NET LOSS

ECONOMIC EFFICACY AND COSTS OF NEONICOTINOID INSECTICIDES USED AS SEED COATINGS: UPDATES FROM THE UNITED STATES AND EUROPE

CENTER FOR FOOD SAFETY

DECEMBER 2016

ABOUT CENTER FOR FOOD SAFETY

CENTER FOR FOOD SAFETY (CFS) is a non-profit public interest and environmental advocacy membership organization established in 1997 for the purpose of challenging harmful food production technologies and promoting sustainable alternatives. CFS combines multiple tools and strategies in pursuing its goals, including litigation and legal petitions for rulemaking, legal support for various sustainable agriculture and food safety constituencies, as well as public education, grassroots organizing and media outreach.

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EXECUTIVE SUMMARY

A vast amount of new information on the risks and benefits of crop seeds coated with neonicotinoid insecticides (primarily clothianidin, imidacloprid and thiamethoxam) arose in 2015 and 2016 from both the United States and Europe. This report provides an update to an earlier Center for Food Safety (CFS) review that indicates that coating crop seeds with these insecticides does not provide economic benefits to farmers in many crop-planting contexts.

Neonicotinoids are the most extensively used insecticides in the United States in terms of land area affected; however, the broad lack of independent data showing economic justification for their use on seeds indicates that they are grossly over-used. In the European Union (EU), there is no evidence that crop production declined due to the 2013 prohibition on most crop-seed uses of neonicotinoids, which was adopted across the continent despite extremely dire industry predictions made at the time. In fact, on average, production to date has risen for major crops. Thus, prohibiting use of the neonicotinoid seed coatings did not deny European farmers any significant economic benefits.

Further, agricultural scientists and other experts in the United States and the United Kingdom have issued extensive new studies and reviews on the lack of overall efficacy of this technology. The lack of economic justification for the prophylactic use of neonicotinoid-coated seeds for soybeans (the second most extensively planted U.S. crop after corn), is virtually uncontested based on the overwhelming weight of independent reviews. Published evidence on weak or non-existent benefits exists for other crops as well, although it is more sporadic.

On the “loss” side, a further array of new U.S., Canadian and U.K. scientific studies solidly document harms occurring from the overuse of neonicotinoid seed coatings. These harms include: continuing chronic effects on honey bee hives — which now more clearly appear to result from synergistic effects of neonicotinoids and increased loads of deadly pathogens in the bees; increases in harmful effects on bumblebees and other wild bees; alarming correlations between amplified coated seed use and reduced butterfly populations; significant adverse impacts on beneficial insects and consequential increases in certain pest populations; and exceedances of safe toxin exposure levels for freshwater-dependent wildlife.

In sum, the net costs of this technology to society outweigh the industry-claimed benefits. This report contains these three **Policy Recommendations** to remedy this imbalance:

1. **The Environmental Protection Agency (EPA) should adopt a moratorium on prophylactic neonicotinoid use as crop seed coatings in the United States, with an immediate focus on coated soybean seeds due to the very strong evidence against that practice.**

2. **EPA should conduct thorough cost-benefit assessments, taking into account all market and non-market factors, including the full range of environmental effects, before allowing further use of any neonicotinoid-coated seeds.**

3. **The EU's prohibition should continue with respect to seed coatings for bee-attractant crops and should continue in Britain if and when it departs the EU.**

KEY UPCOMING DECISIONS

UNITED STATES

December 2016: EPA plans to complete its lengthy, multi-part Risk Assessment as part of its Registration Review for the oldest neonicotinoid seed coating, imidacloprid.[1] (Reviews are done every 15 years for registered pesticides). The final Review should be issued in 2017. Preliminary Risk Assessments for the two other neonicotinoid seed coatings, clothianidin and thiamethoxam, also are scheduled for release as early as December.[2]

January 2017: The Minnesota Legislature is expected to consider Governor Mark Dayton's proposed new legislation to address the exemption of neonicotinoid-coated seeds from regulation in Minnesota.[3] Also, in 2016 the state legislatures in both Vermont and Connecticut enacted new processes for reviewing the risks of coated seeds and their "dust-off," which those two states have recognized to be potentially harmful.[4] These processes are expected to be initiated in 2017.

EUROPE

2017: The European Food Safety Agency is slated to formally conclude whether the facts and science support continuation of the EU's neonicotinoid prohibition.

2017 (estimated): Britain's separation from the EU regulatory system is likely to culminate, thus the UK government will need to consider whether to maintain the EU prohibition or to discard it.

Background

Neonicotinoids are a class of pesticides designed to damage the central nervous system of insects, causing tremors, paralysis and death at very low doses. Since the mid-2000s, their use through various methods has skyrocketed. Methods include sprays, soil drenches, tree injections and others. However, by far their greatest use in terms of U.S. land area affected is as crop seed coatings—a process by which agrichemicals are mixed together with large batches of seeds in order to coat them before the seeds are planted.

Clothianidin, imidacloprid and thiamethoxam are the primary neonicotinoids used for seed coatings. All of these chemicals are "systemic," meaning they are absorbed into the plants when the seeds germinate and are distributed throughout the vascular systems as fluids. Coating a seed with these chemicals renders the entire plant—including roots, leaves, stem, flowers, nectar, pollen and guttation fluid[i] —toxic to insects. The toxicity varies over time depending on the part of the plant, the amount applied and other factors.

