June 6, 2019

Written testimony prepared by Christian Krupke, Ph.D, regarding N.J. Senate Bill 2288
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BIOGRAPHICAL INFORMATION

I am a professor in the Dept of Entomology at Purdue University. I completed my doctoral degree in entomology at Washington State University in 2004, and since 2005 have worked at Purdue with responsibilities in field crops (i.e. corn, soybeans, wheat and other small grains) insect pest management, where I lead active research and extension programs. I also teach a graduate level course in Integrated Pest Management (IPM). My research has focused upon elucidating the strengths and weaknesses of the primary pest management approaches used in corn and soybeans with special focus upon Bt corn and neonicotinoid seed treatments of corn and soybeans. I have published over 50 peer-reviewed manuscripts and given dozens of talks on these subjects to fellow researchers, members of USDA, EPA, USFWS, and a range of stakeholder groups including growers of these commodities, beekeepers, and various conservation organizations.

SUMMARY AND CONCLUSIONS

Neonicotinoids are the major class of insecticides used throughout North America; much of their use is as seed treatments for a range of field crops, including corn and soybeans. Usually applied as seed treatments, they offer a relatively brief, 2-3 week window of protection from certain insect pests. However, an increasing body of research demonstrates that some of the same properties that make neonicotinoids well-suited as seed treatments (highly soluble in water, persistent in soil), cause a range of non-target effects beyond the planted field, often persisting long after the cropping season has ended. These include: lethal and sub-lethal impacts upon managed and wild pollinators and other beneficial insects, contamination of non-crop plants and their pollen and nectar, and widespread contamination of waterways, including effects upon aquatic insects and the animals that depend upon them as a food source. Conversely, the beneficial effects (i.e., pest management and yield protection) of these approaches are either absent or inconsistently observed in independent, peer-reviewed research; this is likely primarily because the target pests are uncommon and even more rarely occur at economically-damaging levels. The resulting situation is one where neonicotinoid use rates far outpace their demonstrable benefit. However, even as concerns about non-target effects have mounted, use rates continue to climb without any documented pest threat or other justification. This is because growers are typically not offered access to seed without neonicotinoids and have relatively few vendors offering elite varieties and hybrids.

NEONICOTINOID SEED TREATMENT USE IN CORN AND SOYBEANS

Neonicotinoids have become the most widely used insecticide class in the world.[1,2] This has occurred largely due to their proliferation in many of the largest-acreage crops grown worldwide, particularly in North America where they are used on virtually all major oilseed and grain crops. Their main use is as a prophylactic neonicotinoid seed treatment (hereafter, NST). Neonicotinoids are nerve toxins that target the nicotinic acetylcholine receptor in insects, high doses cause paralysis and death. The neonicotinoids clothianidin (CLO) and thiamethoxam (TMX) are commonly coated onto crop seeds. Both CLO and TMX are highly water soluble; this is part of the reasoning behind their use as seed treatments – placed on the surface of the seed, NSTs enter the seed with water as the seed imbibes water, germinates and begins to grow. By 2011, US adoption rates exceeded 80% in corn,[3] and although more recent data are unavailable, given the trends at that time, this percentage is likely to have increased. Much of the total annual use of both thiamethoxam (TMX), and its breakdown product clothianidin (CLO), is in the form of NSTs in US corn production, where they are applied at rates of 0.25-1.25 mg of compound/kernel prior to being sold to the grower. In soybeans, foliar applications of CLO are an option, but seldom used, and the vast majority of active ingredient is applied as NSTs. Notably, there has been a trend of increasing per kernel rates of the neonicotinoid active ingredient, resulting in an overall increase of active ingredient per hectare.[4] Whereas the default, lowest rates for NSTs in corn were formerly 0.25 mg/kernel, this rate has been largely supplanted by rates of ≥ 0.5 mg/kernel; this change explains rising NST rates across the landscape, shown graphically below in **Figure 1**.

