacloprid (applied at label-recommended rates) in pollen, nectar, and fruit in squash and tomato plants range from approximately 0.1–15 percent of the concentration in the whole plant.[50, 122] In contrast, a model developed to calculate the distribution of imidacloprid in tomatoes from soil applications estimates the concentrations in tomato fruits at approximately half of that in stems and one-third of the concentration in roots.[123]

Pumpkin plants treated with imidacloprid, thiamethoxam or dinotefuran via foliar sprays or drip irrigation during flowering resulted in neonicotinoid residues as high as 122 μg/kg in pollen and 17.6 μg/kg in nectar.[124] An extensive monitoring study sponsored by Bayer reported imidacloprid residue levels as high as 39.4 μg/kg in the nectar of citrus trees treated at the label application rate.[69] However, the amount of imidacloprid applied per citrus tree is lower than the label application rate for many plants grown in urban landscapes. In other studies, imidacloprid or thiamethoxam concentrations ranged from a high of 6,600 μg/kg for buckwheat[35] and 6,030 μg/kg for milkweed[125] flowers grown in pots treated at the recommended application rate, to a low of 1 μg/kg in the pollen of canola grown from treated seed.[126] The extreme difference in concentrations likely results from the higher amounts of active ingredient permitted by the label in urban landscapes compared to agriculture.

From the available comparison data, it is not possible to predict concentrations in pollen and nectar for all plants in all life stages using residues measured in flowers or whole plant material. However, University of Minnesota studies indicate that application of label-recommended rates of imidacloprid (0.05–0.1 grams per 1 gallon pot) to buckwheat and milkweed—two very attractive plants to pollinators—produced nectar concentrations of 16–29 and 26–53 μg/kg, respectively, at 21 days after treatment.[127] Indeed, these levels were sufficiently lethal to kill a large fraction (the precise kill rate depended on the species and experimental conditions) of ladybugs,[125] parasitic wasps,[35] and lacewings[128] allowed to feed on treated plants compared to a control group.

Table 4 Neonicotinoid Residues in Plants from Other Studies

Plant	Pesticide/Matrix	Concentration (μg/kg)	Study Description	Cite
Buckwheat	Imidacloprid Flowers Flowers Nectar (2004)	 6,600 (1X) 12,300 (2X) 16–29	Pots were treated with soil granules of Marathon 1G® at 14 days at label (1X) and twice label (2X) rate (5–10 grams per 1 gallon pot) as the insecticide can be reapplied. Flowers were sampled 21 days after treatment.	35, 127
Milkweed	Imidacloprid Flowers Flowers Nectar (one application)	 6,030 (1X) 10,400 (2X) 26–53	Pots were treated with soil drench of Marathon 1G® at label recommended rate. Nectar sampled 21 days after treatment.	127
Clover	Clothianidin Nectar	 89–319 Avg = 171 (N = 5)	Nectar extracted one week after application from 100-flower samples of clover from plots treated at the highest label rate (0.40 lb clothianidin/acre) with Arena 50 WDG.	129
Squash-1	Imidacloprid Whole plant Flower base Stamens Thiamethoxam Whole plant Flower base Stamens	 47 10 15 154 10 19	Seed-hole (11 cm diameter) spray application of label-recommended rates of an imidacloprid-containing product (Admire Pro®) or a thiamethoxam-containing product (Platinum®).	50
Squash-2	Imidacloprid Whole plant Flower base Stamens Thiamethoxam Whole plant Flower base Stamens	 218 31 46 362 22 31	Transplants were treated using drip irrigation with label-recommended rates of an imidacloprid-containing product (Admire Pro®) or a thiamethoxam-containing product (Platinum®) five days after transplanting.	50
Sunflower	Imidacloprid Leaves Seeds Flower head Pollen Stem	 520 28 18 13 1	Sunflowers grown from Gaucho (imidacloprid) treated seeds at the commercial loading of 1 mg of imidacloprid active ingredient per seed. Plant tissues were analyzed after two-thirds of the florets were blooming.	130
Sugarbeet	Imidacloprid Leaves	 4,500	Plants grown from seeds treated at the commercial loading rate of 90 g imidacloprid per hectare. Concentrations correspond to foliage sampled 40 days after sowing.	67
Tomato	Imidacloprid Leaves Fruit	 7,400 63	15-day-old tomato plants were transplanted to 1-L pots containing imidacloprid-contaminated soil (0.33 mg/L of soil). Sampled 60 days after transplantation.	122

Table 4 (continued).

Plant	Pesticide/Matrix	Concentration (μg/kg)	Study Description	Cite
Eucalyptus	Imidacloprid plus metabolites Nectar[a]	 286–660	Eucalyptus trees were treated with an imidacloprid soil injection at the label rate 5-months prior to bloom.	62
Orange Trees	Imidacloprid plus metabolites[b, c] Nectar (50–55 DAA) Nectar (227–232 DAA) Hive Honey[d]	 3–48 5–28 32–95	Mature citrus trees were treated with imidacloprid (560 g a.i./ha) via drip irrigation. Nectar was collected 50–55 and 227–232 days after application (DAA). Nectar from hive comb (uncapped honey) was collected following the 3-day foraging period.	69
Corn	Thiamethoxam Whole plant Pollen	 6–62 1–19	Corn plants were grown in fields from seeds treated with the maximum approved label rate (0.85 mg a.i./seed). Whole plant material and honey bee pollen loads were collected during flowering.	126
Canola	Thiamethoxam Whole plant Pollen	 1–9 1–4	Canola plants were grown in fields from seeds treated with the maximum approved label rate (0.02 mg a.i./seed). Whole plant material and honey bee pollen loads were collected during flowering.	126

DAA = Days After Application

[a] Nectar samples from five trees were pooled for analysis. The lower limit is the concentration of imidacloprid only; upper limit is the combined concentration of imidacloprid and degradates.

[b] Comprehensive data were not provided in this paper. Concentration ranges reported here reflect a combination of values reported in data tables and the text, as well as graphical representations of the data (Figures 3–5, reference 69).

[c] Concentration ranges represent an aggregate of the imidacloprid residues plus the residues of two bee-toxic breakdown products (5-hydroxyimidacloprid and imidacloprid olefin).

[d] Honey was collected from honey bee colonies foraging solely on the blossoms of treated citrus trees.

V. How Could Contaminated Flowers and Vegetable Plants Affect Bees?

This study confirms the continuing presence of neonicotinoids in common garden plants sold to unsuspecting consumers at garden centers across the U.S. and Canada. The measured concentrations represent reasonable estimates of the maximum toxic dose available to pollinators because the analysis includes both pesticide active ingredients and common degradation products, some of which are comparable to the parent compound in toxicity. Concentrations in pollen and nectar, the flower materials bees actually consume, may be lower than the levels detected in flowers. Sufficiently high concentrations of neonicotinoids can kill bees; lower concentrations can still impair pollinator behaviors, memory, reproduction and immune functions.

The actual dose of neonicotinoids experienced by either an individual bee or a colony is related to how frequently the bee forages on contaminated plants and how much contaminated food is actually consumed over time. Honeybees forage widely and bring pollen and nectar into the hive from many different sources, so may "dilute" contaminated pollen and nectar with clean forage from other sources. Another confounding factor is that honey bees do not necessarily eat all of the food resources they bring into the hive immediately, so there can be lag time between use of the pesticide in the environment and observed adverse effects.

