UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
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OFFICE OF CHEMICAL SAFETY
AND POLLUTION PREVENTION

MEMORANDUM

SUBJECT: Benefits of Neonicotinoid Seed Treatments to Soybean Production

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SUMMARY

The Biological and Economic Analysis Division (BEAD) analyzed the use of the nitroguanidine neonicotinoid seed treatments for insect control in United States soybean production. Imidacloprid, thiamethoxam, and clothianidin are applied to seeds at mostly downstream seed treating facilities prior to distribution to growers prior to planting. BEAD concludes that these seed treatments provide negligible overall benefits to soybean production in most situations. Published data indicate that in most cases there is no difference in soybean yield when soybean seed was treated with neonicotinoids versus not receiving any insect control treatment. Furthermore, neonicotinoid seed treatments as currently applied are only bioactive in soybean foliage for a period within the first 3-4 weeks of planting, which does not overlap with typical periods of activity for some target pests of concern. This information, along with current usage

data, suggests that much of the existing usage on soybeans is prophylactic in nature. Multiple foliar insecticides are available in instances where pest pressure necessitates a pest management tactic and such foliar insecticides have been found to be as efficacious as neonicotinoid seed treatments for target pests. These alternatives to neonicotinoid seed treatments include foliar sprays of organophosphates (acephate, chlorpyrifos), synthetic pyrethroids (bifenthrin, cyfluthrin, gamma-cyhalothrin, lamba-cyhalothrin, deltamethrin, esfenvalerate, zeta-cypermethrin, permethrin), neonicotinoids (imidacloprid, thiamethoxam, clothianidin), and the recently registered sulfoxaflor, which works in a similar way to neonicotinoids. In most cases, these alternatives are comparable in cost to one another and to neonicotinoid seed treatments. The cost of application was considered in this comparison, although because these alternatives can be tank-mixed with other chemicals that are typically applied to soybeans, additional passes over a field would not be necessary. In comparison to the next best alternative pest control measures, neonicotinoid seed treatments likely provide $0 in benefits to growers and at most $6 per acre in benefits (i.e., a 0%-1.7% difference in net operating revenue). Some neonicotinoid seed treatment usage could provide an insurance benefit against sporadic and unpredictable pests, particularly in the southern United States. However, BEAD did not find information to support the real-world significance of this benefit, and overall evidence indicates that any such potential benefit is not likely to be large or widespread in the United States.

BACKGROUND

This document analyzes how nitroguanidine neonicotinoid seed treatments (imidacloprid and thiamethoxam) are currently used in soybeans (e.g., target pests), alternatives to seed treatments, and the biological and economic benefits of imidacloprid and thiamethoxam seed treatments compared to other pest control options. Clothianidin is also registered for seed treatment use on soybeans, but its usage is minor in comparison to imidacloprid and thiamethoxam, and its relevance will be discussed later. Imidacloprid and thiamethoxam are registered for use as seed treatments on soybeans to control both foliar and soil dwelling pests, particularly soybean aphids, bean leaf beetles, wireworms, seed maggots, cutworms, and other minor pests. These treatments are most often applied to seeds at designated seed treatment facilities in combination with other active ingredients or additives, including fungicides, nematicides, fertilizers, growth enhancers, and/or accompanying stickers, adjuvants, and lubricants. Some growers can buy custom blends of treated seeds based upon their pest management needs, and most do not typically treat their own seeds at planting. Imidacloprid is applied to seeds at a rate of up to 62.5 g active ingredient (AI)/100 lbs of seed, while thiamethoxam is typically applied at 50-100 g Al/100 lbs of seed. While imidacloprid, thiamethoxam, and clothianidin are also registered for post-emergent foliar application to soybeans, this analysis is focused only on the benefits of imidacloprid and thiamethoxam seed treatments. Since foliar sprays ofneonicotinoids (and other insecticides) can target the same pest spectrum as neonicotinoid seed treatments, they are considered as potential alternatives in this analysis.

SOYBEAN PRODUCTION AND UTLIZATION IN THE UNITED STATES

In the United States, the Com Belt, the Great Lakes, and the Northern Plains Regions are the major production areas for soybeans. The primary states include Illinois, Iowa, Minnesota, and North Dakota. Table 1 summarizes U.S. soybean production and values in recent years. From 2009-2013, an average of76 million acres of soybean were harvested annually; this is up from previous years, with average acres harvested from 2004-2008 at 71 million acres annually. The average price per bushel has almost doubled, from $7.65/bu from 2004-2008 to $12.03 from 2009-2013. Although there was only a 7% increase in average annual production from 2004-2008 to 2009-2013, a recent 9% increase in total production from 2012 to 2013 may be an indicator of future increases in soybean production, which is likely in response to recent increases in export demand for soybeans (USDA NASS, 2010-2014; Wilson, 2014).

Table 1: Soybeans: Average Annual Production and Value (2009-2013)

	PRICE RECEIVED	TOTAL ACRES HARVESTED (1000 ACRES)	YIELD (BU/ACRE)	GROSS REVENUE/ ACRE	TOTAL PRODUCTION (1000 BU)	VALUE of PRODUCTION ($1000)
Corn Belt[1]	$12.24	33,636	46.23	$566	1,554,947	$18,908,122
Great Lakes[2]	$11.87	10,610	42.19	$501	447,618	$5,322,595
Northeast[3]	$12.06	1,508	38.69	$466	64,474	$782,909
Northern Plains[4]	$11.86	17,282	38.69	$459	668,692	$7,860,885
Southeast[5]	$12.01	12,724	51.03	$613	485,095	$5,859,460
United States	$12.03	75,760	44.60	$538	3,220,826	$38,733,969

Source: Crop Product Summary and Crop Values Summary (USDA NASS, 2010-2014). Numbers may not add due to rounding.

