AgInfomatics

The value of pyrethroids in U.S. agricultural and urban settings:

Summary of the use of pyrethroid insecticides by U.S. crop farmers and the impacts of the non-pyrethroid scenario on insecticide use and farmer costs

2017

This report series, researched and produced by AgInfomatics, LLC, is an independent and comprehensive analysis of the economic and societal benefits of pyrethroid insecticides (bifenthrin, cyfluthrins, cyhalothrins, cypermethrins, deltamethrin, esfenvalerate, fenpropathrin, permethrin, and tefluthrin). The research was sponsored by the Pyrethroid Working Group, an informal association of firms marketing products based on the above pyrethroid active ingredients. These products are used in agricultural, structural and landscape applications.

AgInfomatics, an agricultural consulting firm established in 1995, conducted an analyses exploring the answer to the question: *What would happen if pyrethroids were no longer available or restricted beyond the current situation?* Comparing this hypothetical future to the economics associated with current applications allowed AgInfomatics to derive an estimate of the value of pyrethroids.

This estimated value was based on robust quantitative and qualitative study methods including econometrics, modeling of insecticide use, crop yield data, market impacts, surveys of growers, surveys of professional applicators and in-depth case studies. All these data sources and methods were used to triangulate on the above question.

The value of pyrethroids in North American agriculture and urban settings

Reports include:

1. Executive summary
2. Methods and assumptions for estimating the impact of pyrethroid insecticides on pest management practices and costs for U.S. crop farmers
3. Summary of the use of pyrethroid insecticides by U.S. crop farmers and the impacts of non-pyrethroid scenario on insecticide use and farmer costs
4. Estimated yield benefits and efficacy of pyrethroid insecticides for major U.S. crops based on a meta-analysis of small plot data
5. Use and value of insect management practices in U.S. alfalfa corn, cotton and soybean production
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1.0 Introduction

This report highlights some of the main findings from the crop-specific analyses reported in the *Methods and Assumptions for Estimating the Impact of Pyrethroid Insecticides on Pest Management Practices and Costs for U.S. Crop Farmers*. That report focuses primarily on providing a detailed and comprehensive description of the process and assumptions used to reallocate cropped acres treated with pyrethroids to be treated with alternative, non-pyrethroid insecticides for a hypothetical non-pyrethroid scenario. The main data used were the extensive GfK Kynetec data on insecticide use by U.S. crop farmers for 2012-2014. The report is more than 160 pages long and mostly technical in nature, with numerous tables and figures reporting results for 14 crops in total. That report provides 1 to 2 page summaries of the crop-specific results, but the broader conclusions and implications regarding the impact of pyrethroid insecticides on U.S. crop farmers are never developed and may be difficult to derive from the numerous tables and figures. As a result, this report aggregates and integrates some of the main findings from that report.

First, this report summarizes the use of pyrethroid insecticides by U.S. farmers based on the GfK Kynetec data for 2012-2014 for the following 14 crops: alfalfa, citrus, corn, cotton, potato, rice, sorghum, soybean, spring wheat, sugar beet, sunflower, sweet corn, tomato and winter wheat. In these reports, the term pyrethroid is used for the following active ingredients: bifenthrin, cyfluthrins, cyhalothrins, cypermethrins, deltamethrin, esfenvalerate, fenpropathrin, permethrin and tefluthrin. As a group, these 14 crops capture the major uses of pyrethroid insecticides in U.S. crop production. This summary focuses on crop acres treated with pyrethroids by crop and method of application, the major target pests for pyrethroids, as well as the importance of pyrethroids relative to other insecticide classes for each crop and the number of insecticide classes used by crop.

Next, this report presents the main results from the hypothetical non-pyrethroid scenario to highlight the role that pyrethroid insecticides play in U.S. crop production. These highlights focus on projected changes in crop acres treated with insecticides by insecticide class and by crop and total pounds of insecticide applied by insecticide class. However, the main focus is on the cost advantage of pyrethroid insecticides and the impact of the non-pyrethroid scenario on projected farmer costs for insecticides in these crops.

2.0 Use of pyrethroid insecticides

Pyrethroid insecticides are the most widely used class of foliar and soil-applied insecticides by U.S. farmers growing the 14 crops examined in this report. The annual average for 2012-2014 was almost 50 million acres treated with a pyrethroid insecticide, or 53% of the more than 93 million acres treated with a foliar or soil-applied insecticide in these crops (Table 1).[1] For these 14 crops, almost half of the foliar-applied insecticides are pyrethroids,

1 Note that these statistics do not include Bt insecticides delivered as plant-incorporated protectants in Bt corn and Bt cotton and do not include insecticides delivered as seed-treatments.

TABLE 1. Three-year average (2012-2014) planted acres and insecticide and pyrethroid treated acres by crop

		--------- Treated Acres ---------		
Crop	**Planted Acres**	**All Insecticides**	**Pyrethroids**	**% Pyrethroids**
Alfalfa*	20,547,000	5,276,364	2,972,708	56%
Citrus**	777,933	6,035,176	1,010,250	17%
Corn (all)	94,417,667	19,360,419	14,237,234	74%
Foliar	94,417,667	6,121,598	3,817,481	62%
Soil	94,417,667	13,238,821	10,419,753	79%
Cotton (all)	11,236,000	20,724,551	5,529,920	27%
Foliar	11,236,000	19,959,003	5,321,048	27%
Soil	11,236,000	765,548	208,872	27%
Potato (all)	1,093,333	3,083,025	718,122	23%
Foliar	1,093,333	2,460,614	691,357	28%
Soil	1,093,333	622,411	26,765	4%
Rice	2,709,667	1,199,260	1,105,696	92%
Sorghum	7,157,667	1,098,370	688,697	63%
Soybean	79,246,333	22,865,780	14,869,265	65%
Spring Wheat	12,337,000	2,428,814	1,517,493	62%
Sugar Beet (all)	1,196,667	853,578	362,985	43%
Foliar	1,196,667	532,234	268,446	50%
Soil	1,196,667	321,343	94,539	29%
Sunflower	1,685,667	1,674,733	1,428,502	85%
Sweet Corn	576,457	2,953,757	1,942,574	66%
Tomato	392,900	2,063,589	483,248	23%
Winter Wheat	42,175,333	3,859,225	2,735,074	71%
Total (all)	**275,549,623**	**93,476,641**	**49,601,768**	**53%**
Total Foliar	**275,549,623**	**78,528,517**	**38,851,839**	**49%**
Total Soil	**275,549,623**	**14,948,123**	**10,749,929**	**72%**

*Planted acres equals reported harvested acres for alfalfa hay and haylage but not seeding.
**Planted acres equals reported citrus bearing acres.

while 72% of all soil-applied insecticides are pyrethroids. Furthermore, foliar applications dominate the use of pyrethroid insecticides in these 14 crops — 38.9 million treated acres or 78% of total pyrethroid treated acres are foliar-applied (Table 1). Soil applications of pyrethroids are only registered for four of these crops: corn, cotton, potato and sugar beet. Of the 10.75 million acres treated with soil-applied pyrethroids, 10.42 million are in corn, showing the dominance of this method of application in this crop — there were only 3.8 million treated acres for foliar-applied pyrethroids in corn. Note, however, that total pyrethroid treated acres vary across these 14 crops, as does the percentage of total insecticide treated acres that these pyrethroid treated acres constitute (Figures 1 and 2).

FIGURE 1. Pyrethroid treated acres by crop (2012-2014 annual average)

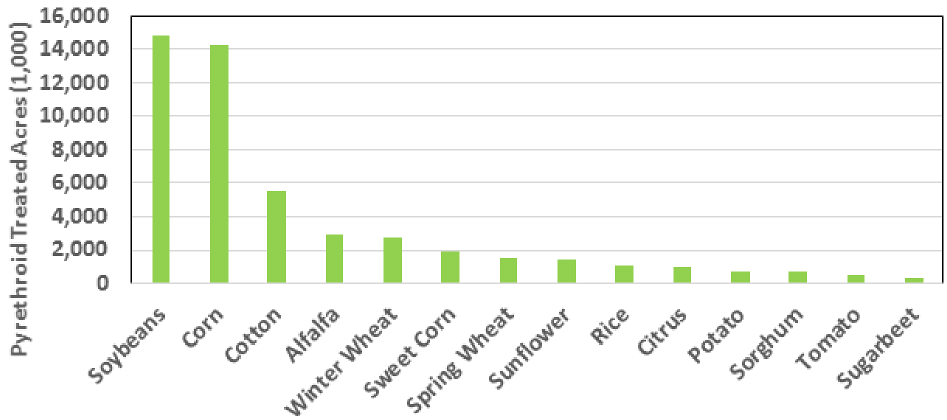


FIGURE 2. Pyrethroid treated acres as a percentage of all insecticide treated acres by crop