Acute Effects

Comparison of the imidacloprid-equivalent concentrations measured in nursery plants to the acute honey bee LC_{50} for imidacloprid[¥] (150 μg/kg in nectar) reveals eight samples exceeding this concentration and several other approaching it.[127, 128] Flowers can have high residue levels than nectar and pollen; therefore, it is not possible to precisely determine what dose the bees would be receiving in the pollen and nectar of these plants. At the levels observed in the flowers sampled, it is possible that consumption of pollen and nectar from the higher concentration samples could lead to a significant impairment of bee health and even death.

Sublethal Effects and Chronic Toxicity

All of the samples with detections could potentially cause sublethal effects and mortality in pollinators following chronic exposure. Beyond acute pollinator mortality from bees receiving a lethal dose, neonicotinoids contribute to impairment in reproduction, learning and memory, hive communications and immune response at doses far below those that cause bee kills (Figure 3). Although not all of the mechanisms of toxicity are fully known, many of these effects stem from the ability of neonicotinoids to interfere with the proper functioning of the insect nervous system,[133] altering learning, memory, spatial orientation and foraging.

¥ Acute oral LC_{50} (in μg/kg) was calculated using the acute oral LD_{50} (in μg/bee) from the U.S. EPA EcoTox Database[114] and the amount of sucrose solution ingested by a bee in an LC_{50} test (26 mg). Specifically, $LC_{50} = LD_{50} / 26$ mg.[115] The resulting LC_{50} (in μg/mg) is corrected to μg/kg using a conversion factor of 1,000,000. For additional details, see Appendix B.

Concentrations of neonicotinoids associated with effects on bees

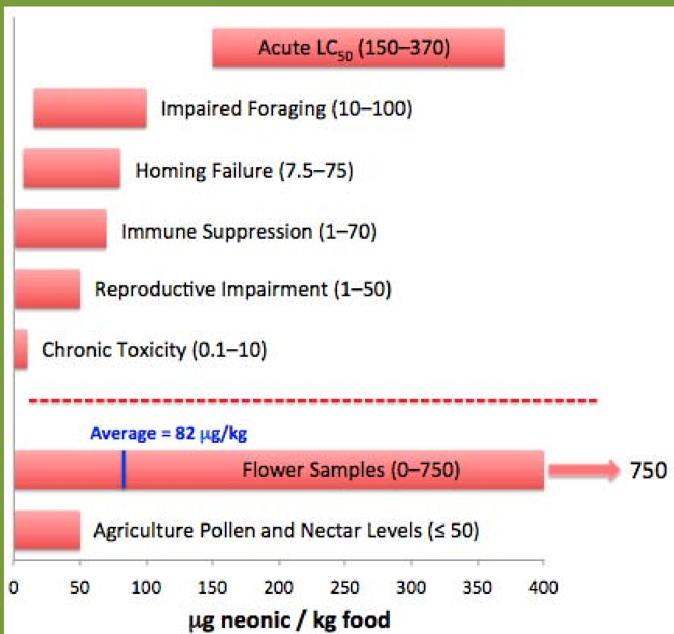


Figure 3: Neonicotinoids are highly toxic to honey bees and bumblebees, but even at low doses they can impair colony health. Concentrations of neonicotinoids are given in micrograms of pesticide per kilogram of food (μg/kg = parts per billion). The homing failure range is based on honey bee exposure to imidacloprid or thiamethoxam. The reproductive impairment range is based on bumble bee exposure to imidacloprid or clothianidin. All other studies are based on imidacloprid exposure. Chronic toxicity refers to increased bee mortality associated with long-term, low-level exposure. Since 2013, the concentration ranges in this graphic have been updated with data from recent open literature studies.

Because the neonicotinoid pesticides are systemic and persistent, exposures to low levels of neonicotinoids in pollen and nectar over an extended period of time (weeks to months) is a realistic consideration. Toxicological studies show that neonicotinoids can produce effects at even very low concentrations, provided the exposure time is sufficiently long.[134] In one study, dietary exposure to field-realistic levels of 1 picogram (pg = 0.000000000001 gram) of imidacloprid per day resulted in bee mortality within 10 days.[117] In contrast, Bayer researchers reported that exposure of bee colonies to imidacloprid concentrations of 2, 5, 10 and 20 μg/kg in honey did not induce any mortality or adverse effects on bee development (μg = 0.000001 gram).[119] The discrepancy in results between the two studies was attributed by the first author to the mode of administration of imidacloprid (in 50% sucrose solution to bees from which food had been withheld for two hours for the first study versus in sunflower honey fed *ad libitum* in the Bayer study) and to the large variability in effects induced by imidacloprid, which depends on the genetics of the bees and, for a given colony, on its physiological state.[117]

Not surprisingly, chronic exposure to low doses of neonicotinoids is also lethal to other non-target insects, as well as natural predators of the pest insects targeted by these systemic pesticides.[135, 136]

The exposures of bumble bees and honey bees to neonicotinoids at sublethal levels can adversely impact the health of individual bees and the colony as a whole. For example, bumble bee colonies foraging for 13 days on clover in turf treated with clothianidin alone or as a premix with the pyrethroid, bifenthrin, had reduced numbers of workers and immature bees, and stored less nectar in the hive.[137] Chronically exposed bumble bee hives have also shown reduced colony growth, queen survival rates and worker movement.[138] In addition, a recent study demonstrated that exposure of bees to neonicotinoids in sublethal amounts impairs the ability of the bees to metabolize and excrete insecticide residues.[139]

Mechanistic studies have correlated these anomalies in honey bee hives to physiological changes related to neonicotinoid exposure. For example, the hypopharyngeal glands (used by nurse bees to produce the royal jelly that is fed to young larvae) were observed to be smaller in honeybees that consumed sugar and pollen treated with imidacloprid during development in comparison to unexposed bees.[140]

ALTHOUGH BEE KILLS ARE VISIBLE IMPACTS OF SYSTEMIC INSECTICIDES, EXPOSURE TO LEVELS OF NEONICOTINOIDS THAT DO NOT CAUSE IMMEDIATE BEE DEATH CAN STILL DAMAGE COLONIES THROUGH THE LESS APPARENT EFFECTS ON THE IMMUNE SYSTEM (MAKING THE BEES MORE VULNERABLE TO DISEASE), LEARNING AND MEMORY (AFFECTING THE BEES' ABILITY TO FIND FOOD AND RETURN TO THE HIVE), AND REPRODUCTION (REDUCING QUEEN FERTILITY AND BROOD SUCCESS).

