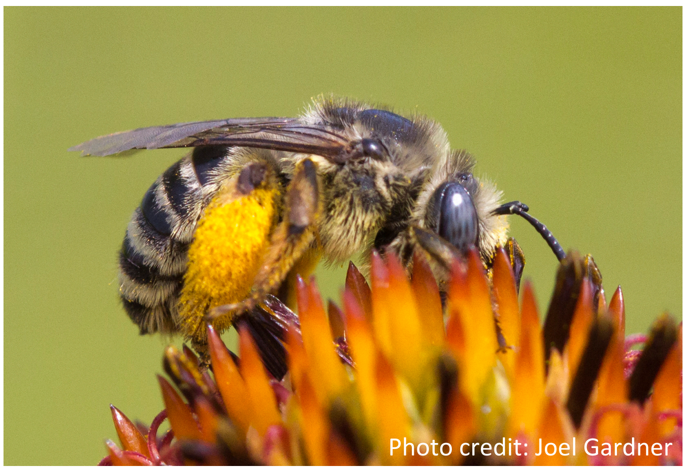
Review of Neonicotinoid Use, Registration, and Insect Pollinator Impacts in Minnesota

August 2016



Minnesota Department of Agriculture

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https://www.mda.state.mn.us/chemicals/pesticides/regs/pestprodreg.aspx
http://www.mda.state.mn.us/en/protecting/bmps/pollinators.aspx

Executive summary

Neonicotinoid insecticides are currently one of the most widely used insecticides in the world because of their properties including potent broad-spectrum toxicity possessing contact, oral, and systemic activity. They are effective at very low concentrations, are less toxic to mammals, and are not cross-resistant to other classes of insecticides including carbamates, organophosphates, and synthetic pyrethroids. However, recent research has suggested potential toxicity concerns for neonicotinoids to various life stages of honey bees, native bees, as well as other pollinating insects. Pollinators are essential in the reproduction of 90% of the world's flowering plants and 30% of the food human's consume. Many plants such as alfalfa, apple, blueberry, sunflower and canola, cannot reproduce without the help from insect pollinators. The pollination services offered by insect pollinators also play a crucial role in the maintenance of biodiversity and ecological balances in natural ecosystems by providing important food and habitat for other wildlife species. Managed honey bees (*Apis mellifera*) alone pollinate more than $17 billion worth of crops in the U.S. each year and are regarded as the most important managed pollinator. Over the last 50 years, honey bees have been faced with a number of stressors that impact their health and survivorship including a number of pests and diseases, fewer flowering plants available to meet their nutritional needs, and a wide variety of pesticides that can be toxic.

Pesticides have long been suspected as a potential cause of contemporary honey bee declines. Honey bees are exposed to pesticides and other chemicals commonly used in agriculture and landscapes via numerous pathways including direct exposure, exposure through the pollen and nectar of plants treated with contact or systemic pesticides and pesticides used by beekeepers themselves. Although many insecticides have been shown to affect honey bees, the attention has focused on neonicotinoid insecticides in recent years. The concern over the use of neonicotinoid insecticides in relation to insect pollinators led the Minnesota State Legislature to request that the Minnesota Department of Agriculture (MDA) report on the process and criteria to be used in a review of neonicotinoid use in Minnesota currently and in the future. Consequently, the Commissioner of Agriculture directed MDA staff, on November 5, 2013, to initiate a special review of neonicotinoid insecticides.

The MDA is the lead state agency for pesticide and fertilizer environmental and regulatory functions in Minnesota under the Pesticide Control Law (Minn. Stat. Chapter 18B). In addition to functions related to pesticide registration and monitoring, the MDA carries out in-depth reviews of pesticides to better understand Minnesota-specific issues related to pesticides. The scope of these special registration reviews varies depending on the potential education, outreach, and enforcement needs identified by the Department. As such, these reviews are not intended to be redundant of analyses and decisions reached by the United States Environmental Protection Agency (USEPA). Rather, these reviews result in a greater understanding of federal registration concerns and provide a variety of Minnesota specific opportunities for action.