Neonicotinoids persist in soil and are readily transported via air, dust and water both within and outside the planted fields.[5] It has been known for several years that these chemicals can kill or weaken more than just the targeted pests. Non-target harm can occur to beneficial invertebrates, as well as to birds and other wildlife, through both direct and indirect effects.[6]

Sublethal doses can result in honey bee (*Apis mellifera*) colony damage through chronic effects, including compromising the behavior, health and immunity of colonies, thus causing them to collapse due to pathogens and parasites.[7] The broad variety of wild bees are even more vulnerable, exhibiting documented population declines when consistently exposed to these toxins.[8]

THE EFFICACY PROBLEM FOR NEONICOTINOID-COATED CROP SEEDS

The U.S. Federal Insecticide, Fungicide and Rodenticide Act (FIFRA) directs the Administrator of the EPA to weigh the foreseeable risks and benefits when making pesticide registration decisions.[9] FIFRA requires that EPA ensures registered products do not cause "unreasonable adverse effects on man or the environment".

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[i] Guttation consists of internal fluids, primarily water, expressed out of the plant, typically along leaf margins.

The law defines unreasonable adverse effects as "any unreasonable risk to man or the environment, taking into account the economic, social, and environmental **costs** and **benefits** of the use of any pesticide."[ii]

Most observers would assume that if farmers are using an insecticide then it must provide them some significant economic return and EPA has considered that "benefit" to farmers in its "weighing". However, in the case of the neonicotinoid-coated crop seeds, evidence shows that in most crop planting contexts, consistent benefits do not accrue. Numerous peer-reviewed scientific studies indicate that the typically "prophylactic" uses of neonicotinoid-coated seeds lack provable economic benefits for farmers. In some cases these powerful insecticides actually harm crop yields.[10]

This report examines the "efficacy" question for neonicotinoid-coated crops seeds in view of two developments:

1) a "before and after" harvest production comparison now exists following the EU's 2013 partial moratorium prohibiting the use of the most widely-used neonicotinoids - clothianidin, imidacloprid and thiamethoxam - on "bee attractant crops," and
2) numerous academic, government agency and other studies over the last two years examined the efficacy question from various angles.

This report also considers a large amount of new scientific information from 2015 and 2016 on the harms and risks these seed-coatings pose to society as a whole.

EARLIER EFFICACY REVIEW

The lack of yield benefits of neonicotinoid seed coatings came to a head in 2014 when Center for Food Safety (CFS) released its *Heavy Costs* report, showing that the weight of peer-reviewed scientific literature then indicated little or no yield increases for major U.S. crops from the use of neonicotinoid-coated seeds.[11] After that report, the pesticide industry, university researchers and EPA itself issued studies on comparable efficacy concerns (see later reports herein). *Heavy Costs* also weighed the extensive environmental and economic costs caused by the seed coatings. It identified these five "heavy cost" categories and identified many **billions** of dollars of potential market and non-market damages consisting of:

1) honey bee colony impacts and resulting reduced yields of pollinated crops,
2) reduced production of honey and other bee products,
3) financial harm to beekeepers and consumers,
4) loss of ecosystem services, and
5) market damage from contamination events.[12]

The present report update focuses on new scientific information from 2015 and 2016. While not reiterating the analysis in the 2014 report, this update concludes, as did *Heavy Costs*, that the lack of documented economic benefits to farmers is disturbing and unsupportable in view of the serious costs these seed coatings pose.

[ii] 7 U.S. Code § 136 (bb) (emphasis added).

NEW EFFICACY INFORMATION AND DEVELOPMENTS: 2015-2016

EUROPEAN CROP PRODUCTION POST-EU PROHIBITION ON NEONICOTINOIDS

Data from Europe since the 2013 EU prohibition continue to show the prudence of this protective measure, now three years old.[13] Initially, through the 2014 harvests, EU-wide production did not decline due to the ban on the neonicotinoid seed coatings (as well as on other uses). Rather it increased in the most common crops to which the prohibition applied. The lack of comprehensiveness of the EU prohibition and variegated nature of it, depending on the timing and extent of the crop plantings, and influenced by derogations from the prohibition taken by several EU countries, make sweeping comparisons difficult. Year-to-year crop yields are influenced by many factors; most notable is the weather. However, the limited EU-wide evidence demonstrates no harm to overall production from the restrictions on use of the primary neonicotinoids on seeds of key affected crops (Table 1).

Table 1. Average EU-wide maize and rapeseed production: before and after 2013 neonicotinoid prohibition.[14]

	2010 – 2013 average 4 years (x 1,000 tons)	2014 – 2015 average 2 years (x 1,000 tons)	Change in Production
Maize	64,358	68,064	5.7 % increase
Oilseed Rape (including turnip rape)	20,006	22,894	14.4 % increase

These significant crop production increases contrast with a vastly-exaggerated Bayer and Syngenta-funded predictive "study" from 2012 that argued overall production across Europe would decline by as much as 40 percent if a complete prohibition on neonicotinoids came into effect.[15] Losses of more than US$10 billion and 50,000 farm jobs over five years across the continent were predicted. In retrospect, the industry study was clearly biased in nature and conclusions were drawn in an attempt to block the EU prohibition.

CROP DEVELOPMENTS IN THE UNITED KINGDOM

The results of the pivotal Budge et al. study, a decade-long (2000 through 2010, inclusive) project involving thousands of fields across England and Wales published in 2015 by the UK Food and Environment Research Agency ("Fera"), provides the most sweeping published answer to the efficacy question.[16] The research found that the neonicotinoid coatings, primarily imidacloprid, applied to oilseed rape ("OSR," which in North America generally is known as "canola") did not produce a consistent benefit. The authors concluded "combining data from across all years found no overall effect of imidacloprid seed treatment." The lack of measurable positive outcomes reported by Fera applied both to crop yields and to farmers' profits.