Learning and Memory

Behavioral and learning impairment caused by neonicotinoid exposure are equally deleterious to long-term bee survival and colony success. One study demonstrated that field level exposure to the neonicotinoid imidacloprid (10 µg/kg in 40 percent sucrose solution) adversely affected the pollen-collecting efficiency of worker bumble bees, leading to reductions in brood development and colony success.[141]

The link between reduced pollen-collecting efficiency and exposure to field realistic levels of neonicotinoids (0.7 µg/kg in 50 percent sugar water and 6 µg/kg in pollen) was recently confirmed in another study of bumble bee colonies.[142] In addition, homing failure following low-level thiamethoxam exposure was observed in 10–30 percent of bees, depending on their familiarity with a particular foraging region.[26] A more recent study provided evidence that neonicotinoids selectively interfere with bee homing ability over other components of honey bee navigation.[143] Other effects of neonicotinoid exposure on pollinator behavior include reduced activity levels,[144] short- and long-term memory impairment,[25, 145] and diminished ability to recruit foragers through waggle dancing.[146]

Although it is well known that neonicotinoids are acutely neurotoxic to bees, the mechanistic underpinnings of these sublethal effects on behavior and memory are poorly understood. Scans of isolated European honey bee brains show that imidacloprid blocks neuronal firing in the cells responsible for learning and memory at concentrations likely encountered by foraging bees.[147] Similar morphological changes in the neuronal cells of Africanized honey bees have also been observed in response to neonicotinoid exposure.[148, 149]

Diminished Fertility and Reproductive Success

Dietary exposure to neonicotinoids has been shown to impair the reproductive capacities of both bumble bees and solitary bees. One study found that imidacloprid doses as low as 1 µg/L in sucrose solution significantly reduced bumble bee brood production.[150] These results suggest that neonicotinoid exposure diminishes bumble bee queen fertility; however, reduced feeding activity in neonicotinoid treated bees was also observed, which could also explain the diminished fecundity rates. Bumble bee colonies foraging for six days on clover in turf treated with a clothianidin grub-control product at label rates not only experienced bee kills, but the surviving bees produced no queens.[129] Chronically exposed bumble bee colonies have also shown substantial (as high as 85 percent) reduction in the production of new queens, thus creating an enormous barrier to colony propagation.[27]

Although no effects were observed on adult solitary bee mortality, sublethal exposure to less than 3.5 μg/kg of a neonicotinoid mixture (thiamethoxam plus clothianidin) in sugar solution decreased the nest building and brood cell construction rates.[151] Offspring production in the treatment group was reduced by almost 50 percent.

Immune System Impairment

Systemic pesticides also weaken the immune response in bees. For example, a recent study reported higher mortality rates in worker honey bees infected with black queen cell virus and exposed to sublethal doses of thiacloprid (100 μg/kg in larval food) versus bees subjected to each stressor individually.[152] The relationship between *Nosema* (a unicellular parasite) infestation and neonicotinoid exposure in honey bees has also been extensively investigated. In three independent studies, a statistically significant increase in mortality rates were observed in test groups simultaneously infected with *Nosema* and exposed to low concentrations of neonicotinoids (5–20 μg/kg of imidacloprid in pollen patties or one percent of the LD_{50} for thiacloprid in sucrose solution) relative to those only infected with *Nosema* or exposed to imidacloprid alone.[31, 153, 154] In addition to increased individual mortality rates, the combination of stress factors adversely affected the ability of worker bees to disinfect larvae and promote immunity.[31] Although this synergistic effect is not completely understood, the data indicate that neonicotinoid exposure exacerbates *Nosema* infections.

Recent mechanistic analyses have shed light on the potential link between enhanced pathogen infections and exposure to neonicotinoids. One study clearly demonstrated that field-realistic dietary doses of imidacloprid and clothianidin promote Deformed Wing Virus (DWV) replication in honey bees, whereas exposure to similar amounts of chlorpyrifos (an acutely bee-toxic organophosphate insecticide) has only a negligible effect on DWV replication.[155] Preliminary mechanistic work in this study suggests that neonicotinoid exposure leads to downregulation of the immune response typically activated during periods of viral infection. Another study echoed these results, showing that neonicotinoids absorbed through the diet repress the expression of immunity-related genes responsible for controlling pathogenic infections, such as *Nosema*, in the honey bee midgut.[156]

Pesticide Manufacturer Positions

Notwithstanding the body of scientific evidence, pesticide manufacturers such as Bayer and Syngenta minimize the potential role neonicotinoids play in the decline of pollinator populations. A recent report out of Harvard University demonstrated a preliminary link between excessive winter colony losses and the exposure of honey bees to sublethal doses (110 μg/kg in sucrose solution)† of imidacloprid during the previous spring and summer.[157, 158] Bayer scientists responded that the study was "seriously flawed" because the bees used in the study were fed "levels of neonicotinoids greater than 10 times what they would normally encounter".[159]

Interestingly, a recent peer-reviewed article co-authored by Bayer scientists found concentrations of imidacloprid and its degradates approaching 50 μg/kg in the nectar of citrus trees treated with a soil drench of the pesticide at the maximum label application rate.[69] Further, these bee-toxic substances were also found at high concentrations (95 μg/kg) in the uncapped honey of honey bee hives foraging solely on imidacloprid-treated citrus trees. The bulk of the scientific information suggests that the imidacloprid concentrations used in the Harvard study are within range of the levels bees encounter in nectar while foraging in some agricultural areas.[160] Urban areas have not been surveyed for neonicotinoids, but laboratory studies

† The concentration in micrograms per kilogram (μg/kg) was calculated by dividing the concentration in micrograms per liter (136 μg/L) by the density of a 50 percent sucrose solution (1.23 kg/L) assumed to be used by Lu et al.

of treated ornamental plants indicate that treatment at label-recommended rates can produce concentrations in nectar ranging from 10 μg/kg to slightly more than 600 μg/kg (see Table 4).[56]

Manufacturers of neonicotinoids also tend to focus on *Varroa* mites, pathogens such as *Nosema* and viruses, and lack of forage as the leading causes of colony losses. While parasites and pathogens have caused serious damage to beehives since their introduction in Europe and the U.S., a recent study of honey bee hives in Kenya suggests that these stressors may not be the sole driving forces behind overwintering colony losses observed in the Northern Hemisphere.[161] The study demonstrated that, although *Varroa*, *Nosema* and several European bee viruses were identified in the Kenyan hives, the presence of these pathogens had no adverse effects on colony size. On the contrary, colonies with *Varroa* mites were actually larger than those lacking mites. Samples of pollen, wax and honey from the suspect Kenyan hives contained very few detectible pesticide residues, a key distinguishing factor between the study hives and managed hives in Europe and the U.S. The genetics of the Kenyan bees may also be contributing to their mite resistance; however, colonies of mite resistant Russian bees kept in agricultural areas in the U.S. are still experiencing colony losses, suggesting that factors in addition to mites are contributing to the excessive colony losses that beekeepers are currently experiencing.

Some industry scientists criticize laboratory studies in the peer-reviewed literature for using controlled conditions and unrealistic neonicotinoid doses. However, these criticisms are not always consistent with the principles of experimental design and the scientific method. In order to conduct a reproducible study and obtain meaningful results, the researcher must focus on a single variable at a time while controlling all other variables and potential confounding factors. Laboratory studies are not always designed to determine colony level effects under field conditions, but these experiments do provide valuable insights into the effects of stressor(s) on individual bees or colonies nonetheless.

It is key to conduct field studies in order to evaluate and validate the results of laboratory studies. Field studies are inherently more difficult to conduct in a controlled manner, but if definitive conclusions are to be drawn, it is important to control as many variables as possible. Researches must consider the importance of study duration, overwintering conditions and how much of the contaminated food sources bees are actually consuming versus the amounts stored in the hive for consumption later in the season or during winter. It is nearly impossible to draw robust conclusions without an understanding of these variables. As a result, there are concerns regarding the validity of the conclusions drawn from the field studies conducted by pesticide manufacturers.[162]

For example, researchers at Syngenta followed honey bee colonies allowed to forage freely on corn and canola grown from untreated and thiamethoxam-treated seeds during bloom.[126] Foraging lasted five to eight days each year during years one through three and 19–23 days during year four. For the vast majority of the year, study bees were kept and allowed to forage in woodland areas removed from agricultural production and presumed to have no local exposure to insecticides. Experimental hives were monitored for several hive strength parameters on a weekly basis. Although treated and control hives exhibited no differences in terms of strength and survival, the overall study provides little insight into the effects of neonicotinoids on colony health due to the limited and unrealistic duration of exposure compared to what managed honey bees and wild pollinators experience throughout the growing season. Pollinators in agricultural areas could be exposed to neonicotinoids used on a variety of crops for several months at a time during the summer growing season.