In order to conduct the current review, the MDA followed a pre-established process to develop the criteria MDA would use to conduct a variety of in-depth pesticide reviews. The MDA has also previously reviewed several neonicotinoids of concern as part of its emerald ash borer insecticide review (including concerns about pollinator exposure). Following the pre-established process, the MDA developed a scoping document after soliciting input from the public and a number of interested stakeholders, including beekeepers, academics, citizens, farmers and their suppliers, and pesticide registrants. In addition, the MDA collaborated with the Minnesota Board of Water and Soil Resources (BWSR), the Minnesota Department of Natural Resources (DNR), the Minnesota Pollution Control Agency (MPCA), and the University of Minnesota (U of M). Based on the scoping document, the review was categorized into six broad criteria including:

- Neonicotinoid background, chemistry, and mode of action;
- Federal, state, and other neonicotinoid registration policies and initiatives;
- Neonicotinoid use and sales;
- Neonicotinoid applications and movement in the environment;
- Risks of neonicotinoid use; and
- Benefits of neonicotinoid use.

Each criterion was explored in relation to Minnesota-specific concerns and opportunities for action.

Neonicotinoid background, chemistry, and mode of action:

Neonicotinoids are used on nearly 140 agricultural crops and in many other uses including garden, turf, residential, and animal use. In the United States, six neonicotinoid insecticides: acetamiprid, clothianidin, dinotefuran, imidacloprid, thiacloprid, and thiamethoxam with potential pollinator impacts were registered for controlling agricultural and urban insect pests. Thiacloprid registration has been cancelled voluntarily by the registrants and will no longer be available after 2016. Neonicotinoids are systemic insecticides with a structure and mode of action similar to nicotine, a naturally occurring plant alkaloid compound toxic to humans. Contact and oral exposures of neonicotinoids target the acetylcholine receptors (nAChR) on the insect nerve cells within an insect nervous system. However, neonicotinoids vary from nicotine in their affinity to different nAChR subtypes, with nicotine showing selective toxicity to vertebrates whereas neonicotinoids are highly selective to insect nAChRs. Their action causes excitation of the insect nerves that lead to trembling, shaking and eventual paralysis, which can lead to death depending on the dose and exposure duration. Neonicotinoids bind at a receptor site specific to insect nerve cells, therefore, they are less toxic to mammals. All neonicotinoid insecticides show similar broad spectrum insecticidal activity but vary in their biological and physicochemical properties such as photolytic stability, soil degradation, metabolism in plants and insects, and toxicity to different animals.

Federal, state, and other neonicotinoid registration policies and initiatives

Both federal and state laws govern the registration and use of neonicotinoid insecticides in Minnesota. The Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) of 1972, amended by the Food Quality Protection Act of 1996, and the Pesticide Registration Improvement Act of 2003, requires all pesticides sold or distributed in the United States (including imported pesticides) to be registered by USEPA. The USEPA registers a pesticide after determining that the pesticide meets the statutory standard and there are no outstanding data requirements. The law requires USEPA to review each pesticide registration at least once every 15 years. Registration reviews for the six neonicotinoid insecticides were initiated between 2008 and 2012 and are expected to be completed between 2016 and 2019. The USEPA released the preliminary imidacloprid, pollinator specific review for agricultural and horticultural crops in January 2016. Work plans for neonicotinoids identified numerous ecological information gaps on toxicity and exposure to honey bee life stages and/or full colonies on acute or chronic exposure basis.