1 Illinois, Indiana, Iowa, Missouri, and Ohio
2 Michigan, Minnesota, and Wisconsin
3 Delaware, Maryland, New Jersey, New York, and Pennsylvania
4 Kansas, Nebraska, North Dakota, and South Dakota
5 Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, Virginia, and West Virginia

USE OF NEONICOTINOID SEED TREATMENTS ON SOYBEANS

On average, from 2008-2012, neonicotinoid-treated seeds were applied on 30% of soybean acres, (with some individual years approaching 40% of soybean acres). This ratio is roughly the same for every region in the United States, with the exception ofthe Northeast, where only 16% of acres were planted with neonicotinoid-treated seeds. By comparison, approximately 46% of soybean acres were reported to receive a seed treatment of some type as of 2009, which also included treatment with other insecticides, fungicides, nematicides, etc. Most of these seed treatments (39% of U.S. soybean acreage) were applied at downstream seed treating facilities, compared to 5% applied at commercial seed treating facilities and 2% applied by the grower prior to planting (Proprietary Seed Treatment Survey Data, 2009).

The primary neonicotinoid seed treatments for soybeans are imidacloprid and thiamethoxam. While clothianidin is also registered for use on soybeans as a seed treatment, it is used on less than 1 million acres on average from 2008-2012 (EPA Proprietary Data, 2014), which is low in comparison to imidacloprid and thiamethoxam. Furthermore, since the bioactivity and efficacy against target pests of clothianidin is functionally equivalent to thiamethoxam on soybeans, the conclusions from this memo would also apply to clothianidin seed treatments. Overall, slightly more acres of soybeans receiving neonicotinoid seed treatments in the United States were with thiamethoxam relative to imidacloprid; however this varies by region (Table 2). The highest use in terms of acres treated and pounds applied for both imidacloprid- and thiamethoxam-treated seeds was in the Com Belt, followed by the Northern Plains.

Table 2. Soybean Acreage and Neonicotinoid Seed Treatment Usage Data, 2008-2012

	Corn Belt[1]	Great Lakes[2]	Northeas	Northern Plains[4]	Southeast[5]	Total
Acres Grown	33,900,000	10,782,000	1,505,800	17,210,000	13,165,600	76,563,400
Percent Acres Treated						
Imidacloprid	16%	11%	9%	10%	7%	12%
Thiamethoxam	16%	20%	7%	22%	22%	19%
Total[6]	32%	31%	16%	32%	28%	31%
Acres Treated						
Imidacloprid	5,413,000	1,141,000	133,000	1,663,000	908,000	9,258,000
Thiamethoxam	5,368,000	2,142,000	109,000	3,818,000	2,830,000	14,267,000
Total[6]	10,781,000	3,283,000	242,000	5,481,000	3,738,000	23,526,000
Pounds Applied						
Imidacloprid	433,600	92,000	12,400	123,700	74,100	735,700
Thiamethoxam	151,700	63,800	3,300	110,800	85,600	415,200
Total[6]	585,300	155,800	15,700	234,400	159,700	1,151,000

Source: Crop Product Summary and Crop Values Summary (USDA NASS, 2010-2014); EPA Propnetary Data. Numbers are rounded and reflect 5-year averages.

1 Illinois, Indiana, Iowa, Missouri, and Ohio
2 Michigan, Minnesota, and Wisconsin
3 Delaware, Maryland, New Jersey, New York, and Pennsylvania
4 Kansas, Nebraska, North Dakota, and South Dakota
5 Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, Virginia, and West Virginia
6 Totals do not include the small amount of acreage treated with clothianidin (less than 1 million acres annually)

KEY EARLY-SEASON INSECT PESTS OF SOYBEANS

EPA proprietary usage data, derived from grower pesticide usage surveys (2004-2012) indicate that when insect pests are explicitly targeted by seed treatments, the national leading target pests are soybean aphid and bean leaf beetle. These pests were targets for seed treatments on approximately 20% of soybean acreage nationally from 2004-2012. Most growers (approximately 65%) did not indicate any specific target insect pests driving their usage of soybean neonicotinoid seed treatment products, suggesting that a large majority of usage in soybean could actually be prophylactic in nature, rather than in response to a specifically identified problem.

Of the pests identified as being targets for neonicotinoid seed treatments, soybean aphid is a particular pest of concern given its recent arrival to the U.S. Soybean aphid *(Aphis glycines* Matsumura) is an invasive pest that was first discovered in the mid-western U.S. in 2000 (Krupke et al., 2010). It is a piercing/sucking insect pest that feeds on soybean foliage and causes stress to the plant that can adversely affect yield at high aphid densities. The bean leaf beetle *(Cerotoma trifurcata)* is a chewing feeder on soybean foliage. Other identified pests, measured as the percentage ofU.S. crop acreage treated, include wireworm (10%), seed maggots (9%), and cutworms (4%). Because multiple target pests can be listed in the surveys that comprise the usage data, these percentages are not additive. In southeastern states in the U.S., the three-cornered alfalfa hopper was also listed by survey respondents as a significant early season target pest for seed treatments on soybeans. This pest does not typically occur in problematic numbers in regions outside the Southern U.S. (NC State, 2014) and is most often a problem in reduced-tillage systems and areas near unmanaged field margins due to the pest overwintering in plant debris (Ste\\(art et al. 2014).

Because of the limited early season bioactivity of seed treatments (3-4 weeks from planting) (MSU, 2014; NDSU, 2014; Purdue, 2014; PSU, 2014), only early-season occurring pests are considered in this analysis. These pests include soybean aphids, bean leaf beetles, cutworms, thrips, three-cornered alfalfa hoppers (which mostly only occur in the Southern U.S.), and the soil pest complex, which includes wireworms and seed maggots. Management of other pests that occur later in the season---{)r those that fall outside the activity spectrum of imidacloprid and thiamethoxam, such as other Lepidopteran pests of soybeans-are not considered in this analysis and may have a different spectrum of alternative treatments and/or require different management approaches than the pests listed above.

