INSTITUTE FOR AGRICULTURE AND TRADE POLICY

Unknown Benefits, Hidden Costs

Neonicotinoid Seed Coatings, Crop Yields and Pollinators

By Jim Kleinschmit and Ben Lilliston

Institute for Agriculture and Trade Policy

August 2015

Unknown Benefits, Hidden Costs: Neonicotinoid Seed Coatings, Crop Yields and Pollinators

By Jim Kleinschmit and Ben Lilliston

Published August 2015

The Institute for Agriculture and Trade Policy works locally and globally
at the intersection of policy and practice to ensure fair and sustainable food, farm and trade systems.

More at iatp.org

There is a growing body of science directly implicating neonicotinoid (neonic) pesticides in the significant decline of bees and other pollinators.[1] Neonicotinoids are applied in multiple ways in many parts of agriculture and horticulture, but are most prevalent as a seed coating material for agricultural commodity crops like corn and soybeans. Based on convincing and mounting evidence and data, beekeepers, scientists and other individuals concerned about pollinators are working together to spur regulatory action and shifts in the marketplace to reduce the use of neonicotinoids.

In May 2015, the White House issued an interagency report entititled "National Strategy to Promote the Health of Honey Bees and other Pollinators."[2] The strategy focuses on efforts to restore honey bee loss, increase monarch butterfly populations and restore pollinator habitats. But, the White House plan virtually ignores the on-the-ground farm economics that directly contribute to rising neonic use in seed coating–specifically the role of a few large companies that have a stranglehold on the seed market. The concentrated market power in the seed industry has allowed a few multi-billion dollar companies to significantly limit U.S. farmers' choice around seed coating.

This lack of choice—in most cases, the seed is coated with neonicotinoids whether wanted or not—in turn has made it difficult for farmers and their advisors to assess the actual value of these pesticides in crop production, or to understand their true financial and environmental costs. Most farmers understand the value of pollinators to plant growth and the food system and would not intentionally harm them. However, without credible information on the risks or the freedom to choose their seed coating, farmers are left with little choice but to accept what their seed company delivers.

Fortunately, there are some independent seed companies and dealers willing to provide farmers with information and choice around seed coatings. Representing a small segment of a highly consolidated industry, independent seed producers and dealers are able and willing to respond to market changes and farmer preferences associated with not only neonicotinoids, but also other areas of market interest, such as non-genetically modified organisms (GMOs), cover and specialty crops. But a farmer's ability to choose what kind of seed coatings they want to utilize as part of their crop management system should be the rule, not the exception, in farming and the seed market.

One of the most basic and necessary aspects of a free market is available and accurate information about products and their efficacy, cost and benefits. It should go without saying, then, that in a competitive marketplace, farmers should receive accurate, up-to-date information from researchers and other farmers at field days about the actual costs and benefits of neonicotinoids and other seed coatings related to both crop production and the environment, including pollinators. Yet this isn't happening with neonicotinoids or other seed coating ingredients today. With such a clear market failure, it appears farmers—together with research partners and farm organizations—need resources to take this matter into their own hands. We need credible, farmer-led field trials that compare different seed coatings and traits, and that information should be shared with other farmers. Only with complete information and choice—about neonicotinoids, but also other crop management tools—can farmers make smart choices that allow them to produce crops and take care of pollinators and the environment.

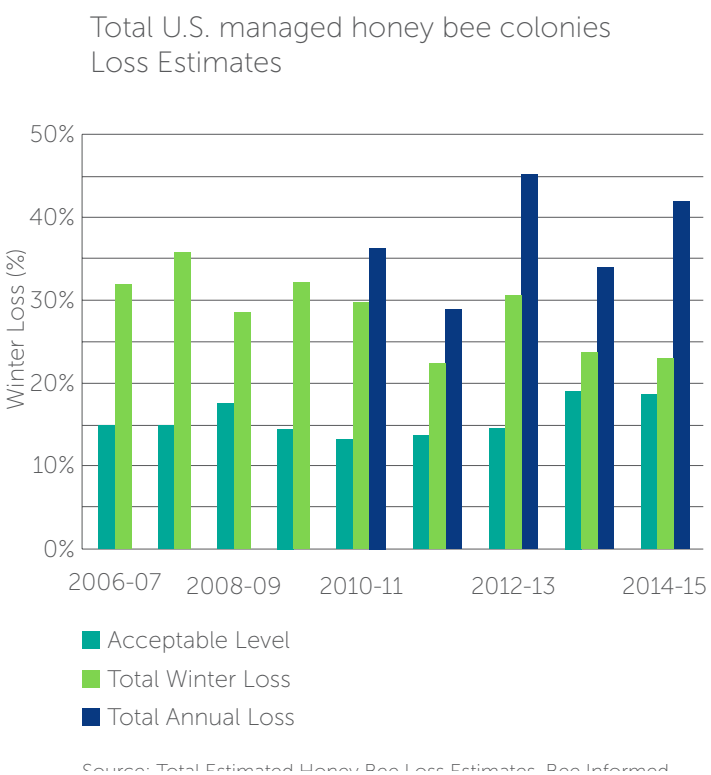
Neonicotinoids and Pollinator Decline: Clear Connections

