Chapter 1. Executive Summary. cornell.app.box.com/v/2020-neonicitinoid-report

Insecticides are effective tools for controlling pests and therefore provide aesthetic, economic, agricultural, or conservation benefits to farmers, land managers, and other stakeholders. For some insect pests, chemical insecticides are currently the only practical, economical means of control. At the same time, insecticides can harm non-target organisms. This includes pollinators, some of which are currently experiencing range contractions and population declines. The scientific consensus is that, along with loss of habitat, climate change, parasites/disease, and inadequate management practices, insecticidesand other pesticides are contributing to pollinator declines.

Since neonicotinoid insecticides first became commercially available in the early 1990s, they have become the most widely used class of insecticides in the world. Neonicotinoids are used as foliar sprays, soil drenches, trunk injections, and applied as seed coatings before planting. As with any pest management product or practice, the use of neonicotinoids has both benefits and risks. They are highly effective at controlling many types of insect pests and exhibit relatively low toxicity to humans, including pesticide applicators. All neonicotinoids are systemic, meaning they absorb into plant tissues and spread throughout the plant, providing continuous protection for a length of time. On the other hand, neonicotinoids can persist in the environment, accumulate in pollen and nectar, and are highly toxic to many non-target organisms, including insect pollinators.

In August 2018, with funding provided through the Environmental Protection Fund to research potential adverse impacts of pesticides, such as neonicotinoids, Cornell began developing a risk-benefit analysis of neonicotinoid insecticide usage in New York State with the following three goals: 1) Estimate the pest control and plant protection benefits of neonicotinoid insecticides under current usage in New York, 2) Estimate the risk from neonicotinoids to pollinators, and 3) Evaluate the relative benefits and risks of likely neonicotinoid substitutes (i.e., other insecticides or pest control strategies) compared to neonicotinoids. This report summarizes the research undertaken to address those goals.

As the scope of this report is limited to direct economic benefits to users and risk to pollinators, it is intended to complement existing studies and risk assessments, particularly the comprehensive reviews of neonicotinoid active ingredients conducted by the U.S. Environmental Protection Agency (USEPA) and New York State Department of Environmental Conservation (NYSDEC). At the same time, this risk assessment is unique in that it summarizes new analyses and quantifies benefits to users and risk to pollinators in a side-by-side manner for five major application contexts: field crops (corn, soybean, wheat), fruit crops (e.g., apple, strawberry, blueberry), vegetable crops (e.g., squash, pumpkin); ornamentals, turf, & landscape management (e.g., golf courses, ornamental plant nurseries), and conservation & forestry.

While this risk assessment is intended to support evidence-based decisions, we make no recommendations or policy prescriptions. Instead, this document aims to clarify the trade-offs between benefits to users and risk to pollinators that may be inherent to policy decisions or regulatory actions regarding neonicotinoid insecticides.

Value of neonicotinoids in New York State

Neonicotinoid products used outdoors1 in New York contain the active ingredients acetamiprid, clothianidin, dinotefuran, imidacloprid, or thiamethoxam. These active ingredients are available in many formulations and labelled for use against numerous agricultural and landscape/ornamental pests, including aphids, adelgids, leafhoppers, flies, whiteflies, borers, leaf-feeding beetles, and white grubs. Neonicotinoids are also widely used for managing invasive forest pests such as hemlock woolly adelgid, emerald ash borer, and Asian longhorned beetle.

1 Though not addressed in this report, neonicotinoids are also used in some veterinary (e.g., flea treatments) and household (e.g., control of bed bugs) applications.

While alternative insecticides or pest control strategies exist for nearly all relevant target pests, switching from neonicotinoids usually entails a direct or indirect cost to users. Farmers and pesticide applicators choose products with care. When they use a neonicotinoid insecticide, it is typically because that product is the best option when considering price, efficacy, safety, insecticide rotation pattern, and other factors. The value of a neonicotinoid to users is the expected increase in benefits from using the neonicotinoid product instead of the best available non-neonicotinoid pest control product or technique. Many neonicotinoid-based products have important advantages that are difficult to quantify with existing data (e.g., safety for pesticide applicators, or the "insurance value" of preventive products that protect against unpredictable pests).