Results from the first OSR crop grown in the UK without the seed treatments (due to the EU prohibition) were significantly positive. In the summer of 2015 there was a bumper national crop: well above average yields – 3.6 to 3.8 tons/hectare from fields grown without neonicotinoids compared with ten-year mean crop yields of 3.4 tons/hectare. In short, average yields for farmers increased by about seven percent in 2015 compared to typical yields over the previous ten years.[17]

Similarly, a scientific trial reported by the UK's Agriculture and Horticulture Development Board addressed neonicotinoid-coated OSR seeds against other treatments and untreated controls, to assess the effects of the EU's prohibition.[18] The authors concluded: "There was no statistically significant effect of treatment on crop yield." In Scotland, a detailed government survey of crop yields in 2015, in the wake of the prohibition found:[19]

> *[T]otal Scottish oilseed rape production increased by one per cent due to a four per cent increase in yield. Average yield also increased in the surveyed crop in 2015.*

UK GOVERNMENT ACTIONS

In a notable turn, in 2016 the UK government changed course on neonicotinoid seed coatings for Britain's OSR crop.[20] Having opposed the proposed EU prohibition in 2013 and publicly rejected the EU's reasoning even after it was adopted, the government was sympathetic to farmers seeking a "derogation" from the prohibition, that is, to be allowed to use neonicotinoids notwithstanding the EU vote. In 2015, the government did grant a limited derogation requested by the National Farmers Union (NFU), for five percent of oilseed rape fields based on claims of damage to crop yields. However, in 2016 the government rejected NFU's follow-on application based on "insufficient information" to support it. In short, after three years of opposing the EU's prohibition, the UK government, in effect, acted to accept it.

Britain's impending likely separation from the EU ("Brexit") is changing matters yet again. With no further obligation in relation to the EU's policies, the government must independently decide its position on approval of these products. How and when that may occur remains uncertain; however some decisions may be expected in 2017.

UNITED STATES: NEW DATA

Lacking any broad new restrictions on neonicotinoid-coated seed use, there is no opportunity for a "before and after" harvest comparison in the United States. However, many new U.S. scientific reports on economic efficacy of the coatings were published during 2015-2016. They are summarized here.

SOYBEANS

Douglas et al. 2015.[21] Pennsylvania State University researchers evaluated whether coated soybean seeds led to financial benefits for farmers via increased crop yields – and found they did not. Douglas, Rohr and Tooker showed that for soybeans in typical Mid-Atlantic field settings using a thiamethoxam-coated seed actually *increased* pest harm and *reduced* farmers' yields. This occurred via unexpected mortality caused to non-target carabid beetles which are natural biocontrol insects that prey on slugs — a major pest in soybeans in the region. The research exposed a:

> *…. previously unconsidered ecological pathway through which neonicotinoid use can unintentionally reduce biological control and crop yield. Trophic transfer of neonicotinoids challenges the notion that seed-applied toxins precisely target herbivorous pests.*

A parallel paper by Douglas and Tooker documents how seed treatments have driven a rapid increase in the use of neonicotinoid insecticides for preemptive, prophylactic pest management in several U.S. field crops beyond just soybeans.[22] They concluded that:

> *… carefully targeted efforts could considerably reduce neonicotinoid use in field crops without yield declines or economic harm to farmers, reducing the potential for pest resistance, non-target pest outbreaks, environmental contamination, and harm to wildlife, including pollinator species.*

Hurley et al. 2016.[23] This is a journal-published version of an unpublished 2014 industry report of a survey of farmers regarding their use of neonicotinoids on soybean seeds. Funding for the research came from neonicotinoid manufacturers Bayer, Syngenta and Valent. Only 51 percent of soybean farmers reported use of coated soybean seeds. The authors calculated that users had an estimated average yield gain of 128.0 kg/hectare treated in 2013, or about $42.20/hectare treated, net of seed treatment costs. However, the substantial benefits calculated by the authors were weakly-supported as the paper was not scientifically based and it employed opaque assumptions and dubious methods of data collection, including financial payments ($10) made to farmers who responded. Indeed, the authors concede, that such "surveys may suffer from non-response bias since participation is voluntary and some farmers may choose not to participate for reasons that are systematically related to the research objectives."[24]

North et al. 2016.[25] A study in the mid-South (Arkansas, Louisiana, Mississippi and Tennessee) regarding use of imidacloprid and thiamethoxam soybean seed coatings was touted as showing economic returns to farmers in that region. Prepared by Mississippi State University lead authors, the study actually shows limited, inconsistent benefits. The technology offered statistically-significant average financial returns for farmers in only four of the ten years studied. In the last six years studied (2009-2014, inclusive), only one year (2012) had a significant average economic return. In two of those six years (2009 and 2013), farmers on average actually incurred financial losses by using coated seeds (although not statistically significant losses). The authors stated: "When analyzed by state economic returns, the neonicotinoid seed treatments were significantly greater than fungicide-only treated seed in Louisiana and Mississippi". The corollary of that is that planting neonicotinoid-coated soybean seeds did not provide economic returns at all in Tennessee or Arkansas. That is, *no* benefits were observed, on average, in two of the four states across the ten-year study period. This is notable as "the South" is where most claims arise that neonicotinoids are needed to combat soybean pests.

Orlowski et al. 2016.[26] This was a complex, nine-state, three-region (North, Central, South), three year (2012-2014) analysis of the value of a variety of soybean inputs, conducted by researchers from nine universities. In terms of the likelihood of hitting the economic "break even" point across various scenarios and prices, the authors noted: "Seed treatment inputs had low break-even probabilities". This was true in the South as well as in the other two regions. The authors advised: "Instead of considering planned insecticide applications regardless of pest pressure, soybean producers should closely monitor insect populations through scouting and only apply insecticides once pest populations reach threshold levels as part of integrated pest management (IPM) systems."