ENVIRONMENTAL IMPACTS OF NEONICOTINOID SEED TREATMENTS

Despite initial claims to the contrary, there are significant risks of non-target exposure associated with planting seeds treated with neonicotinoids. These occur both during planting and long after the seeds have germinated.

Planter dust, resulting from routine planting activities rubbing the coating off of seeds, accounts for a loss of up to 12.6% of active ingredient in corn. This dust is often dispersed over a wide area by the air/exhaust systems of planting equipment and prevailing winds.[5] Furthermore, the translocation efficiency (i.e., the amount that actually enters the target plant) is reported at <1.5% of the applied active ingredient in the field.[6] Young seedlings of both corn and soybeans exhibit high concentrations of NSTs in their tissues, although these levels drop off substantially within 2-3 weeks after planting, and soon after that, the plant tissues are not significantly different from those of plants grown from untreated seeds. [7,8] The remainder of neonicotinoid active ingredient applied to the seeds remains largely unaccounted for, although it is likely to be partitioned between ground and surface waters and the soil.

The inability to readily purchase NST free seed,[3,9] leads to a continual and repeated dose of neonicotinoids entering in the soil year after year, which in turns raises concerns regarding the potential of NSTs to contribute to environmental loading and water contamination via leaching and field runoff.[10] The Groundwater Ubiquity Score (GUS) reported by the Pesticide Properties Database,[11] while not the only metric used in leaching risk assessments, places CLO and TMX at a high leaching risk,[12] and there is increasing evidence of environmental loading, with increasing reports of detections of neonicotinoids in a range of surface and ground waters. Contamination has been suggested as a direct result of runoff and/or leaching, coupled with the long (typically several years) half-life of these compounds in soils, [12-16]and recorded concentrations have exceeded either acute or chronic freshwater invertebrate toxicity benchmarks.[17] Non-target environmental impacts of neonicotinoids in aquatic systems have been the subject of increased research effort only relatively recently. Several correlative studies have linked declines in aquatic macroinvertebrates and birds to neonicotinoids in the environment.[18-20] Regarding birds, the authors proposed this decrease is a result of neonicotinoid contamination of waterways resulting in the loss of insect food sources (which have part of their life cycle in water) for the birds.

Most of the work investigating non-target effects of neonicotinoids has focused upon pollinators. Honey bees are of particular interest, and both CLO and TMX are toxic to honeybees at extremely low concentrations, via both oral and contact exposure routes. Honey bees are, by far, our most economically important pollinator and the easiest species to work with in terms of experimental design. In honey bees alone, the work documenting the effects of neonicotinoids encompasses dozens of manuscripts and cannot be covered thoroughly in this document. However, some trends have emerged, and they are summarized here. **While honey bees, and pollinators generally, have little reason to encounter corn and soybean fields before and during planting, there are several documented routes for intersection between NSTs and honey bees.[21]** These are summarized below in **Figure 2** and can be subdivided into two main sub-categories: 1) acute exposures, which are typically short (minutes or hours) in duration, include high concentrations, and may be lethal; and 2) chronic exposures, which occur over a longer period of time (days to months) and include exposures to sub-lethal concentrations of neonicotinoids. The latter are more difficult to document, both because it is difficult to follow bees and colonies through time and because the effects are often subtle, and include behavioral effects such as impaired navigation or reduced foraging.[21]

Acute exposures occur most commonly during the sowing of treated seeds, particularly corn. Most North American planters are pneumatic, or air planters, and this means that planter exhaust containing neonicotinoid seed dust, along with contaminated soil are disturbed during planting and often move up and away from the planted field. An analysis of this exposure route that documented residues landing in areas surrounding fields in Indiana estimated that over 90% of foraging honey bees in that state would be exposed to these residues, including at lethal levels; this is borne out by observations of dead bees at apiaries during corn planting, with subsequent analyses revealing lethal levels of neonicotinoids used only in NSTs on dead and dying bees.[4]