CHEMICAL CONTROL OF KEY EARLY-SEASON INSECT PESTS OF SOYBEANS

Historically, insecticide use on soybeans has been infrequent. EPA's source of proprietary usage information (2014) did not survey insecticide usage on soybeans prior to 2004. Historical data from USDA showed that total U.S. insecticide usage on soybeans averaged less than 430,000 lbs active ingredient (AI) per year between 1987-2004 (Fernandez-Cornejo et al., 2014), compared with an average of 3.9 million lbs AI (3.0 million lbs AI if seed treatments are excluded) per year from 2008-2012 (EPA Proprietary Data, 2014). In general, soybeans are known to be well adapted to foliage stress, compensating for foliage loss from insects and other damage sources without significant loss of bean yield. Foliage loss thresholds range from 15-35% depending on the time of the season (PSU, 2014). Prior to the arrival of the invasive soybean aphid, historically lower soybean prices probably resulted in few instances where insecticide usage on soybeans would have been economically justifiable.

Neonicotinoid seed treatments were first registered for use on soybeans in 2004 and grower adoption has increased appreciably since the uses were first captured in 2006 usage surveys

(EPA Proprietary Data, 2014). Numerous effective alternatives (foliar sprays) are also registered for the same foliar pests of soybeans that are targeted by neonicotinoid seed treatments. Table 3 summarizes the published extension recommendations from research universities representing the Com Belt, the Northern Plains, the Southeast, and the Northeast for control of soybean aphids, bean leaf beetles, cutworms, and three cornered alfalfa hoppers. Recommended foliar alternatives include organophosphates (acephate, chlorpyrifos), synthetic pyrethroids (bifenthrin, cyfluthrin, gamma-cyhalothrin, lamba-cyhalothrin, deltamethrin, esfenvalerate, permethrin, zeta-cypermethrin), neonicotinoids (imidacloprid, thiamethoxam, clothianidin), and the recently registered sulfoxaflor, which is classified as neonicotinoid-like. It is notable that none of the cited extension sources recommended neonicotinoid seed treatments for control of soybean aphid. Additional questionnaire data from soybean extension experts (NCIPMC, 2014), which will be discussed later in more detail, indicate that in most instances, seed treatments are ineffective against soybean aphids, as these aphids are not typically present/active in soybean fields during the early season period ofneonicotinoid bioactivity in newly emerged soybeans. While soybean aphids can occur during the early season, most infestations, especially those above treatment thresholds, occur later in the growing season. However, seed treatments are only effective at killing soybean aphids when aphids are active in soybean fields during this 3-4 week period of bioactivity. Therefore, insecticidal seed treatments on soybeans are not often effective at managing most soybean aphid infestations on a season-long basis. Since aphid populations are often low in the early season, it is difficult to predict how such an early season impact may affect subsequent population growth. For the states that do recommend seed treatments for bean leaf beetle (PSU, 2014) and three cornered alfalfa hopper control (MSU, 2014), the recommendations again are clearly qualified to indicate that control should only be expected for the first 3-4 weeks after planting.

Table 3: University Extension Recommendations for Insecticide Tools Targeting 4 Important Foliar Pests of Soybeans Based on Efficacy

	Soybean Aphid		Bean Leaf Beetle		Cutworms		Three-Cornered Alfalfa Hopper	
Insecticide	Extension Recommended Materials? {Yes= Y) with Sources of Recommendations							
Acephate	y	2,3	y	1, 2, 3			y	1
Chlorpyrifos	y	2,3,4	y	2,3,4	y	3,4		
Cyfluthrin	y	2,3,4	y	1, 2, 3, 4	y	1, 3, 4	y	1
Bifenthrin	y	2, 3,4	y	1, 2,3,4	y	1,3,4		
Deltamethrin	y	2,3, 4	y	2,3,4	y	3,4		
y-cyhalothrin	y	2,3,4	y	1, 2,3,4	y	1, 3, 4	y	1
A-cyhalothrin	y	2,3,4	y	1, 2,3,4	y	1, 3, 4	y	1
Esfenvalerate	y	2,3, 4	y	1, 2,3,4	y	1, 3, 4	y	1
Z-cypermethrin	y	2,4	y	1,2,4	y	1, 4	y	1
Permethrin			y	1, 2, 3,4	y	1, 3, 4		
Imidacloprid {foliar)	y	3	y	3				
Clothianidin {foliar)	y	3	y	3	y	4		
Sulfoxaflor {foliar)	y	3						
Imidacloprid {seed trt.)			Y*	2			Y#	1
Thiamethoxam {seed trt.)			Y*	2			Y#	1

Sources:
!-Mississippi State University, 2014
2-Penn State University, 2014
3-North Dakota State University, 2014
4-Purdue University, 2014
*Indicates that control is for early season only
#Indicates that control is only seen for the first 3-4 weeks after planting

Product Performance Against Foliar Pests of Soybeans:

Beyond the published extension efficacy recommendations listed above, BEAD evaluated available product performance data for the neonicotinoid seed treatments and alternative foliar sprays against the most important soybean pests. There were relatively few instances where significant yield protection was demonstrated for neonicotinoid seed treatments in comparison to an untreated control (i.e., applying no insecticides). For soybean aphid and bean leaf beetle in particular, only 5 out of 60 published comparisons showed any significant yield protection from either thiamethoxam or imidacloprid seed treatments when compared to doing nothing (Hammond, 2006; Jewett and DiFonzo, 2007a; Magalhaes et al., 2009; McCornack and Ragsdale, 2006a; Whitworth, 2005).