Practical Farmers. 2015.[27] Side-by-side soybean efficacy trials in 2014-2015 were conducted by three farmers in the Field Crops Research program of the Practical Farmers of Iowa, a cooperative association. Their conclusions, comparing treated and controls were: "at each farm there were no differences in soybean yields" and "the cost of the seed treatment cannot be justified on these farms".

Robertson et al. 2015; Serrano et al. 2015.[28] Two important Iowa State studies on soybean seed coatings were released in 2015. Funded by the Iowa Soybean Association, the researchers used coated seeds provided *gratis* by the major pesticide companies. Looking over two years, 2014 and 2015, the results showed no yield benefit from the use of a variety of neonicotinoid-coated soybean seeds in several field trials compared to the uncoated controls.

SUNFLOWERS

Bredesen and Lundgren. 2015.[29] Similar research on sunflowers in the Upper Midwest found no yield benefits from "nearly ubiquitous" neonicotinoid seed coatings in sunflowers. Authors Michael Bredesen (South Dakota State University) and Jonathan Lundgren (formerly of United States Department of Agriculture [USDA], Agricultural Research Service), found no difference in sunflower yield between coated seed and uncoated seed sites across three site-years.

COTTON AND PEANUTS

Knight et al. 2015.[30] The authors addressed thiamethoxam seed coatings, as well as other pest control interventions, for two major crops, cotton and peanuts. The study had USDA funding and material support from Bayer CropScience, Syngenta, Monsanto and other agrochemical companies. In cotton, they found yield effects were occasionally positive but inconsistent. However, for peanuts they found no yield benefit from coating the chemical onto the seeds.

Other recent studies, while mixed, often show lack of efficacy.[31] There is no trend in independent, published, scientific or economic studies that demonstrates these insecticides are justified.

EPA'S SOYBEAN BENEFITS ASSESSMENT

The most detailed report on the "efficacy" question came from EPA itself, publicly issued in 2015.[32] The agency's Biological and Economic Analysis Division (BEAD) confirmed the findings of Douglas et al. and other researchers as far as no benefits from coated soybean seeds, but expanded that lesson nationwide, stating:

> *This analysis provides evidence that U.S. soybean growers derive limited to no benefit from neonicotinoid seed treatments in most instances. Published data indicate that most usage of neonicotinoid seed treatments does not protect soybean yield any better than doing no pest control. Given that much of the reported seed treatment usage in the U.S. on soybeans is not associated with a target pest, BEAD concludes that much of the observed use is preventative and may not be currently providing any actual pest management benefits.*

BEAD went on to observe, based on EPA's survey of agriculture extension experts nationwide (emphasis added):[33]

> *When asked how the use of neonicotinoid-treated seeds affected soybean yields, **74%** of respondents (14/19) responded that **yield either stayed the same or decreased**.*

It was documented that EPA's Office of Pesticide Programs also had a parallel Corn Seed Benefits Assessment underway in 2014.[34] However, resistance from pesticide manufacturers and from USDA appears to have stifled that assessment. Experts described the EPA decision to delay the corn assessment as "political".

Very likely the concern arose that the corn assessment would, like the soybean assessment, show gross overuse of coated seeds in relation to their actual benefits (although those benefits may exceed those for soybean seeds). EPA now claims such an assessment may accompany the full Registration Reviews for the primary corn seed coating, clothianidin, when that is complete.[35] Under current EPA projections, the agency will not complete that Registration Review until 2018 — and that deadline is not fixed.

MULTI-UNIVERSITY EXTENSION PUBLICATION ON COATED SOYBEANS

After the EPA's Benefits Assessment, the second most-influential U.S. publication is a 2015 report co-authored by numerous agriculture extension experts, entitled, *The Effectiveness of Neonicotinoid Seed Treatments in Soybean*.[36] With financial support from USDA, the analysis came from a coalition of twelve of the leading Midwestern agricultural research and extension universities. These experts reviewed the studies and concluded: "for typical field situations, independent research demonstrates that neonicotinoid seed treatments [for soybeans] do not provide a consistent return on investment."[37] In addition to the lack of benefits, the authors indicated high concern about the overall cost of their overuse, such as (citations and emphasis in original omitted):

> *Dust can move beyond field margins and land on flowers and other vegetation and potentially expose non-target insects (including honey bees and other pollinators). Neonicotinoids are highly soluble in water, which facilitates movement beyond field borders via tile drainage and runoff. Studies also show that neonicotinoid contamination in water bodies has a negative effect on arthropod communities, which are the bases of local food webs…There is evidence that neonicotinoid residues disrupt biological control or may be absorbed by the host plants of other insects, including milkweed, the food source for monarch butterfly caterpillars.*

The multi-university report concluded that IPM was the most sensible approach for farmers, rather than prophylactic use of soybean seed coatings.

DEVELOPMENTS IN MINNESOTA

Minnesota is the only state to take aggressive, broad, government action against the overuse of neonicotinoids in agriculture. On Aug. 25, 2016, Governor Mark Dayton issued the *Executive Order - Directing Steps to Reverse Pollinator Decline and Restore Pollinator Health.*[38] The order followed on a three-year Special Registration Review conducted by the Minnesota Department of Agriculture (MDA), which found sufficient scientific evidence that neonicotinoid pesticides present toxicity concerns for honey bees and native bees, as well as other pollinating insects. It is noteworthy that soybeans are a major crop in Minnesota. The governor directed the MDA to "requir[e] a 'verification of need' prior to the use of neonicotinoid pesticides". While the governor has limited authority over the sale and use of coated seeds directly via executive order, he called on the Minnesota Legislature to act to bring them under state regulation. A draft bill supported by the governor will be considered in early 2017.