After the cropping season, neonicotinoids persist in soil. A recent review of the available data suggested that accumulation plateaus after 2–6 years of repeated application.[22] **The annual sowing of neonicotinoid-treated seed results in chronic levels of neonicotinoid soil contamination in the range of 3.5–13.3 ng/g for CLO and 0.4–4.0 ng/g for TMX. This acts as a constant source of exposure for sensitive soil organisms, such as earthworms, and as a source for uptake, with groundwater, by plants growing in these soils in subsequent seasons.** Organisms living in the soil are difficult to observe and study, so data on the long-term effects of NSTs on them are relatively scarce. We now know that NSTs in soil are taken up by non-target plants, and many studies have found them in pollen, nectar, and foliage of non-crop plants surrounding agricultural areas.[Reviewed in 21-23] Although bees collecting pollen from plants grown using NSTs may receive the highest neonicotinoid concentrations, exposures can be expected from pollen and nectar of wild or weedy plants as well.

EFFICACY AND UTILITY OF NEONICOTINOID SEED TREATMENTS

Although insects are a perennial consideration for producers of many crops, both corn and soybeans across the Midwestern US benefit from systems where insect outbreaks are relatively rare. In corn, classical plant breeding and improved plant genetics are estimated to account for at least 50% of yield gains since the 1930's through 2005.[24] Beginning in 1996, insecticidal toxins originating with the bacterium *Bacillus thuringiensis* (i.e., Bt corn*)* were introduced into corn for control of a key pest, the European corn borer. This has been an example of effective pest management of a key pest for over two decades.[25] The year 2004 represents another key milestone in corn insect pest management, as a Bt toxin targeting the other key pest of corn, the corn rootworm complex, was first deployed on a wide scale in the US.[25] That same year saw the initial deployment of neonicotinoid insecticides on corn seed.

Ever since that time, Bt corn and NSTs are deployed together, making assessing the current contributions of NSTs to yield difficult. Growers of corn are effectively locked into a pest management approach that they cannot assess, no on-farm research or cost/benefit analysis can readily be performed. This is a relatively new, but problematic conundrum for modern agriculture and runs contrary to Integrated Pest Management (IPM) principles, which emphasize that pesticides be used only when insects are present at potentially damaging levels. The vast majority of corn and soybean acreage where NSTs are used is unlikely to meet that criterion. This was highlighted in a recent review that pointed out the disconnect between this widespread approach and long-established IPM principles.[26] Bt corn hybrids are the cornerstone of corn insect pest management, and according to a recent publication by USDA scientists, most of the secondary pests targeted by NSTs (i.e., those not covered by Bt corn hybrids) are uncommon, and when they do occur, rarely exceed economic thresholds.[27] A similar study in soybeans showed similar trends.[28] **The inefficiency of NSTs as a soybean pest management approach was demonstrated by a recent multi-year, seven state field study across the Midwest that demonstrated that producers would benefit little from NSTs for management of the primary pest, the soybean aphid, and were more likely to achieve reliable pest management using IPM principles and established thresholds (i.e. apply foliar insecticide sprays only when pests were present at economically damaging levels).**

The majority of independent and peer-reviewed data demonstrate that, while NSTs are used prophylactically in the vast majority of corn and soybean systems, this approach is not justified by pest populations or economic thresholds. Discussions of any change to the status quo in terms of NST use invariably moves to questions about “replacements” for these tools, in the event they are restricted or their use curtailed in any way. This assumes that NSTs are necessary, and that without them some loss would be incurred. Across the majority of the region where corn and soybeans are grown, this is a baseless argument. **While there is no question that some pesticides are a necessary tool in modern**

agriculture, available data suggest that in most cases, no replacement would be necessary to ensure production of corn and soybean crops if NSTs were eliminated. Bt corn remains an effective tool for key pests that comprise the main threats to yield. Soil insecticides, both granular and liquid formulations, are as effective as NSTs and more readily turned "on and off" for specific fields at planting time.[29] In short, the current approach of NSTs on every corn acre and most soybean acres, every year, is not justified by either current or historical pest trends.[27,28]

