HEAVY COSTS

WEIGHING THE VALUE OF NEONICOTINOID INSECTICIDES IN AGRICULTURE

CENTER FOR FOOD SAFETY

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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 agriculture. 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

This report tackles the question: **Are neonicotinoid insecticidal seed treatment products beneficial or not?** Center for Food Safety reviewed and summarized 19 articles from scientific journals that studied the relationship between neonicotinoid treatments and actual yields of major US crops: canola, corn, dry beans, soybeans, and wheat. In sum, we found that numerous studies show neonicotinoid seed treatments do not provide significant yield benefits in many contexts. European reports of crop yields being maintained even after regional neonicotinoid bans corroborate this finding. Opinions from several independent experts reinforce that neonicotinoids are massively overused in the US, without a corresponding yield benefit, across numerous agricultural contexts. The bottom line is that toxic insecticides are being unnecessarily applied in most cases.

Neonicotinoids have acute and sublethal effects on honey bees and other pollinators and are considered a major factor in colony collapse. It appears that in approving these insecticide products, the Environmental Protection Agency (EPA) has overvalued the "insurance" neonicotinoids offer against the mere risk of pest pressures, which are often not realized. This has led to heavy costs to the agricultural community and the nation as a whole. "Pre-sterilizing" fields has, in effect, rendered integrated pest management (IPM), in which pesticides are only used if economic pest damage thresholds are exceeded, obsolete for many major field crops.

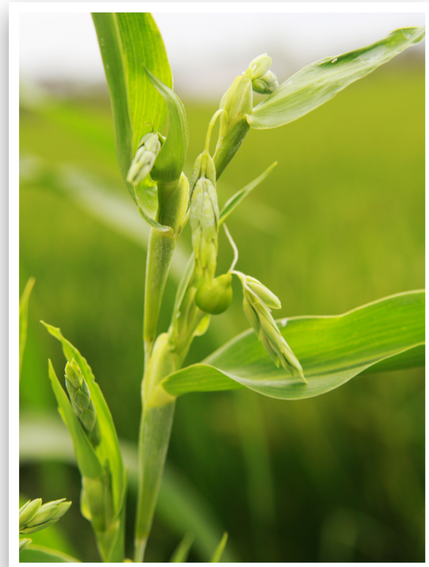
RECOMMENDATIONS

In order to fully evaluate future insecticide registration applications and comply with EPA's mandate to account for both benefits and costs, the agency should:

- Fully weigh both quantifiable and unquantifiable values in assessments of proposed systemic insecticide products, including at a minimum these foreseeable cost categories:
    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.
- Require verification by independent scientists and economists (preferably published in peer-reviewed journals) for claims of efficacy, crop yields, and economic benefits associated with all products.
- Reject applications to register any prophylactic insecticides that undermine basic IPM principles, may harm organic farm production, or are not cost-effective, either for the farmer or the nation as a whole.
- For all insecticidal seed treatment products, repeal the agency's waiver for "product performance data" in the EPA Product Performance regulation at 50 CFR § 158.400(e)(1) because of their prophylactic overuse, lack of efficacy, unique persistence, and high overall costs. Related to that, EPA also should promptly enforce the mandate in its regulation that: "each registrant must ensure through testing that his [sic] product is efficacious when used in accordance with label directions and commonly accepted pest control practices."

In light of the findings of this report, EPA should suspend all existing registrations of neonicotinoid seed treatment products whose costs and benefits have not been adequately weighed until this accounting is completed.

EVALUATING THE RISKS OF NEONICOTINOIDS



Neonicotinoids are a class of insecticides that damage the central nervous system of insects, causing tremors, paralysis, and death at very low doses. The primary neonicotinoids registered for use in the US are six relatively new (within the last 20 years) active ingredients: acetamiprid, clothianidin, dinotefuran, imidacloprid, thiacloprid, and thiamethoxam. All are "systemic," meaning they are absorbed into treated plants and distributed in their vascular systems with water that moves up through the plant. Treating a plant or just coating a seed with neonicotinoids can render parts of the plant—including the roots, leaves, stem, flowers, nectar, pollen, and guttation fluid—toxic to insects. The toxicity of the plant varies over time depending on the part of the plant, the amount of neonicotinoid applied, and other factors. Neonicotinoids are persistent in soil and easily transported via air, dust and water to habitats in or near crop fields.[1] There, they can kill or weaken beneficial invertebrates, as well as birds and other wildlife, through direct and indirect effects.[2] 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.[3]

The risks of using neonicotinoid pesticides are widely reported in the literature—evidence of their harms to pollinators and other beneficial insects is abundant—but what about the *benefits* of using these compounds? Seed of major crops in the US is widely treated with neonicotinoids, ostensibly to protect emerging seedlings from pests and thus improve yields. Almost all of the corn seed and approximately half of the soybeans in the US are treated with neonicotinoids.[4] More than 90% of the canola seeded in North America is treated.[5] This prophylactic pre-planting application occurs regardless of the pest pressure expected in the field, as typically there is no monitoring or sampling of crop fields for pest presence prior to application. Neonicotinoid treated seeds are commonly the only option for farmers purchasing seed. Despite marketing of these products that promotes their benefits to farmers, many peer-reviewed studies show little or no yield benefit associated with their use on crops, especially where there is low or moderate pest pressure. The studies reviewed in this report suggest that farmers are frequently investing in crop protection that is not providing them with benefits. In addition to the short-term economic costs, this presents long-term risks to sustainability for American farmers and the rural environment.