In a semi-field study submitted by the manufacturer for registration of the new neonicotinoid pesticide sulfoxaflor, the control hive had a heavy *Varroa* infestation, while the treatment hive did not, thus a conclusion that the treated hive fared no differently than the control hive had little meaning.[163] In that same study, the treated hives were observed for adverse effects for only seven days, which may not be long enough to see colony-level effects.

Two additional field studies have attempted to determine the impacts to bees foraging on canola grown from clothianidin-treated seeds.[164, 165] No differences in bee mortality, worker longevity, brood development or colony weight gains were observed between treatment and control (foraging on canola grown from untreated seeds) colonies. However, it is likely that both groups were actually foraging on crops with similar contamination levels since the treatment and control colonies were placed within one kilometer of each other,[164] which is well within the honey bee foraging range. Likewise, pesticide residue analyses of hive pollen in the follow-up study indicate that similar levels of clothianidin were being brought into treatment and control hives despite researchers increasing the distance between these groups to approximately 10 kilometers.[165] Sweet corn being grown in neighboring fields was a possible source of the clothianidin contamination of control hives.

Pesticide Risk Assessment for Pollinators

Updated risk assessment methodologies that take into account realistic exposure scenarios, sublethal effects and chronic toxicity, and pollinator species other than honey bees are required to adequately protect these vital insects. A recent peer-reviewed risk assessment of all pesticides commonly found in honey bee and bumble bee hives based on actual pollen and nectar levels indicates significant concern for exposure of these pollinators to neonicotinoids.[166] In particular, this risk assessment evaluated more realistic scenarios for acute and chronic toxicity as well as synergistic toxicity associated with mixtures of the neonicotinoids thiacloprid and acetamiprid, as well as certain fungicides.

In 2013, the European Food Safety Authority (EFSA) released new pollinator risk assessment guidelines,[167] which requires the registrant to provide additional data regarding the sub-lethal effects of pesticides on adult bees and larvae. Scientists from the pesticide industry, regulatory agencies and academia have developed recommendations on pesticide risk assessment for pollinators. This June, the U.S. EPA, Health Canada's PMRA and the California Department of Pesticide regulation released formal guidance for quantifying the risks to beneficial insects, particularly honey bees.[89] It remains to be seen what impact these new risk assessment methods will have on pollinator protection and U.S. EPA's registration review of neonicotinoids and other systemic, bee-toxic pesticides.

VI. Conclusion

This study represents the first large-scale investigation of neonicotinoid insecticide concentrations in "bee-friendly" nursery plants sold to consumers at garden centers in cities across the U.S. and Canada. The high percentage of contaminated plants (51 percent) and their neonicotinoid concentrations suggest that this problem is widespread, and that many home gardens have likely become a source of exposure for bees. The results indicate that neonicotinoids occur in both flowers and in stems and leaves, with some samples having higher concentrations in flowers than greenery and other samples showing the reverse. Although pollen and nectar were not directly analyzed, comparison of our sampling results to published data in which concentrations of neonicotinoids in nectar and/or pollen were compared to levels in stems, leaves, or other plant parts indicate that adverse effects on bees and other pollinators are possible. Potential effects on bees due to neonicotinoid exposure range from impaired navigation, reduced fertility, and immune suppression to bee death.

These results underscore the need for further studies into the concentrations of systemic pesticides (including insecticides, fungicides and herbicides) found in flowers in urban areas. Specifically, samples comprised of sufficient plant material to directly measure pollen and nectar concentrations of systemic pesticides in plants treated with both foliar and soil applications would help to clarify some of the questions raised by this work and extend the knowledge base to systemic fungicides and herbicides. Additional studies that measure the distribution of systemic pesticides to different parts of the plant over time for different pesticides, plants and soil types are also necessary to enable prediction of pesticide concentrations in pollen and nectar and the environmental fate of those residues introduced into our gardens.

VII. Recommendations for Reducing Risks to Pollinators

As this study demonstrates, large retailers continue to sell plants pretreated with neonicotinoids and consumers may unwittingly be purchasing bee-attractive plants that have been pretreated with neonicotinoid pesticides that may be harming or killing bees and other threatened pollinators essential to food production and ecosystem health. Unfortunately for bees, other pollinators, and for all of us, the now common cosmetic use of neonicotinoid pesticides in gardens, lawns, and landscapes may be an important factor in declining health of managed and wild pollinators.

Bee Action Campaign: "Bee" part of the global movement!

Due to a successful campaign by Friends of the Earth England, Wales, Northern Ireland (EWNI) and allies, a majority of the UK's largest garden retailers, including Homebase, B&Q, Wickes and the Garden Centre Group, and a growing number of U.S. companies have made public commitments to no longer sell products containing pesticides linked to declining bee populations. Friends of the Earth U.S. and allies have an ongoing campaign at *BeeAction.org*, calling on U.S. garden retailers to take similar actions in absence of meaningful action by the U.S. EPA. Through the campaign, Friends of the Earth-U.S. has joined its sister organization Friends of the Earth England, Wales, Northern Ireland and other allies, beekeepers, farmers, gardeners, scientists, parents, educators and many others in a global movement to save bees and other pollinators and speed the essential transition to sustainable, just, ecological agriculture. More than half a million people and numerous allies have joined the campaign and demanded that top retailers stop selling these bee-killing pesticides. More information is available for the U.S. at www.BeeAction.org and for Canada at http://BeeCauseCanada.org.

We are also asking consumers, retailers, suppliers, institutional purchasers and local, county, state and federal regulators and policymakers to take action to restrict neonicotinoid pesticides to help protect bees and other pollinators.

Bee Action.org

Recommendations for Garden Retailers:

- Do not sell off-the-shelf neonicotinoid insecticides for home garden use.
- Require neonicotinoid-free vegetable and bedding plants from suppliers and do not sell plants or plant starter mixes pre-treated with these insecticides.
- Offer third-party certified organic starts and plants.
- Educate your customers on why your company has made the decision to protect bees and other pollinators.

Recommendations for Wholesale Nursery Operations Supplying Retailers:

- Use only untreated seeds for plants grown from seed.
- Do not use neonicotinoid insecticides as soil drenches, granules, or foliar treatments when growing vegetable and bedding plants.
- Offer neonicotinoid-free and organic vegetable and bedding plants to your customers and label them as such.
- Educate your customers about why your nursery operation made the choice to limit the use of neonicotinoid pesticides.

- If quarantine regulations require use of systemic insecticides on certain plants that are hosts for invasive pests, treat only those plants, minimize the number of treatments and label treated plants accordingly. Do not use neonicotinoids if less toxic systemic pesticides are approved for use on the target pest. Use pest exclusion systems wherever possible to avoid having to treat plants with pesticides.