Historically, the USEPA's testing paradigm for pollinators relied on qualitative evaluations rather than precise quantitative measurements. The process relied primarily on developing an understanding of the types of effects that might be caused by the pesticide (hazard characterization), based on toxicity studies using honey bees as surrogate species. In 2012, the USEPA in collaboration with Health Canada's Pest Management Regulatory Agency (PMRA) and the California Department of Pesticide Regulation (CalDPR) developed a new risk assessment framework for bees. The new framework takes into account multiple lines of evidence including registrant-submitted data, open literature, and ecological incident data. The USEPA has acknowledged some uncertainties with initial registration of neonicotinoid insecticides regarding their potential environmental fate and effects, particularly as they relate to pollinators. Considering these uncertainties, the USEPA amended label language to clarify the risk some of the neonicotinoid products may have to non-target insect pollinators. One of the major changes USEPA made to neonicotinoid insecticide products approved for outdoor foliar uses, is the addition of a "Protection of Pollinators" box. This box visually alerts the user of application restrictions when bees are present by displaying a bee icon, near important information, and accenting key phrases in red "Application Restrictions" and "This product can kill bees and other insect pollinators." The "Protection of Pollinators" box further describes how foliar applications of these insecticides can result in pollinator exposure, and provides steps an applicator can take to reduce non-target impacts. However, there remains criticism of the ability of these label amendments to reduce impacts on pollinators. In addition, some states and communities around the United States have decided to minimize any potential impacts of neonicotinoids on insect pollinators through ordinances or commitments to minimize their use on city, township, or university/school district property. In Minnesota, 16 cities, townships, or school districts including Minneapolis and Saint Paul currently have some ordinance limiting the use of neonicotinoid insecticides on the land they own.

Canada's providence of Ontario implemented new laws beginning July 1, 2015 that aim to reduce prophylactic use of neonicotinoid treated corn and soybean seed, through requiring farmers to demonstrate that a pest problem exists before allowing the sale of treated seed. The goal is to reduce the number of acres planted with neonicotinoid treated corn and soybean seed by 80% by 2017. The plan requires farmers to ensure that neonicotinoid-treated corn and soybean seeds are used only when there is a demonstrated pest problem. In addition, Canada added a new seed packaging label with updated advisories and is requiring farmers to use Bayer's new seed lubricant call Fluency Agent that may reduce the amount of active ingredient abraded from seeds. Claims of abrasion reductions has been variable in the US and Canada ranging from 0, 55, and 65%. The European Union member countries have been restricting neonicotinoid use on certain crops since 1999. More recently, the EU as a whole, enacted a moratorium (December 1, 2013 – December 1, 2015) applying to imidacloprid, clothianidin, and thiamethoxam seed, soil and foliar treatments to bee-attractive crops and cereal grains. Updated risk evaluations are proposed to be completed by January 2017. At present, and despite high use of neonicotinoids on the Australian continent, honey bee populations are generally not considered to be in decline and insecticide impacts to pollinators are not considered a highly significant issue.

Neonicotinoid use and sales:

In the global insecticide market, neonicotinoids accounted for 24% of total insecticide use in 2008. The seed treatment market, initially dominated by insecticides from the carbamate family, was 80% comprised of neonicotinoid insecticides by 2008. Neonicotinoid insecticides, used primarily as seed treatments, accounted for more than 98% of the annual average 133 million acres of corn, soybean, wheat, cotton, and sorghum acres farmers treated in North America.

In Minnesota, there were 510 registered neonicotinoid products in 2015 to control soil (wireworms, seedcorn maggot, corn rootworm, white grubs, etc.) and foliar insect pests (corn earworm, flea beetles, aphids, armyworms, plant bugs, leaf hoppers, grasshoppers, etc.). With the introduction of soybean aphid in 2004, use of neonicotinoids has increased significantly in soybean in Minnesota through seed treatments or foliar applications. In addition to crop protection, applications of neonicotinoid insecticides in non-agricultural fields such as urban household, lawn and garden and animal health have also expanded in recent years. Total sale of neonicotinoid products in Minnesota from 2010 to 2013 was 381.30 thousand pounds. The bulk (>99%) of neonicotinoid products sold from 2010 to 2013 in Minnesota comprised of clothianidin, thiamethoxam, and imidacloprid. In comparison to all pesticides (pounds sold of all chemistries including nonagricultural pesticide products), neonicotinoids accounted for 0.05, 0.12, 0.06, and 0.09% of all pesticide products sold in Minnesota in 2010, 2011, 2012, and 2013, respectively. Because, the State does not have the authority to regulate the sale and use of pesticide treated seeds, almost all corn seed and about 20% of soybean seed treated outside of Minnesota's borders and shipped into the state for planting is not tracked by the MDA. Gross sales and revenues from neonicotinoids and all pesticides in Minnesota showed wide variation from 2010 to 2013 and may not be related to pounds sold each year because price of the same pesticide can vary from year to year and also from seller to seller (manufacturers/retailer). The MDA collected $332,480 from registration of neonicotinoid products (pesticide fee+ AACRA fee + registration fee), which was 3.7% of total revenue for all pesticide registration in 2013.