Pollinators are essential to the environment and our food supply. Nearly one out of every three bites of food relies on pollination from honey bees. Beyond the many crops that are almost entirely pollinator-dependent, pollinators also have been shown to boost yield and quality in less dependent crops, providing clear economic benefits to almost all farmers.[3] Most people know that honey and wild bees are pollinators, but there are many others, including butterflies, moths, beetles, flies, bats and hummingbirds. They carry seeds and pollen between plants, facilitating plant reproduction. Without them, we would lose much of our food supply, put wildlife food and habitat at risk, and compromise plants that stabilize soils against erosion and buffer waterways.

Pollinator decline has been found on every continent in the world, and hundreds of pollinator species are on the verge of extinction. Since 2006, bees in the U.S. have been dying off or seemingly abandoning their hives—a phenomenon known as Colony Collapse Disorder.[4]

While there are many contributors to pollinator decline, two of the most important are the loss of habitat and the introduction and expansion of use of new pesticides on agricultural cropland. A specific concern centers on neonicotinoids, a relatively new class of systemic insecticides,often applied as a seed coating in commodity agriculture.

Neonicotinoids are used to control a wide variety of insects. The first neonicotinoid, *imidacloprid* (Admire), became available in the United States in 1994 and is currently present in over 400 products on the market. Other neonic insecticides include *acetamiprid*, *clothianidin*, *dinotefuran*, *nitenpyram*, *thiocloprid*, and *thiamethoxam*. In 2006, neonicotinoids accounted for over 17 percent of the global insecticide market.[5] Two of them—*clothianidin* and *thiamethoxam*—dominate the global



market for insecticidal seed treatments and are used to coat the seeds of most of the annual crops planted around the world. In fact, more than 94 percent of the corn and more than 30 percent of the soy planted in the United States is pretreated with neonicotinoids.[6]

When first introduced, neonicotinoids were touted as an improvement over other organophosphate pesticides because they didn't need to be sprayed in the same way. Now, two decades into their expanded use, the evidence is increasingly clear that this class of pesticides is particularly harmful to bees and other pollinators.[7,8] Neonicotinoids are water soluble and systemic, meaning they travel through a plant's vascular system when applied and are transported throughout all parts of the plant, including leaves, stems, flowers, fruit, pollen and nectar. Their systemic nature and persistence was the initial selling point, as it reduced exposure to humans and others, but it turns out it creates multiple avenues for pollinators to be exposed, from feeding on pollen and nectar to drinking water with neonic residues in it or even walking on the leaves of treated plants. As the name suggest, neonicotinoids are similar in structure to nicotine and paralyze or disorient insects by blocking a pathway that transmits nerve impulses in the insect's central nervous system.

For pollinators, their exposure to neonicotinoids is primarily when they get pollen or nectar from a plant that has been seed coated with neonicotinoids (there is also the potential for pollinators to ingest neonicotinoids from the guttation droplets – small drops of liquid exuded by some plants). That pollen then gets passed onto other plants, or taken to the hive in the case of bees, where it can impact other pollinators. Although thought to be less harmful to birds and mammals than many other insecticides, neonicotinoids are incredibly toxic to bees and other insects.[9] They are harmful to bumble bees by reducing the number of new queens for the hive, impairing foraging ability and reducing reproductive capacity, according to the Xerces Society for Invertebrate Conservation. Recent research shows that seed coatings can negatively impact wild bees.[10] In addition, the pharmacological action associated with neonicotinoids, like nicotine, continually draws bees to it, as found by another new study published in *Nature*.[11] Chronic exposure is likely to occur when pollinators are foraging in agricultural settings where almost all crops have been treated with neonicotinoids in some form.