Recommendations for Home Gardeners and Institutional Purchasers (such as schools, universities, private companies, hospitals, and others):

- Stop using all neonicotinoid insecticides on your property and facilities (e.g. landscaping around parking lots, grounds and gardens) and only plant neonicotinoid-free plants.
- Specify in contracts with landscaping companies that service your grounds and trees not to use neonicotinoid insecticides and not to install plants pretreated with neonicotinoids.
- Provide critical habitat for pollinators by planting pollinator friendly trees and flowers.

Recommendations for Cities, Counties and U.S. States:

- Suspend the use of neonicotinoids and other insecticides for cosmetic purposes on ornamental and landscape plants, like the ban now in force in Ontario, Canada.[169]
- Pass resolutions to ensure that neonicotinoids are not used on city- and county-owned property, including schools, parks and gardens.
- Require that bee-toxic insecticides be prominently labeled as such in displays of these chemicals at garden centers, hardware stores and nurseries.
- Provide critical habitat for pollinators by planting pollinator-friendly trees and flowers.

Recommendations for the U.S. EPA:

- Suspend the registrations of neonicotinoids for agricultural as well as cosmetic and other unnecessary uses pending the results of pesticide re-evaluation.
- Require a bee hazard statement on the label of all products containing systemic insecticides toxic to pollinators, including soil drenches and foliar use products.
- Prioritize the systemic insecticides for Registration Review starting in 2014, and ensure inclusion of independent, peer-reviewed research on the acute and chronic effects of systemic insecticides on bees.
- Expedite the development and implementation of valid test guidelines for sublethal effects of pesticides on pollinators and require data from these studies for all currently registered and any new pesticides.

Recommendations for the U.S. Congress:

- Support and pass H.R. 2692, the Saving America's Pollinators Act, introduced by Representatives John Conyers (D, Mich.) and Earl Blumenauer (D, Ore.). This legislation will suspend seed treatment, soil application, or foliar uses of certain neonicotinoid pesticides on bee-attractive plants until:
  - all of the scientific evidence is reviewed by the U.S. EPA, and
  - field studies can be done to evaluate both short- and long-term effects of these pesticides on pollinators.

Recommendations for Health Canada's Pesticide Management Regulatory Agency (PMRA):

Suspend the registrations and temporary registrations of neonicotinoid pesticides in both agriculture and minor use pending the results of the PMRA re-evaluation.

Recommendations for Canadian Provinces:

Enact an immediate moratorium on the sale of neonicotinoid-treated seeds on field crops

as well as for minor use in horticulture in each respective province, pending the results of the PMRA re-evaluation of neonicotinoids.

Recommendations for Consumers:

Take Action U.S.: Join the Friends of the Earth U.S. Bee Action campaign at www.BeeAction.org and sign our petition to garden retailers asking that they stop selling neonicotinoid treated plants and products that contain neonicotinoids. You can also contact your member of Congress and encourage them to support the Saving America's Pollinators Act. You can find action, and bee-friendly gardening tips at www.BeeAction.org.

Take Action Canada: Join the Friends of the Earth Canada campaign – take part in The Bee Cause work (www.BeeCauseCanada.org) and sign the petition to influence garden centres in Canada to stop selling neonicotinoid treated plants.

Raise Your Voice Locally: Let your local nursery manager know that you will only purchase plants free of neonicotinoids and ask the manager to communicate your request to their corporate headquarters and suppliers who grow the plants they sell. Find a sample letter for U.S. companies and more ideas for action at www.BeeAction.org. For a sample letter for Candian companies, visit the FOE Canada website at http://foecanada.org/en/files/2014/03/Model_Letter_on_Neonics_to_Garden_Centres.pdf.

Grow Bee-Safe: Avoid buying neonicotinoid-treated seeds and seedlings. Purchase organic plant starts or grow your plants from untreated seeds in organic potting soil for your home vegetable and flower gardens.

Practice Bee-Safe Pest Control: Avoid the use of systemic bee-toxic pesticides in your garden (see Appendix A) and use alternative approaches such as providing habitat to attract beneficial insects that prey on pest insects in your garden. If pest pressure is too high, use insecticidal soaps or oils and other eco-friendly pest control products. For more tips and links to more resources for pollinator and eco-friendly gardening, visit www.BeeAction.org and www.garden4bees.com.

Do not buy products that contain neonicotinoids: Read the label and avoid using off-the-shelf neonicotinoid insecticides in your garden. These products may contain acetamiprid, clothianidin, imidacloprid, thiamethoxam and dinotefuran as active ingredients. See Appendix A at the end of this report for a list of common consumer products containing neonicotinoids.

Do a clean sweep: See if you have these products at home, dispose of them as municipal hazardous waste or take them back to the store where you bought them.

Appendix A: Common Names of Neonicotinoid-Containing Products Used on Ornamental Plants in Nurseries or Sold to Consumers for Home Garden Use

There are approximately 300 insecticide products containing neonicotinoid insecticides as active ingredients used on ornamental plants in either nursery or home garden settings. The specific active ingredients include acetamiprid, clothianidin, dinotefuran, imidacloprid, thiacloprid, and thiamethoxam. Some products contain these chemical names in the product name. Many other products contain neonicotinoids, but do not have the active ingredient in the product name. These product names are included in the table below. Some of these same products go by several different distributor names, such as the Ortho™, Bayer Advanced™ or other brand names. Inspect the label of any insecticide labeled as "systemic" for the presence of neonicotinoid active ingredients. To protect pollinators, avoid using these products.

Insecticide Product Name	Active Ingredient(s)
ALIAS	Imidacloprid
ALLECTUS	Imidacloprid, bifenthrin
ALOFT	Clothianidin, bifenthrin
ARENA	Clothianidin
ASSAIL	Acetamiprid
ATERA	Imidacloprid, bifenthrin
AURA	Imidacloprid
BITHOR	Imidacloprid, bifenthrin
BOUNTY	Imidacloprid
CARAVAN	Thiamethoxam, azoxystrobin
CORETECT	Imidacloprid
DERBY	Thiamethoxam, lambda-cyhalothrin
DINO	Dinotefuran
DOMINION	Imidacloprid
EQUIL ADONIS	Imidacloprid
FLAGSHIP	Thiamethoxam
FLOWER, ROSE & SHRUB CARE	Clothianidin, imidacloprid, tebuconazole
GAUCHO	Imidacloprid
GRUB-NO-MORE	Imidacloprid
GRUBOUT	Imidacloprid
HAWK	Imidacloprid
I MAXXPRO	Imidacloprid
IMA-JET	Imidacloprid
IMI INSECTICIDE	Imidacloprid
IMID-BIFEN	Imidacloprid, bifenthrin
IMIDA-TEB GARDEN SC	Imidacloprid, tebuconazole
IMIDAPRO	Imidacloprid

Appendix A (continued).

Insecticide Product Name	Active Ingredient(s)
IMIGOLD	Imidacloprid
LADA	Imidacloprid
LANCER GOLD	Imidacloprid, acephate
MALICE	Imidacloprid
MALLET	Imidacloprid
MANTRA	Imidacloprid
MARATHON	Imidacloprid
MERIDIAN	Thiamethoxam
MERIT	Imidacloprid
NUPRID	Imidacloprid
OPTIGARD FLEX	Thiamethoxam
PASADA	Imidacloprid
POINTER INSECTICIDE	Imidacloprid
PRONTO	Imidacloprid
PROTHOR	Imidacloprid
ROTAM	Imidacloprid
SAFARI	Dinotefuran
SAGACITY	Dinotefuran
SCORPION	Dinotefuran
STARKLE	Dinotefuran
TANDEM	Thiamethoxam, lambda-cyhalothrin
TRIMAX	Imidacloprid
TRIPLE CROWN INSECTICIDE	Imidacloprid, bifenthrin, zeta-cypermethrin
TRISTAR	Acetamiprid
TURFTHOR	Imidacloprid
WRANGLER	Imidacloprid
XYTECT	Imidacloprid

Some common off-the-shelf neonicotinoid plant treatments

Appendix B: Methods of Sampling, Sample Analysis, and Data Analysis

This project involved the determination of neonicotinoid insecticide residues found in the flowers and green plant tissues (stems and leaves) of bee-friendly garden plants commonly purchased at commercial garden centers.