To assess the direct economic value of neonicotinoid insecticides for users, this report draws on data from over 5,000 paired field trials that compare the performance of a neonicotinoid-based insecticide to that of a chemical or non-chemical alternative. For many applications, the data show that neonicotinoids consistently increase net income, reduce crop damage, or provide superior pest control compared to likely substitutes. For other applications, the benefit to New York users is small or ambiguous.

For many New York fruit and vegetable crops, soil- and foliar-applied neonicotinoid products provide consistent benefits for farmers and are important components of insecticide rotations. For a handful of important pests, such as root-form phylloxera (grape), root weevils (berries), boxwood leafminer (ornamentals), and thrips and Swede midge (cabbage), there are few or no effective chemical alternatives available in New York. In cases where there are effective alternatives, they may be more expensive, require greater safety protection for applicators, or need to be applied more frequently. Even if there are effective, affordable substitutes for neonicotinoid products, farmers benefit from access to insecticides with diverse modes of action. The removal of any one insecticide from a rotation increases the risk of developing insecticide-resistant pest populations and increasing long-term pest management costs to farmers. In some foliar applications, products based on the neonicotinoid acetamiprid, which has relatively low toxicity to beneficial insects including pollinators, can be an effective alternative to those based on the nitroguanidine neonicotinoids imidacloprid and thiamethoxam.

In contrast to neonicotinoid applications in fruit and vegetable crops, routine use of neonicotinoid-treated seeds does not consistently increase net income for New York field corn or soybean producers. Treated seeds are commonly used as a preventative measure rather than in response to site-specific risk from pests. While seed treatments benefit farmers when there is high early-season pest pressure, these benefits are limited to a small proportion of fields. Specifically, 87-93% of field trials find no increase (or a decrease) in corn yield compared to chemical alternatives or untreated controls when neonicotinoid-treated seeds are used in corn fields within the state, region, or North America. Even when compared to plots using no insecticides, 89% of field trials observe no increase in corn yield when neonicotinoid-treated seeds are used. Similarly, 82-89% of field trials find no increase (or a decrease) in soybean yield compared to chemical alternatives or untreated controls when neonicotinoid-treated seeds are used in soybean fields within the state, region, or North America. Nevertheless, neonicotinoid-treated seeds are used by nearly all conventional field corn farmers and, likely, the majority of soybean producers in New York. In part, this is due to the insurance value of neonicotinoid-treated seeds. Even if routine use of neonicotinoid-treated seeds does not increase expected net income, such preventative pest control products protect growers against unpredictable, potentially severe, losses from early season pests. Incentives and policies to reduce usage of neonicotinoid-treated seeds may benefit from recognizing their value as inexpensive crop insurance as well as a pest management tool.

Risk of neonicotinoids to pollinators in New York State

Neonicotinoid insecticides potentially pose a risk to pollinators due to their high toxicity, systemic activity in plants (i.e., they spread throughout the entire plant, contaminating pollen and nectar, which are food sources for pollinators), and relatively lengthy persistence in the environment. A recent worldwide meta-analysis of in-hive pesticide residue studies found that, under current use patterns, five insecticides pose substantial risk to bees: thiamethoxam, phosmet, chlorpyrifos, imidacloprid, and clothianidin. Three of those five insecticides are neonicotinoids (thiamethoxam, imidacloprid, and clothianidin).2
However, this study and others suggest that risk to pollinators from neonicotinoid insecticides varies greatly with the conditions of their use. Thus, to assess when and where neonicotinoids pose substantial risk to bees, we conducted a systematic review of over 400 peer-reviewed studies, performed a quantitative risk assessment based on the literature review, and conducted new research with honey bees and bumble bees in New York to assess exposure and risk in multiple settings.

2Phosmet and chlorpyrifos are organophosphate insecticides.

The analysis shows that neonicotinoids can, but do not always, result in risk to bees in New York and elsewhere. The most comprehensive data come from field crops settings, particularly in and near corn and soybean fields. Data from ninety-six exposure assessments indicate that 74% of neonicotinoid exposures are likely to impact honey bee physiology, 58% of exposures are likely to impact honey bee behavior, and 37% of exposures are likely to impact honey bee reproduction.