BEAD reviewed 34 published comparisons for thiamethoxam and 26 comparisons for imidacloprid from a total of 26 published efficacy studies in online university extension publications and the Entomological Society of America's online journal of Arthropod

Management Tests (Davis et al., 2010; Echtenkamp and Hunt, 2005, 2006a-b, 2007; Estes et al., 2004a-b, 2005a-b, 2006, 2007; Hammond, 2002, 2003, 2005, 2006; Heeren et al., 2008; Hodgson and VanNostrand, 2011; Jewett and DiFonzo, 2007a-c; McCornack and Ragsdale, 2006b; Tinsley et al., 2007, 2011; Way et al., 2005 Whitworth, 2005, 2006). BEAD also reviewed 9 peer-reviewed articles that evaluated the field efficacy of neonicotinoid seed treatments in some way (Cox et al., 2008; Cox and Cherney, 2011; Johnson et al., 2009; Magalhaes et al., 2009; McCornack and Ragsdale, 2006b; Ohnesorg et al., 2009; Reisig et al., 2012; Seagraves and Lundgren, 2012; Tinsley et al., 2013). In studies that included a comparison to foliar insecticides, there were no instances where neonicotinoid seed treatments out-performed any foliar insecticide in yield protection from any pest. In the majority of cases, yield was not significantly different between plots treated with neonicotinoid seed treatments at planting versus those treated with foliar sprays. In the few instances where significant differences were reported, it was the foliar spray treatments that resulted in higher yields than soybeans with seed treatments.

Other Regional/Sporadic Pest Considerations:

Soil insects, such as wireworms and seed maggots, are also listed as target pests for some of the surveyed usage ofneonicotinoid seed treatments (EPA Proprietary Data, 2014). One efficacy study demonstrated that an imidacloprid seed treatment protected soybean yield in a field with a high infestation of seed corn maggot. The observed efficacy was comparable to seed treatments of permethrin, diazinon, and lindane (Hammond, 2002). However, other similar studies in the same region failed to show significant yield effects for either imidacloprid or thiamethoxam when compared to untreated controls (Hammond, 2003, 2005). BEAD found no studies that explicitly evaluated efficacy against wireworms in soybeans, though efficacy against wireworm in other crops such as corn, cotton, and vegetables is well-established. Historically, usage of soil insecticides has been negligible on U.S. soybeans (EPA Proprietary Data, 2014). Furthermore, usage of alternative chemical seed treatments, including permethrin, which is a commonly recommended alternative for seed maggot control (Purdue 2014, NDSU 2014), is also negligible overall, with use never exceeding 0.5% of U.S. soybean acreage from 2004-2012 (EPA Proprietary Data, 2014). This indicates that soil pests such as seed maggot and wireworms have not historically driven pesticide usage in soybeans.

Another pest consideration that is unique to soybean growers in the Southern U.S. is the three cornered alfalfa hopper. Extension publications indicate that this pest is sporadic in nature and is often a higher risk in low-tillage systems and late planted (or later season double-crop) soybeans (MSU, 2014; Stewart et al. 2014). However, extension sources do recommend usage of seed treatments against this pest when planting into a known area of pest pressure (MSU, 2014). Hopper feeding causes girdling damage to young soybean plants and the thresholds for treatment are based upon the number or percentage of plants damaged by this feeding. One study from Louisiana compared a number of seed treatments for yield protection from three-cornered alfalfa hopper and showed that an experimental thiamethoxam seed treatment (similar in AI dosing to the commercial products) did significantly protect yield. However, yields from eight other formulations of thiamethoxam and imidacloprid in the same study were no different than an untreated control (Davis et al, 2010). Another efficacy study from Texas also showed no difference in yield between neonicotinoid seed treatments and an untreated control (Way et al., 2005). Much like the situation discussed above with soil insects, historical insecticide usage targeting this pest is very low, averaging less than 1% of national soybean acreage from 2004-2012 (EPA Proprietary Data, 2014). Given the known ability of soybeans to compensate for reductions in plant/foliage density and the sporadic occurrence of this pest, it difficult to project how much, if any, yield protection is gained by seed treatments targeting three-cornered alfalfa hopper.

Additional Unpublished Data:

In the summer of2014, the North Central IPM Center (NCIPMC) collected information through a questionnaire and additional unpublished data on neonicotinoid seed treatment efficacy, target pests, and benefits from national research and extension experts on a number of crops. The stated purpose of the questionnaire was to "gather input from researchers who have been working on neonicotinoid seed treatment projects and whose results/data have not yet been published." Overall, researchers completed a total of37 questionnaires. For the soybean portion ofthis questionnaire effort, 21 respondents representing 17 states (IA, IN, KS, LA, MD, MI, MN, MS, NC, ND, NE, OH, PA, SD, TN, TX, and VA) submitted responses.

Some key fmdings of the questionnaire were related to the perceived yield benefits of neonicotinoid seed treatments and the impact on the number of foliar insecticide sprays made to soybeans. When asked how the use ofneonicotinoid-treated seeds affected soybean yields, 74% of respondents (14/19) responded that yield either stayed the same or decreased. All ofthe 5 respondents who indicated that seed treatments increased soybean yield were researchers working in the Southern U.S., specifically LA, MS, and TN (NCIPMC, 2014). When asked if the use of seed treatments affected the amount of foliar pesticide applications on soybeans, 100% of the respondents indicated that foliar sprays (both aerial and ground) either stayed the same or actually increased (NCIPMC, 2014).