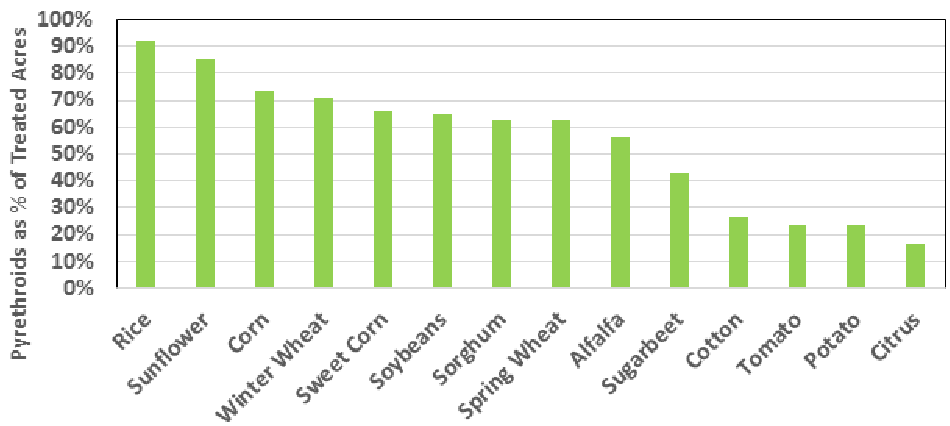


FIGURE 3. Average number of pyrethroid applications per planted acre (2012-2014 average)

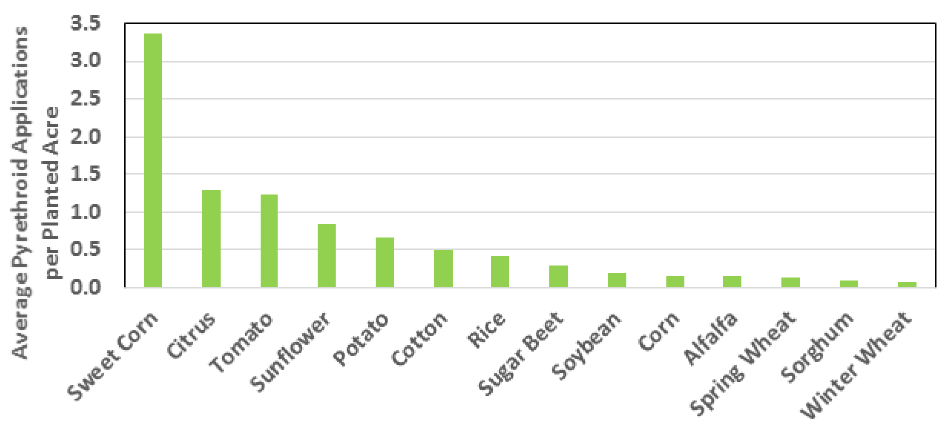


Figure 1 plots pyrethroid treated acres by crop from Table 1, sorted from largest to smallest. Soybean and corn uses dominate, with each crop having more than 14 million pyrethroid treated acres based on the 2012-2014 average. Cotton also has significant pyrethroid treated acres, with more than 5.5 million. The remaining crops have fewer pyrethroid treated acres, ranging from roughly 3 million for alfalfa to almost 363,000 for sugar beet. These results show that soybean and corn dominate pyrethroid use in terms of treated acres — together these two crops constituted almost 59% of the roughly 50 million pyrethroid treated acres. However, these treated acre data do not adequately indicate the importance of pyrethroids in some of these crops. For example, over this same 2012-2014 period, corn and soybean on average had more than 94 million and 79 million planted acres, respectively, while sugar beet had 1.1 million planted acres (Table 1). As a

result, Figures 2 and 3 were created to illustrate the relative importance of pyrethroids in these crops.

Figure 2 plots the percentage of insecticide treated acres for each crop that are pyrethroids to indicate how important pyrethroids are for insect management in these crops. Of all the insecticide treated acres in rice, 92% were pyrethroids, while 85% of insecticide treated acres in sunflower were pyrethroids, indicating the importance of pyrethroids for managing insects in rice and sunflower. This measure of relative importance is more than 70% for corn and winter wheat, more than 60% for sweet corn, soybean, sorghum, and winter wheat, and more than 50% for alfalfa. However, for the remaining crops, pyrethroids do not have as central of a role — less than 20% of insecticide treated acres were pyrethroids in citrus, and less than 30% for potato, tomato and cotton. These crops have a greater need for a wide range of insecticides to address the relatively larger pest spectrum that typically occurs during the life cycle of these crops, as well as the lower tolerance for direct insect damage and disease transmission in these crops.

Figure 3 plots the average number of pyrethroid applications per planted acre, which helps indicate the importance of pest management for a crop, especially when interpreted in light of the results in Figure 2.[2] Sweet corn has the largest number, with 3.37 pyrethroid applications per acre on average. This result implies that the crop receives multiple insecticide applications and, since Figure 2 shows that pyrethroids constituted about two-thirds of insecticide use, insect management is important for this crop and pyrethroids are an important part of this management. In Figure 3, the next two largest are citrus and tomato, each with around 1.25 pyrethroid applications per acre on average. Since Figure 2 shows that pyrethroids were a significant but small part of insect management for these crops, these results together imply that insect management is very important in these crops and that pyrethroids have a significant but small part to play, likely for insect resistance management. All the other crops in Figure 3 have less than one application of pyrethroids on average and can also be interpreted as the average proportion of planted acres treated with one application of a pyrethroid. For crops such as sunflower, pyrethroids play a major role in insect management — on average almost all sunflower acres receive an insecticide treatment and most of these treatments are pyrethroids. On the other hand, crops such as sorghum, winter wheat and spring wheat have a strong reliance on pyrethroids when managing pests (Figure 2), but a small proportion of planted acres for these crops require pest management (Figure 3).

Table 2 aggregates the target pest information for pyrethroids across the 14 crops, reporting the total treated acres targeted at that pest and separating it into foliar and soil-applied and then lists the top three crops. Because of the multiple species, lepidopteran pests were grouped together in the initial analysis and, because of the importance of these pests, the group is the largest target pest category for pyrethroid use, with corn, soybean and cotton the primary crops. Other leading target pests for pyrethroids

2 These averages should be interpreted with care since very different activities can generate the same average. For example, treating one-third of planted acres three times and all planted acres once both give an average of one application per planted acre.

TABLE 2. Target pests, treated acres and the three crops with the most treated acres by pest

Pest	Total	Foliar	Soil	Top Three Crops
Lepidopteran	12,706,469	9,372,657	3,333,812	Corn, soybean, cotton
Stink Bug	7,165,501	7,158,208	7,293	Soybean, cotton, rice
Aphid	6,111,331	6,108,432	2,899	Soybean, wheat, alfalfa
Corn Rootworm	4,962,188	703,990	4,258,198	Corn, sweet corn
Beetle	3,422,808	3,422,808	--	Soybean, wheat, sunflower
Mite	2,573,315	2,565,796	7,519	Soybean, corn, cotton
Weevil	2,360,804	2,360,804	--	Alfalfa, sunflower, rice
Orthopteran	2,057,510	2,054,611	2,899	Soybean, corn, wheat
Wireworm	1,368,172	18,417	1,349,755	Corn, sugar beet, potato
Plant Bug	1,305,767	1,295,547	10,220	Cotton, potato
Psyllid	953,745	953,745	--	Citrus, potato
White Grub	935,101	--	935,101	Corn, sugar beet, potato
Seed Corn Maggot	812,325	--	812,325	Corn
Leafhopper	733,574	733,574	--	Alfalfa, potato, sugar beet
Treehopper	572,014	572,014	--	Soybean
Flea Beetle	249,541	246,748	2,793	Corn, potato, sugar beet
Fly	236,912	236,912	--	Sorghum
Thrips	198,588	194,715	3,872	Cotton, tomato, citrus
Midge	183,617	183,617	--	Wheat
Hessian Fly	130,576	130,576	--	Wheat
Colorado Potato Beetle	120,708	116,763	3,945	Potato
Leafminer	116,122	116,122	--	Citrus, sugar beet, tomato
Japanese Beetle	110,497	110,497	--	Sweet corn
Sawfly	69,805	69,805	--	Wheat
Whitefly	53,210	52,191	1,019	Tomato, sugar beet
Root Maggot Adult	42,560	42,560	--	Sugar beet
Springtail	20,611	13,217	7,394	Sugar beet
Greenbug	8,264	8,264	--	Sorghum
Root Maggot Larvae	7,404	--	7,404	Sugar beet
Root Aphid	5,104	5,104	--	Sugar beet
Fleahopper	3,480	--	3,480	Cotton
All	**49,597,623**	**38,847,694**	**10,749,929**	

Order	Total	Foliar	Soil	Top Three Crops
Hemiptera	16,911,990	16,887,079	24,911	Soybean, cotton, wheat
Coleoptera	13,529,820	6,980,028	6,549,792	Corn, soybean, alfalfa
Lepidoptera	12,822,591	9,488,780	3,333,812	Corn, soybean, cotton
Class Arachnida	2,573,315	2,565,796	7,519	Soybean, corn, cotton
Orthoptera	2,057,510	2,054,611	2,899	Soybean, corn, wheat
Diptera	1,413,394	593,664	819,730	Corn, wheat, sorghum
Thysanoptera	198,588	194,715	3,872	Cotton, tomato, citrus
Hymenoptera	69,805	69,805	--	Wheat
Class Collembola	20,611	13,217	7,394	Sugar beet

include stink bugs, aphids, rootworms (primary soil use in corn and sweet corn) and other beetles, mites, and weevils, with a long list of other pests. To help make more sense of the target pests, the pests were grouped by insect order in the bottom portion of Table 2. This grouping shows that bugs (Hemiptera) are the largest target pest group, with stink bugs and aphids the largest sub-groups, but also key pests such as plant bugs, psyllids, and various "hoppers", with almost all of these applications foliar-applied. The next largest group are beetles (Coleoptera), with corn rootworm, weevils, wireworm, white grubs, as well as other specific beetles (flea beetles, Colorado potato beetle, Japanese beetle). Many of these applications are soil-applied and targeted at the larval phase of the insects below-ground, so that as a group, coleopteran insects constituted about two-thirds of the target insects for soil-applied pyrethroids. Lepidopteran pests are the third largest group, including various pests such as armyworms, cutworms, bollworms/earworms/budworms, stalk borers and loopers, most commonly the larval phase for above-ground foliar applications. Together, these three orders constituted 43.3 million treated acres or 87% of the total 49.6 million pyrethroid treated acres. The remaining groups are smaller in terms of treated acres treated but still significant. These include mites (class Arachnida), Orthoptera (primarily grasshoppers), various flies, midges and maggot larvae (Diptera), thrips (Thysanoptera), and finally, specific target pests for single crops — sawflies from order Hymenoptera in wheat and springtails (class Collembola) in sugar beet.