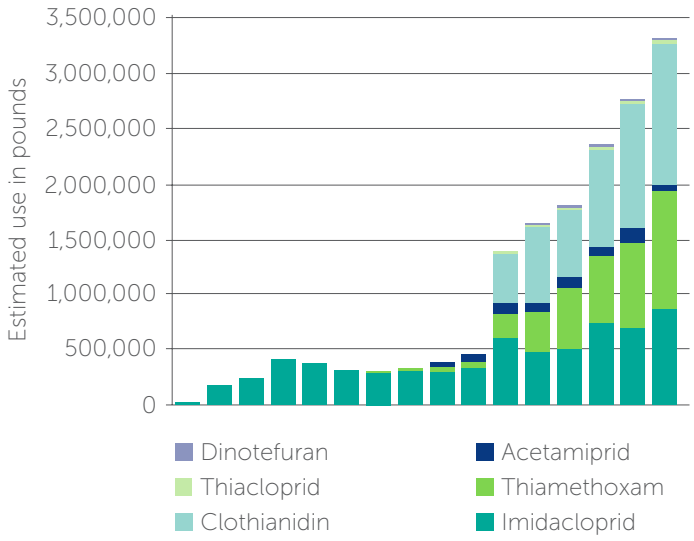
Death is not the only outcome of pesticide exposure. Sublethal doses of neonicotinoids can disrupt pollinators' cognitive abilities, communication and physiology. Neonicotinoids also have harmful synergistic impacts on pollinators in combination with other chemicals in the field, compounding their effects. Scientists have shown in multiple studies that the combined presence of neonicotinoids and some fungicides can increase the potency of neonicotinoids by more than 1,000-fold.[12]

In addition to their toxicity, neonicotinoids persist in plants much longer than most other insecticides, thereby compounding their impact on pollinators. They can reside in plant tissues for over a year, and some can persist for even longer in the soil. This means pollinators and other animals are exposed to the chemicals for extended periods of time and in some regions year round.

Seed treatment applications are prophylactic, meaning they are used whether or not there is any evidence of pest pressures. At least 30 percent of soybean seeds planted annually (approximately 22.5 million out of 75 million acres) are pretreated with neonic insecticides (two of the primary four being imidacloprid and thiamethoxam).[13] But corn has the highest use and acreage with around 94 percent of U.S. corn treated with a neonicotinoid.[14] That widespread use has quickly elevated the Midwest to the highest levels of neonicotinoid use in the country. These neonicotinoids don't stay in the plants and soil however, but find their ways into the water as well. A recent U.S. Geological Survey report confirmed this, finding neonicotinoids were common in streams throughout the Midwest.[15]

Research from Purdue University has found high levels of neonicotinoids clothianidin and thiamethoxam in dust from planters of neonic-treated corn, showing some of the coatings

Total pounds of neonicotinoid insecticides used in agriculture, 1994–2009[13]



can come off in the planting process. Not surprisingly, neonicotinoids were found in the soil in fields that were planted, but more worryingly also in fields that weren't planted. Plants like dandelions in neighboring fields also contained neonicotinoids in their pollen. Neonic-laced pollen from the corn and the neighboring dandelions was returned to the bee hive, where the neonicotinoids were transferred to the hive.[16] The spreading of neonic-laden dust is well recognized even by neonic manufacturers. Recently the world's biggest neonic-maker, Bayer, introduced a new lubricant called a Fluency Agent, to reduce friction in the planter and in an effort to decrease neonic seed dust while planting.[17] However, while the Fluency Agent reduces the dust emitted by planters by up to 67 percent, it only appears to decrease emissions of neonic active ingredients by 28 percent, which means there is definitely less dust coming out with the Fluency Agent, but it has higher concentrations of neonicotinoids.[18]