Sampling

Plants were purchased from large commercial garden centers, including Home Depot (Eugene, OR; Raleigh, NC; San Francisco Bay, CA area; Minneapolis, MN; Boston, MA; Washington, DC; Sacramento, CA; Austin, TX; Boulder, CO; Portland, ME area; New York, NY; Atlanta, GA; Baltimore, MD area; Ann Arbor, MI; St. Augustine, FL in the U.S. and London, ON; Montreal, QC; Vancouver, BC in Canada), Lowe's (NC, DC, TX, ME, GA) and Walmart (OR, FL). Three to four nursery plants were sampled per location, and typically consisted of ornamental bee-friendly flowers.

Once purchased, all flowers and emerging buds were cut at the base of the flower head (where the flower joins the stem) and packaged together for pesticide residue analysis of flowers only. The remaining plant material was cut at the base of the stem, above the roots and level of the soil, and packaged together for pesticide residue analysis of greenery only. Roots and dirt were not included in the analysis. To avoid cross contamination between samples, a new plastic sheet and pair of gloves were used for each new sample, and scissor blades used to cut the plants were wiped down multiple times with rubbing alcohol wipes.

Following sample preparation, the samples were placed in a Ziploc® bag in an insulated shipping container with cold packs to limit degradation of the plant material and pesticide residues. The samples were shipped cold overnight to the lab and stored in the refrigerator until analysis.

Sample Preparation

An accredited independent analytical laboratory prepared all submitted samples for quantitative analysis according to AOAC Official Method 2007.01, *Pesticide Residue in Foods by Acetonitrile Extraction and Partitioning with Magnesium Sulfate*. An exact mass (approximately 3 grams) of each sample was first subjected to QuEChERS extraction using a buffered acetonitrile extraction solution (one percent acetic acid/sodium acetate in acetonitrile) and magnesium sulfate ($MgSO_4$) to enable partitioning of the acetonitrile layer from the water in the sample. Dispersive solid phase extraction (d-SPE) was then performed to remove organic acids, excess water, and other components. Extracts were analyzed using high performance liquid chromatography (HPLC) with mass spectrometry (MS), as described below in the following section.

Analysis

An Agilent 1200 Series liquid chromatograph (LC) equipped with an Agilent Model 6430 Triple Quadrupole Mass Spectrometer (MS) and Zorbax Eclipse Plus C18 Rapid Resolution HD column was employed for multiresidue neonicotinoid residue analysis of the extracted plant tissues. Calibration curves for all neonicotinoids included in the screen were constructed to determine the concentrations of any neonicotinoids detected during analysis. The limits of detection (LODs) for screened neonicotinoids and degradation products were 1 μg/kg (clothianidin, imidacloprid, imidacloprid 5-hydroxy, imidacloprid urea, thiacloprid, and thiamethoxam), 2 μg/kg (acetamiprid, dinotefuran, imidacloprid des nitro HCl), 8 μg/kg (flonicamid), 10 μg/kg (imidacloprid olefin), 16 μg/kg (imidacloprid olefin des nitro), 30 μg/kg (6-chloronicotinic acid), and 50 μg/kg (clothianidin MNG, clothianidin TMG, clothianidin TZMU, and clothianidin TZNG). Prior to analysis, the sample extract (described above in "Sample Preparation") was allowed to warm to room temperature, and 100–300 μL of the extract was transferred to an auto-sampler vial (2 mL) for LC-MS/MS analysis. Following analysis, all compounds detected in a sample were positively identified and confirmed.

Quality Assurance / Quality Control

Both extraction blank and matrix spike samples were prepared and analyzed for quality control/quality assurance. The same reagents, volumes, and laboratory manipulations as those for sample preparation were employed in preparing the blank in order to demonstrate that the extraction batch is devoid of any interference from glassware or reagents that could produce a false positive. The matrix spike consists of a sample that is fortified with the QC stock solution of neonicotinoids included in the analysis (acetamiprid, clothianidin, dinotefuran, imidacloprid, thiacloprid, thiamethoxam) to demonstrate acceptable recovery in matrix.

Unmarked trip blank and trip spike samples were also provided to the contracted laboratory for quality assurance purposes. Analysis of the trip blank revealed no neonicotinoid residues, confirming that the method of preparing and packaging, as well as the laboratory's analysis was free of unintended contamination. Likewise, the neonicotinoid concentrations determined for the trip spike were within acceptable limits of percent recovery. Details regarding the calculated and expected concentrations of neonicotinoid residues in the trip blank and trip spike samples are provided below in Table B-1.

Determination of total plant toxicity in imidacloprid equivalents

The analytical results of the study of nursery plants indicated the presence of more than one neonicotinoid pesticide in some of the plants sampled. In order to account for the total neonicotinoid toxicity of the pesticides in the plants, we developed Relative Potency Factors (RPFs) based on oral LD_{50} values for the five neonicotinoid insecticides found in this study. Toxicity was expressed in units of imidacloprid toxicity. The observed neonicotinoids include acetamiprid, clothianidin, dinotefuran, imidacloprid, and thiamethoxam. Oral LD_{50} values for the five neonicotinoids were available from the U.S. EPA Office of Pesticide Programs Pesticide Ecotoxicity Database.[131] The oral LD_{50} values for imidacloprid olefin and 5-hydroxyimidacloprid were obtained from references 117 and 119, respectively. The LD_{50} values are shown in Table 2 in the report, reproduced below for reference.

The creation of RPFs is based on the assumption of a common mechanism of action for mortality caused by the neonicotinoid insecticides. All of these chemicals bind to the nicotinic acetylcholine receptors (nAChR), blocking their function.[170] The RPF methodology is similar to the U.S. EPA's use of RPFs for organophosphorus (OP) pesticides based on cholinesterase inhibition.[171] The key difference between these methodologies is the active ingredient used as the reference chemical for the particular pesticide class. Imidacloprid was selected as the reference chemical for the neonicotinoid RPF approach.

Table B-1. Results of LC-MS/MS Analysis of Trip Blank and Spiked Samples

Sample	Neonicotinoid	Expected (µg/kg)	Reported (µg/kg)	Percent Recovery (%)
Trip Blank	ND	0	0	– –
Trip Spike (Daisy)	Acetamiprid	16.7	7.7	46
	Imidacloprid	41.7	27.5	66
	Thiamethoxam	33.3	21.2	64

ND = No Detections

Table 2. Relative Acute Toxicity of Neonicotinoid Insecticides and Degradation Products to Honey Bees

Pesticide	Oral LD_{50} (μg/bee)	Oral LC_{50} (μg/L)	Relative Potency Factor
Acetamiprid	14.53	558,846	0.0003
Clothianidin	0.0037	142	1.06
Dinotefuran	0.023	885	0.17
Imidacloprid	0.0039	150	1.00
5-Hydroxy Imidacloprid	0.159	6,115	0.025
Imidacloprid Olefin	0.023	885	0.17
Thiamethoxam	0.005	192	0.78

Described below is the stepwise procedure for estimating the toxicity of the observed plant residue levels in terms of LC_{50} values for imidacloprid in foods consumed by bees.