Figure 4 reports the number of insecticide classes used for each crop, focusing only on these classes with more than 1% of total insecticide treated acres for each crop based on the GfK Kynetec data for 2012-2014. For tomato, potato and citrus with relatively more intensive insecticide use, 10 to 13 insecticide classes were used, indicating that pyrethroids are one of many classes used in rotations to manage insecticide resistance. The next group are primarily large-acre commodity crops, including cotton, corn, soybean, alfalfa and sorghum, plus sugar beet, and sweet corn, using 4 to 6 insecticide classes. In these crops, pyrethroids are part of a much smaller suite of classes used. In many cases, a substantial portion of the insecticide treated acres in these crops, as Figure 2 shows. In these crops, managing insecticide resistance is even more important due to the large number of planted acres for most of these crops and the fewer insecticide classes used. In these crops, pyrethroids are often the primary insecticide used, but rotations to other insecticide classes are important for managing insecticide resistance, and in many cases, these alternatives are more costly. The final group includes crops using 2 or 3 insecticide classes, which seems too few. As Figure 2 shows, pyrethroids are the dominant insecticide used in these crops and without rotation to other insecticide classes, the risk of insect resistance developing would seem high.

Table 3 reports data on farmer expenditures for insecticides to demonstrate the cost advantage of pyrethroids relative to non-pyrethroid alternatives. Based on the GfK Kynetec data for 2012-2014, Table 3 reports the average farmer spending in dollars per treated acre for pyrethroids and non-pyrethroids for each crop. These averages are calculated by summing average total spending on pyrethroids for the three years and dividing by the average total pyrethroid treated acres over the three years. As a

FIGURE 4. Number of insecticide classes by crop, for all classes with more than 1% share of treated acres

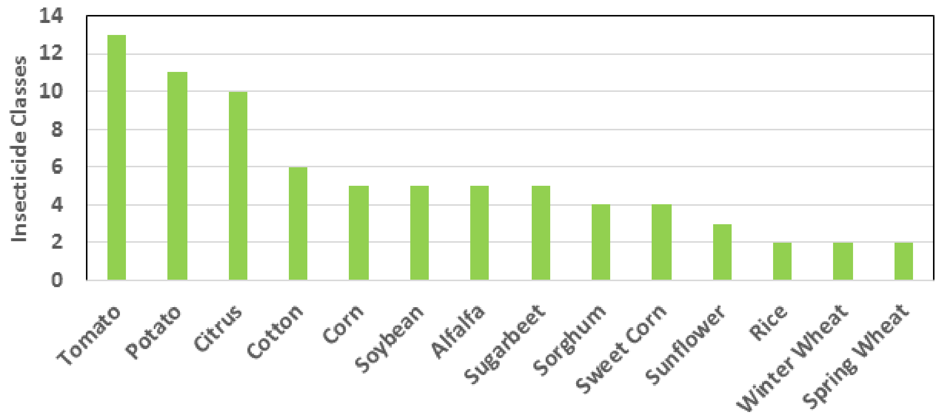


TABLE 3. Average cost advantage for pyrethroids relative to non-pyrethroids by crop, based on 2012-2014 average expenditures per insecticide treated acre

	Average Cost ($/Treated Acre)		Average Pyrethroid Cost Advantage	
Crop	**Pyrethroid**	**Non-Pyrethroid**	**$/Treated Acre**	**%**
Alfalfa	$4.35	$6.79	$2.44	36%
Citrus	$9.06	$19.22	$10.16	53%
Corn: Foliar	$4.58	$8.51	$3.93	46%
Corn: Soil	$5.59	$14.44	$8.85	61%
Cotton: Foliar	$3.86	$5.23	$1.37	26%
Cotton: Soil	$2.49	$12.18	$9.69	80%
Potato: Foliar	$3.71	$16.78	$13.07	78%
Potato: Soil	$10.66	$17.69	$7.03	40%
Rice	$4.03	$8.75	$4.72	54%
Sorghum	$3.83	$5.33	$1.50	28%
Soybean	$3.56	$4.77	$1.21	25%
Spring Wheat	$3.20	$3.49	$0.29	8%
Sugar Beet: Foliar	$4.24	$13.90	$9.66	69%
Sugar Beet: Soil	$4.48	$16.55	$12.07	73%
Sunflower	$3.51	$6.49	$2.98	46%
Sweet Corn	$4.62	$12.94	$8.32	64%
Tomato	$5.51	$18.15	$12.64	70%
Winter Wheat	$3.51	$4.86	$1.35	28%
Weighted Average				
Foliar only	**$3.99**	**$6.78**	**$2.79**	**41%**
Soil only	**$5.53**	**$14.42**	**$8.89**	**62%**
All	**$4.32**	**$8.50**	**$4.18**	**49%**

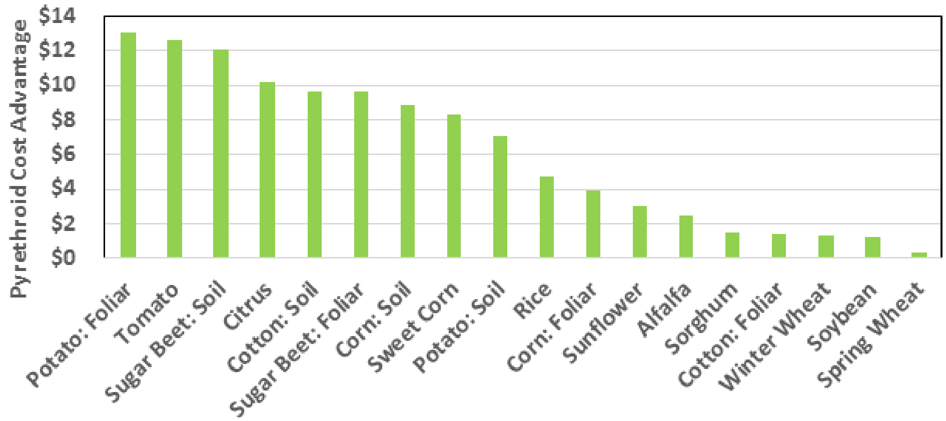
result, these averages are acreage weighted averages across three years that weight over application rates based on spending per acre and are based on actual farmer practices. All pyrethroid active ingredients were grouped as pyrethroids, and all other active ingredients were grouped as non-pyrethroids. The results in Table 3 show the cost advantage of pyrethroids relative to non-pyrethroids as a group. For all crops and application methods, the average cost advantage of pyrethroids is $4.18 per treated acre or a 49% reduction relative to the non-pyrethroid average. For soil-applied insecticides, the average cost advantage is $8.89 per treated acre but falls to $2.79 per treated acre for foliar-applied insecticides, which are roughly 40% to 60% reductions relative to the non-pyrethroids.

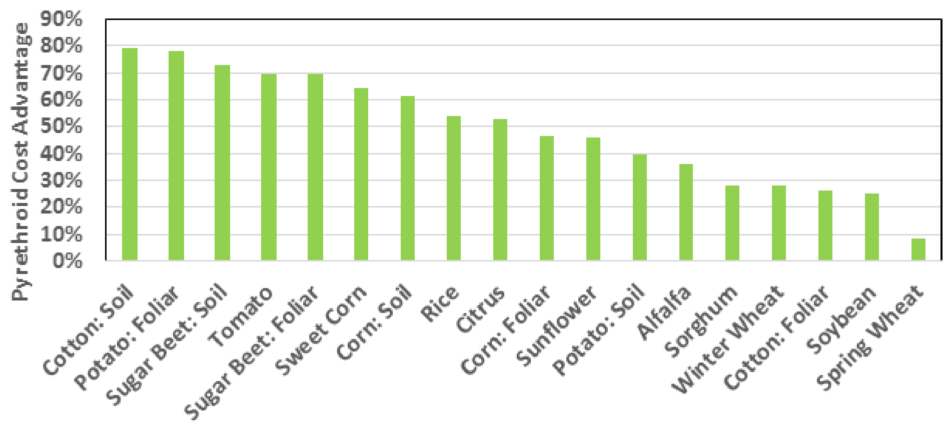
Figure 5 plots these same data but sorted from largest to smallest to facilitate visual comparisons across crops. The cost advantages are around $12 to $13 per acre for foliar-applied insecticides in potato and tomato, and soil-applied insecticides in sugar beet, and around $10 per acre for citrus, soil-applied insecticides in cotton and foliar-applied insecticides in sugar beet. The cost advantage is much lower on the other end of the spectrum — only $0.29 per acre for spring wheat and between $1 and $2 per acre for foliar applications in soybean, winter wheat, cotton and sorghum. The remaining crops range between $8.85 for soil-applied insecticides in corn to $2.44 for foliar applications in alfalfa.