Neonicotinoid applications and movement in the environment:

Neonicotinoid insecticides are widely used for seed treatment on various crops. Studies of the uptake for each neonicotinoid seed dressing chemistry into a target crop suggest that between 1.6 and 20% of the active ingredient is absorbed by the plant, depending on the chemistry, while the remainder enters the soil. As with any other pesticide, the behavior of neonicotinoids in soils, and hence their bioavailability and transfer to other environmental compartments (i.e. atmosphere, water bodies, etc.), is governed by a variety of complex dynamic physical, chemical, and biological processes, including adsorption–desorption, volatilization, chemical, photo and biological degradation, uptake by plants, run-off, and leaching. The rate and magnitude of transport of pesticides to environmental compartments is also influenced by factors like properties of the pesticide (water solubility, adsorption, chemical structure, acid dissociation constant, etc.) and soil (bulk density, organic matter, texture, pH, etc.), the soil hydrologic cycle, how the pesticide was applied, proximity to sensitive aquatic resources (streams, rivers, etc.), and environmental conditions surrounding the application. These processes directly control the transport of pesticides within the soil and their transfer from the soil to water, air or food. The relative importance of these processes varies with the pesticide compound and the properties of the soil. The high water solubility and low Koc for neonicotinoids indicate low tendency for adsorption to soil particles. Laboratory and field studies have produced a wide range of values for soil dissipation half-lives (7 to 6,931 days) of neonicotinoid compounds. In general, half-lives have been reported to be longer for N-nitroguanidines (imidacloprid, thiamethoxam, clothianidin, and dinotefuran) than N-cyanoamidines (acetamiprid and thiacloprid). However, the highest and lowest values may not represent typical half-life values under Minnesota-specific conditions. Neonicotinoid half-life in soils will vary with soil type, climate, soil pH, moisture, temperature, light intensity, use of organic fertilizers, presence or absence of ground cover, etc. For example, the half-life for imidacloprid is estimated to be longer in temperate regions than in the mid and higher latitudes, because of fewer sun hours, lower sun light intensity, and lower average seasonal temperatures.

Chemicals applied to the soil or plant surfaces may be transported to groundwater or surface water through leaching, runoff, and drift. Presence of pesticides in water poses a concern for humans relying on groundwater as a source of drinking water, and for aquatic communities of invertebrates, fish, and plant life. Owing to high water solubility, some neonicotinoid insecticide compounds may be more prone to leaching into groundwater or running off into surface water. Both thiamethoxam and imidacloprid have been shown to be highly mobile in soils with a high potential to leach downward through the soil profile or laterally through soil flow paths to contaminate surface and groundwater. The persistence of neonicotinoids in aqueous environments depends upon its exposure to sunlight, the soil or water's pH and temperature, the composition of microorganisms and other biotic communities, the concentration of the pesticide in a given water resource, and the pesticide's product formulation. For example, imidacloprid and thiamethoxam have been shown to degrade more rapidly in alkaline media than in acidic or neutral conditions.

MDA regularly monitors groundwater and surface water for presence of neonicotinoids in Minnesota. When a pesticide is detected frequently and benchmarks are reached, it triggers regulatory agencies to take additional actions to mitigate future exposure to the pesticide of concern. To date, the detected neonicotinoid insecticide concentrations in groundwater samples have been below the Minnesota Department of Health (MDH) drinking water guidance values of concern. Clothianidin, imidacloprid, and thiamethoxam detected in 4.3% (71 out of total 1,644 samples) of groundwater samples collected in Minnesota in 2014. The highest concentration for clothianidin, imidacloprid, and thiamethoxam in groundwater was 391, 59, and 14.8 times below the drinking water level of concern concentrations, respectively. There were no detections in urban areas and private drinking water wells.