Exposures were often found at over 100 times the concentration known to impact pollinators. Furthermore, exposures `in field crops settings occurred months and even years after neonicotinoids were used, indicating widespread contamination in and near corn and soybean fields. Particularly concerning is the ubiquity soils containing neonicotinoids at levels known to be toxic to pollinators. These contaminated soils pose a threat to ground-nesting bees, which comprise 54% of New York's 417 species of bees.

In addition to risk in field crops settings, the data indicate that neonicotinoids used on cucurbits and turf containing weedy flowers result in exposures that are likely to impact honey bee reproduction in 85% and 100% of cases, respectively. The USEPA has recently recognized the high risk of neonicotinoids in cucurbits, issuing a recommendation to prohibit use of imidacloprid-, clothianidin-, and thiamethoxam-based products on cucurbits between vining and harvest to protect pollinators. Our analysis extends this window before the vining stage, since applications before or during planting (i.e., treatments applied to soils before seeding or at the time of transplanting) result in exposures known to impact honey bee reproduction. In turfgrass settings, a simple and effective risk mitigation strategy exists: mowing turf before spray applications of imidacloprid is known to reduce concentrations in weedy flowers by 98%. In addition, use of the anthranilic diamide chlorantraniliprole as a substitute for imidacloprid results in much less risk to bees while providing similar control against important turfgrass pests.

Less comprehensive pollinator exposure data exists for other application contexts, limiting what can be inferred regarding risk from neonicotinoids in these contexts. This surprising knowledge gap is an important finding of this report. Specifically, aside from cucurbits, only four exposure assessments for pollinators (all from sunflower) have been conducted for other vegetable crops. Similarly, only eighteen exposure assessments have been conducted for ornamental plants, and only twenty-four exposure assessments exist for fruit crops. From these assessments, the data indicate that risk to bees can be high; 89% of neonicotinoid exposures in ornamentals are likely to impact honey bee physiology, 83% of exposures are likely to impact honey bee behavior, and 61% of exposures are likely to impact honey bee reproduction.3 The data from fruit crops also indicate that risk to bees can be high, but is lower than other application contexts; 50% of neonicotinoid exposures in fruit crops are likely to impact honey bee physiology, 38% of exposures are likely to impact honey bee behavior, and 17% of exposures are likely to impact honey bee reproduction. Additional studies focusing on neonicotinoid exposures to pollinators in vegetable crops, fruit crops, and ornamentals contexts would be helpful for understanding whether the limited data to date are representative of overall patterns.

Finally, it is important to emphasize that neonicotinoid usage does not always result in risk to pollinators, nor are neonicotinoids the only pesticides contributing to risk. For example, our own data from New York apple orchards and strawberry plantings during bloom shows that applications of acetamiprid result in the greatest insecticide exposures to bees in these crops. However, this neonicotinoid poses low risk to bees due to its low toxicity compared to the two nitroguanidine neonicotinoids (imidacloprid and thiamethoxam) and other non-neonicotinoid insecticides (e.g., chlorpyrifos and indoxacarb) that are currently used in New York fruit crops. In addition, risk to pollinators is likely negligible following trunk injections for invasive forest pests such as hemlock woolly adelgid, emerald ash borer, and Asian longhorned beetle, simply because pollinators are not likely to be exposed to neonicotinoids in those contexts. Thus, specific neonicotinoid active ingredient and application context are key considerations when evaluating risk from neonicotinoids and other pesticides to pollinators.

Relative benefits and risk of neonicotinoids compared to likely substitutes in New York State

Neonicotinoid insecticide applications in New York State have real benefits for insecticide users and real risks for insect pollinators. However, those benefits and risks vary greatly among common application contexts.