Despite their extensive use, there is a relatively small body of independent literature examining neonicotinoid use on crops. In 2011, scientists noted "there have been few peer-reviewed studies on seed-applied insecticide/fungicides probably because of the recent commercialization of these products."[6] This report surveys peer-reviewed literature that evaluates the efficacy of neonicotinoid seed treatments and finds that they are not providing a benefit to farmers for pest management across numerous agricultural contexts. The studies reviewed address major commodity crops grown in the US and Canada, but reports from other countries also show that neonicotinoids may not be providing a benefit. These studies were conducted in several regions, representing a range of climatic conditions and pest pressure levels encountered by American farmers.

WEIGHING COSTS AND BENEFITS

The Environmental Protection Agency (EPA) has the authority to approve or deny new pesticides under the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA).[7] FIFRA directs EPA to evaluate whether the use of pesticides (including neonicotinoids) proposed for registration presents "any unreasonable risk to man or the environment, taking into account the economic, social, and environmental *costs* and *benefits* [emphasis added]."[8] If EPA's weighing of the foreseeable costs of a proposed product exceeds its foreseeable benefits, then FIFRA compels the agency to deny registration.

Although not all records are public, to date, no indication exists that EPA has *ever* formally denied a full registration for any proposed neonicotinoid product because its foreseeable costs exceeded its benefits.[9] Since the late 1990s, the agency has approved neonicotinoid products whose applications are estimated to now exceed 150 million acres and very likely more than 200 million acres in annual applications nationwide.[10] It is estimated that more than 500 different neonicotinoid products exist, approved for more than 150 crop, landscape, ornamental, and other uses such as structures, poultry litter, pets, and termite control. In short, it is apparent that EPA routinely judges the foreseeable costs of neonicotinoids to be outweighed by the benefits they will provide to farmers and other users. Indeed, EPA's own Product Performance regulation has waived the obligation for pesticide manufacturers to demonstrate that new pesticide products are efficacious before they are registered, with limited exceptions.[11] This indicates the agency's weighing of the products' costs versus benefits is not rigorous.

Although there is no doubt that neonicotinoids are highly toxic to insects, this does not mean they are routinely effective in pest management. This report aims to answer the question: **Are neonicotinoid insecticidal seed treatment products beneficial or not?** Center for Food Safety reviewed and summarized 19 peer-reviewed articles from scientific journals that studied the relationship between neonicotinoid treatments and actual yields of major US crops: canola, corn, dry beans, soybeans, and wheat. In sum, we found that numerous studies have documented that neonicotinoid insecticides do not provide significant crop yield benefits in many contexts. The risks and costs of using neonicotinoid seed treatments outweigh their potential benefits.

The scope of this inquiry is limited to *agricultural* benefits, because such benefits have a ready measure: relative units of crop yield. While yield is not the only possible benefit, it is certainly the one that garners the most attention from crop producers and impacts their planting decisions. It should be noted that neonicotinoids are also used in scores of landscaping, ornamental, and other non-agricultural contexts where quantification of benefits is typically infeasible because it includes aesthetics and other largely subjective measures. Deploying powerful insecticides—particularly persistent systemic compounds—in gardening and ornamental uses has been heavily criticized because of the potential for harm to beneficial insects and other positive environmental attributes.[12] Without yield as a measure, EPA's weighing of benefits, or the lack thereof, necessarily is more qualitative than quantitative for non-agricultural uses, but accurate accounting remains vitally important.

ASSESSING THE LITERATURE

This literature review compiles independent peer-reviewed studies on the use of neonicotinoid seed treatments, and concludes that in many cases, the compounds are not providing a yield or economic benefit to farmers. The studies represent a wide range of locales and weather patterns, demonstrating that the results are robust across various agricultural contexts and growing conditions. In cases where there was moderate or low pest pressure, the reviewed studies found that neonicotinoids were even less likely to provide a yield benefit. The findings indicate there is often no economic justification for using neonicotinoids as a prophylactic control measure because the cost of treatment tends to exceed that of other control options that can be used when pests reach economic levels.

The following are the major findings from this literature review:

- **Neonicotinoids either did not provide a yield benefit (8 studies[13]), or provided an inconsistent yield benefit (11 studies[14]).**
- **Using neonicotinoids frequently does not provide an economic benefit to farmers compared to alternative control methods or not treating fields when pest pressure is minimal.**
- **Efficacy of neonicotinoids varies and is difficult to predict, especially for pests that emerge around the same time in the season that the bioactivity of neonicotinoids declines.**

Several authors concluded that using neonicotinoids at best provided sporadic pest control and, for some pest species, were typically ineffective. Although neonicotinoids occasionally provided benefits in terms of reduced pest damage or other growing season parameters, in many cases these observed benefits did not translate into increased yield at the end of the season. For pests like soybean aphid, which typically emerge at an economic level after the neonicotinoids are no longer active in the plants, scientists recommend that "management should be based on scouting and applying an insecticide only when populations exceed the economic threshold."[15] They also note that the prophylactic nature of neonicotinoid seed treatments means farmers are paying to treat a threat that may or may not exist, as "producers incur a control cost prior to the manifestation of pest pressure, and this cost is not recouped with higher yield if economically damaging populations of herbivores do not occur prior to loss of bioactivity."[16] It is evident that prophylactically treating crops for pests is not benefitting farmers in terms of yield or economics when pest pressure is uncertain. Given the demonstrated harmful effects of neonicotinoids on honey bees and other beneficial insects, it is clear that they are widely overused in American agriculture to the detriment of pollination services, farmers, and the environment.