With regard to specific pest efficacy, there was almost universal agreement that neonicotinoid seed treatments are not typically effective against soybean aphids. This is because the limited period of bioactivity in soybeans (i.e., first 3-4 weeks) does not usually align with periods of soybean aphid presence/activity. Similarly, neonicotinoid seed treatments are not effective in controlling bean leafbeetles as this pest occurs too late in the season (NCIPMC, 2014). In both cases, adequate alternatives are available to control these pests via foliar applications. And in both cases, foliar applications of insecticides are more amenable to treating pest outbreaks on a threshold basis. When asked when (i.e., under what conditions) growers should use neonicotinoid seed treatments, 11 of20 respondents (55%) indicated that they should only be used under specific conditions-for example, when planting soybeans into a known area of high infestation, when double-cropping soybeans after wheat, or when planting early in the season. Ten percent of respondents (2 of20) indicated that seed treatments should always be used on soybeans (both respondents were from the Southern U.S.) to protect yield from unpredictable early season pest issues. One third of respondents (7 of21) indicated that neonicotinoid seed treatments should never be used on soybeans because they are too costly and do not deliver a significant pest management benefit. One of the respondents who indicated that seed treatments should only be used under specific conditions cited evidence from a manuscript submitted for peer review, and shared with BEAD, that indicates seed treatments used in the Northeastern U.S. may actually decrease soybean yields by increasing the populations of soybean-damaging slugs. Interestingly, it appears this happens due to a tri-trophic disruption of predator populations that would otherwise control slugs (Douglas, et al., unpublished data).

ECONOMIC BENEFITS OF NEONICOTINOID SEED TREATMENTS

There are no clear or consistent economic benefits of neonicotinoid seed treatments in soybeans. The next best alternative to neonicotinoid seed treatment is foliar spraying of various organophosphate, pyrethroid, and neonicotinoid insecticides. Nearly all soybean growers are already making foliar pesticide applications of some sort and thus have access to the necessary equipment for application. In addition, growers would not have to make an additional field pass as foliar alternative insecticides that target the same pest spectrum as neonicotinoid seed treatments are applied at the same time as a number of current foliar sprays (including herbicides, fungicides, miticides, etc.) and can be tank mixed. No yield gains are expected from neonicotinoid seed treatments, which means the only potential economic impact would be the cost of an insecticide used as a foliar spray. In the case of soybeans, thiamethoxam and imidacloprid seed treatments cost approximately $7 and $8 an acre, respectively, with an average cost of$7.50 (weighted by acres treated) (EPA Proprietary Data, 2014). Ofthe 11 viable foliar insecticides identified in this study that could potentially be used for the control of foliar soybean pests (including co-formulated mixes of multiple AI's), all cost less than $7/A, with the exception offlubendiamide which, on average, costs around $14/A. This also includes foliar sprays of the neonicotinoid insecticides thiamethoxam, clothianidin, and imidacloprid. In making a conservative estimate (i.e., assuming the highest possible grower benefits from using neonicotinoid seed treatments), BEAD considers the cost per acre offlubendiamide, the most expensive alternative. Given this upper-bound alternative cost assumption, growers are still not expected to see more than a 1.7% increase in net operating revenue using neonicotinoid seed treatments in lieu of a foliar spray (Table 4). This upper bound scenario is unlikely however, given the historically low use of flubendiamide on soybeans. More likely, soybean growers in need of a foliar alternative to neonicotinoid treated seeds will select equivalently priced, commonly used alternatives, thus incurring no economic impact. It is also possible that growers may experience a loss in net revenue when applying prophylactic seed treatments if there are no pests present to be targeted, as they would not have derived any benefit from the treatment.

Table 4: Upper Bound Estimate of the Average Economic Benefits to Soybean Growers in the US. from Using Neonicotinoid Seed Treatments.

	Neonicotinoid Seed Treatments Scenario	Flubendiamide Foliar Treatment Scenario
Yield (bu/A)	45	45
Price ($/bu)	$12.03	$12.03
Gross Revenue ($/A)	$536	$536
Insecticide Costs ($/A)		
seed treatment	$8	
foliar spray		$14
Other Variable Costs($/A)[1]	$173	$173
Total Variable Operating Costs ($/A)	$180	$186
Net Operating Revenue	$356	$350
Percent Change in Net Operating Revenue	+1.70%	

Source: Crop Product Summary and Crop Values Summary (USDA NASS, 2010-2014); USDA ERS Commodity Costs and Returns (2013); EPA Proprietary Data, 2014. Numbers may not add due to rounding.

1. Includes the cost of other insecticides, chemical applications, and seeds. Has been adjusted to account for the cost/A of neonicotinoid seed treatments.

Since no significant yield gains are expected for soybeans from the use of neonicotinoid seed treatments, any national benefits will be reflected in net operating revenue through changes in production costs. When considering the upper bound estimate, growers may derive a value from neonicotinoid treated seed of approximately $6/acre if switching to the most costly foliar treatment. EPA proprietary data show that on average from 2004 to 2012, approximately 65% of soybean growers in the U.S. indicated that they had no pest they were targeting when using neonicotinoid-treated seed. With 30% of the 75 million acres of soybeans in the U.S. being treated with neonicotinoid seed treatments, this implies that approximately 8.6 million of the 23 million soybean acres using neonicotinoid seed treatments derive potential benefits from the application. Multiplying through, if 8.6 million acres of soybeans derive benefits from neonicotinoid-treated seeds, the total benefit to soybean growers in the U.S. from neonicotinoid-treated seed is at most $52 million, or 0.14% of the total value of soybean production in the U.S., with the total value of soybeans being $38.7 billion/year, on average, from 2009-2013. Again, these benefits are unlikely given the very low historical usage of the most costly foliar alternative and the equivalent cost of comparable alternatives for the pests targeted by neonicotinoid treated soybean seeds.

GROWER CHOICE IN SEED TREATMENT USAGE

One issue of note is the availability of untreated seed relative to treated seed. While proprietary survey data indicates that the vast majority of soybean seed receiving seed treatment is treated at a downstream seed treating facility (EPA Proprietary Data, 2009), data from researchers and extension experts (NCIPMC, 2014) indicate that some growers currently have some difficulty obtaining untreated seed. Of the 20 responses from NCIPMC's soybean seed treatment expert questionnaire on the question of seed availability, 45% indicated that soybean seed not treated with neonicotinoids is either "difficult to obtain" (8 of 20 respondents) or "not available" (1 of

20 respondents). The other 55% (11 of20 respondents) indicated that untreated seed was "easy to obtain." One respondent indicated that even with downstream-treated seeds, growers sometimes have problems de-coupling insecticide options from other seed treatment products such as fungicides. For example, a grower purchasing seed treated with a particular fungicide may have no choice but to purchase neonicotinoid insecticide treatments on the same lot of seeds (NCIPMC, 2014).