1. Oral LD_{50} values (in mg/bee) were obtained from U.S. EPA EcoTox database for acetamiprid, clothianidin, dinotefuran, imidacloprid, and thiamethoxam

2. The oral LD_{50} of imidacloprid was divided by the LD_{50} of each neonicotinoid to obtain an Imidacloprid Relative Potency Factor for chemical *x*:

$$RPF_x = \frac{LD_{50\,(imidacloprid)}}{LD_{50(x)}}$$

   The calculated RPFs are shown in Table 2 in the report (and reproduced above).

3. The observed neonicotinoid concentrations in plants were transformed to Imidacloprid-Equivalent Toxicity, where the concentration of each neonicotinoid in each plant sample was expressed as a concentration equivalent to the same amount of imidacloprid:

$$Imidacloprid\ Equiv\ Toxicity\ (\mu g/kg) = Neonicotinoid_x\ Conc.(\mu g/kg) \times RPF_x$$

4. For samples having multiple neonicotinoid residues, the Imidacloprid Equivalent Toxicity values for each neonicotinoid were summed to provide the Total Toxicity per Plant in Imidacloprid Equivalents. For those having only one residue, the Total Toxicity value is equivalent to the Imidacloprid Equivalent Toxicity.

5. Dividing Total Toxicity per Plant in Imidacloprid Equivalents by the LC_{50} of imidacloprid normalizes the Total Toxicity Per Plant relative to the acute dose of imidacloprid that is lethal to bees. The oral LC_{50} for imidacloprid was determined using the equation of Fischer et al.[132] in which the reported oral LD_{50} is divided by the amount of a 50 percent (weight/volume) sucrose solution ingested by a bee in an oral acute toxicity test (26 mg), and converted to parts per billion (or mg/kg):

$$LC_{50}\left(\frac{\mu g\ pesticide}{kg\ of\ nectar}\right) = \left(\frac{LD_{50}\left(\frac{\mu g\ pesticide}{bee}\right)}{26\ mg\ nectar}\right) \times 1{,}000{,}000\ \frac{mg}{kg}$$

Appendix C. Comprehensive Table of Results by Location

Location	Sample Type	Sub-Sample	List of Chemicals and Concentrations (µg/kg)
BC	Shasta Daisy	Flower	ND
		Stems & Leaves	ND
	Lavender	Flower	Flonicamid (95.3)
		Stems & Leaves	Flonicamid (199)
	Salvia	Flower	Imidacloprid (21.2)
		Stems & Leaves	Imidacloprid (14.5)
	Scabiosa	Flower	ND
		Stems & Leaves	ND
CA	African Daisy	Flower	Clothianidin (3.6), Thiamethoxam (16.1)
		Stems & Leaves	Clothianidin (2.1), Thiamethoxam (53.9)
	Gerbera Daisy	Flower	Imidacloprid (13.8), Thiamethoxam (26.0)
		Stems & Leaves	Clothianidin (348), Imidacloprid (176), Imidacloprid 5-hydroxy (114), Imidacloprid des nitro HCl (37.8), Imidacloprid olefin (679), Imidacloprid olefin des nitro (128), Thiamethoxam (1425)
	Paludosum Daisy	Flower	ND
	Lavender	Flower	Clothianidin (100), Imidacloprid (11.3), Thiamethoxam (74.1)
		Stems & Leaves	Clothianidin (110), Imidacloprid (18.0), Thiamethoxam (38.7)
		Composite, 7 wks later[1]	Clothianidin (13.2), Thiamethoxam (7.9)
	Salvia	Flowers	ND
CO	Coreopsis	Flower	ND
	African Daisy	Flower	Imidacloprid (2.7)
		Stems & Leaves	Imidacloprid (2.9)
	Salvia	Flower	Imidacloprid (12.3), Imidacloprid des nitro HCl (6.7)
		Stems & Leaves	Imidacloprid (19.1)
	Yarrow	Flower	ND
DC	Coreopsis	Flower	Imidacloprid (4.4)
		Stems & Leaves	ND
	Salvia	Flower	ND
		Stems & Leaves	Clothianidin (5.9), Thiamethoxam (3.9)
	Scabiosa	Flower	Imidacloprid (2.2)
		Stems & Leaves	ND
	Yarrow	Flower	ND

Appendix C. (continued).

Location	Sample Type	Sub-Sample	List of Chemicals and Concentrations (µg/kg)
FL	Daisy	Flower	ND
	Coreopsis	Flower	ND
	Gaillardia	Flower	ND
		Stems & Leaves	Dinotefuran (225), Imidacloprid (2.0)
	Salvia	Flower	ND
GA	African Daisy	Flower	Clothianidin (76.9), Imidacloprid (78.0), Thiamethoxam (754)
		Stems & Leaves	Clothianidin (258), Dinotefuran (93.5), Imidacloprid (52.1), Thiamethoxam (1670), Clothianidin TZMU (19.9)
	African Marigold	Flower	Imidacloprid (86.8), Imidacloprid olefin (263)
		Stems & Leaves	Imidacloprid (1100), Imidacloprid 5-hydroxy (237), Imidacloprid des nitro HCl (71.6), Imidacloprid olefin (3560), Imidacloprid olefin des nitro (209)
	Salvia	Flower	Clothianidin (11.2), Thiamethoxam (8.5)
		Stems & Leaves	Clothianidin (47.6), Thiamethoxam (11.3)
	Yarrow	Flower	ND
MA	Anemone	Flower	ND
	English Daisy	Flower	Imidacloprid (322), Imidacloprid 5-hydroxy (139), Imidacloprid des nitro HCl (52.7), Imidacloprid olefin (499), Imidacloprid olefin des nitro (127)
		Stems & Leaves	Imidacloprid (486), Imidacloprid 5-hydroxy (225), Imidacloprid des nitro HCl (162), Imidacloprid olefin (566), Imidacloprid olefin des nitro (324)
	Marigold	Flower	Imidacloprid (3.2)
		Stems & Leaves	Imidacloprid (3.6)
	Primrose	Flower	Imidacloprid (240), Imidacloprid des nitro HCl (38.9)
		Stems & Leaves	Imidacloprid (1580), Imidacloprid 5-hydroxy (932), Imidacloprid des nitro HCl (101), Imidacloprid olefin (2010), Imidacloprid olefin des nitro (2100)

Appendix C. (continued).