METHODOLOGY

Studies included in this review were identified by conducting online scientific literature searches for independent research that evaluated yield of major North American crops in response to neonicotinoid seed treatments.[17] This report does not provide all studies that have assessed yield and we recognize that several other studies have found benefits. However, these studies are often neither published in a peer-reviewed journal nor independent of pesticide manufacturer funding. We identified four studies that showed yield benefits from neonicotinoids in independent literature,[18] and also located industry-sponsored papers and presentations that mention yield benefits but do not include full data or methodology.[19] Benefits of neonicotinoid seed treatments have been promoted by their manufacturers, and the EPA does not require independent testing to ensure their efficacy before registering the insecticides. Given the widespread adoption of neonicotinoid seed treatments, it is concerning that there is such a small body of independent literature assessing the efficacy of the products, especially considering that many of the published studies cast doubt on their benefits.

CORN

Cox et al. (2007) evaluated the use of clothianidin seed treatment on corn in the northeastern United States, where there is occasional early-season pest pressure. The experiment included two levels of clothianidin treatment and a control without insecticides (all seed was treated with fungicides), and found that neither crop development nor grain yield were affected by clothianidin seed treatment. Weather conditions varied in the two years of the study, representing the growing conditions faced in the region. Clothianidin's use in the absence of strong pest pressure did not increase corn yields, and thus was not beneficial to farmers. The authors concluded that "we do not recommend clothianidin seed treatment as inexpensive insurance against early-season soil insect damage when corn follows soybean in the northeastern United States."

Jordan et al. (2012) tested a method of fall sampling to predict spring white grub infestations in Virginia corn fields, as well as the use of clothianidin seed treatment. The fall sampling method was able to predict the level of pest population in the spring, and thus the amount of insect damage that could be expected, which could help farmers make an informed decision about using crop protection products. Clothianidin was applied at two rates to seeds in test plots, along with untreated control seeds. Seed treatment did increase corn stand (quantity of viable plants) in two of the three years. Despite this improved stand, there was only a yield benefit in one of the three years (at the higher application rate), when the below-threshold fields were removed from the analysis. The lower application rate for clothianidin was not different from the control in this year, despite the fact that the low rate is labeled for control of white grubs. There was no yield benefit in the second and third years of the experiment (even when the below-threshold fields were excluded). When the nine fields that had below-threshold pest populations were evaluated, there was no yield difference between treated and untreated seed. These results suggest that clothianidin treatment does not improve yields in the absence of pest pressure, and is not consistently effective with pest pressure.

Petzold-Maxwell et al. (2013) investigated the use of *Bacillus thuringiensis* (Bt) corn and clothianidin seed treatment alone and in combination to control rootworm populations at sites in the midwestern United States (Iowa, Nebraska, and Illinois). There was no significant difference between the control seeds (which were treated with a low rate of thiamethoxam to manage other corn pests) and the clothianidin treatment for the survival of western corn rootworm. Although clothianidin did not significantly reduce adult survival for western corn rootworm, it did affect northern corn rootworm. Root injury levels did not differ amongst Bt varieties, but were lower in non-Bt plots treated with clothianidin versus the control. Despite this reduction in root injury, there was no yield benefit from using clothianidin in either Bt or non-Bt crops. The authors note that "the additional cost of an insecticide may not have offered farmers any economic benefits."

Wilde et al. (2007) evaluated the effects of clothianidin and thiamethoxam seed treatment on corn fields in several Kansas locations. In the absence of noticeable insect pressure, no consistent effect on yield was identified at either high or low application rates, with no significant yield difference across all plots. In those locations where there were differences, control plots occasionally had higher yields than the treated plots, suggesting that the effects of the neonicotinoids are inconsistent at best. There was no consistent effect of treatment at any application rate on grain moisture, days to silk, plant population, or yield. Experiments were also conducted in infested fields for various pests, with variable results. Some plots had increased yields from treatment, and others reduced plant damage but did not see a yield benefit. Greenhouse tests to measure emergence and growth parameters found no significant effect of treatment. While the experiments showed that clothianidin and thiamethoxam are effective against some corn pests, they failed to demonstrate a consistent yield benefit during field trials in the absence of pest pressure. The authors concluded that their tests "did not detect significant differences in plant growth of corn that resulted in consistent increases in yield."

SOYBEANS

Cox et al. (2008) evaluated the use of thiamethoxam, imidacloprid, and fungicide seed treatments to manage soybean pests in fields in New York. Seed treatments did not affect plant density, pod density, and seed yield; and had inconsistent effects on seeds per pod and seed mass. The thiamethoxam/fludioxnil treatment produced the most seeds per pod, but the authors did not attribute this result to the effects of the compounds because they are no longer active in the plant by the time soybean reaches late reproductive stages and seed development begins. The results showed a limited effect of neonicotinoids on soybeans, thus indicating that insecticide/fungicide seed treatment is not required for soybean production in the northeastern US.

Cox and Cherney (2011) treated soybeans with clothianidin or imidacloprid and fungicides in plots following corn in New York to explore the effects of seed treatment and planting rate. Interactions between sites and seed treatment for emergence showed that the results are highly variable and site-dependent, with no clear trend of benefits. Seed treatment had inconsistent effects, increasing plant densities at some sites (up to 22%), but not at others. In terms of yield, the plots showed less than 4%, or no, increases with seed treatment. In the economic analysis, the authors suggest "there appears to be no significant advantage in partial return when using seed-applied insecticide/ fungicides vs. untreated seed after adjusting for the respective optimum seeding rates." The lower seed cost from reducing planting rates was offset by the cost of treating the seed, so the switch to lower rates and treated seed was not financially beneficial. Soybean seed cost averaged $2.29/kg in 2009-2010, and the average cost of seed treatment was $0.485/kg. The authors concluded that "growers should not expect a big or consistent response to seed-applied insecticide/fungicides under typical growing conditions in the Northeast United States."