UPDATES ON KEY HARMS ASSOCIATED WITH NEONICOTINOID USE

It is not feasible to reiterate here all of the extensive recent science on harm to pollinators and other environmental concerns from the neonicotinoid seed coating applications. The most prominent 2015 and 2016 articles showing harm are summarized below.[iii] The relatively large number of major UK studies is indicative of both its strong research emphasis and the country's wealth of biological monitoring data that allow for historical comparisons that often cannot be drawn in the United States.

It should be noted that significant other non-journal published "gray literature" exists documenting very high U.S. national annual bee mortality, major kills of commercially-managed bee colonies and reduced honey production that is beyond the scope of this <u>published</u> science-focused report.

A separate section addresses studies on harm to butterflies, a new and very alarming development in recent years. Lastly, three important new overview reports are featured on: a) water contamination, b) synergistic effects of the neonicotinoids and 3) human health effects.

STUDIES FOCUSED DIRECTLY ON EFFECTS OF NEONICOTINOID-COATED SEEDS

Alburaki et al. 2015.[39] One of several studies highlighted here that indicates neonicotinoid exposures increase pathogen risks and weaken honey bee colonies:

> *Thirty-two honeybee (Apis mellifera) colonies were studied in order to detect and measure potential in vivo effects of neonicotinoid pesticides used in cornfields (Zea mays spp) on*

[iii] The study abstract excerpts are verbatim from the articles, with emphases added.

honeybee health...Hives were extensively monitored for their performance and health traits over a period of two years. Honeybee viruses (brood queen cell virus BQCV, deformed wing virus DWV, and Israeli acute paralysis virus IAPV) and the brain specific expression of a biomarker of host physiological stress, the Acetylcholinesterase gene AChE, were investigated using RT-qPCR...In addition, general hive conditions were assessed by monitoring colony weight and brood development. Neonicotinoids were only identified in corn flowers at low concentrations. However, honeybee colonies located in neonicotinoid treated cornfields expressed significantly higher pathogen infection than those located in untreated cornfields. AChE levels showed elevated levels among honeybees that collected corn pollen from treated fields. ***Positive correlations were recorded between pathogens and the treated locations. Our data suggests that neonicotinoids indirectly weaken honeybee health by inducing physiological stress and increasing pathogen loads.***

Botias et al. 2016.[40] Seed-coating of canola with neonicotinoids in the UK led to frequently high-level contamination of marginal vegetation:

…we analysed samples of foliage collected from neonicotinoid seed-treated oilseed rape plants and also compared the levels of neonicotinoid residues in foliage (range: 1.4–11 ng/g) with the levels found in pollen collected from the same plants (range: 1.4–22 ng/g). We then analysed residue levels in foliage from non-target plants growing in the crop field margins (range: ≤0.02–106 ng/g). Finally, in order to assess the possible risk posed by the peak levels of neonicotinoids that we detected in foliage for farmland phytophagous and predatory insects, we compared the maximum concentrations found against the LC50 values reported in the literature for a set of relevant insect species. ***Our results suggest that neonicotinoid seed dressings lead to widespread contamination of the foliage of field margin plants with mixtures of neonicotinoid residues, where levels are very variable and discontinuous, but sometimes overlap with lethal concentrations reported for some insect species.***

David et al. 2016.[41] Marginal vegetation near treated-seed canola fields was contaminated with high levels of neonicotinoids and other chemicals with synergistic effects:

*…Here, we quantify concentrations of neonicotinoid insecticides and fungicides in the pollen of oilseed rape, and in pollen of wildflowers growing near arable fields. We then compare this to concentrations of these pesticides found in pollen collected by honey bees and in pollen and adult bees sampled from bumble bee colonies placed on arable farms. We also compared this with levels found in bumble bee colonies placed in urban areas. Pollen of oilseed rape was heavily contaminated with a broad range of pesticides, as was the pollen of wildflowers growing nearby. Consequently, pollen collected by both bee species also contained a wide range of pesticides, notably including the fungicides carbendazim, boscalid, flusilazole, metconazole, tebuconazole and trifloxystrobin and the neonicotinoids thiamethoxam, thiacloprid and imidacloprid...****It is notable that pollen collected by bumble bees in rural areas contained high levels of the neonicotinoids thiamethoxam (mean 18 ng/g) and thiacloprid (mean 2.9 ng/g),***

along with a range of fungicides, some of which are known to act synergistically with neonicotinoids.

Mogren and Lundgren. 2016.[42] Set-aside vegetation strips near farms did not protect bees from nutritional harms caused by adjacent corn fields planted with clothianidin-coated seeds:

> *…Pollinator strips were tested for clothianidin contamination in plant tissues, and the risks to honey bees assessed. An enzyme-linked immunosorbent assay (ELISA) quantified clothianidin in leaf, nectar, honey, and bee bread at organic and seed-treated farms. Total glycogen, lipids, and protein from honey bee workers were quantified. The proportion of plants testing positive for clothianidin were the same between treatments. Leaf tissue and honey had similar concentrations of clothianidin between organic and seed-treated farms. Honey (mean ±SE: 6.61 ± 0.88 ppb clothianidin per hive) had seven times greater concentrations than nectar collected by bees (0.94 ± 0.09 ppb). Bee bread collected from organic sites (25.8 ± 3.0 ppb) had significantly less clothianidin than those at seed treated locations (41.6 ± 2.9 ppb). Increasing concentrations of clothianidin in bee bread were correlated with decreased glycogen, lipid, and protein in workers.* ***This study shows that small, isolated areas set aside for conservation do not provide spatial or temporal relief from neonicotinoid exposures in agricultural regions where their use is largely prophylactic.***