These results demonstrate a significant source of value for pyrethroid insecticides — they are a relatively low cost insecticide class. When combined with the data on the number of insecticide classes used for each crop as reported in Figure 4, an additional benefit becomes evident — they are a low cost class to use in rotation with more costly insecticides in order to reduce the likelihood that insecticide resistance will develop, either to the low cost and effective pyrethroid class or to more costly non-pyrethroid insecticides. Pyrethroids are an economical way to manage insecticide resistance by rotating insecticide classes.

In summary, pyrethroids are the most used insecticide class among foliar and soil-applied insecticide treatments. For the 14 crops examined, the 2012-2014 average was almost 50 million pyrethroid treated acres or 53% of the total foliar and soil-applied insecticide for these crops. In these crops, about three-fourths of the pyrethroid applications were foliar-applied, and pyrethroids as a group constituted about half of all foliar-applied insecticides but almost three-fourths of all soil-applied insecticides. In terms of total pyrethroid treated acres, corn, soybean and cotton were the largest users — these three crops together constituted about 34.6 million pyrethroid treated acres or almost 70% of total pyrethroid treated acres. However, in terms of the intensity of use, pyrethroids were 92% of all insecticide treated acres for rice, 85% for sunflower and were more than 50% of insecticide treated acres for many other crops (corn, winter wheat, sweet corn, soybean, sorghum, spring wheat, alfalfa). As another measure of the intensity of use, the average number of pyrethroid applications per planted acre for pyrethroids shows more than three for sweet corn and more than one for tomato and citrus. Overall, these results show that pyrethroids play a very significant role in insect management in these crops.

FIGURE 5. Average pyrethroid cost advantage as dollars per treated acre (top) and as percentage reduction in average insecticide cost for pyrethroids relative to non-pyrethroids (bottom)





Examining the usage data for 2012-2014 also indicates two benefits of pyrethroids. First, their relative cost advantage and their role in managing insect resistance. First, averaging across acres, rates, years and crops, pyrethroids have a relative cost advantage of $4.18 per treated acre compared to non-pyrethroids as a group or almost 50% lower than non-pyrethroids. For foliar-applied insecticides, this cost advantage is $2.79 per treated acre or a 41% reduction compared to non-pyrethroids, while for soil-applied pyrethroids this cost advantage is $8.89 per treated acre or a 62% reduction compared to non-pyrethroids. These results show that compared to non-pyrethroid insecticides as a group, pyrethroids have a tremendous cost advantage. In addition, a key role that pyrethroids play is as an effective insecticide class to rotate with more expensive classes in order to reduce the likelihood of insecticide resistance developing, to either pyrethroids or non-pyrethroids. The data show that some crops use as few as two insecticide classes, raising concerns that resistance problems may arise. Overall, pyrethroids help preserve the efficacy of multiple insecticide classes by providing a low cost alternative class to use in an insecticide rotation.

3.0 Non-pyrethroid scenario

As part of a comprehensive assessment of the economic benefits of pyrethroid insecticides, a non-pyrethroid counterfactual scenario was constructed for these 14 crops. Counterfactual analysis is a commonly used technique that involves developing hypothetical scenarios and examining

differences between a base case and these scenarios to estimate benefits. For this analysis, the counterfactual process involved developing a description of how farmer active ingredient uses and costs would change for these crops if pyrethroid insecticides were not available. Differences between the 2012-2014 base case and this non-pyrethroid scenario then indicate the impact of pyrethroids on farmer active ingredient uses and costs. These 14 crops were chosen for the analysis because they are not only important crops in terms of total acres and crop value, but also because, as shown in the previous section, farmers rely on pyrethroid insecticides to manage serious insect pests when growing these crops. Furthermore, these are major U.S. crops for which economic models already exist for analyzing policies of this sort, or USDA data exist to develop such models. That analysis is described and the results presented in *An Economic Assessment of the Benefits of Pyrethroid Insecticides in the United States.*

The non-pyrethroid scenario was developed by reallocating pyrethroid treated acres to non-pyrethroid active ingredients based on market shares, target pest information and application method data as reported by GfK Kynetec for 2012-2014. The full description of the methods and assumptions used to make the reallocation of pyrethroid treated acres to non-pyrethroid alternatives is presented in the report *Methods and Assumptions for Estimating the Impact of Pyrethroid Insecticides on Pest Management Practices and Costs for U.S. Crop Farmers.* That report also includes crop specific results, and so this section focuses on presenting an overview of results across crops.

4.0 Impact of the non-pyrethroid scenario on insecticide use

Table 4 summarizes the impact of the non-pyrethroid scenario on insecticide treated acres by insecticide class. The 2012-2014 average for each class is reported, then the new treated acres added for active ingredients in that class, then the resulting total treated acres for that class for the non-pyrethroid scenario. To help add context, the percentage change is reported relative to the 2012-2014 average, plus the number of crops using that insecticide class.

Overall, the results show that 49.6 million pyrethroid treated acres would be replaced by 47.5 million non-pyrethroid treated acres, with the decrease in treated acres occurring because the GfK Kynetec data show that farmers use slightly fewer applications on average for non-pyrethroids relative to pyrethroids. By far the largest projected increase in total treated acres is for organophosphates — 34.7 million treated acres are added, increasing organophosphate treated acres by 155% (57 million in total). The next largest is 4.7 million treated acres added for neonicotinoid active ingredients (75% increase), resulting in a new total of 11.0 million treated acres. Projected changes for other insecticide classes are much smaller in terms of total treated acres. Figure 6 illustrates the projected shifts. In terms of the other insecticide classes, carbamates add 2.2 million treated acres for a 345% increase, diamides add 1.9 million treated acres for a 213% increase, and benzoylureas add 1.1 million treated acres for a 99% increase. The key point

TABLE 4. Estimated impact of the non-pyrethroid scenario on insecticide treated acres by insecticide class when totaled over all modeled crops

		---------------- Treated Acres ----------------			
		2012-2014	Non-Pyrethroid Scenario		
Insecticide Class	# of Crops	Average	Added	New Total	Change
Avermectins	4	1,783,554	445,775	2,229,328	25.0%
Azadirachtin	4	106,084	122,468	228,553	115%
Benzoylureas	6	1,126,517	1,114,930	2,241,447	99.0%
Bifenazate	1	4,463	223	4,686	5.0%
Carbamates	10	645,209	2,226,509	2,871,717	345%
Cryolite	1	19,859	11,128	30,988	56.0%
Cyromazine	2	30,836	3,312	34,148	10.7%
Diacylhydrazines	4	338,868	319,379	658,247	94.2%
Diamides	12	896,584	1,907,040	2,803,624	213%
Flonicamids	2	340,162	56,696	396,858	16.7%
Microbial Disruptors	5	148,077	254,632	402,709	172%
Mite Growth Inhibitors	3	454,856	152,675	607,530	33.6%
Mitochondrial Complex I	1	37,537	6,663	44,200	17.8%
Neonicotinoids	9	6,288,508	4,696,578	10,985,086	74.7%
Organophosphates	14	22,307,161	34,685,084	56,992,245	155%
Oxadiazines	5	406,460	506,559	913,019	125%
Phenylpyrazoles	1	78,714	8,008	86,722	10.2%
Propargite	2	536,901	102,952	639,853	19.2%
Pymetrozine	1	120,578	67,603	188,180	56.1%
Spinosyns	6	1,786,446	538,415	2,324,860	30.1%
Tetronic Acid Derivatives	5	842,466	90,867	933,333	10.8%
Unknown	6	1,274,287	208,861	1,483,148	16.4%
Total Non-Pyrethroids	**14**	**39,574,126**	**47,526,354**	**87,100,480**	**120%**
Total Pyrethroids	**14**	**49,601,766**	**-49,601,766**	**0**	**-100%**
Total		**89,175,892**	**-2,075,412**	**87,100,480**	**-2.3%**

to note is that all treated acre changes are dwarfed by the large increase in organophosphate treated acres.

Figure 7 graphically presents the projected treated acreage shifts by crop. Sunflower and sugar beet show small increases in insecticide treated acres for the non-pyrethroid scenario (around 2 to 4%), while several other crops show negligible changes. The largest total treated acre reductions are projected for corn, winter wheat, alfalfa and cotton. Corn and winter wheat each have a projected decrease of more than 250,000 treated acres, while projected alfalfa treated acres decrease by nearly 490,000 and cotton by almost 880,000. However, in terms of percentage decreases in treated acres, the largest estimated decrease is for alfalfa at more than 9%, while sorghum, winter wheat and spring wheat each have projected decreases

around 6%. Because corn and cotton are relatively large acreage crops, the percentage decrease in insecticide treated acres for cotton is 4.2% and 1.3% for corn.