Location	Sample Type	Sub-Sample	List of Chemicals and Concentrations (µg/kg)
MD	Salvia	Flower	ND
		Stems & Leaves	ND
	Scabiosa	Flower	Dinotefuran (268), Imidacloprid (75.5), Imidacloprid des nitro HCl (104), Imidacloprid olefin (456), Imidacloprid olefin des nitro (823)
		Stems & Leaves	Dinotefuran (223), Imidacloprid (116), Imidacloprid des nitro HCl (35.4), Imidacloprid olefin (570), Imidacloprid olefin des nitro (200)
	Yarrow	Flower	ND
		Flower	ND
ME	Coreopsis	Flower	Imidacloprid (3.2)
		Stems & Leaves	Imidacloprid (3.2)
	English Daisy	Flower	Imidacloprid (8.7)
		Stems & Leaves	Imidacloprid (5.3)
	Poppy	Flower	ND
	Scabiosa	Flower	Dinotefuran (879), Imidacloprid (163), Imidacloprid 5-hydroxy (85.5), Imidacloprid des nitro HCl (9.0), Imidacloprid olefin (668), Imidacloprid olefin des nitro (226)
		Stems & Leaves	Dinotefuran (782), Imidacloprid (137), Imidacloprid 5-hydroxy (84.1), Imidacloprid olefin (1680), Imidacloprid olefin des nitro (677)
MI	Gerbera Daisy	Flower	Imidacloprid (100), Imidacloprid olefin (133)
		Stems & Leaves	Imidacloprid (182), Imidacloprid 5-hydroxy (184), Imidacloprid olefin (450)
	Dianthus	Flower	ND
	Marigold	Flower	ND
	Phlox	Flower	Imidacloprid (3.7)
		Stems & Leaves	Imidacloprid (4.3)
MN	African Daisy	Flower	ND
		Stems & Leaves	Flonicamid (5.0)
	Poppy	Flower	ND
	Salvia	Flower	ND
	Salvia	Stems & Leaves	Dinotefuran (20.0)
	Scabiosa	Flower	ND
		Stems & Leaves	Dinotefuran (33.2)

Appendix C. (continued).

Location	Sample Type	Sub-Sample	List of Chemicals and Concentrations (µg/kg)
NC	Coreopsis	Flower	ND
	African Daisy	Flower	Acetamiprid (2.7), Flonicamid (21.0), Imidacloprid (27.1), Thiamethoxam (3.4)
		Stems & Leaves	Flonicamid (106), Imidacloprid (18.6), Thiamethoxam (11.9)
	Gerbera Daisy	Flower	Imidacloprid (2.0)
		Stems & Leaves	Imidacloprid (11.7)
	Phlox	Flower	ND
NY	African Daisy	Flower	ND
		Stems & Leaves	Imidacloprid (5.0)
	Dianthus	Flower	ND
	Phlox	Flower	ND
	Wallflower	Flower	ND
ON	Calibrachoa	Flower	Imidacloprid (9.5), Thiamethoxam (17.2)
	Gerbera Daisy	Flower	Imidacloprid (13.7), Thiamethoxam (9.4)
	Shasta Daisy	Flower	Imidacloprid (6.6), Thiamethoxam (10.7)
	Zonal Geranium	Flower	Thiamethoxam (9.9)

Appendix C. (continued).

Location	Sample Type	Sub-Sample	List of Chemicals and Concentrations (μg/kg)
OR	Anemone	Flower	ND
	Lavender	Flower	ND
	Rhododendron	Flower	ND
	Strawberry	Flower	ND
QC	Alyssum	Flower	Imidacloprid (2.7), Imidacloprid 5-hydroxy (38.3)
	Apache beggarticks	Flower	ND
	African Daisy	Flower	ND
	Salvia	Flower	Imidacloprid (51.8)
SAC	African Daisy	Flower	ND
		Flower	ND
	African Daisy	Stems & Leaves	ND
		Stems & Leaves	ND
	Gaillardia	Flower	ND
		Stems & Leaves	ND
	Scabiosa	Flower	ND
		Stems & Leaves	ND
TX	Coreopsis	Flower	ND
	Shasta Daisy	Flower	Imidacloprid (43.0), Imidacloprid des nitro HCl (12.6)
		Stems & Leaves	Dinotefuran (38.1), Imidacloprid (3.7)
	Scabiosa	Flower	ND
		Stems & Leaves	ND

‡Composite sample of new flowers and stems were taken seven weeks following the initial sampling event.

ND = No Detections

Appendix D. Measures to Protect Pollinators and Reduce Pesticide Use at State and Local Levels in the U.S.

City/State	Policy Number	Description
Oregon	HB4139-A	Requires pesticide applicators to receive education on best practices, creates a task force to study bee-protection measures, directs Oregon State University and the Department of Agriculture to develop educational materials to protect bees, and provides measures the Legislature could pursue in 2015 to protect bees.[95]
Eugene, OR	Resolution 5101	Unanimously passed to ban neonicotinoids on all city owned property.[96] The resolution extends the Pesticide-Free Parks Program and endorses the parks and calls for all departments within the City of Eugene to adopt an IPM policy as the Parks and Open Space Division.[172]
Minnesota	HF 2798	Introduced by Rep. Hansen, would not allow plants treated with pollinator lethal insecticides from being labeled or advertised as beneficial to pollinators.[97]
Minnesota	SF 2695	Introduced by Senator Dziedic as companion legislation to HF 2798[173]
Minnesota	HF 2908	Introduced by Rep. Hansen, would establish an emergency response team for pollinators and provide beekeepers compensation if bee deaths are determined to be a result of pesticide poisoning[174]
Minnesota	SF 2727	Introduced by Senator Dibble, would establish an emergency response team for pollinators and provide beekeepers compensation if bee deaths are determined to be a result of pesticide poisoning [175]
Minnesota	HF 3172	Bills SF 2727 and HF 2908 passed by way of HF 3172, an omnibus appropriations bill.[98]
Minnesota	SF 2723	Introduced by Senator Dziedic, would amend state preemption law to allow the four largest cities in Minnesota to regulate non-agriculture pesticides.[176]
Minnesota	HF 2799	Introduced by Rep. Davnie, would amend state preemption law to allow the four largest cities in Minnesota to regulate non-agriculture pesticides.[177]

Appendix D. (continued).

City/State	Policy Number	Description
California	AB-1789	Introduced by Assembly Member Williams in February 2014, would amend existing law to require the Department of Pesticide Regulation to issue a determination on their evaluation of neonicotinoids by July 1, 2018 and adopt control measures to protect pollinator health after making the determination.[178]
Maine	LD 1587	Introduced by Representative Jones, which would ban the use, sale and distribution of neonicotinoids for two years.[179] The bill didn't pass out of committee.
Maryland	HB 1285	Introduced by Representative Healey, to designate neonicotiniods as a restricted use pesticide; authorizing the distribution, sale and application of neonics under specific circumstances. The bill was withdrawn after an unfavorable report by the Environmental Matters Committee.[180]
New York	AO 8148	Introduced by Assembly Member Clark to prohibit the use of neonicotinoids uses in seed dressings, treatments or coating. The bill remains in committee.[181]
New York		State restricted use of clothianidin, dinotefuran and thiamethoxam, on urban landscapes or agriculture.[92, 93, 94]
Long Island, NY		In 2005, restricted use of Imidacloprid. It is not sold at garden centers to consumers and only trained applicators can use imidacloprid on landscapes, but must report all use and sales to the Department of Environmental Conservation.[91]
New Jersey	NJ A1373	Introduced by Assembly Member Stender, would prohibit the use or sale of neonicotinoids.[182]
New Jersey	NJ A3355	Introduced by Assemblyman Wilson, would require training for pesticide applicators and operators concerning pollinating bees.[183]
Alaska	House Bill NO. 224	Introduced by Representative Drummond, would not allow the application of neonicotinoids to seeds, foliage or soil unless contained within a greenhouse.[184]
Vermont	S. 232	Introduced by Senator Galbraith to ban the use, sale and application of neonicotinoids.[185]

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