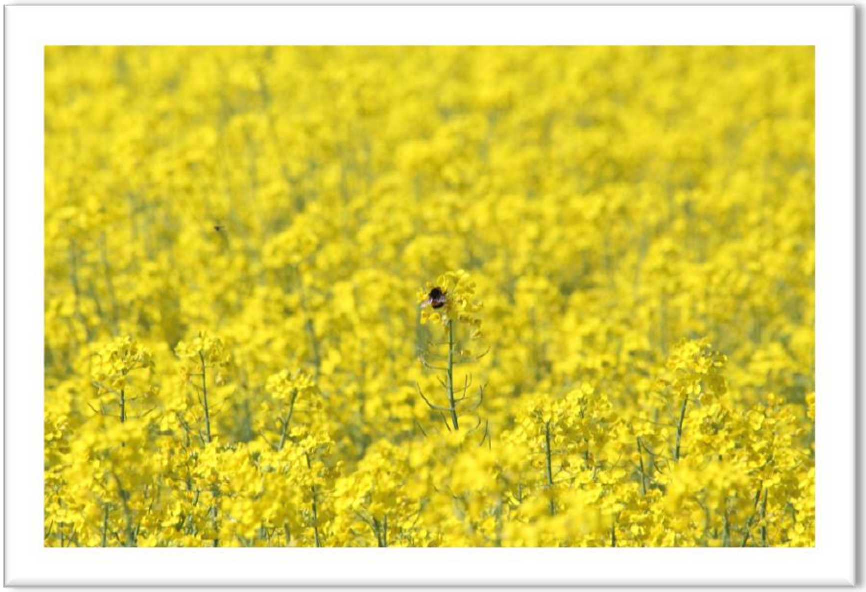
Rundlof et al. 2015.[43] Harm to wild bumblebees and other wild bees (which mostly are solitary) from clothianidin-coated canola seeds in a major field study in Sweden, published in *Nature*:

> *…Here we show that a commonly used insecticide seed coating in a flowering crop can have serious consequences for wild bees. In a study with replicated and matched landscapes, we found that* ***seed coating with Elado, an insecticide containing a combination of the neonicotinoid clothianidin and the non-systemic pyrethroid b-cyfluthrin, applied to oilseed rape seeds, reduced wild bee density, solitary bee nesting, and bumblebee colony growth and reproduction under field conditions. Hence, such insecticidal use can pose a substantial risk to wild bees in agricultural landscapes, and the contribution of pesticides to the global decline of wild bees may have been underestimated.*** *The lack of a significant response in*

honeybee colonies suggests that reported pesticide effects on honeybees cannot always be extrapolated to wild bees.

Woodstock et al. 2016.[44] Planting neonicotinoid-treated canola seed is an important factor in the extinction of wild bee species in Britain:

> ***We relate 18 years of UK national wild bee distribution data for 62 species to amounts of neonicotinoid use in oilseed rape. Using a multi-species dynamic Bayesian occupancy analysis, we find evidence of increased population extinction rates in response to neonicotinoid seed treatment use on oilseed rape****. Species foraging on oilseed rape benefit from the cover of this crop, but were on average three times more negatively affected by exposure to neonicotinoids than non-crop foragers. Our results suggest that sub-lethal effects of neonicotinoids could scale up to cause losses of bee biodiversity.* ***Restrictions on neonicotinoid use may reduce population declines.***

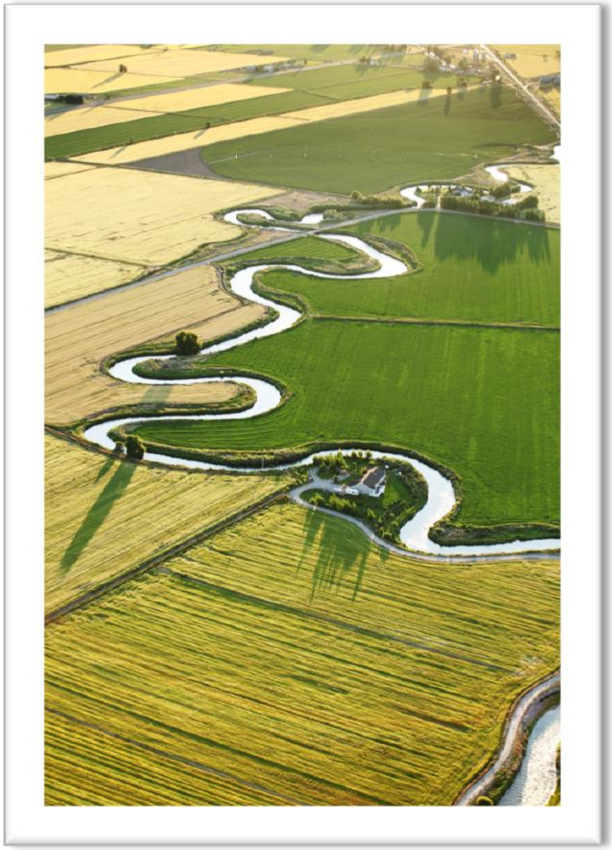


OTHER STUDIES RELEVANT TO SEED COATING RISKS

Dussaubat et al. 2016.[45] This is one of several studies linking harm to queens to decreased colony success:

> *The effects of the common neonicotinoid pesticide imidacloprid in a chronic and sublethal exposure together with the wide distributed parasite Nosema ceranae have therefore been investigated on queen's physiology and survivorship in laboratory and field conditions. Early physiological changes were observed on queens…Furthermore,* ***single and combined effects of pesticide and parasite decrease survivorship of queens introduced into mating hives for three months. Because colony demographic regulation relies on queen's fertility, the compromise of its physiology and life can seriously menace colony survival under pressure of combined stressors.***