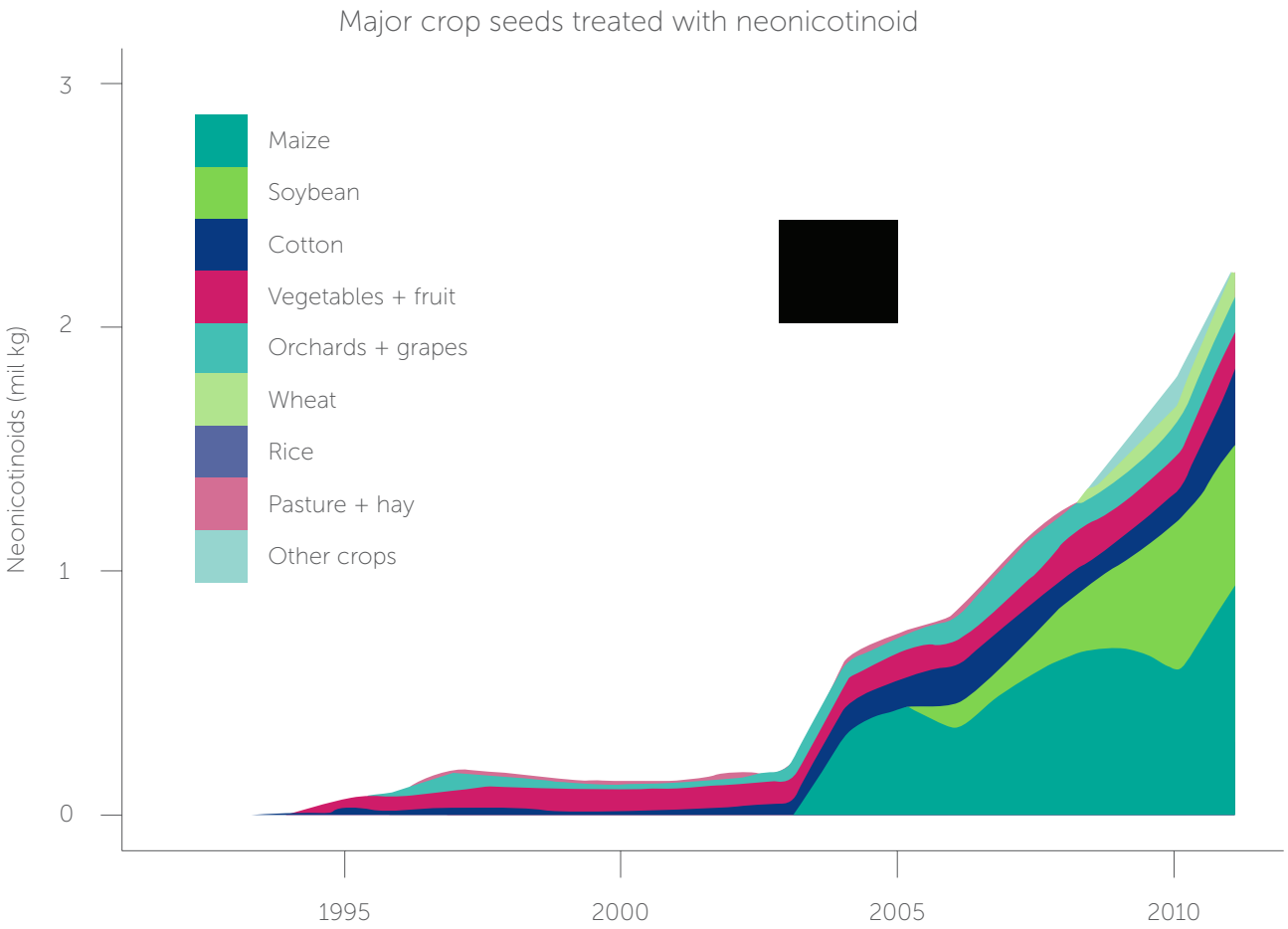
Neonicotinoids and Crop Production: Unclear Benefits, Costs and Choice

Most U.S. farmers who grow commodity crops purchase their seed through a local seed dealer. The seed dealer is usually someone from the community who has relationships with one or more specific seed companies. As seed dealer, they are both salesman and advisor—doing their best to help farmers pick the right seeds for their preferred crop, soils and conditions.

Far and away, the most widely deployed use of neonicotinoids is as a seed coating. Within a typical corn or soybean seed coating may be many different "ingredients," including fertilizer, growth promoters, insecticides, fungicides and polymers, all intended to protect the seed when in the ground and during the plant's early life. Seeds can be coated for precision placement of insecticide near the young, growing roots of a just-emerged plant. This is a period when plant root systems are at greatest risk for root feeding damage. As the neoniccoating dissolves, the chemical kills nearby insects that might otherwise damage roots, and it is also absorbed into the roots as they grow and spread. As the plant grows, the insecticide travels inside the plant and becomes part of its tissues, where it provides protection from insects.

Considering the variety of ingredients and marketed benefits associated with the different seed coating ingredients, including neonicotinoids, there is no question that these are significant crop management tools. One would then expect that farmers would get to decide which ingredients they want and don't want, based on their specific field and crop needs. Unfortunately, that is not the case with most of the U.S. seed industry. Currently, most U.S. commodity crops (corn, soy, wheat, rice and cotton) come with a combination of ingredients determined by the seed company, not farmers. And almost all of these seed coatings include neonicotinoids.