Esker and Conley (2012) explored the economic considerations for seed treatment by looking at the probability that the yield response will cover the cost of treatment. They evaluated one fungicide-only treatment and a fungicide with thiamethoxam against an untreated control for soybeans grown in Wisconsin. The primary insecticidal targets in Wisconsin are aphids, bean leaf beetle, and seed corn maggot. The more expensive thiamethoxam treatment provided a 50% or greater probability of breaking even in 22-56% of the plots analyzed. The responses were very dependent on the cultivar, and it is difficult to predict how cultivars will respond because new ones are introduced so rapidly. The authors found that there were no strong conclusions to be made from their results, noting "the complexity of the results regarding the probability of breaking even with the application of seed treatments suggests that making specific recommendations is difficult."

Johnson et al. (2009) evaluated thiamethoxam seed treatment, a prescribed insecticide/fungicide foliar spray (regardless of pest pressure), and an integrated pest management (IPM) strategy for control of soybean aphid in the midwest. IPM relies on scouting fields for insect populations and only applying foliar sprays when the economic damage threshold is reached. All three treatments protected yield and reduced aphid pressure compared to the control, but there was no significant difference in yield between the three treatments. The authors assessed the cost effectiveness of each treatment and found that the IPM strategy had the highest probability of being cost effective. Neonicotinoid efficacy is typically diminished by the time aphid densities increase (they lose effectiveness 35-42 days after planting). Given that the occurrence of soybean aphid outbreaks is highly variable, IPM strategies are the best choice because they avoid treating fields that are not susceptible to economic damages from pest pressure. "Although there was little difference in yield among the three insecticide treatments, there was a large difference among the probability of recouping treatment costs," and neonicotinoid treatment had the lowest probability of recouping its cost. "The IPM approach was clearly the most profitable in our break-even analysis, which fits with findings across [a] broad range of US crops where IPM practices have been adopted."

McCornack and Ragsdale (2006) trialed thiamethoxam seed treatment to manage soybean aphid populations in Minnesota. Their results showed that thiamethoxam significantly reduced aphid pressure and reproduction but was only effective at causing aphid mortality and reducing reproduction during early vegetative growth stages. Late season aphid infestations cannot be controlled with seed treatment, and cannot be predicted at planting, so could require additional foliar applications, negating any advantage from using treated seed. Thiamethoxam did not significantly increase yield in years with low aphid density, but did increase yield in one year with high aphid pressure as compared to the untreated control (but was not significantly different from foliar spray plots). "In terms of yield, there was no advantage using a seed treatment over a foliar applied insecticide in any location-year." The authors concluded "at-planting application of thiamethoxam for soybean aphid control provides little consistent benefit to the grower."

Magalhaes et al. (2009) investigated the efficacy of imidacloprid and thiamethoxam seed treatments to control soybean aphids in Nebraska. The first year of the study had low aphid pressure (all below the economic threshold), and there were no differences in yield amongst the treatments. Aphid pressure was greater in the second year, and yield was higher in the treated plots than the untreated controls. Thiamethoxam kept aphid densities below the economic threshold, and imidacloprid reduced aphid densities, but not below the economic threshold. In fields managed based on threshold spraying, this would have resulted in a foliar spray still being applied to the imidacloprid treatment, negating the use of the neonicotinoid. While there was some yield benefit seen in this study, the planting dates were later, so systemic neonicotinoids were still active in the plants when aphid populations increased—this is not typically the case with soybean planting dates. Higher aphid pressures may overwhelm seed treatments and require secondary management strategies. Despite the moderate yield increases associated with neonicotinoid use in some portions of this study, the authors do not recommend their use, instead noting that "Nebraska soybean farmers would likely receive more consistent economic return by scouting fields and applying foliar insecticides only when necessary as indicated by economic thresholds."

Ohnesorg et al. (2009) utilized imidacloprid and thiamethoxam seed treatments to control soybean aphids in fields in Iowa. They compared seed treatments to foliar insecticides and an untreated control. The plots with foliar insecticides had lower soybean aphid populations and higher yields than those with seed-applied insecticides. During the first year of the experiment, some of the seed treatments provided significant yield benefits compared to the untreated control. In both years, the untreated control and seed treatment plots had the greatest exposure to aphid pressure, and in the second year, with moderate aphid pressure, there was no yield advantage from treating fields for aphids. The neonicotinoid seed treatments "provided limited, inconsistent yield protection to soybean that was occasionally not significantly different from the untreated control."

Reisig et al. (2012) investigated imidacloprid and thiamethoxam seed treatments (all treated seed also included fungicides) for the control of thrips in soybean fields in Virginia and North Carolina. Thrips are the primary early season pest of soybeans in the region. The neonicotinoid seed treatments reduced the larval and adult thrips abundance, and thiamethoxam was more effective than imidacloprid at reducing adult thrips density. Despite this, there was no difference in yield between any treatments, and no yield benefit from neonicotinoid treatment. The authors note that "very little data have been published regarding the impact of insecticidal seed treatments, despite their widespread use in the mid-South."

Seagraves and Lundgren (2012) evaluated imidacloprid and thiamethoxam seed treatments in lab trials and field conditions (South Dakota) for their effects on soybean crops and insects. Lab experiments showed that seed treatment bioactivity was gone by 46 days after planting, which would typically be prior to aphid populations damaging crops in the field. There was no consistent effect of insecticidal seed treatments on soybean aphids, thrips, and grasshoppers, but bean leaf beetles were more abundant in the untreated plots in field experiments. In South Dakota, soybean aphid typically only exceeds economic thresholds after August 1, which is well beyond the bioactivity of seed treatments. Over the two years of the study, there was no yield benefit from using treated seeds. Insecticidal seed treatment is estimated to cost producers $12-15/acre, which is a cost that will not be recouped with additional yield if economically damaging pest populations do not occur while the compounds are active. The authors conclude that this research "not only confirms that insecticidal seed treatments have little effect on the key pest of soybeans, but also suggests that this prescriptive use of some of these insecticides may harm long-term IPM of soybean pests by reducing the abundance of their key natural enemies."