UNCERTAINTIES IN THE ANALYSIS:

With regard to three-cornered alfalfa hoppers and soil insects such as wireworms and seed maggots, which are commonly found in high numbers in the Southern U.S., our analysis indicated that these pests have not historically driven pesticide usage. However, it is possible that soybean growers have achieved some yield protection or 'insurance' benefit by usage of neonicotinoid seed treatments. Indeed, extension publications do recommend the use of a seed treatment (either neonicotinoids or permethrin) when planting soybeans into a known area of high seed maggot infestation or prior damage. Similarly for three-cornered alfalfa hoppers, Mississippi State University (2014) lists seed treatments as an effective tactic for protecting soybeans for 3-4 weeks after planting.

Given the sporadic nature of these pests, it is difficult to project how much actual yield protection is gained on a year to year basis from the use of seed treatments, especially without knowing the potential for injury prior to planting. It is of note that all ofNCIPMC's informational responses (5 of 19, 26%) that indicated seed treatments led to an increase in soybean yield (NCIPMC, 2014) were from researchers working in the Southern U.S. (LA, MS, and 1N). These respondents indicated that three-cornered alfalfa hoppers, thrips, and the soil pest complex were the main drivers behind the benefits of seed treatments. When asked how the loss ofneonicotinoid seed treatments would affect production in their states, three ofthe five respondents indicated that major yield losses were not likely to occur on a widespread basis. Three of the five respondents also indicated that soybeans would be more at risk from early season pests. One respondent estimated that regional yield losses would be less than three bushels per acre, while one other respondent estimated that profitability would be decreased in most situations. When asked when (i.e., under what circumstances) growers should use neonicotinoid seed treatments, two responded "always" and three responded "only under specific circumstances" which included "cool, high stress" or "wet" conditions and early planting conditions where pest pressure is expected to be high, such as on land that was previously used for pasture or left fallow (NCIPMC, 2014).

Earlier in this memo, BEAD discussed data indicating that the yield impact of thrips is not significant for the Southern U.S. (Reisig et al., 2012). While seed treatments could potentially provide some insurance benefit for losses by seed maggots or alfalfa hoppers in cases where early season pressure is high, it is unknown how common or widespread this situation might be. Further, in many instances, the potential severity of pest pressure, especially for soil pests, can be difficult to predict. Given the availability of effective alternatives and the historically negligible usage of permethrin seed treatments, soil insecticides, or other foliar insecticides targeting these pests, BEAD at this time sees no evidence to indicate that associated yield loss risks on soybeans would be large or widespread in the absence of neonicotinoid seed treatments. Furthermore, depending on the effectiveness of scouting and efficacy of other threshold-based pest management tactics, the relative benefit of such preventative control may be reduced if/when growers are aware of pest activity soon after planting and have time to apply an insecticide. However, given cropping practices, pest pressure considerations and the difficulty of scouting for pest pressure prior to planting, it appears at least plausible that insurance benefits of seed treatment usage could be higher for the Southern U.S. growing region relative to the rest of the country. Conversely, it is also possible that even though historical usage of soil insecticides is reported to be low, future shifts to soil insecticide applications could potentially offer a similar insurance benefit to that observed by usage of neonicotinoid seed treatments

The following additional information, with supporting evidence, would be helpful to EPA in addressing existing or heretofore unknown uncertainties regarding benefits of neonicotinoid seed treatments on soybeans:

1. Whether significant 'insurance' benefits exist in the southern United States or elsewhere for prophylactic neonicotinoid seed treatment, including specific information on the yield impacts of sporadic pests and the corresponding impacts of preventative seed treatments on soybean yield.

2. The positive or negative consequences of neonicotinoid seed treatment usage within the broader soybean IPM context.

3. The impacts of seed treatment to pesticide resistance management in soybeans.

4. Additional cost savings or expenditures for soybean production that were not adequately captured by BEAD's benefit analysis.

CONCLUSION

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. In cases where pest pressure does necessitate some type of insect control, efficacious alternatives are available for the key foliar pests of soybeans at a comparable cost per acre. These alternatives include foliar sprays of the same neonicotinoid active ingredients that are currently being used as seed treatments. These alternatives are sometimes already used in combination with (i.e., subsequent to) neonicotinoid seed treatments, as seed treatments ultimately have a very short early-season period ofbioactivity.

At most, the benefits to soybean growers from using neonicotinoid treated seeds are estimated to be 1.7% of net operating revenue in comparison to soybean growers using foliar insecticide treatments. This estimate is very conservative because it is based on the assumption that growers currently using neonicotinoid seed treatments will choose to use the most expensive foliar alternative, which has historically low usage against the pests targeted by neonicotinoid seed treatments. It is more likely, based on the available data that growers will choose to make no application or use foliar alternatives that are equivalently priced to neonicotinoid seed treatments.

In instances where seed treatments may provide some insurance benefit against unpredictable outbreaks of sporadic pests, such as seed maggots or three cornered alfalfa hoppers, BEAD cannot quantify benefits with currently available information. However, this insurance benefit may exist for some growers, particularly those in the Southern U.S. Given currently available information, BEAD projects that any such benefits are not likely to be large or widespread, given the negligible historical pesticide usage targeting these pests in soybeans.

REFERENCES

Cox, W.J., Shields, E., and Cherney, J.H., 2008. Planting date and seed treatment effects on soybean in the northeastern United States. Agronomy Journal. 100(6): 1662-1665.

Cox, W.J., and Cherney, J.H., 2011. Location, variety, and seedling rate interactions with soybean seed-applied insecticides/fungicides. Agronomy Journal. 103(5): 1366-1371.