Table 5 and Figure 8 report results for projected change in pounds of active ingredients applied. Given the large projected increase in organophosphate treated acres, not surprisingly, the total projected pounds of organophosphates applied increases by 17.7 million pounds or 174%. The next largest increase is 3.7 million pounds for insecticides with unknown modes of action, in this analysis primarily sulfur. These are compounds used at high application rates, the 3.7 million pound increase only represents a 15% increase in total pounds applied from the 2012-2014 average of 24.8

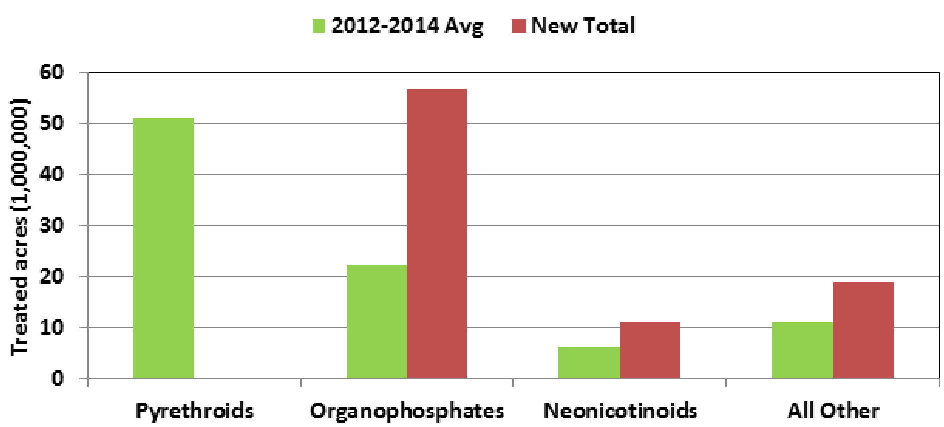
TABLE 5. Estimated impact of the non-pyrethroid scenario on pounds of insecticide applied by insecticide class when totaled over all modeled crops

		---- Pounds of Active Ingredient Applied ---			
		2012-2014	Non-Pyrethroid Scenario		
Insecticide Class	**# of Crops**	**Average**	**Added**	**New Total**	**Change**
Avermectins	4	19,771	4,740	24,511	24.0%
Azadirachtin	4	4,444	5,188	9,632	117%
Benzoylureas	6	82,538	82,564	165,101	100%
Bifenazate	1	2,232	111	2,343	5.0%
Carbamates	10	576,641	954,363	1,531,004	166%
Cryolite	1	322,066	180,474	502,540	56.0%
Cyromazine	2	4,128	539	4,667	13.1%
Diacylhydrazines	4	58,265	30,223	88,489	51.9%
Diamides	12	51,503	85,349	136,852	166%
Flonicamids	2	27,099	4,511	31,610	16.6%
Microbial Disruptors	5	19,132	33,728	52,860	176%
Mite Growth Inhibitors	3	41,715	11,142	52,857	26.7%
Mitochondrial Complex I	1	1,893	336	2,229	17.8%
Neonicotinoids	9	514,517	381,636	896,153	74.2%
Organophosphates	14	10,164,071	17,730,288	27,894,359	174%
Oxadiazines	5	26,711	109,143	135,854	409%
Phenylpyrazoles	1	7,699	783	8,483	10.2%
Propargite	2	1,135,719	485,292	1,621,010	42.7%
Pymetrozine	1	16,443	9,219	25,662	56.1%
Spinosyns	6	100,424	35,249	135,673	35.1%
Tetronic Acid Derivatives	5	132,253	24,394	156,647	18.4%
Unknown	4	24,758,507	3,738,531	28,497,038	15.1%
Total Non-Pyrethroids	**14**	**38,067,770**	**23,907,804**	**61,975,574**	**62.8%**
Total Pyrethroids	**14**	**3,294,296**	**-3,294,296**	**0**	**-100%**
Total		**41,362,066**	**20,613,508**	**61,975,574**	**49.8%**

million pounds. The next largest projected increase is 954,000 pounds for carbamates, a 166% increase. Overall, the analysis projects that 3.3 million pounds of pyrethroids are replaced with 23.9 million pounds of non-pyrethroids, of which about three-fourths are organophosphates.

In summary, the non-pyrethroid scenario replaces pyrethroid insecticides with non-pyrethroid alternatives based on market shares and target pests. The projected shift is to replace 49.6 million pyrethroid treated acres with 47.5 million acres treated with non-pyrethroids. In general, the largest projected replacement insecticides are organophosphates — 34.7 million of the 47.5 million non-pyrethroid treated acres added or 73% of the replacement treated acres. As a result, organophosphates treated acres increase by 155%. Projected changes for other insecticide classes are smaller in terms of new treated acres — the next largest increase is 4.7 million treated acres added for neonicotinoids (a 75% increase), while carbamates add 2.2 million treated acres (345% increase), diamides increase 213% by adding 1.9 million treated acres, and benzoylureas adding 1.1 million treated acres (99% increase).

FIGURE 6. Estimated impact of the non-pyrethroid scenario on treated acres by insecticide class for major use classes (top) and moderate use classes (bottom)
All Other category in bottom plot includes five minor use classes, see Table 4



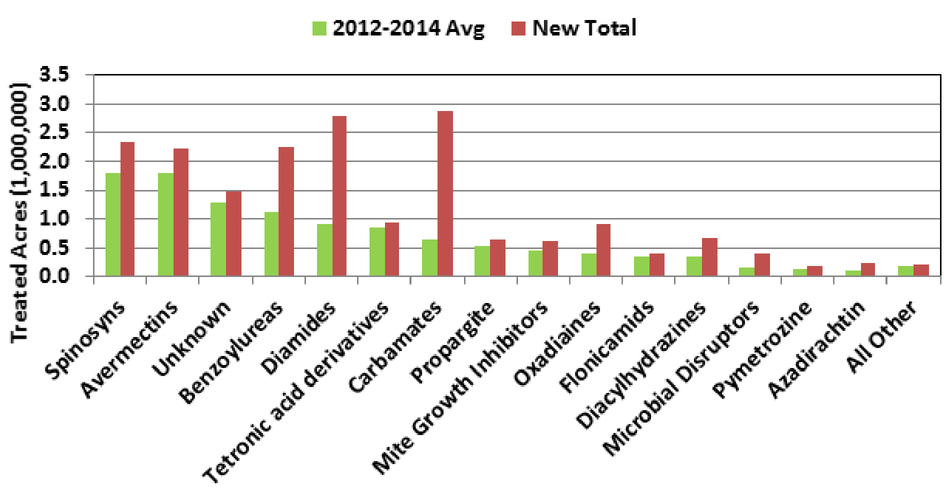
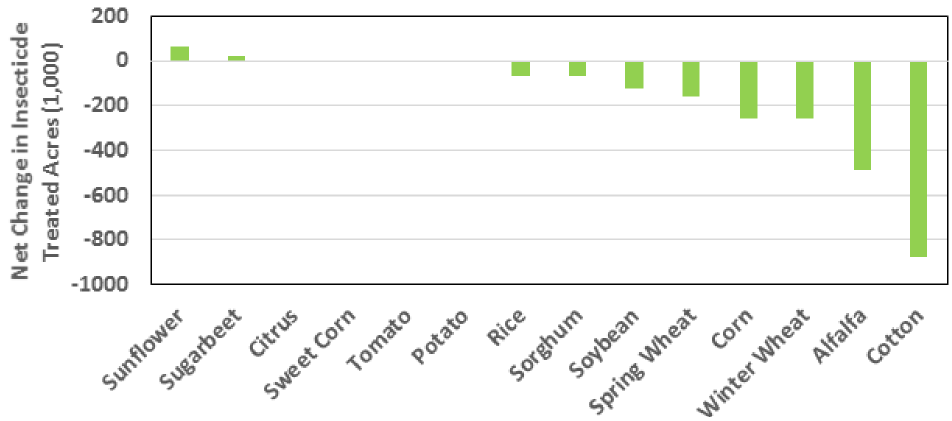


TABLE 6. Estimated impact of the non-pyrethroid scenario on insecticide treated acres by crop and change relative to the 2012-2014 average

Crop*	2012-2014 Average Treated acres for Pyrethroids	Non-Pyrethroid Treated acres to Replace Pyrethroids	Net Change**	Change**
Alfalfa	2,972,708	2,483,779	-488,929	-9.3%
Citrus	1,010,250	1,010,250	0	0.0%
Corn (all)	14,237,234	13,983,516	-253,718	-1.3%
Foliar	3,817,481	3,614,464	-203,017	-3.3%
Soil	10,419,753	10,369,051	-50,702	-0.4%
Cotton (all)	5,529,920	4,651,174	-878,746	-4.2%
Foliar	5,321,048	4,456,651	-864,397	-4.3%
Soil	208,872	194,523	-14,349	-1.9%
Potato (all)	718,122	712,280	-5,842	-0.2%
Foliar	691,357	690,142	-1,214	0.0%
Soil	26,765	22,137	-4,628	-0.7%
Rice	1,105,696	1,036,013	-69,683	-5.8%
Sorghum	688,697	618,736	-69,962	-6.4%
Soybean	14,869,265	14,746,451	-122,814	-0.5%
Spring Wheat	1,517,493	1,356,756	-160,737	-6.6%
Sugar Beet (all)	362,985	386,935	23,950	2.8%
Foliar	268,446	292,257	23,812	4.5%
Soil	94,539	94,678	139	0.0%
Sunflower	1,428,502	1,495,290	66,788	4.0%
Sweet Corn	1,942,574	1,942,574	0	0.0%
Tomato	483,248	483,248	0	0.0%
Winter Wheat	2,735,074	2,480,800	-254,274	-6.6%

*Treated acres for each crop are for foliar-applied insecticides unless noted otherwise.
**Relative to 2012-2014 average reported for all insecticides in Table 1.