Morrissey et al. 2015.[46] Seed coatings are singled out as a major driver of water contamination in the comprehensive review, *Neonicotinoid contamination of global surface waters and associated risk to aquatic invertebrates*:



> *The environmental profile of this class of pesticides indicate that they are persistent, have high leaching and runoff potential, and are highly toxic to a wide range of invertebrates. Therefore, neonicotinoids represent a significant risk to surface waters and the diverse aquatic and terrestrial fauna that these ecosystems support. This review synthesizes the current state of knowledge on the reported concentrations of neonicotinoids in surface waters from 29 studies in 9 countries world-wide in tandem with published data on their acute and chronic toxicity to 49 species of aquatic insects and crustaceans spanning 12 invertebrate orders.* ***Strong evidence exists that water-borne neonicotinoid exposures are frequent, long-term and at levels (geometric means = 0.13 μg/L (averages) and 0.63 μg/L (maxima)) which commonly exceed several existing water quality guidelines. …Therefore, it appears that environmentally relevant concentrations of neonicotinoids in surface waters worldwide are well within the range where both short- and long-term impacts on aquatic invertebrate species are possible over broad spatial scales.***

Sanchez-Bayo et al. 2016.[47] The honey bee colony collapse phenomenon is explained by links between neonicotinoid/fipronil exposures and bee parasites and disease:

> *…At sub-lethal level (bLD50), neurotoxic insecticide molecules are known to influence the cognitive abilities of bees, impairing their performance and ultimately impacting on the viability of the colonies. In addition,* ***widespread systemic insecticides appear to have introduced indirect side effects on both honey bees and wild bumblebees, by deeply affecting their health.*** *Immune suppression of the natural defences by neonicotinoid and phenyl-pyrazole (fipronil) insecticides opens the way to parasite infections and viral diseases, fostering their spread among individuals and among bee colonies at higher rates than under conditions of no exposure to such insecticides.* ***This causal link between diseases and/or parasites in bees and neonicotinoids and other pesticides has eluded researchers for years because both factors are concurrent: while the former are the immediate cause of colony collapses and bee declines, the latter are a key factor contributing to the increasing negative impact of parasitic infections observed in bees in recent decades.***

Straub et al. 2016.[48] Neonicotinoid insecticides can act as unintended "contraceptives" for male honey bees, thus also possibly explaining queen failure:

> ***Our results demonstrate for the first time that neonicotinoid insecticides can negatively affect male insect reproductive capacity, and provide a possible mechanistic explanation for managed honeybee queen failure and wild insect pollinator decline.*** *The widespread prophylactic use of neonicotinoids may have previously overlooked inadvertent contraceptive effects on non-target insects, thereby limiting conservation efforts.*

Wu-Smart and Spivak. 2016.[49] Colony function harm is mediated through effects on queens:

> *We found adverse effects of imidacloprid on queens (egg-laying and locomotor activity), worker bees (foraging and hygienic activities), and colony development (brood production and pollen stores) in all treated colonies. Some effects were less evident as colony size increased, suggesting that larger colony populations may act as a buffer to pesticide exposure.* ***This study is the first to show adverse effects of imidacloprid on queen bee fecundity and behavior and improves our understanding of how neonicotinoids may impair short-term colony functioning.***

BUTTERFLY STUDIES

Forister et al. 2016.[50] A California study shows increased use of neonicotinoids correlates with declines in lowland butterfly populations:

> *The butterfly fauna of lowland Northern California has exhibited a marked decline in recent years that previous studies have attributed in part to altered climatic conditions and changes in land use. Here, we ask if a shift in insecticide use towards neonicotinoids is associated with butterfly declines at four sites in the region that have been monitored for four decades.* ***A negative association between butterfly populations and increasing neonicotinoid application is detectable while controlling for land use and other factors, and appears to be***

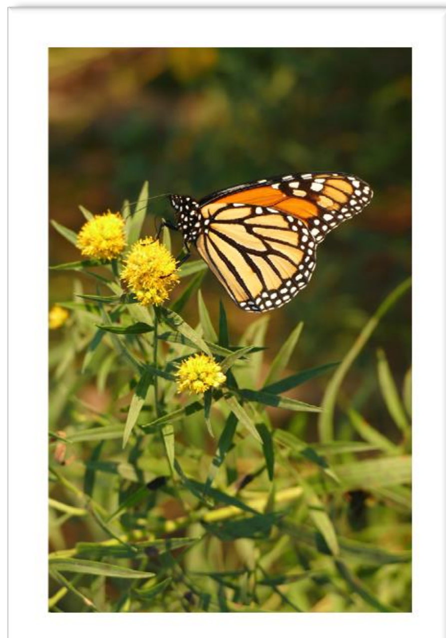
more severe for smaller-bodied species. These results suggest that neonicotinoids could influence non-target insect populations occurring in proximity to application locations*…*

Gilbourn et al. 2016.[51] A similar but more comprehensive study of the declines of butterflies in UK farmlands also shows correlation with increasing neonicotinoid use:

> *In England, the total abundance of widespread butterfly species declined by 58% on farmed land between 2000 and 2009 despite both a doubling in conservation spending in the UK, and predictions that climate change should benefit most species...the number of hectares of farmland where neonicotinoid pesticides are used is negatively associated with butterfly indices.* ***Indices for 15 of the 17 species show negative associations with neonicotinoid usage****. The declines in butterflies have largely occurred in England, where neonicotinoid usage is at its highest. In Scotland, where neonicotinoid usage is comparatively low, butterfly numbers are stable.* ***Further research is needed urgently to show whether there is a causal link between neonicotinoid usage and the decline of widespread butterflies…***