Davis, J.A., Kamminga, K.L., and Richter, A.R., 2010. Insecticide Seed Treatment Effects on Agronomic Factors and Early Season Soybean Insect Pests, 2009. Arthropod Management Tests 35:F44.

Douglas, M.R., Rohr, J.R., and Tooker, J.F., 2014. Penn State University, University of South Florida. Unpublished Data, Manuscript In Review.

Echtenkamp, G.W., and Hunt, T.E., 2005. Control of Bean Leaf Beetle in Soybeans, 2004. Arthropod Management Tests 30:F66.

Echtenkamp, G.W., and Hunt, T.E., 2006a. Control of Bean Leaf Beetle in Soybeans, 2005. Arthropod Management Tests 31:F32.

Echtenkamp, G.W., and Hunt, T.E., 2006b. Control of Soybean Aphid in Soybeans, 2005. Arthropod Management Tests 31:F33.

Echtenkamp, G.W., and Hunt, T.E., 2007. Control of Bean LeafBeetle in Soybeans, 2006. Arthropod Management Tests 32:F47.

Environmental Protection Agency (EPA), 2004-2014. EPA Proprietary Usage Data.

Estes, R.E., Steffey, K.L., and Gray, M.E., 2004a. Syngenta-sponsored evaluation of insecticides and fungicides to manage pests in soybeans, and effects on soybean yield in

Illinois, 2004. 2004 Annual Summary of Field Crop Insect Management Trials, Department of Crop Sciences, University of Illinois. <ipm.illinois.edulontarget/2004report.pdf> pp 20-21.

Estes, R.E., Steffey, K.L., and Gray, M.E., 2004b. Evaluation of seed- and foliar-applied insecticides to manage bean leaf beetles (Cerotoma trifurcate) in soybeans in Illinois,
2004. 2004 Annual Summary of Field Crop Insect Management Trials, Department of Crop Sciences, University of Illinois. <ipm.illinois.edu/ontarget/2004report.pdf> pp 24-25.

Estes, R.E., Schroeder, J.B., Steffey, K.L., and Gray, M.E., 2005a. Evaluation of insecticidal seed treatments to control soybean aphids (Aphis glycines Matsumura) in Illinois. 2005
Annual Summary of Field Crop Insect Management Trials, Department of Crop Sciences, University of Illinois. <ipm.illinois.edu/ontarget/2005report.pdf> pp 27-28.

Estes, R.E., Schroeder, J.B., Steffey, K.L, and Gray, M.E., 2005b. Evaluation of insecticidal seed treatments and foliar applied insecticides to control soybean aphids (Aphis Glycines Matsumura) in Illinois, 2005. 2005 Annual Summary of Field Crop Insect Management Trials, Department of Crop Sciences, University of Illinois. <ipm.illinois.edu/ontarget/2005report.pdf> pp 29-30.

Estes, R.E., Schroeder, J.B., Steffey, K.L, and Gray, M.E., 2006. Evaluation of foliar and seed-applied insecticides to control soybean aphid (Aphis glycines) in Illinois, 2006. 2006 Annual Summary of Field Crop Insect Management Trials, Department of Crop Sciences, University of Illinois. <ipm.illinois.edu/ontarget/2006report.pdt> pp 37-39.

Estes, R.E., Steffey, K.L., and Gray, M.E., 2007. Evaluation of foliar and seed-applied insecticides to control soybean aphids (Aphis glycines) in Illinois, 2007. 2007 Annual Summary of Field Crop Insect Management Trials, Department of Crop Sciences, University of Illinois. <ipm.illinois.edu/ontarget/2007report.pdf> pp 22-24.

Fernandez-Cornejo, J., Nehring, R., Osteen, C., Wechsler, S., Martin, A., and Vialou, A., 2014. Pesticide Use in U.S. Agriculture: 21 Selected Crops, 1960-2008. USDA-Economic Research Service Economic Information Bulletin Number 124. pp 65-68.

Hammond, R.B., 2002. Seedcorn Maggot Control with Seed Treatments on Soybean, 2001. Arthropod Management Tests 27:F100.

Hammond, R.B., 2003. Seed Treatments for Control of Insects in Soybean, 2002. Arthropod Management Tests 28:F98.

Hammond, R.B., 2005. Seedcorn Maggot Control with Seed Treatments in Soybean, 2004.· Arthropod Management Tests 30:F71.

Hammond, R.B., 2006. Seed Treatments in Soybean, 2005. Arthropod Management Tests 31:F36.

Heeren, J.R., Estes, R.E., Tinsley, N.A., Steffey, K.L., and Gray, M.E., 2008. Evaluation of foliar- and seed-applied insecticides to control soybean aphids (Aphis glycines) in Illinois, 2008. 2008 Annual Summary of Field Crop Insect Management Trials, Department of Crop Sciences, University of Illinois. <ipm.illinois.edu/ontarget/2008report.pdf> pp 28-29.

Hodgson, E.W., and VanNostrand, G., 2011. Evaluation oflnsecticides for Control of Soybean Aphid, 2009. Arthopod Management Tests 36:F87

Jewett, M.R., and DiFonzo, C.D., 2007a. Soybean Aphid Control Using Seed Treatments and Foliar Insecticides in Michigan, 2005. Arthropod Management Tests 32:F50.

Jewett, M.R., and DiFonzo, C.D., 2007b. Evaluation of Foliar Insecticides and Gaucho Seed Treatment under Low Soybean Aphid Numbers, Michigan, 2006. Arthropod Management Tests 32:F52.

Jewett, M.R., and DiFonzo, C.D., 2007c. Evaluation ofFoliar Insecticides and Cruiser Seed Treatment under Low Soybean Aphid Pressure, Michigan, 2006. Arthropod Management Tests 32:F53.