FIGURE 7. Estimated impact of the non-pyrethroid scenario on insecticide treated acres by crop relative to 2012-2014 average, as net acreage change (top) and as percentage change (bottom)



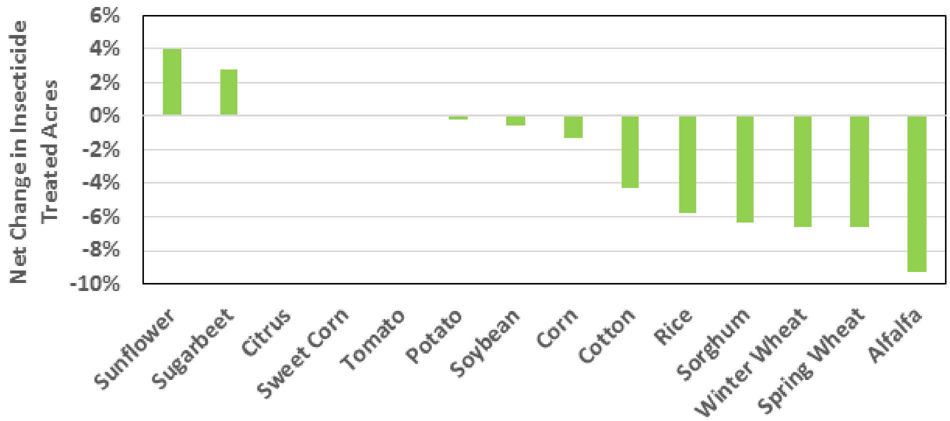
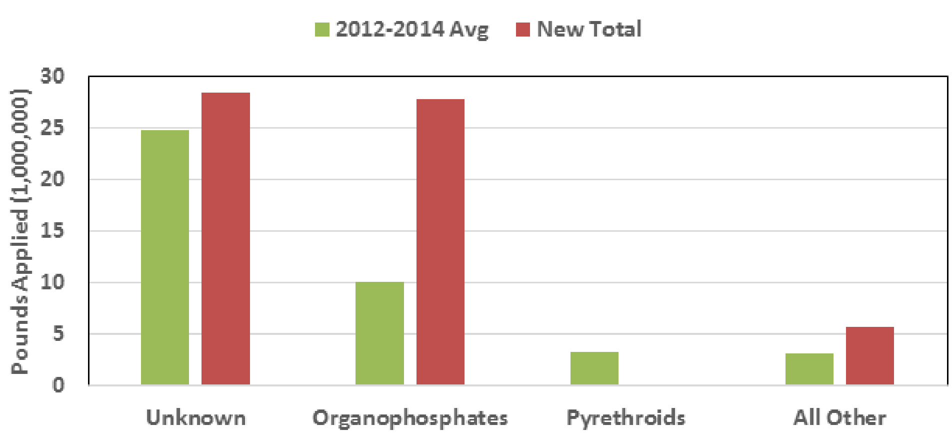
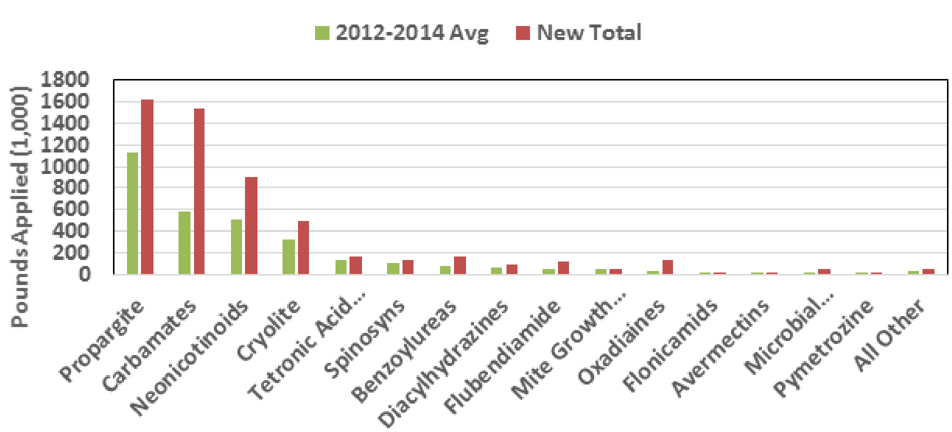


FIGURE 8. Estimated impact of the non-pyrethroid scenario on pounds of active ingredient applied by insecticide class for major use classes (top) and moderate use classes (bottom)
All Other category in bottom plot includes seven minor use classes, see Table 5





5.0 Impact of the non-pyrethroid scenario on farmer costs

Table 7 reports the projected impact of the non-pyrethroid scenario on farmer costs for buying insecticide active ingredients by crop. The first column of data reports the 2012-2014 average annual spending for pyrethroid insecticides by crop, and the next column reports the cost to replace these with non-pyrethroid active ingredients, and then the next columns gives

TABLE 7. Estimated impact of the non-pyrethroid scenario on insecticide active ingredient costs by crop and change relative to the 2012-2014 average spending for all insecticides

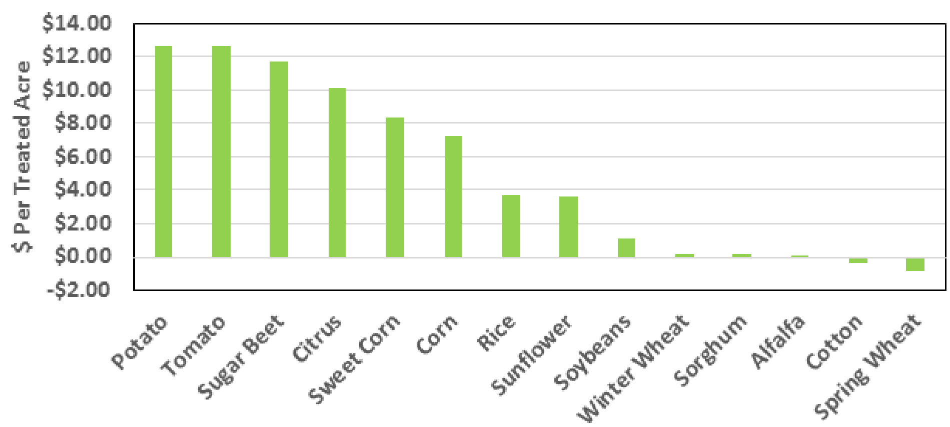
		-------------------- Non-Pyrethroid Scenario --------------------		
Crop*	2012-2014 Average Spending for Pyrethroids	Spending to Replace Pyrethroids	Net Change**	Change**
Alfalfa	$12,933,731	$16,856,839	$3,923,108	14%
Citrus	$9,152,618	$19,412,111	$10,259,493	10%
Corn (all)	$75,720,867	$180,443,826	$104,722,959	77%
Foliar	$17,486,493	$30,743,796	$13,257,303	36%
Soil	$58,234,374	$149,700,030	$91,465,656	92%
Cotton (all)	$21,079,435	$25,675,353	$4,595,918	4.4%
Foliar	$20,559,456	$23,306,351	$2,746,895	2.8%
Soil	$519,979	$2,369,002	$1,849,023	25%
Potato (all)	$2,850,071	$11,970,147	$9,120,076	21%
Foliar	$2,564,879	$11,578,464	$9,013,585	28%
Soil	$285,192	$391,683	$106,491	1.0%
Rice	$4,452,560	$9,067,478	$4,614,918	88%
Sorghum	$2,637,202	$3,297,514	$660,312	14%
Soybean	$52,971,319	$70,280,898	$17,309,579	19%
Spring Wheat	$4,850,175	$4,729,179	-$120,996	-1.5%
Sugar Beet (all)	$1,560,525	$5,627,487	$4,066,962	45%
Foliar	$1,137,157	$4,061,225	$2,924,068	61%
Soil	$423,368	$1,566,262	$1,142,894	27%
Sunflower	$5,008,165	$9,711,835	$4,703,669	71%
Sweet Corn	$8,970,434	$25,141,368	$16,170,934	73%
Tomato	$2,664,370	$8,772,899	$6,108,529	19%
Winter Wheat	$9,590,644	$12,066,083	$2,475,440	16%
Total (all)	**$214,442,115**	**$403,053,018**	**$188,610,903**	**31%**
Total Foliar	**$154,979,202**	**$249,026,041**	**$94,046,838**	**19%**
Total Soil	**$59,462,912**	**$154,026,977**	**$94,564,065**	**78%**

*Results for each crop are for foliar-applied insecticides unless noted otherwise.
**Relative to 2012-2014 average for all insecticides.

the net change in costs for purchasing insecticide active ingredients. Lastly, to help add context, the final column reports the percentage change relative to the 2012-2014 average spending for all insecticides. Table 8 follows the same general format and structure but focuses on projected changes in insecticide application costs by crop for the non-pyrethroid scenario. Finally, Table 9 combines results from these two tables to report changes in total cost by crop for the non-pyrethroid scenario.