Pecanka and Lundgren. 2015.[52] Experimental and field evidence shows clothianidin seed coatings pose chronic effects risk to Monarch butterflies (which are proposed for Endangered Species Act listing).[53]

> *Monarch butterflies…frequently consume milkweed in and near agroecosystems and consequently may be exposed to pesticides like neonicotinoids. We conducted a dose response study to determine lethal and sublethal doses of clothianidin using a 36-h exposure scenario. We then quantified clothianidin levels found in milkweed leaves adjacent to maize fields. Toxicity assays revealed LC10, LC50, and LC90 values of 7.72, 15.63, and 30.70 ppb, respectively.* ***Sublethal effects (larval size) were observed at 1 ppb. Contaminated milkweed plants had an average of 1.14 ±0.10 ppb clothianidin, with a maximum of 4 ppb in a single plant. This research suggests that clothianidin could function as a stressor to monarch populations.***



THREE NEW OVERVIEWS

Center for Food Safety 2015 report: ***Water Hazard - Aquatic Contamination by Neonicotinoid Insecticides in The United States.***[54] This overview, building on the comprehensive water study by Morrissey et al., 2015, above, found that aquatic contamination resulting from overuse of neonicotinoid insecticides is widespread, threatening a range of invertebrates including insects and crabs. The report draws attention to the use of the seed coatings, up to 95 percent of which ends up in the environment. It provides representative state case studies for Maryland, Iowa and California, each of which is experiencing widespread neonicotinoid contamination exceeding recommended standards determined by experts in aquatic species toxicology. The report also highlights contamination elsewhere, including New York, South Dakota, Texas and Wisconsin. It describes the contributing roles of irrigation and field drainage and discusses the growing risks to aquifers, vulnerable wetlands and the valuable wildlife inhabiting those areas, such as migratory birds and sport fish.

Center for Biological Diversity (CBD) 2016 report, *Toxic Concoctions: How the EPA Ignores the Dangers of Pesticide Cocktails.* [55] Although pesticide mixtures in the environment are extensively documented, the EPA generally only assesses the toxicity of pesticides individually, in isolation from common, real-life scenarios where they may interact with other chemicals. The EPA typically rationalizes this approach by stating that studies measuring mixture toxicity are often not available. The CBD's analysis, however, contradicts that EPA claim by utilizing data from the U.S. Patent and Trademark Office that provides a disturbing picture of pesticide synergy and the potential for widespread danger to people, waterways and wildlife. All these are risks the EPA has repeatedly failed to identify and consider during its registration process. Registered neonicotinoid products, including several seed coatings, contain mixtures that increase their dangers to pollinators, rare plants and other elements of the environment. The report makes the case that these synergies must be fully addressed.

Cimino et al. 2016. *Effects of Neonicotinoid Pesticide Exposure on Human Health: A Systematic Review.* [56] This is the most comprehensive human health review ever published on the risks of exposures to neonicotinoids, not limited to coated seeds. While it is inconclusive due to the lack of sufficient, high-quality, methodologically-robust studies, it raises alarms, as the authors found that all four of the extant studies that addressed the potential of neonicotinoids to cause chronic effects indeed found such effects. Their conclusion: based on the "increasing detection in U.S. food and water, more studies on the human health effects of chronic (non-acute) exposure are needed."

CONCLUSIONS

In view of the lack of compensating yield benefits for farmers as compared to the high harm and economic costs that already are occurring from neonicotinoid seed coatings, and the excessive risks going forward, it appears clear that the result is a **net loss** for society as a whole. This is against an agroeconomic background of massive overproduction of soybeans, corn and other crops.[57] These surpluses are driving prices down for farmers.

At risk for society as a whole are not just managed honey bees, wild bees, butterflies, other beneficial species, aquatic ecosystems and the environment generally, but also potentially human health. Rapid reforms are needed.

CFS MAKES THESE THREE POLICY RECOMMENDATIONS TO REMEDY THIS IMBALANCE:

1. **The Environmental Protection Agency (EPA) should adopt a moratorium on prophylactic neonicotinoid use as crop seed coatings in the United States, with an immediate focus on coated soybean seeds due to the very strong evidence against that practice.** Currently the over-use of pre-coated seeds regardless of pest pressure, which conflicts with the principles of IPM, poses unacceptable risks and costs that EPA has failed to weigh against the seeds' claimed benefits. Such claims do not stand up to rigorous, peer-reviewed, scientific analysis. EPA's own Benefits Assessment and numerous independent academic reviews show that soybean seed coatings in particular do not make economic sense for farmers — and those assessments do not even consider the broader environmental harms that have resulted.

2. **EPA should conduct thorough cost-benefit assessments, taking into account all market and non-market factors including the full range of environmental effects, before allowing further use of any neonicotinoid-coated seeds.** The agency's FIFRA-based obligation to weigh risks versus benefits must be fairly observed. Americans on the whole are highly concerned about effects on honey bees, beekeepers, beneficial invertebrates, butterflies, aquatic ecosystems and other downstream effects. EPA's assessments must take all non-market values into account.

3. **The EU's prohibition should continue there with respect to seed coatings for bee-attractant crops and should continue in Britain if and when it departs the EU.** Europe's prohibition "experiment" since 2013 sheds invaluable light on the absence of economic harm from stopping the use of most neonicotinoid-coated crop seeds. Farmer production did not suffer — indeed, in many cases production increased. The lessons learned from the crop data support the continuation of Europe's prohibition and expanding it elsewhere.

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