Respectfully,

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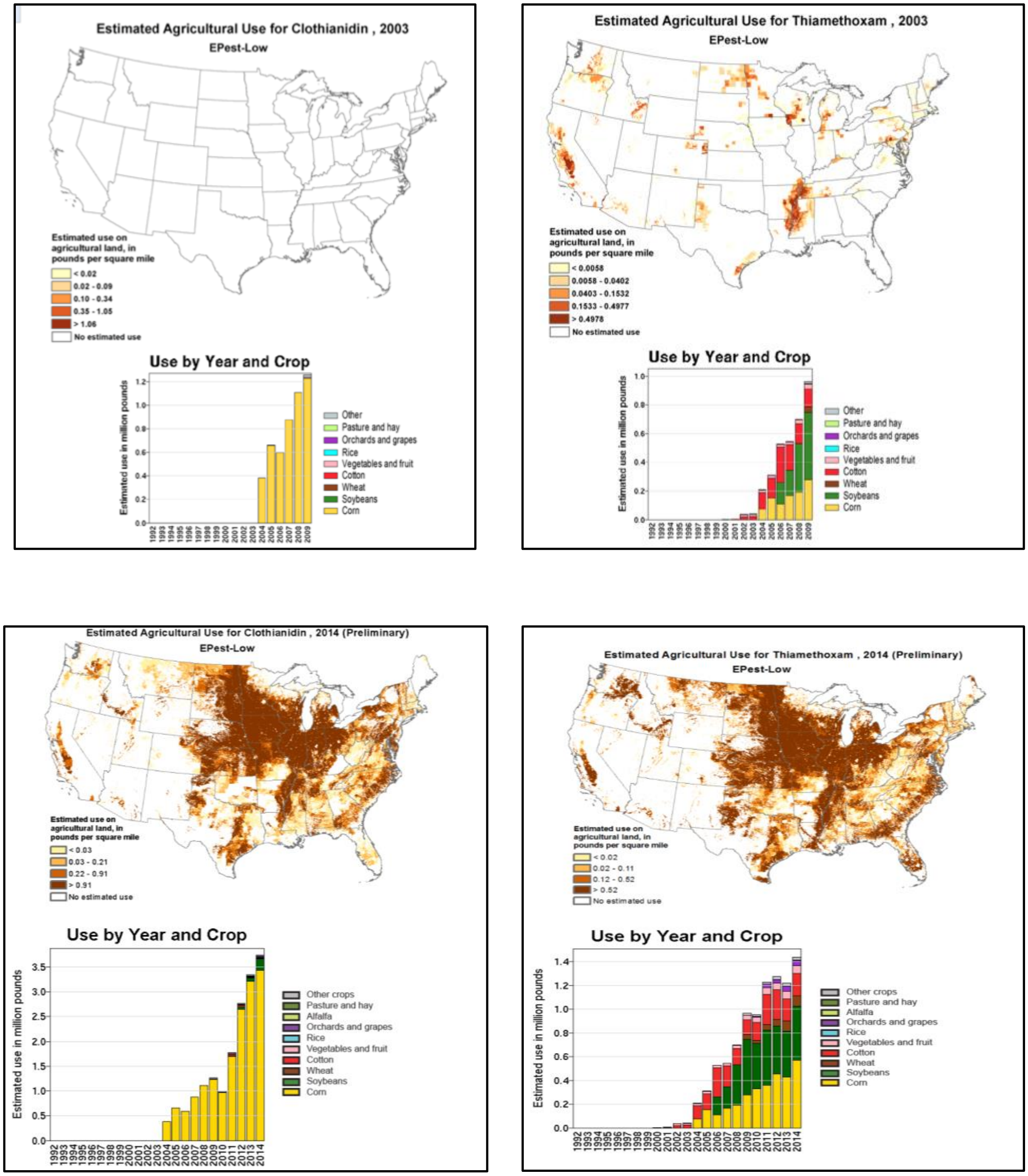

Figure 1. Estimated agricultural use of clothianidin and thiamethoxam, by year and by crop. The top panels show data from 2003, the lower panels show 2014 data. The USGS no longer estimates agricultural use for these compounds, so updated data are unavailable. Source: USGS National Water Quality Assessment Project, Pesticide National Synthesis Project. Available at https://water.usgs.gov/nawqa/pnsp/usage/maps/compound_listing.php.