Despite their widespread use, there is surprisingly little field trial research available on the efficacy of neonicotinoids in providing yield benefits. A series of recent reports are actually pointing in the other direction, with evidence that indicates that neonicotinoids are of dubious value to farmers and in fact, under certain circumstances, may even inhibit yield. A review of 19 studies in scientific journals looked at how neonic treatments affect yields of major U.S. crops: corn, soybeans, canola, dry beans, and wheat. The review by the Center for Food Safety (CFS) found that in most studies, neonic treatments did not increase yield. This was particularly the case when there was only moderate or low pest pressure, which is the reality on the majority of crop acres. European reports of crop yields before and after neonic bans were in place additionally show no discernable difference, further confirming the lack of measurable yield benefits.[19]



Source: Douglas, Margaret R. and John F. Tooker. "Large-Scale Deployment of Seed Treatments Has Driven Rapid Increase in Use of Neonicotinoid Insecticides and Preemptive Pest Management in U.S. Field Crops." *Environmental Science & Technology*, March 20, 2015, http://pubs.acs.org/doi/abs/10.1021/es506141g (accessed July 23, 2015).

In October 2014, the Environmental Protection Agency published a study analyzing the effectiveness of neonicotinoids for soybean production. The conclusion mirrored the analysis by CFS, indicating that neonic seed treatments provide little or no benefit for soybean production in almost all cases.[20] Dr. Christian Krupke, of Purdue University has done extensive research of neonicotinoids in the field.

> We have not demonstrated a consistent yield benefit of neonicotinoid seed treatments in either case (corn or soybeans), over many sites and many years. This is not because the products are not toxic; it is because insect pressure at the time that neonicotinoids are active (a brief window extending only a few weeks after planting) is either absent, or too high for neonicotinoids to effectively reduce pest damage. Because there are no demonstrable benefits in the vast majority of fields/years we have surveyed, it is apparent that seed treatments are dramatically overused in these crops.[21]

With questionable benefits for yield and unclear economic and environmental costs, why then have farmers widely adopted neonicotinoids? The answer lies not in agronomy, but in the market power of a few seed and pesticide companies. Monsanto and Syngenta, the undisputed leaders in patented genetically engineered seeds, also have close relationships with the leading global neonic producer, Bayer. The resulting "package deal" that exists around GMOs and neonicotinoids should not then be too surprising. Most new commodity crops are increasingly coming to farmers with stacked traits, which means more than one transgenic alteration. These genetically engineered and transplanted traits are marketed to farmers as providing benefits such as resistance to multiple herbicides, pests, funguses, heat and drought.

The introduction of neonicotinoids into the agricultural marketplace occurred around the same time as the introduction of GMO crops in the mid-to-late 1990s. The immediate pairing of herbicide and insect resistant GMO crops and

neonic seed coating treatments led to a prophylactic approach to crop production – where pesticides and herbicides were to be used regardless of actual field conditions or weed and pest pressure. This pre-emptive use of what used to be "tools of last resort" has understandably also led to a decline in the application of Integrated Pest Management (IPM) strategies. As opposed to the prophylactic approach, IPM starts from an assessment of the type and scale of the pest problem, and includes a bigger "toolbox" for dealing with problems beyond herbicides and insecticides (crop rotations, beneficial insects, etc.).[22]

While historically seed dealers sold seed from multiple companies, providing a level of competition, over the last few decades, there has been a consolidation in the industry, much like in other parts of agribusiness. Now most seed dealers have a relationship with only one or two seed companies at most. If a seed company only offers a variety with a seed coating package, as is generally the case, the seed dealer has no choice. Similarly, even when seed comes to the dealer untreated, if that seed company requires under licensing or other dealership agreements that their seeds be coated with certain products, including neonicotinoids, then the seed dealer has no option but to comply. Backing this up are often strong marketing relationships that provide incentives for seed dealers to use specific treatment products, which in turn encourage them to use these treatments on all seeds —whether or not a farmer requests such treatments or the treatment is expected to actually help with yield.

This lack of choice and information brings to mind new car sales before the internet. In those days, there were many "add ons" and dealer options—think rust proofing, paint and fabric protection, etc.—that car dealers would add to car prices and that sounded important for taking care of their car despite being of little to no value to the customer. Instead, the value was in the high profit center for the car dealer. Farmers, more than almost anyone, understand the value of pollinators and would not want to do them harm. But the link between pollinator decline and neonic-coated seeds is just beginning to be recognized in the farming community. For farmers that are aware of this emerging science and want to eliminate neonicotinoids from their farm, there are many challenges to finding good information on neonicotinoids or seed coating options.

After conversations with numerous seed dealers throughout the Midwest, it appears that it is nearly impossible to purchase most types of GMO corn without neonic seed coatings. In several conversations with seed dealers we were told that selling seed corn with certain genetically engineered traits without a neonic seed treatment is not allowed. More than one company told us that "Neonics have to be on traited [genetically engineered] seed corn. It's a requirement of the license." Non-treated soybeans are more available, but even when neonic-free coatings are available, most of the large seed companies do not promote this choice to their farmer customers. Since the cost of the coating is not broken out from the total seed bag price, it is unclear for farmers and others how much they are actually paying for this "protection" product which they didn't request and increasingly aren't sure will provide a benefit for their crop yield.