Johnson, K.D., O'Neal, M.E., Ragsdale, D.W., Difonzo, C.D., Swinton, S.M., Dixon, P.M, Potter, B.D, Hodgson, E.W., and Costamagna, A.C., 2009. Probability of cost-effective management of soybean aphid (Hemiptera: Aphididae) in North America. Journal of Economic Entomology. 102(6): 2101-2108.

Krupke, C.H., Obermeyer, J.L., and Bledsoe, L.W., 2010. Soybean Aphid. Purdue University Online Extension Publication E-217.W. <extension.entm.purdue.edu/publications/E-217.pdf.>

Magalhaes, I.C., Hunt, T.E., and Siegfried, B.D., 2009. Efficacy ofneonicotinoid seed treatments to reduce soybean aphid populations under field and controlled conditions in Nebraska. Journal ofEconomic Entomology. 102(1): 187-195.

McComack, B.P., and Ragsdale, D.W., 2006a. Efficacy ofthiamethoxam to suppress soybean aphid populations in Minnesota soybean. Crop Management. 5(1).

McComack, B.P., and Ragsdale, D.W., 2006b. Efficacy of Registered and Experimental Rates ofThiamethoxam for Soybean Aphid Control, 2005. Arthropod Management Tests 31:F42.

MSU, 2014. Mississippi State University Extension Service Online Insect Control Guide for Agronomic Crops. <msucares.com/pubs/publications/p247l.pdf.> pp 22-44.

NC State, 2014. Three Cornered Alfalfa Hopper. North Carolina State University Cooperative Extension Online Soybean Production Guide. <soybeans.ces.ncsu.edu/three-cornered- alfalfa-hopper>

NDSU, 2014. 2014 Field Guide Insect Management, Online Soybean Insect Guide. <ag.ndsu.edu/extensionentomology/field-crops-insect-pests/Documents/nd-field-crop-insect-mgt.-guide/e-1143-2014>

North Central IPM Center, 2014. Neonicotinoid Seed Treatment Expert Opinion Questionnaire. Informal Survey ofNational Subject Matter Experts, Coordinated and Prepared by Jean Haley and Lynnae Jess, North Central IPM Center. Proprietary Questionnaire Feedback and Unpublished Data Provided to EPA, September 2, 2014.

Ohnesorg, W.J., Johnson, K.D., and O'Neal, M.E., 2009. Impact of reduced-risk insecticides on soybean aphid and associated natural enemies. Journal of Economic Entomology.
102(5): 1816-1826.

Purdue, 2014. Soybean Insect Control Recommendations-2014. Purdue Extension Online Publication. <extension.entm.purdue.edu/publications/E-77.pdf.>

PSU, 2014. Penn State Agronomy Guide, Soybean Pest Management. <extension.psu.edu/agronomy-guide/pm/sec4/sec43a>

Reisig, D.D., Herbert, D.A., and Malone, S., 2012. Impact ofneonicotinoid seed treatments on thrips and soybean yield in Virginia and North Carolina. Journal of Economic Entomology. 105(3): 884-889.

Seagraves, M.P. and Lundgren, J.G., 2012. Effects ofneonicotinoid seed treatments on soybean aphid aphid and its natural enemies. Journal of Pest Science. 85: 125-132.

Stewart, S., McClure, A., and R. Patrick, 2014. Soybean Insects: Three cornered Alfalfa Hopper. University of Tennessee Online Extension Publication W201. <https://utextension.tennessee.edu/publications/documents/W201.pdf>

Tinsley, N.A., Estes, R.E., Steffey, K.L, Gray, M.E., and Diers, B., 2007. Evaluation of resistant cultivars and seed-applied insecticides to control soybean aphids (Aphis glycines) in Illinois, 2007. 2007 Annual Summary of Field Crop Insect Management Trials, Department of Crop Sciences, University of Illinois. <ipm.illinois.edu/ontarget/2007report.pdf> pp 25-27.

Tinsley, N.A., Estes, R.E., and Gray, M.E., 2011. Evaluation of insecticidal seed treatments to control soybean aphids (Aphis glycines) and other insect pests of soybean in Illinois,
2011. 2011 Annual Summary of Field Crop Insect Management Trials, Department of Crop Sciences, University of Illinois. <ipm.illinois.edu/ontarget/2011report.pdf.> pp 33-34.

Tinsley, N.A., Steffey, K.L., Estes, R.E., Heeren, J.R., Gray, M.E., and Diers, B.W., 2012. Field-level effects of preventative management tactics on soybean aphids (Aphis glycines Matsumara) and their predators. Journal of Applied Entomology. 136: 361-371.

United States Department of Agriculture, Economic Research Service (USDA ERS). 2014. Commodity Costs and Returns: Soybeans. <ers.usda.gov/data-products/commodity-costs-and-returns.aspx#.U3yycfldWZ8>

United States Department of Agriculture, National Agriculture Statistics Service (NASS). 2010-2014. Soybean Prices and Yields. <nass.usda.gov/Quick_Stats/>

WayM.O, Nunez, M.S., McNauley, G.N., and Minton, B., 2005. Evaluation of Soybean Insecticide Seed Treatments, 2003. Arthropod Management Tests 30:F77.

Whitworth, R.J., 2005. 2005 Soybean Seed Treatment Trial. Online publication, Kansas State University Department of Entomology. <entomology.k-state.edu/doc/efficacy- trials/seed-treatment-trial-2005.pdf>

Whitworth, R.J., 2006. 2006 Thrips Insecticide Efficacy Trial (Soybean Seed Treatment). Online publication, Kansas State University Department of Entomology. <entomology.k-state.edu/doc/efficacy-trials/seed-treatment-trial-2006.pdf>

Wilson, 2014. Soybean Prices Rise Most in Five Weeks on China Demand. Bloomberg News. January 15, 2014._<bloomberg.com/news/2014-01-13/com-extends-biggest-gain-since-august-as-u-s-supply-seen-lower.htm1>