Table 7 shows that the projected costs for replacing pyrethroids with non-pyrethroid alternatives would increase farmer costs in all cases except for spring wheat. Based on the GfK Kynetec data for 2012-2014, overall farmers growing the 14 crops spent more than $214 million for pyrethroid insecticides, $155 million for foliar pyrethroids and $59 million for soil-ap-

FIGURE 9. Estimated impact of the non-pyrethroid scenario on farmer costs to buy and apply insecticides by crop expressed as the net increase in $ per treated acre (top) and as the percentage change (bottom) relative to 2012-2014 average



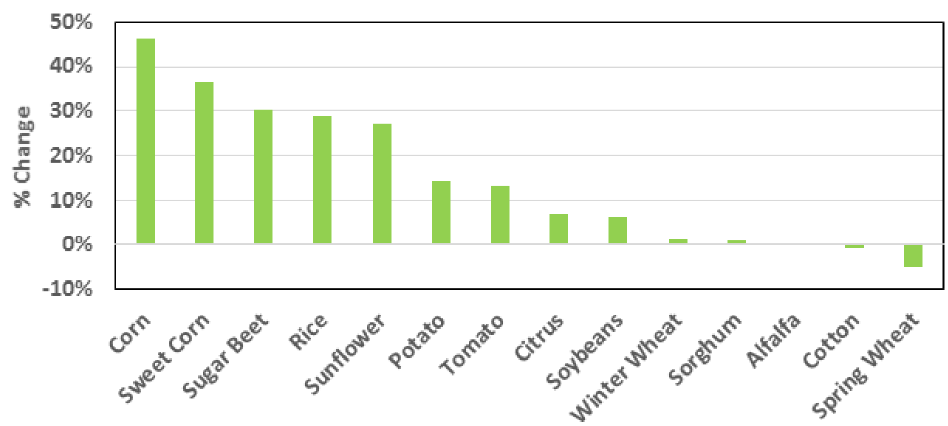
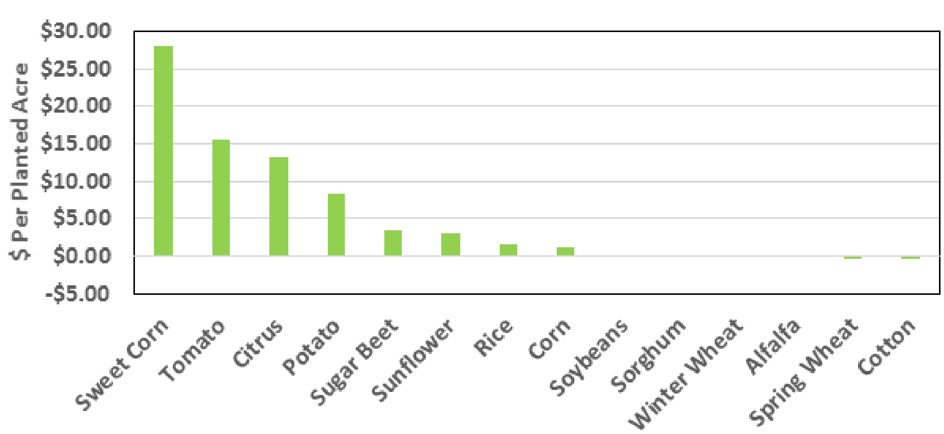


FIGURE 10. Estimated impact of the non-pyrethroid scenario on farmer costs by crop expressed as the net increase in $ per planted acre relative to 2012-2014 average



plied pyrethroid insecticides. The projected cost to replace these pyrethroids with non-pyrethroid alternatives is $403 million in total for these 14 crops, $249 million for foliar alternatives and $154 million for soil-applied alternatives. As a result, the net cost increase totals $189 million or a 31% increase relative to the 2012-2014 average spending for all insecticides. This net cost increase was roughly split evenly between foliar and soil-applied insecticides, and so the cost increase was 78% for soil-applied insecticide but only 19% for foliar insecticides.

TABLE 8. Estimated impact of the non-pyrethroid scenario on insecticide application costs by crop and change relative to the 2012-2014 average application costs for all insecticides

		-------------------- Non-Pyrethroid Scenario --------------------		
Crop*	**2012-2014 Average Spending for Pyrethroids**	**Spending to Replace Pyrethroids**	**Net Change****	**Change****
Alfalfa	$22,176,404	$18,528,992	-$3,647,412	-9.3%
Citrus	$7,536,465	$7,536,465	$0	0.0%
Corn (all)	$60,883,838	$59,211,653	-$1,672,185	-1.9%
Foliar	$28,478,406	$26,963,903	-$1,514,503	-3.3%
Soil	$32,405,432	$32,247,750	-$157,682	-0.4%
Cotton (all)	$40,344,609	$33,851,584	-$6,493,025	-4.3%
Foliar	$39,695,018	$33,246,617	-$6,448,401	-4.3%
Soil	$649,591	$604,966	-$44,624	-1.9%
Potato (all)	$5,240,760	$5,217,310	-$23,450	-0.1%
Foliar	$5,157,521	$5,148,463	-$9,058	0.0%
Soil	$83,239	$68,847	-$14,392	-0.7%
Rice	$8,248,492	$7,728,659	-$519,833	-5.8%
Sorghum	$5,137,682	$4,615,768	-$521,914	-6.4%
Soybean	$110,924,714	$110,008,524	-$916,190	-0.5%
Spring Wheat	$11,320,495	$10,121,400	-$1,199,096	-6.6%
Sugar Beet (all)	$2,296,621	$2,474,687	$178,066	3.6%
Foliar	$2,002,605	$2,180,239	$177,635	4.5%
Soil	$294,016	$294,447	$431	0.0%
Sunflower	$10,656,627	$11,154,863	$498,235	4.0%
Sweet Corn	$14,491,600	$14,491,600	$0	0.0%
Tomato	$3,605,028	$3,605,028	$0	0.0%
Winter Wheat	$20,403,652	$18,506,765	-$1,896,887	-6.6%
Total (all)	**$323,266,987**	**$307,053,297**	**-$16,213,690**	**-2.6%**
Total Foliar	**$289,834,709**	**$273,837,286**	**-$15,997,423**	**-2.7%**
Total Soil	**$33,432,278**	**$33,216,011**	**-$216,267**	**-0.5%**

*Results for each crop are for foliar-applied insecticides unless noted otherwise.
**Relative to 2012-2014 average for all insecticides.

In terms of crop specific results, the largest percentage increase was for soil insecticides used in corn, a projected cost increase of 92%, while for rice the projected cost increase was 88%. Other crops with large projected cost increases for replacement active ingredients included sweet corn, sunflower at 73% and 71% respectively, and 61% for foliar insecticides for sugar beet. On the other extreme, spring wheat had a projected cost decrease of 1.5%, while soil-applied active ingredient costs for potato increased only 1% and only 2.8% for foliar cotton insecticides. The remaining crops were between these extremes, a projected 36% increase for corn foliar insecticides and 10% increase for citrus.

TABLE 9. Estimated impact of the non-pyrethroid scenario on total insecticide costs by crop and change relative to the 2012-2014 average total costs for all insecticides

		------------------- Non-Pyrethroid Scenario -------------------		
Crop*	2012-2014 Average Spending for Pyrethroids	Spending to Replace Pyrethroids	Net Change**	Change**
Alfalfa	$35,110,135	$35,385,831	$275,696	0.4%
Citrus	$16,689,083	$26,948,576	$10,259,493	6.8%
Corn (all)	$136,604,704	$239,655,479	$103,050,775	46%
Foliar	$45,964,899	$57,707,699	$11,742,800	14%
Soil	$90,639,805	$181,947,780	$91,307,974	65%
Cotton (all)	$61,424,044	$59,526,937	-$1,897,107	-0.7%
Foliar	$60,254,474	$56,552,968	-$3,701,506	-1.5%
Soil	$1,169,570	$2,973,969	$1,804,399	19%
Potato (all)	$8,090,831	$17,187,458	$9,096,627	14%
Foliar	$7,722,400	$16,726,927	$9,004,527	18%
Soil	$368,431	$460,531	$92,100	0.7%
Rice	$12,701,052	$16,796,137	$4,095,086	29%
Sorghum	$7,774,884	$7,913,282	$138,398	1.1%
Soybean	$163,896,033	$180,289,422	$16,393,389	6.3%
Spring Wheat	$16,170,670	$14,850,579	-$1,320,091	-5.0%
Sugar Beet (all)	$3,857,146	$8,102,174	$4,245,028	30%
Foliar	$3,139,762	$6,241,465	$3,101,703	35%
Soil	$717,384	$1,860,709	$1,143,325	22%
Sunflower	$15,664,793	$20,866,697	$5,201,905	27%
Sweet Corn	$23,462,034	$39,632,968	$16,170,934	37%
Tomato	$6,269,398	$12,377,927	$6,108,529	13%
Winter Wheat	$29,994,296	$30,572,848	$578,553	1.3%
Total (all)	**$537,709,102**	**$710,106,315**	**$172,397,213**	**14%**
Total Foliar	**$444,813,911**	**$522,863,326**	**$78,049,415**	**7.3%**
Total Soil	**$92,895,190**	**$187,242,988**	**$94,347,798**	**56%**

*Results for each crop are for foliar-applied insecticides unless noted otherwise.
**Relative to 2012-2014 average for all insecticides.