Tinsley et al. (2012) investigated the control of soybean aphids provided by aphid-resistant soybean lines and by thiamethoxam seed treatment. Soybean aphids reached economically significant levels in both years. Resistant plants experienced fewer cumulative aphid days, but yields were not significantly different. Thiamethoxam also reduced cumulative aphid days in one year of the study, but not the second year, and did not provide a yield benefit. "Evidence for the ability of thiamethoxam to reduce densities of soybean aphids in this experiment was inconclusive." Seed treatments are less effective against late-season pests—thiamethoxam's utility is limited and dependent on the timing of the infestation because the bioactivity of the compound declines throughout the season. This study "reinforces the economic utility of scouting for soybean aphids and only applying a foliar insecticide when densities reach economically threatening levels."

CANOLA, DRY BEANS, AND WHEAT

Soroka et al. (2008) investigated the efficacy of acetamiprid and clothianidin seed treatments to control flea beetle damage on canola in Manitoba and Saskatchewan. The authors compared various percentages of treated seeds in the planting mix to assess whether farmers could reduce the percentage of treated seed they are planting and still maintain yields. Decreasing treated seeds by one-third (67% treated) had no consistent effect on damage, yield, or cash return. Yields for 100% treated seed were only consistently above those with 67% treated seed under very heavy flea beetle pressure. In most trials, the damage levels on the 100% treated seed exceeded the economic threshold, which would have triggered a foliar insecticide application. In the year with the least pest pressure, feeding levels did not correlate with the amount of treated seed, suggesting that efficacy is reduced in moderate years and neonicotinoids are not providing benefits in those years. The authors concluded "reducing the proportion of treated seed sown by one third can be an effective means of reducing pesticide load to the environment while maintaining efficacy, especially in situations of low-to-medium flea beetle feeding pressure."

Pynenburg et al. (2011a) studied thiamethoxam seed treatment's ability to alleviate stress from weed pressure and white mold in dry bean fields in Ontario. The authors noted "no known published literature was found that studied the effect of thiamethoxam on plant vigor" and pesticide manufacturer representatives said that "more consistent benefits of thiamethoxam on plant vigor have been observed in dicot than monocot crops, and the benefits were more pronounced under abiotic stress conditions." Thiamethoxam had inconsistent effects with respect to plant emergence and vigor, harvested weight, seed weight, and economic returns. Each of these parameters was increased in some thiamethoxam plots and decreased in others compared to the controls, suggesting that overall, "the plant growth benefits of thiamethoxam are unclear and hard to quantify."

Pynenburg et al. (2011b) evaluated thiamethoxam seed treatment's plant enhancement abilities for dry bean production in Ontario to combat the stresses of annual weed pressure and anthracnose. Thiamethoxam increased emergence and vigor at only one location, contradicting reports of benefits from treatment. Seed quality was improved by thiamethoxam when results were pooled over all locations, but the authors could not explain this result because anthracnose severity was not reduced in thiamethoxam plots. Thiamethoxam had no effect on net yield or economic return. The authors concluded "thiamethoxam's potential to increase plant vigor was not clearly demonstrated, as it did not affect plant height, disease severity, net yield, or net economic return."

Royer et al. (2005) investigated the ability of imidacloprid seed treatment to control pests in hard red winter wheat grown in Oklahoma with several planting dates. Applying imidacloprid had varying results for aphid abundance, and in some cases the aphid abundance was not different from the untreated control. Grain yields increased with increased rates of imidacloprid application, but the economic return from imidacloprid was not usually positive. The lowest imidacloprid rate was the only rate to consistently provide a positive economic return across all planting dates. The authors note that "these data show how difficult it is to predict whether a prophylactic insecticide seed treatment will consistently pay for itself."

Wilde et al. (2001) evaluated thiamethoxam and imidacloprid seed treatments for insect control in winter wheat fields in Kansas. No yield benefit was seen in the field experiments, which had low to no pest pressure. Control of early season pests was demonstrated in greenhouse experiments with infested plants, but late season pest control was less effective and inconsistent. While the authors note that seed treatment could be useful in fields with chronic pressure from several pests, they conclude that "the use of seed treatments is economically risky where insect populations are variable" and that foliar treatments based on action thresholds are a better option.

EXPERTS WEIGH IN ON LACK OF YIELD BENEFITS

Summary reports from France and Italy show neonicotinoids provide little if any economic benefit in many contexts. Unlike North American reports, these provide detailed *before* and *after* case studies because these countries have restricted neonicotinoid use on various crops. These examples support the limited yield benefits from neonicotinoids shown in North American research:

- France banned the use of imidacloprid on sunflowers in 1999 and on corn in 2004, but the yield trends for both crops through 2007 show that the productivity was not harmed by the loss of seed treatment as a pest control measure.[20]
- The Italian Ministry of Health announced in June 2012 that it would continue the suspension of clothianidin and thiamethoxam on corn originally imposed in 2009 in response to mass bee kills that clearly resulted from neonicotinoid use. Researchers found no evidence that the suspensions caused any economic harm in Italy; corn farmers there have seen no serious pest attacks on untreated seed crops and have maintained their yields.[21]
- In 2013, the European Union voted for a two-year minimum suspension of clothianidin, thiamethoxam, and imidacloprid on bee-attractive crops and limited ornamental use to approved applicators. This may provide another broad case study to assess yield impacts if reliable follow-up monitoring occurs. However, the potentially short duration of the suspension may not provide enough time to identify changes in honey bee health as the neonicotinoids persist in soil and may be taken up by subsequent crops.