Choice is more apparent when talking with the remaining independent seed dealers and producers. Farmers who decide to grow new, traditional non-GMO or conventional hybrids have decidedly more options when it comes to seed coatings and neonics. With these independent companies, farmers are able to source seed with custom coating options that allow them to choose which products they want to help with their crop protection and production. As the non-GMO marketplace is one of the sectors where there is increasing awareness about the pollinator crisis, this could represent a double win for those farmers; their seed costs should be lower, while at the same time there is the possibility of a non-GMO premium. For organic farmers, neonic and other pesticide seed coatings are of course prohibited, so organic seed is one of the most obvious and safest options for avoiding neonic treatments, but the cost can be prohibitive for non-organic certified farmers.

Regulatory approaches

In 2013, the European Union banned the use of three neonicotinoids for two years, pending further study of their safety. Health Canada's Pest Management Regulatory Agency is in the process of doing a joint re-evaluation of neonicotinoid use with the US EPA. Health Canada has also released a neonic mitigation strategy to reduce contaminated dust through planting, and required improved seed labels for farmers. In late 2014, the Ontario Ministry of Agriculture, Food and Rural Affairs proposed to reduce by 80 percent the number of acres of commodity crops where neonicotinoids are used.[23]

In April 2015, the EPA imposed a moratorium on new uses of neonic applications in outdoor settings until the agency concludes its review of the chemicals, including their impact on pollinators, in 2016.[24] The EPA also has proposed a rule to create temporary pesticide-free zones to protect honey bees hives contracted for pollination.[25] The rule would apply mostly to almond and fruit production where contracted pollination is common, and would only restrict pesticide application, including neonicotinoids, when plants are in bloom. The proposed rule does not apply to seed coatings.

As mentioned earlier, the Obama Administration's Pollinator Health Task Force (led by the EPA and USDA) issued their strategy plan in May 2015—primarily focusing on improving communications and research specifically around honey bee loss, expanding monarch butterfly populations and restoring pollinator habitat. The strategy plan did not include regulatory actions, though the Administration has banned the use of neonicotinoids on the grounds of federal facilities and in national wildlife refuges.[26] In the U.S. Congress, Congressman Earl Blumenauer and John Conyers have introduced the Saving America's Pollinators Act, which would suspend the use of neonicotinoids until further research is done on the impacts on pollinators.[27]

At the state level, a growing number of states are beginning to look into options for regulating neonicotinoids. For the first time, Minnesota regulators are considering banning or restricting neonicotinoids.[28] Oregon, New York, New Jersey, California and Maryland are considering various steps to regulate neonicotinoids.[29] Some cities are also taking action. Eugene, Oregon; Seattle and Spokane, Washington; and Shorewood, Minnesota are among the cities that have banned neonicotinoid use on city-owned land.

Neonic regulation has also been mentioned as part of the Transatlantic Trade and Investment Partnership (TTIP) negotiations by Syngenta—who would like to remove Europe's ban of neonicotinoids as part of the negotiations.[30]

Neonicotinoids and Farmers: The Clear Need for More Information and Choice from the Seed Market

Farmers recognize and benefit from the critical role pollinators play in plant growth and food production. As the scientific evidence linking neonicotinoid use and pollinator decline mounts, it is critical that farmers have the option to purchase non-neonic seed, especially when there are increasing questions about the reality of crop production benefits provided by these products. But, farmers can't be expected to make the right choices if they don't have real information about the effectiveness of these tools or the ability to purchase what they want in the marketplace.

A primary follow-up to the White House Pollinator Task Force strategy report should be a focus on more transparent data and a more open marketplace in seeds, seed coatings and pesticides. Farmers, like all consumers, need accurate information about the costs and impacts of what they are purchasing, and should be able to opt-out of neonic and other seed coating components they don't want. Part of the focus should be on the relationship between multinational seed companies such as Monsanto, Syngenta and Bayer to see if the nature of those relationships has inhibited market choices for farmers around seed coatings. Corporate consolidation of the seed industry has been a long-standing issue of contention, and the subject of Justice Department and USDA workshops earlier in the Obama Administration. A determination should be made on whether the highly concentrated seed industry is negatively impacting farmers' ability to access information and choice around seeds and seed coatings. If so, changes should be made to the rules governing the seed and pesticide sector.