In surface water, neonicotinoids insecticides were detected in up to 4.5% of surface water samples (58 out of total 1,284 samples) in 2014. No neonicotinoids have been found in any lake samples; however, they are being detected in rural and some urban river and stream sites, and in wetland water and sediment samples. The maximum values for clothianidin and imidacloprid was 22.23% and 44.5% of EPA's chronic aquatic life benchmarks for aquatic invertebrates, respectively.

Risk of neonicotinoid use:

For an insecticide to become lethal to an organism, the organism must be exposed to a sufficient amount of active ingredient for a sufficient period of time. Bees and other insect pollinators can be exposed to insecticides primarily through contaminated plant parts (pollen and nectar) and through unintended, exposure pathways like insecticide drift and abraded seed dust generated during planting. Pollinators may also be exposed to pesticides via plant guttation droplets, contaminated surface water, or soil. However, the extent to which bees may be exposed via direct contact with guttation, surface water, or soil is considered uncertain. Exposure from contaminated plant parts depends upon factors such as attraction or frequency of visitation to the pollen or nectar source, concentration of residue in plant parts collected and daily amount of pollen and nectar consumed by a pollinator. Insecticide residues can vary greatly in their concentration at an exposure point and are a function of the type and amount of active ingredient applied, application methods used, and ability of the plant to uptake the active ingredient. In addition, there are factors that influence an active ingredient's rate of degradation and movement in the soil thus impacting the amount of residues available to the plant for uptake at a given time. The complexity of these interacting factors makes it difficult to anticipate the environmental exposure to pollinators over a period of time.

Wide variation has been reported in neonicotinoid residue concentrations in various exposure points. Review of several studies revealed that, foliar or soil treatments closer to blooming resulted in higher concentrations of active ingredients in pollen and nectar of plants as compared to the seed treatments. For example, in one study, it was shown that residue concentrations in pollen from seed treated with ≤ 1 mg imidacloprid resulted in an average of 2.1 ppb imidacloprid in corn pollen (5.4% of a honey bees oral LD_{50}). While, foliar treatments of pumpkin at 96 g thiamethoxam/ha resulted in up to 127 ppb thiamethoxam in the pollen (2.5 times a honey bees oral LD_{50}).

Abraded dust when released into the air during planting, can contain insecticide concentrations toxic to bees. Bees could be directly 'powdered' by insecticides if their flight path went through airborne planter dust or bees may be exposed to the vegetation on which planting dust has settled during planting. In addition to amount and type of active ingredient applied on seed, concentration of residues in treated seed planting dust may depend upon the type of planter and seed lubricant used, application distance from bee hives/nesting sites and abiotic factors such as temperature, relative humidity, and wind. In one study where honey bees presumably flew through dust abraded from the seed during planting, individuals were exposed to an average of 5,700 ppb and up to 12,400 ppb clothianidin. These levels far exceed clothianidin's honey bee acute contact LD_{50} value.

It is important to note that many pesticides, not just neonicotinoids, can make their way into honey bee colonies and possibly result in adverse effects on honey bee colony health and behavior. Field experiments studying pesticide residue accumulation in wax, pollen, water, and individual honey bees, showed colonies located near high intensity agricultural areas accumulated many pesticides in a single sample. For example, residues of up to 39 different pesticides were detected from one sample of the wax of brood comb, while analysis of bees revealed residues of up to 25 different pesticides on or within their bodies.

Based on acute LD_{50} values, four of the six neonicotinoids (clothianidin, dinotefuran, imidacloprid, thiamethoxam) are highly toxic to insect pollinators. Typically, lethal effects to insect pollinators are considered on an acute (single) exposure basis, however, chronic (multiple or duration-based) exposures to an insecticide at levels below an organism's acute LD_{50} can also cause mortality in insect pollinators. There are several ways in which sublethal concentrations of neonicotinoid residues might adversely affect honey bees or other pollinators such as by impacting their orientation, learning, memory, feeding, movement, foraging, reproduction, or colony health. However, there have been relatively few field studies that confirm or invalidate the findings associated with these adverse sublethal effects found in laboratory studies. Further research is needed to identify sublethal exposure thresholds according to standardized protocols that can be reproducible across all pesticide chemistries.