Professor David Goulson's 2013 review of impacts, after documenting the lack of any identifiable crop yield increases in the United Kingdom associated with the introduction of neonicotinoids, states:

> "Given their widespread use, it is surprising that few studies have attempted to compare the effectiveness of neonicotinoids with alternative means of pest control. Bueno et al. (2011) compared managing soya pests in Brazil using either an IPM approach or prophylactic use of insecticides (the latter primarily based on imidacloprid). Crop yields were indistinguishable in the two treatments, but pesticide use and costs were much lower in the IPM treatment, demonstrating that this remains the best alternative in this system. In North America, Seagraves & Lundgren (2012) compared yield of either imidacloprid or thiamethoxam seed dressings on soya with untreated controls and found no difference in yield in either of the 2 years of their study, but populations of beneficial natural enemies were depressed in treated plots. In this system, the evidence would suggest that the cost of seed treatment (~$30 ha) is not being recouped by the farmer. This is in accordance with a several similar studies of soya which found either no yield benefits (McCornack & Ragsdale 2006; Cox, Shields & Cherney 2008; Ohnesorg, Johnson & O'Neal 2009) or yield benefits below those which could be achieved more economically using foliar insecticides applied only when pests exceeded a threshold (McCornack & Ragsdale 2006; Johnson et al. 2009). Similarly, studies of the efficacy of imidacloprid dressing of winter wheat in North America suggest that yield benefits are small (compared to unprotected, control crops) and often exceeded by the cost of the pesticide (Royer et al. 2005)."[22]

Other respected experts concur with Dr. Goulson's overview:

- Dr. Christian Krupke, Department of Entomology, Purdue University, stated: "Part of the mission of my research and extension program is annual evaluation of pest management technologies in corn and soybeans—this is a critical source of unbiased efficacy data for growers. We attempt to challenge these technologies by placing them in fields with histories of pest damage. We have not demonstrated a consistent yield benefit of neonicotinoid seed treatments in either case, 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 is no demonstrable benefit in the vast majority of fields/years we have surveyed, it is apparent that seed treatments are dramatically overused in these crops (all corn and the majority of soybeans are treated)."[23]
- Dr. Jonathan Lundgren, a leading USDA Agricultural Research Service entomologist studying the effects of neonicotinoids, stated: "Farmers should question whether applying neonicotinoid seed treatments are more harmful than helpful on their farms. Public sector research on insecticidal seed treatments in soybeans from across the US consistently shows that spraying pests when they exceed thresholds is more profitable than prophylactic use of insecticidal seed treatments. In corn, I have not seen evidence that there are insect pests—beyond those targeted by Bt—that warrant consistent and prophylactic management. Finally, pest management decisions need to account for the costs that insecticides have against non-target organisms like predators and pollinators."[24]
- Tracy Baute, an Ontario Ministry of Agriculture and Food entomologist and IPM expert, stated: "Based on my experience, only 10 to 20% of the corn and soybean acres are actually at risk of most of the soil pests on the [neonicotinoid] product labels."[25] In other words, 80 to 90% of the use is unnecessary. Ontario's corn and soybean growing practices are similar to those in the northern portions of the US midwest corn and soybean regions.
- Dr. Christy Morrissey, Department of Biology, University of Saskatchewan, stated: "Although the dogma that has been promoted is that we really need these chemicals in order to protect crops…there actually is very little evidence to support the extremely widespread use of these chemicals."[26]

COSTS AND DETRIMENTAL IMPACTS OF NEONICOTINOIDS

The use of neonicotinoid seed treatments is associated with a wide range of detrimental impacts, the majority of which are not fully considered by EPA as the agency evaluates proposed product registrations. These market and other impacts, summarized below, are not without additional consequences. Major financial institution reports indicate that neonicotinoid harms to honey bees and related pollinator declines could depress stock values of some publicly-held companies and harm critical agricultural sectors.[27] Farmers are paying unnecessarily for pest protection that in many cases they are not receiving. EPA must weigh all of the costs, both documented and foreseeable, along with the lack of significant crop yield benefits.

HONEY BEE COLONY IMPACTS

Science has linked neonicotinoid use to honey bee and bumblebee impacts.[28] Hundreds of documented reports detail acute mass honey bee kills via contaminated dust (graphite and talc) from planting treated corn seeds. Further, chronic ingestion of neonicotinoids can harm their foraging success and colony strength, as honey bees are social insects that rely heavily on memory, cognition, and communication. Researchers "clearly demonstrate[d] an increase in pathogen growth within individual bees reared in colonies exposed to one of the most widely used pesticides worldwide, imidacloprid, at below levels considered harmful to bees," suggesting that nonlethal effects to honey bees from low exposure levels may be extremely damaging.[29]

Prior to 2006—when neonicotinoids were beginning to be used on a nationwide scale—commercial beekeepers and honey producers typically anticipated losing fewer than 10% of their bees each year, mostly due to overwintering mortality. Losses of that magnitude were sustainable because they could be recovered by splitting hives, adding new queens, and other measures. Since 2006, however, overwintering losses have risen dramatically. While this correlation does not equate to causation, the trend is remarkable. Surveys conducted by the Department of Agriculture (USDA) show that 28% to 33% of total honey bee colonies died each winter from 2007 to 2011.[30] Winter losses dipped to 22% in 2012, but the 2013 survey indicated 31% of colonies died.[31] Compounding these overwintering losses is a marked increase in summer mortality, the season when bee populations should be thriving. According to USDA, "since 2006 an estimated 10 million bee hives at an approximate current value of $200 each have been lost, and the total replacement costs of **$2 billion dollars** has been borne by the beekeepers alone [emphasis added]."[32] That statement refers to a six-year period, thus a rough estimate of annual replacement cost is **about $300 million per year.** This magnitude of annual uninsured losses is unsustainable.