The reality is that there continues to be little available research into the efficacy of neonicotinoids in the field. Since seed companies are so reluctant to share such information, it is incumbent upon the public and farmers themselves to support and engage in the kind of independent research that will assess not only the efficacy of neonicotinoids, but also compare the effectiveness and costs of other pest control approaches, such as integrated pest management (IPM), that have proven benefits and economic returns. With current agricultural commodity prices already near or below cost of production for many farmers, every input needs to be scrutinized to determine actual costs and benefits, and there is no reason neonicotinoids and other seed coating ingredients shouldn't be assessed similarly.

Conclusion

Considering the mounting concerns and questions around neonicotinoids and the clear problems arising with our rapidly declining pollinator populations, something has to be done to help farmers make informed decisions. Neonicotinoids are a recent invention and, while useful in particular circumstances, are by no means the only or best option for managing pests despite their ubiquitous use. No farmer intentionally chooses to kill pollinators in their farming system, and if it is apparent that is happening at a cost and without clear economic benefits, farmers would likely reduce their usage of neonic-treated seed if that choice were made available to them.

Markets, by definition, are supposed to meet customer demands, and the seed sector should be no different. All seed companies should provide farmers with real and complete information on seed coatings and crop traits. Currently, some of the smaller and independent dealers are fulfilling that role. However, all farmers deserve this same choice, and the industry needs to respond, for the betterment of market competition, pollinators and farmers' bottom lines.

Resources on Neonic impacts

- "Pesticides and Honey Bees: State of the Science" by Pesticide Action Network (PAN) North America: http://www.panna.org/issues/publication/pesticides-and-honey-bees-state-science
- "Heavy Costs: Weighing the Value of Neonicotinoid Insecticides in Agriculture" by the Center for Food Safety: http://www.centerforfoodsafety.org/reports/2999/heavy-costs-weighing-the-value-of-neonicotinoid-insecticides-in-agriculture
- "Beyond the Birds and the Bees" by the Xerces Society for Invertebrate Conservation: http://www.xerces.org/beyond-the-birds-and-the-bees/
- "No Longer a Big Mystery, Recent scientific research confirms the role of pesticides in pollinator decline," Pesticides and You 34, no. 1 (Spring 2014), Beyond Pesticides: http://www.beyondpesticides.org/pollinators/nolongeraBIGmystery.pdf
- "Worldwide Integrated Assessment" by The Task Force on Systemic Pesticides: http://www.tfsp.info/worldwide-integrated-assessment/
- "A Farmer and Landowner Guide to Pollinators and Neonicotinoids" by the Institute for Agriculture and Trade Policy: http://www.iatp.org/documents/a-farmer-and-landowner-guide-to-pollinators-and-neonicotinoids

Endnotes

1. The Task Force on Systemic Pesticides. "Worldwide Integrated Assessment." January 2015. http://www.tfsp.info/worldwide-integrated-assessment/ (Accessed May 28, 2015).

2. Pollinator Task Force. "A National Strategy to Promote the Health of Honey Bees and Other Pollinators." May 19, 2015. https://www.whitehouse.gov/sites/default/files/microsites/ostp/Pollinator%20Health%20Strategy%202015.pdf. (Accessed May 28, 2015).

3. Ignasi Bartomeus et al., "Contribution of Insect Pollinators to Crop Yield and Quality Varies with Agricultural Intensification," PeerJ.com, March 27, 2014, https://peerj.com/articles/328/.

4. USDA Agricultural Research Service, "Honey Bees and Colony Collapse Disorder," http://www.ars.usda.gov/News/docs.htm?docid=15572 (accessed June 2014).

5. Jim Kleinschmit and Tara Ritter, "A Farmer and Landowner Guide to Pollinators and Neonicotinoids," Institute for Agriculture and Trade Policy, July 17, 2014, http://www.iatp.org/documents/a-farmer-and-landowner-guide-to-pollinators-and-neonicotinoids#sthash.ZPsLHJV4.dpuf.

6. Ibid.

7. Jennifer Hopwood et al., "Beyond the Birds and the Bees: Effects of Neonicotinoid Insecticides on Agriculturally Important Beneficial Invertebrates," The Xerces Society for Invertebrate Conservation, September 2013, http://www.xerces.org/wp-content/uploads/2013/09/XercesSociety_CBCneonics_sep2013.pdf (accessed May 21, 2015).

8. Chensheng Lu, Kenneth M. Warchol, and Richard A. Callahan, "Sub-lethal exposure to neonicotinoids impaired honey bees winterization before proceeding to colony collapse disorder," Bulletin of Insectology 67, no. 1 (2014):125-130.

9. Hopwood et al., Beyond the Birds and the Bees."

10. M. Rundlof et al., "Seed coating with a neonicotinoid insecticide negatively affects wild bees," Nature 521, no. 7550 (May 2015): 77-80, doi:10.1038/nature14420.