TABLE 10. Estimated impact of the non-pyrethroid scenario on farmer costs by crop, expressed as $ per pyrethroid treated acre and $ per planted acre

	- Active Ingredient Cost-		--Application Cost--		-------Total Cost-------	
Crop*	$/Treated Acre	$/Planted Acre	$/Treated Acre	$/Planted Acre	$/Treated Acre	$/Planted Acre
Alfalfa	$1.32	$0.19	-$1.23	-$0.18	$0.09	$0.01
Citrus	$10.16	$13.19	$0.00	$0.00	$10.16	$13.19
Corn (all)	$7.36	$1.11	-$0.12	-$0.02	$7.24	$1.09
Foliar	$3.47	$0.14	-$0.40	-$0.02	$3.08	$0.12
Soil	$8.78	$0.97	-$0.02	$0.00	$8.76	$0.97
Cotton (all)	$0.83	$0.41	-$1.17	-$0.58	-$0.34	-$0.17
Foliar	$0.52	$0.24	-$1.21	-$0.57	-$0.70	-$0.33
Soil	$8.85	$0.16	-$0.21	$0.00	$8.64	$0.16
Potato (all)	$12.70	$8.34	-$0.03	-$0.02	$12.67	$8.32
Foliar	$13.04	$8.24	-$0.01	-$0.01	$13.02	$8.24
Soil	$3.98	$0.10	-$0.54	-$0.01	$3.44	$0.08
Rice	$4.17	$1.70	-$0.47	-$0.19	$3.70	$1.51
Sorghum	$0.96	$0.09	-$0.76	-$0.07	$0.20	$0.02
Soybean	$1.16	$0.22	-$0.06	-$0.01	$1.10	$0.21
Spring Wheat	-$0.08	-$0.01	-$0.79	-$0.10	-$0.87	-$0.11
Sugar Beet (all)	$11.20	$3.40	$0.49	$0.15	$11.69	$3.55
Foliar	$10.89	$2.44	$0.66	$0.15	$11.55	$2.59
Soil	$12.09	$0.96	$0.00	$0.00	$12.09	$0.96
Sunflower	$3.29	$2.79	$0.35	$0.30	$3.64	$3.09
Sweet Corn	$8.32	$28.05	$0.00	$0.00	$8.32	$28.05
Tomato	$12.64	$15.55	$0.00	$0.00	$12.64	$15.55
Winter Wheat	$0.91	$0.06	-$0.69	-$0.04	$0.21	$0.01
Total (all)	**$3.80**	**$0.68**	**-$0.33**	**-$0.06**	**$3.48**	**$0.63**
Total Foliar	**$2.42**	**$0.34**	**-$0.41**	**-$0.06**	**$2.01**	**$0.28**
Total Soil	**$8.80**	**$0.34**	**-$0.02**	**$0.00**	**$8.78**	**$0.34**

*Results for each crop are for foliar-applied insecticides unless noted otherwise.

The estimated cost of insecticide applications was $7.46 per acre for a foliar application and $3.11 for a soil application, regardless of the crop or active ingredient. As a result, the projected changes in insecticide application costs for the non-pyrethroid scenario reported in Table 8 are driven by changes in insecticide treated acres. The first column of data, the 2012-2014 average cost for applying pyrethroids, is $7.46 or $3.11 multiplied by the total pyrethroid treated acres for each crop. Similarly, the spending to replace these applications is the added non-pyrethroid treated acres again multiplied by either $7.46 or $3.11. As a result, the net change as a percentage match the treated acre percentage changes by crop in Table 6.

Overall, the results in Table 8 show that the estimated 2012-2014 average total cost to apply pyrethroid insecticides was $323 million, with $290 million for foliar applications and $33.4 million for soil applications. Total spending to apply the non-pyrethroid replacement active ingredients was $307 million, again mostly for foliar applications. As a result, total application costs decrease by an estimated $16.2 million (or 2.6%), due to the net decrease in insecticide treated acres projected for the non-pyrethroid scenario, almost all for foliar applications. In terms of crop specific results, projected application costs increase for sugar beet and sunflower by around 4% and remain unchanged for several crops. However, for many crops, projected application costs decrease, as much as 9.3% for alfalfa. Again, these estimated changes in application costs occur due to changes in insecticide treated acres projected for the non-pyrethroid scenario.

Table 9 combines the projected cost changes from Tables 7 and 8 to give the total cost change to purchase and apply non-pyrethroid alternatives for the non-pyrethroid scenario. Since most of the cost increases for alternative active ingredients were larger than the small cost decreases for the application costs, the net change is a cost increase for almost all crops. Overall, $538 million in active ingredient and application costs for pyrethroids would be replaced by $710 million for purchasing and applying non-pyrethroid alternatives for a net cost increase of more than $172 million (14% increase). Of this $172 million increase, $94 million would be for soil-applied insecticides, which is a 56% increase from the 2012-2014 average, while $78 million would be for foliar-applied insecticides, a 7% increase from the 2012-2014 average.

In terms of results for specific crops, the largest change is for soil-applied insecticides in corn, with a net cost change of $91.3 million (65% increase). The total cost increase for corn when foliar insecticides are included is $103 million, which is almost 60% of the total $172 million cost increase projected across all 14 crops for the non-pyrethroid scenario. The next largest cost increases are $16.4 million for soybean and $16.2 million for sweet corn. For soybean, this represents a 6% increase, while for sweet corn this is a 37% increase, the second largest percent increase among all crops. Other large increases are $10.3 million for citrus and $9.1 million for potato, $6.1 million for tomato and $5.2 million for sunflower. Two crops have projected cost decreases — a $3.7 million decrease for foliar-applied insecticides in cotton and a $1.8 million decrease for spring wheat, which represent a 1.5% decrease for cotton and a 5.0% decrease for spring wheat.

Table 10 uses the net costs from Tables 7- 9, and normalizes them to $ per treated acre and $ per planted acre for each crop. Figure 9 plots the net total cost change in $ per treated acre and the associated percentage change, while Figure 10 reports the $ per planted acre for each crop. In terms of $ per treated acre, the largest cost increase is for foliar insecticides for potato at more than $13 per treated acre. Other crops have cost impacts of more than $10 per treated acre, including tomato, sugar beet and citrus, while sweet corn has a cost increase of $8.32 and corn of $7.24 per treated acre. In terms of percentage changes in cost per treated acre, these cost change represent an increase of 46% for corn and 37% for sweet corn, the two largest relative cost increases (Figure 9). The cost increase for sugar beet, rice

and sunflower are 25% to 30% while those for tomato and citrus are 10% to 15%. At the low end, spring wheat has a cost decrease of $0.87 per treated acre, and cotton has a decrease of $0.34 per treated acre, which in terms of percentage changes are negligible for cotton and less than 5% for spring wheat.

The report *An Economic Assessment of the Benefits of Pyrethroid Insecticides in the United States* uses the estimated cost impact of the non-pyrethroid scenario on a $ per planted acre basis to estimate the net increase in average cost and hence the shift in the supply curve for each crop. These values in Table 10 are also plotted in Figure 10 for each crop. By far the largest cost impact is $28.05 per planted acre for sweet corn. The cost per treated acre is only $8.32 for sweet corn, but on average, each sweet corn acre receives 3.37 pyrethroid applications (Figure 3), and so the cost impact per planted acre becomes much larger. The next largest impact is $15.55 per planted acre for tomato and $13.19 for citrus. Impacts for the remaining crops are less than $10 per planted acre, ranging from $8.32 for potato to $0.01 per acre for alfalfa. The cost impact for corn was large in total ($103 million in Table 9), but on a planted acre basis, the cost impact is $1.09 since there are so many planted acres (Table 1). The outcome is similar for soybean, the crop with the second largest total cost impact, since on a $ per planted acre basis the cost impact $0.21. Similarly, though cotton and spring wheat had cost decreases for the non-pyrethroid scenario, the estimated cost decrease for spring wheat is only $0.11 per planted acre and $0.17 for cotton.

In summary, the estimated cost impact of the non-pyrethroid scenario is a net increase of farmer costs of $172 million in total across the 14 crops examined here. Most of this cost increase is projected for more costly non-pyrethroid alternatives — active ingredient spending for all insecticides increase 31% in aggregate but 78% for soil-applied insecticides. Because insecticide treated acres decrease slightly, total cost for active ingredients and application for all insecticides increases only 14%. However, the largest portion of this $172 million increase is for soil-applied insecticides to replace pyrethroids — more than $94 million, which is a 56% increase in aggregate spending on all soil insecticides and their application.

In terms of total aggregate cost impacts, most of the effects are for corn — $103 million of the $172 million total, with soybean second with a $16.4 million total cost impact. However, on a per acre basis, the cost impacts are much larger for specialty crops — the cost is more than $28 per planted acre for sweet corn, $15.55 for tomato, $13.19 for citrus, $8.32 for potato, $3.55 for sugar beet, $3.09 for sunflower, and $1.51 for rice. Corn is the first large-acre commodity crop with a cost impact of $1.09 per planted acre, with impacts for other commodity crops less than for corn. In brief, the aggregate impact is largest for corn and soybean but on a per planted acre basis, is largest for specialty crops.