The role of neonicotinoids in honey bee decline continues to be debated. Just as there is no unassailable scientific study, there is no "smoking gun" to point to as the cause of honey bee decline. Honey bees are impacted negatively by many interacting, and sometimes synergistic, stressors. However, there are many studies across various scales that clearly demonstrate that neonicotinoids negatively affect honey bees. Whether this role is large or small may depend on the intensity of neonicotinoid use in a given region. However, when this is balanced against the reality that neonicotinoids provide little tangible benefit across the cropping systems where they are most widely used, it rapidly becomes apparent that the status quo can, and should, change.

REDUCED CROP POLLINATION BY HONEY BEES

The nationwide decline of honey bee colonies is not only a financial and personal crisis for commercial beekeepers and honey producers; it is also a direct hazard to the nation's food supply. Scientists estimate that one-third of the food people eat—and an even greater proportion of high value nutrient and vitamin sources—comes from crops that will not make fruit or seed unless they are pollinated.[33] As summarized by USDA:

> "It is imperative that we increase honey bee survival both to make beekeeping profitable but more importantly to meet the demands of US agriculture for pollination and thus ensure food security.… Currently, the survivorship of honey bee colonies is too low for us to be confident in our ability to meet the pollination demands of US agricultural crops."[34]

A prominent USDA researcher has warned that, unless trends are reversed, "[w]e are one poor weather event or high winter bee loss away from a pollination disaster."[35]

In weighing the costs to pollinators and other beneficial insects, EPA must consider the role of neonicotinoids in relation to managed honey bee and other pollinator populations. These have been valued by Kansas State University at **$12.8 billion**, based on documented average annual yield benefits for ten major crops.[36] There are more than 100 crops in North America that benefit from pollinators.[37] Kansas State researchers found that through 2010, the value of US agriculture declined by approximately **$75 million per year** compared to 1986 values due to declining pollinator numbers for the major crops they assessed. While recognizing several factors in these declines, they identified neonicotinoids as key drivers:

> "Insecticides and pesticides are applied not only on agricultural fields, but also on golf courses, in residential areas, across rangelands, etc. These pesticides and insecticides generally do not kill pollinators outright, but instead impair their development and behavior (Johnson 2010); for example, agrochemicals cause impaired odor discrimination and abnormal communication dances, which can cause mistakes in estimating distances and direction to food sources (Kearns and Inouye 1997; Thompson 2003). Gill et al. (2012) reported reduced worker foraging performance, especially pollen collecting efficiency, with chronic exposure of neonicotinoid and pyrethroid pesticide in bumblebees. Also they showed field-level exposure of these pesticides caused reduction in brood development and colony success. When agrochemical use is associated with reduced use of crop rotations, crop diversity and availability of other pollen sources are also lessened, which compounds the negative impacts on pollinators."[38]

These findings of pollinator impacts have been consistently observed and confirmed by independent scientists. According to EPA's and USDA's estimates, pollination contributes **$20 to $30 billion** in crop production annually to the US economy.[39] These massive and declining pollinator-driven crop yield benefits must be weighed against the often marginal or illusory neonicotinoid-driven crop yield benefits. The values in the Kansas State and the EPA and USDA estimates, are national-level and omit accounting for lost earnings and other financial damage to commercial beekeepers themselves, who create the bulk of that crop yield enhancement through their pollination services and colony management. Compounding the sting of these losses is the fact that EPA currently lacks a complete accounting of the economic benefits of honey bees as the agency weighs the costs insecticides pose to beekeepers.[40]

The ongoing operational and financial damage to the small cadre of fewer than 1,000 major commercial pollinating beekeepers nationwide is jeopardizing **tens of billions of dollars** of national crop-yield benefit from pollination. As bee losses mount, beekeepers must replace them to fulfill pollination contracts and raise their prices accordingly, the costs of which are, in turn, passed on to producers and consumers. If the aging and dwindling beekeeper workforce continues to struggle financially and fades away, major shockwaves would reverberate through the agricultural economy.[41]

Given the data we review in this report, over many years, locations, and cropping systems, there are no consistent benefits from using treated seeds in pest management. Coupled with EPA and USDA's own estimates, it is unreasonable for EPA's pesticide registration department to continue to allow the pursuit of non-existent or insignificant yield benefits for corn, soybeans, and other crops while contributing to mass declines in pollinators, major yield reductions in pollinator-dependent crops, and financial damages to beekeepers.

REDUCED PRODUCTION OF HONEY & OTHER BEE PRODUCTS

The impacts of neonicotinoids on honey and other bee product declines are complex. It is clear that total US honey production has dropped by more than 25% since 1994, when the first neonicotinoid (imidacloprid) was registered for use.[42] The national crop from 2013 is expected to be the *smallest honey crop ever reported* by a large margin, with a mid-range estimate of 114 million pounds compared to a mid-range estimate of 135 million pounds in 2012.[43] The average bulk wholesale value of the lost production of **21 million pounds** compared to 2012 was approximately **$38 million**.

Analysis of crop reductions over time indicates that the states with drastic honey crop declines in recent years are those in the Corn Belt with the most widespread use of neonicotinoid treated seeds, including, but not limited to, Illinois, Indiana, Iowa, Kansas, Missouri, and Nebraska.[44] Honey production in Florida, which as recently as 2000 was very high, has dropped roughly in half since the citrus psyllid was found and orange grove infections led to massive increases in use of neonicotinoids and other insecticides.[45] While statistical certainty on the causes of declines across a broad industry sector will remain elusive, the apparent contributing role of neonicotinoid-induced colony losses in huge reductions in honey, beeswax, and other valuable bee products must be taken into account.