11. Sébastien C. Kessler et al., "Bees prefer foods containing neonicotinoid pesticides," Nature 521, no. 7550 (May 2015): 74-76, doi:10.1038/nature14414.

12. Takao Iwasa et al., "Mechanism for the differential toxicity of neonicotinoid insecticides in the honey bee, Apis mellifera," Crop Protection 23 (2004): 371-378, doi:10.1016/j.cropro.2003.08.018.

13. United States Environmental Protection Agency, "Benefits of Neonicotinoid Seed Treatments to Soybean Production," http://www2.epa.gov/sites/production/files/2014-10/documents/benefits_of_neonicotinoid_seed_treatments_to_soybean_production_2.pdf (accessed October 15, 2014).

14. Eric Stokstad, "Pesticides Under Fire for Risks to Pollinators," Science 10 vol. 340 no. 6133 (May 2013): 674-676, doi: 10.1126/science.340.6133.674.

15. United States Geological Survey, "Insecticides Similar to Nicotine Widespread in Midwest," http://www.usgs.gov/newsroom/article.asp?ID=3941#.VGKfAvnF_6E (accessed July 24, 2014).

16. Christian A. Krupke et al., "Multiple Routes of Pesticide Exposure for Honey Bees Living Near Agricultural Fields," January 3, 2012, doi: 10.1371/journal.pone.0029268.

17. Government of Canada, "Requirement when using Treated Corn / Soybean Seed," Health Canada Consumer Product Safety, http://www.hc-sc.gc.ca/cps-spc/pubs/pest/_fact-fiche/pollinator-protection-pollinisateurs/treated_seed-2014-semences_traitees-eng.php (accessed March 9, 2015).

18. Corn Dust Research Consortium, "Addendum, Preliminary Report," Pollinator Partnership, January 2014, http://www.pollinator.org/PDFs/CDRCfinalreport2013.pdf (accessed May 2014).

19. Center for Food Safety, "Heavy Costs: Weighing the Value of Neonicotinoid Insecticides in Agriculture," March 24, 2014, http://www.centerforfoodsafety.org/reports/2999/heavy-costs-weighing-the-value-of-neonicotinoid-insecticides-in-agriculture# (accessed May 2014).

20. United States Environmental Protection Agency, "Benefits of Neonicotinoid Seed Treatments to Soybean Production," http://www2.epa.gov/pollinator-protection/benefits-neonicotinoid-seed-treatments-soybean-production (accessed March 25, 2015).

21. Center for Food Safety, "Heavy Costs."

22. Michael E. Gray, "Relevance of Traditional Integrated Pest Management (IPM) Strategies for Commercial Corn Producers in a Transgenic Agroecosystem: A Bygone Era?" Journal of Agricultural and Food Chemistry 59 (2011): 5852–5858, doi: 10.1021/jf102673s.

23. Ontario Government. "Pollinator Health." http://www.ontario.ca/environment-and-energy/pollinator-health (accessed May 28, 2015).

24. United States Environmental Protection Agency, "April 2015 Letter to Registrants Announcing New Process for Handling New Registrations of Neonicotinoids," http://www2.epa.gov/pollinator-protection/april-2015-letter-registrants-announcing-new-process-handling-new (accessed April 3, 2015).

25. Carey Gillam, "US EPA Proposing Temporary Pesticide-Free Zones for Honey Bees," Reuters, May 28, 2015. http://www.reuters.com/article/2015/05/28/epa-agriculture-honeybees-idUSL1N0YJ10C20150528

26. Barack Obama, "Presidential Memorandum -- Creating a Federal Strategy to Promote the Health of Honey Bees and Other Pollinators," The White House, Office of the Press Secretary, June 20, 2014, https://www.whitehouse.gov/the-press-office/2014/06/20/presidential-memorandum-creating-federal-strategy-promote-health-honey-b.

27. Earl Blumenauer, "The Save America's Pollinators Act of 2013," Third District of Oregon, House of Congress, 2013, http://blumenauer.house.gov/images/stories/2013/Save_Americas_Pollinators_One_Pager.pdf.

28. Tony Kennedy, "State raises possibility of banning neonicotinoids," Star Tribune, October 29, 2014, http://www.startribune.com/state-considers-banning-class-of-pesticide-to-help-bees/280703022/.

29. "Community Passes Resolution Banning Neonicotinoids" Beyond Pesticides, March 5, 2014, http://www.beyondpesticides.org/dailynewsblog/?p=12881.

30. "Trading Away Our Bees" (webinar), Institute of Agriculture and Trade Policy, November 4, 2014, http://www.iatp.org/video/trading-away-our-bees.