For some application contexts, the quantifiable benefits of neonicotinoids are minor or confined to a small number of users. Notably, neonicotinoid-treated corn and soybean seeds do not consistently increase expected net income compared to untreated seeds or pyrethroid insecticide alternatives.[4] At the

same time, widespread use of neonicotinoid-treated seeds incurs risks for insect pollinators. In studies of neonicotinoid exposures in field crops, 37-74% of known exposures are predicted to have adverse impacts on honey bee behavior, physiology, or reproduction. Because pyrethroids are not systemic in plants and are less environmentally persistent, these alternatives likely pose less risk to pollinators compared to neonicotinoid-treated seeds. In addition, the anthranilic

3 These summary values are only for ornamentals, while the summary values in Figures 6.6 & 6.7 also include turfgrass exposures.
4 There is stronger evidence of net income benefits for neonicotinoid-treated seeds in vegetable crops, and field crops growers do benefit from the insurance value of neonicotinoid-treated seeds.

diamides chlorantraniliprole and cyantraniliprole show promise as alternative systemic insecticide seed treatments for corn and soybean, respectively, though they are currently more expensive than neonicotinoids. Finally, a main reason why preventative seed treatments are used so extensively in field crops is due to the unpredictable nature of early-season pest outbreaks. Further work to improve the predictability of such outbreaks via degree-day modeling that includes site-specific characteristics, or to control early-season pests with non-synthetic chemical insecticides (e.g., biocontrols, biopesticides or RNA-based approaches), will increase the sustainability and security of field crops production in New York.

In other application contexts, a shift away from neonicotinoids will likely place a greater burden on farmers and pesticide applicators. As noted above, there are few or no effective chemical alternatives to neonicotinoids for several important agricultural pests (e.g., root-form phylloxera, root weevils, boxwood leafminer, Swede midge). Even when effective substitutes are available, the loss of neonicotinoids from insecticide rotations would be problematic for some New York crops. Long-term control of the Colorado potato beetle and other important pests may be difficult without access to insecticides with several different modes of action, including neonicotinoids. If treated repeatedly with a single class of insecticide, pest populations can develop resistance more rapidly. That said, chemical insecticides are not the only means of controlling the vast majority of agricultural and non-agricultural insect pests in New York. Integrated Pest Management (IPM) that includes pest monitoring, non-synthetic chemical insecticides, and new technologies that are rapidly emerging in the digital and precision agriculture fields, provide multiple tools for farmers and pesticide applicators to control insect pests.Again, greater development and adoption of these non-synthetic chemical pest control options will increase the sustainability and security of New York agriculture, while also reducing risk to non-target organisms in non-agricultural contexts such as turf/ornamentals and conservation/forestry.

For a few application contexts, restrictions on neonicotinoids could have negative environmental consequences. Most importantly, New York relies on neonicotinoid-based products to contain and control hemlock woolly adelgid. There are currently no effective, affordable alternatives for slowing progress of this pest, which kills almost 100% of infested trees. Hemlocks are the third most common tree in New York, and are an ecologically important foundation species, so ending control of hemlock woolly adelgid with neonicotinoids could have severe consequences for New York forests. Because pollinators are not known to interact extensively with wind-pollinated hemlocks, risk to pollinators is likely negligible following trunk injections with neonicotinoids in this context.

Overall, this report aims to summarize current knowledge regarding the direct economic benefits of neonicotinoid insecticides to users and risk to pollinators in New York. The report does not assess other environmental risks or indirect economic impacts associated with usage of neonicotinoid insecticides.We suggest a key contribution of the report is showing that benefits and risks of neonicotinoids vary based on numerous factors such as neonicotinoid type, crop or pest system, application method and timing, and landscape context. Furthermore, it is essential to consider risk from neonicotinoids in relation to their likely substitutes. No pest management product or technique is risk-free, and several likely alternatives to neonicotinoid products pose risks of their own. To this end, we make note
of contexts in which IPM approaches, non-synthetic chemical insecticides, and other pest control technologies are likely to be effective. A key recognition of this report is the need for continual, science- based, adaptive approaches to IPM through investment in research and extension of that research to farmers and other pesticide applicators in New York. With new technologies rapidly emerging in digital and precision agriculture, along with more biologically-based solutions, there is an ongoing need for pest control tools that are effective while also being environmentally sustainable. Farmers and other pesticide applicators will adopt environmentally sustainable solutions when such solutions are easy to use, relatively inexpensive, safe and effective.

As outlined above and throughout the report, while this risk assessment is intended to support evidence-based decisions, we make no recommendations or policy prescriptions. Finding the "best policy" or "best policies" for neonicotinoid insecticides in New York will require thoughtful choices between competing priorities.