LOSS OF ECOSYSTEM SERVICES

EPA must weigh the frequent lack of neonicotinoid yield benefits against the tremendous environmental and economic benefits and ecosystem services that neonicotinoids are jeopardizing. This goes far beyond more readily-quantified reductions in managed honey bees and bee products. Acute and chronic effects similar to those impacting honey bees can harm bumblebees and other valuable, beneficial invertebrates such as lady bugs, ground beetles, earthworms, and parasitoid wasps.[46] Beneficial invertebrates are essential, often unnoticed, components of healthy agricultural fields, landscapes, gardens, and natural systems.

In 2006, researchers estimated the value of native insect pollination for US crops at **$3.07 billion**.[47] More recently, in California alone, researchers estimated wild pollinators produce between **$937 million and $2.4 billion** per year in economic value.[48] Beyond crop pollination, beneficial predatory and parasitic insects and other arthropods provide natural pest suppression to farms, an ecosystem service valued at more than **$4.5 billion** per year, as well as to natural areas and developed landscapes.[49] Water contamination from neonicotinoids has been identified in several agricultural regions and linked to detrimental impacts in aquatic ecosystems.[50]

There are sweepingly important indirect benefits—virtually beyond calculation—gained by non-crop plant communities sustained through pollination.[51] These include the aesthetic values of flowers and ornamental plants, reduction of soil erosion, food and forage for wildlife, and maintenance of forest, grassland, desert, and other broad ecological dynamics. In 2006, Losey and Vaughan calculated the value of ecosystem services to humans from all wild insects in the US to reach **$60 billion**.[52]

MARKET DAMAGE FROM CONTAMINATION EVENTS

New financial harm from neonicotinoids has also surfaced. In February 2014, exports from Canada to Japan of the specialty, high-value grain buckwheat, were rejected due to levels of thiamethoxam contamination exceeding Japan's maximum residue limit.[53] The buckwheat farmers apparently did not use thiamethoxam on that crop—it persisted in contaminated soil from earlier plantings of other crops or was carried into their fields via air or dust. This sole incident led to the costly rejection of two container loads of buckwheat and is an ongoing problem could lead to the loss of additional export markets.[54]

CONCLUSIONS

It appears EPA has overvalued the "insurance" neonicotinoids offer against often non-existent or insignificant pest pressures in many contexts. This overuse, a direct result of EPA's regulatory approval process, imposes heavy costs to the agricultural community and the nation as a whole. "Pre-sterilizing" fields has, in effect, rendered integrated pest management, in which pesticides are only used if economic pest damage thresholds are exceeded, obsolete for those crops:

> "The widespread adoption of neonicotinoids as seed dressings has led to a move away from integrated pest management (IPM), a philosophy of pest management predicated on minimizing use of chemical pesticides via monitoring of pest populations, making maximum use of biological and cultural controls, applying chemical pesticides only when needed and avoiding broad-spectrum, persistent compounds."[55]

A 2014 report by the multi-stakeholder Corn Dust Research Consortium on neonicotinoid seed treatments and their impacts on honey bees contains these related recommendations:

- Minimize unnecessary use of seed treatment insecticides. Use them only when needed, such as where historic pest infestations are above threshold or high risk factors for pest pressure have been anticipated or determined.
- Follow the principles of integrated pest management.[56]

The broadly-supported Corn Dust Research Consortium report undercuts EPA's history of enabling unrestricted neonicotinoid use and promotes IPM as the better alternative. However, exhortations and voluntary recommendations will not change the reality of overuse spurred by advertising campaigns promoting these products directly to seed dealers and farmers. The market for seeds is heavily monopolized by a few companies.[57] In reality, US farmers often have almost no choice—untreated seeds are simply not available in most markets. It must also be recognized that synthetic neonicotinoid insecticides are not approved in organic agriculture. The harms neonicotinoids pose in and around conventional farm fields can damage nearby organic operations that rely on healthy ecosystems.

In conclusion, recent reports evaluated here examining the benefits of neonicotinoid seed treatments for crop yields in North America found they were largely illusory. European reports of crop yields being maintained even after regional neonicotinoid bans corroborate this finding. Opinions from several independent experts reinforce that neonicotinoids are massively overused in the US, without a corresponding yield benefit, across numerous agricultural contexts. The bottom line is that toxic insecticides are being unnecessarily applied in most cases.

RECOMMENDATIONS

In order to fully evaluate future insecticide registration applications and comply with the FIFRA mandate to account for costs and benefits, EPA should:

- Fully weigh both quantifiable and unquantifiable values in assessments of proposed systemic insecticide products, including at a minimum these foreseeable cost categories:
  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.
- Require verification by independent scientists and economists (preferably published in peer-reviewed journals) for claims of efficacy, crop yields, and economic benefits associated with all products.
- Reject applications to register any prophylactic insecticides that undermine basic IPM principles, may harm organic farm production, or are not cost-effective, either for the farmer or the nation as a whole.
- For all insecticidal seed treatment products, repeal the agency's waiver for "product performance data" in the FIFRA Product Performance regulation at 50 CFR § 158.400(e)(1) because of their prophylactic overuse, lack of efficacy, unique persistence, and high overall costs. Related to that, EPA also should promptly enforce the mandate in that regulation that: "each registrant must ensure through testing that his [sic] product is efficacious when used in accordance with label directions and commonly accepted pest control practices."

In light of the findings of this report, EPA should suspend all existing registrations of neonicotinoid seed treatment products whose costs and benefits have not been adequately weighed until this accounting is completed.

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