Although this review was scoped to evaluate the impacts of neonicotinoids on insect pollinators, neonicotinoid concentrations can persist, and possibly accumulate under certain soil, water, and sediment conditions and may pose a risk to other taxa (mammals, birds, fish, arthropods, etc.) living in these environments. In general, neonicotinoids pose low to moderate risks (acute or chronic) to mammals and birds. Relative toxicity of neonicotinoids to fish and amphibians varies from practically nontoxic to moderately toxic. However, chronic exposure to neonicotinoids at sublethal concentrations could be a concern to various taxa.

Benefits of neonicotinoid use:

Neonicotinoid insecticides have some distinct advantages over other classes of insecticides such as organophosphates, carbamates, pyrethroids, and chlorinated hydrocarbons. They provide very effective control of piercing and sucking insect pests and some difficult-to-control foliage- and root-feeding insects, such as Colorado potato beetles, termites and white grubs, which have developed resistance to other classes of insecticides. Neonicotinoids show distinct advantages in pest control including efficacy against boring insects and root-feeding insects, both of which cannot easily be controlled using foliar sprays of non-systemic compounds. Neonicotinoids are also known to suppress the secondary spread of insect-transmitted plant pathogens in various crops such as barley yellow dwarf virus in cereal crops. Seed treatment provides efficient and prolonged control of insect pests at low dosages when plants are small and most vulnerable to pests. Seed treatment applications also, generally limit non-target organism direct exposure, or field runoff from foliar, or soil-applied liquid and granular products. Neonicotinoids were registered by USEPA as "reduced risk" pesticides due to their low mammalian toxicity, thus protecting applicators and farm workers from adverse impacts. Several of the alternatives (older chemistries) are considered to be more toxic to bees, mammals, birds, and aquatic organisms than neonicotinoids. In addition, pest management programs that rely on fewer chemical choices and foliar applications may result in the evolution of resistance in insect populations.

Based on the review, the MDA identified several opportunities for action to minimize the impact of neonicotinoids on pollinators.

Proposed action steps regarding use of neonicotinoids

1. Pursue the creation of a Treated Seed program (requires legislative action):
   A Treated Seed program would provide the State with the authority to regulate seeds treated with pesticides, fund research to develop need based recommendations for the use of seed treatments, and may require that untreated seeds and seeds treated at lower pesticide application rates are available in the market.
2. Pursue the creation of a dedicated pollinator protection account (requires legislative action):
   The dedicated pollinator protection account would support activities related to pollinators including evaluating and supporting research on economic thresholds, development of an educational campaign on the use of pesticides and development of stewardship materials.
3. Require formal verification of need prior to use of neonicotinoid pesticides, where appropriate:
   The MDA will work with the U of M and other stakeholders to develop pest thresholds and acceptable IPM criteria. Once pest thresholds and IPM criteria are established, the MDA will ensure that pesticide applicators understand the verification process and requirements. The MDA will ensure that applications of neonicotinoids are made only when a qualified individual verifies that there is a demonstrated pest problem and there is a need for neonicotinoid pesticide use. The MDA will develop a formal process for verification of need by a trained and approved individual prior to the use of neonicotinoid pesticides on crops.
4. Develop an educational campaign for homeowners and residential users of insecticides:
   An educational campaign, with an emphasis on neonicotinoids, will educate homeowners and other residential users of the appropriate and safe use of insecticides and emphasize practices related to the creation of pollinator habitat.
5. Review product labels for appropriate use of neonicotinoids for homeowners and residential users:
   On an ongoing basis, the MDA will review product labels for appropriate urban and suburban uses and restrictions of neonicotinoids to minimize the impact to pollinators.
6. Develop Minnesota specific pollinator stewardship materials:
   The MDA will work with pesticide registrants to develop a Minnesota-specific stewardship program to promote practices targeted at minimizing non-target exposure to pollinators in Minnesota.
7. Increase use inspections for insecticides that are highly toxic to pollinators:
   The MDA will increase use inspections for insecticides that are classified as highly toxic to pollinators on acute exposure basis.
8. Review label requirements for individual neonicotinoid products:
   The MDA will review product labels for enforceable language and appropriate requirements. After reviewing and identifying the language, steps may be taken to clarify and revise the label language.