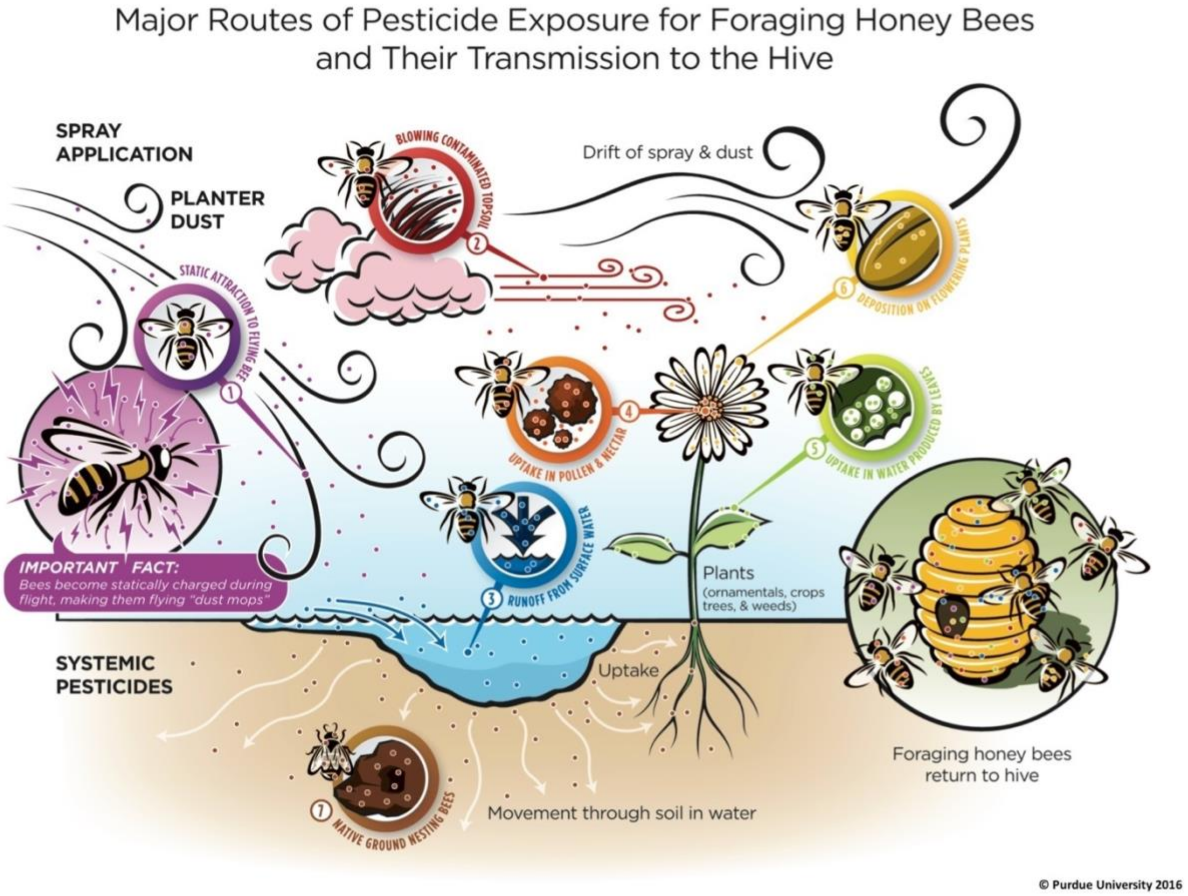

Figure 2. Summary of exposure routes for foraging honey bees and pesticides, including NSTs. Source: Purdue University Extension: "The Complex Life of the Honey Bee: Environmental, Biological, and Chemical Challenges to Colony Health" May 2017. Available at: https://mdc.itap.purdue.edu/item.asp?Item_Number=PPP-116.

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