AgInfomatics

The Value of Neonicotinoids in North American Agriculture:

Methods and Assumptions for Estimating the Impact of Neonicotinoid Insecticides on Pest Management Practices and Costs for U.S. Corn, Soybean, Wheat, Cotton and Sorghum Farmers

2014

This report series, researched and produced by AgInfomatics, LLC, is a comprehensive analysis of the economic and societal benefits of nitroguanidine neonicotinoid insecticides in North America. The research was sponsored by Bayer CropScience, Syngenta and Valent in support of regulatory review processes in the United States and Canada, with Mitsui providing additional support for the turf and ornamental studies.

AgInfomatics, an agricultural consulting firm established in 1995 by professors from the University of Wisconsin-Madison and Washington State University, conducted independent analyses exploring the answer to the question: *What would happen if neonicotinoids were no longer available?* Comparing that answer to current product use revealed the value of neonicotinoids.

Robust quantitative and qualitative study methods included econometrics modeling of insecticide use, crop yield data and market impacts; surveys of growers, professional applicators and consumers; regional listening panel sessions; and in-depth case studies.

Active ingredients in the study included clothianidin, dinotefuran, imidacloprid and thiamethoxam.

The Value of Neonicotinoids in North American Agriculture

Reports include:

Estimated Impact of Neonicotinoid Insecticides on Pest Management Practices and Costs for U.S. Corn, Soybean, Wheat, Cotton and Sorghum Farmers

Methods and Assumptions for Estimating the Impact of Neonicotinoid Insecticides on Pest Management Practices and Costs for U.S. Corn, Soybean, Wheat, Cotton and Sorghum Farmers

Value of Insect Pest Management to U.S. and Canadian Corn, Soybean and Canola Farmers

A Meta-Analysis Approach to Estimating the Yield Effects of Neonicotinoids

An Economic Assessment of the Benefits of Nitroguanidine Neonicotinoid Insecticides in U.S. Crops

A Summary of Grower and Agri-Professional Perspectives From Regional Listening Sessions in the United States and Canada

A Case Study of Neonicotinoid Use in Florida Citrus

A Case Study of Neonicotinoid Use in Mid-South Cotton

Executive Summary

The Value of Neonicotinoids in Turf and Ornamentals

Reports include:

Estimating the Economic Value of Neonicotinoid Insecticides on Flowers, Shrubs, Home Lawns and Trees in the Homescape

The Value of Neonicotinoids to Turf and Ornamental Professionals

A Case Study of Neonicotinoid Use for Controlling Chinch Bug in Florida St. Augustinegrass

A Case Study of Neonicotinoid Use for Controlling Emerald Ash Borer—The Naperville, Illinois, Experience

A Case Study of Neonicotinoid Use for Controlling Silverleaf Whitefly in Ornamentals

Executive Summary

For more information, please contact
AgInfomatics@gmail.com

Contents

Executive Summary

This report describes the methods and assumptions used to estimate the cost benefits of the nitroguanidine neonicotinoid insecticides clothianidin, dinotefuran, imidacloprid and thiamethoxam for U.S. corn, soybean, wheat, cotton, and sorghum farmers. A counter-factual approach, which estimates how farmer pest management practices would change if they no longer had neonicotinoid insecticides to use, is described. The difference between farmer costs for their practices and insecticide use patterns during 2010-2012 and this non-neonicotinoid scenario is then used to estimate the cost benefit of neonicotinoid insecticides. This report is not an academic paper and so it is not integrated into the existing literature. Rather, it is technical documentation primarily focused on providing a detailed description of the process and assumptions used, not only for transparency, but also so it could be replicated by others with the same data or other similar data. However, key results are highlighted regarding projected changes in insecticide use patterns and other practices and per acre costs if neonicotinoids were not available for corn, soybean, winter wheat, spring wheat, cotton and sorghum.

The analysis relies primarily on GfK Kynetec data, which are widely recognized as among the best survey-based data on agricultural chemical use, having been collected annually for almost 50 years. Collected data include acres treated by each active ingredient (AI), application method and target pests for each crop, as well as expenditures for each AI. In 2013, approximate sample sizes were 4,300 for corn, 4,300 for soybean, 3,200 for wheat (both winter and spring), 1,350 for cotton and 800 for sorghum – the crops that are the focus of this analysis. For these crops, the GfK Kynetec data included 98 different AIs and 72 target pests, as well as acres treated with insecticides using seed treatments, foliar applications and soil applications. Seed treatments apply pesticides as a coating directly on the seed so that they protect the seed and the roots, with some insecticides like neonicotinoids becoming systemic and protecting the whole plant. Soil-applied insecticides are applied into the soil using various methods, usually at the time of planting, in order to protect the seed and roots, while foliar-applied insecticides are sprayed on the above-ground plant tissues after the crop has emerged.

Understanding the differences between planted acres, base acres and product acres in the GfK Kynetec data is important for this analysis. For a crop, planted acres are the number of acres planted, base acres are the unique number of these planted acres treated with an insecticide once or more, and product acres are the number of acres treated with insecticides, potentially the same acre more than once. For example, if a farmer treats the same planted acre twice, this acre counts as one base acre treated and as two product acres. In aggregate, the difference between cotton neonicotinoid base acres and product acres is not large. The 2010-2012 three-year average for cotton is 8.2 million cotton neonicotinoid base acres treated and 9.3 million product acres or a 13 percent difference, which, among the crops analyzed here, is by far the largest difference between base acres and product acres; corn has the next largest difference at 1.4 percent.

Cotton is used here to illustrate the method because it was the only major U.S. commodity crop with significant use of neonicotinoid seed treatments and foliar applications, as well as significant use of non-neonicotinoid soil-applied insecticides. In addition to cotton, detailed results are reported for corn, soybean, winter wheat, spring wheat and sorghum in 4.0 Appendix: Results for Other Crops with a brief explanation about how the method for each crop varies from the process for cotton described in the main text. Additionally, a summary of the data and main results for each crop is provided in this report. A broader summary of the main findings is provided in *Estimated Impact of Neonicotinoid Insecticides on Pest Management Practices and Costs for U.S. Corn, Soybean, Wheat, Cotton, and Sorghum Farmers*. These crops were chosen for this analysis since they are modeled by the Taylor's (1993) AGSIM policy analysis model, which is used to estimate the market-level benefits of neonicotinoid insecticides as summarized in *An Economic Assessment of the Benefits of Nitroguanidine Neonicotinoid Insecticides in U.S. Crops.* A similar analysis of the effects of the non-neonicotinoid scenario on pest management practices and farmer costs could be conducted for other crops for which the appropriate data exist, but such analyses have not been completed at this time.

This analysis uses the 2010-2012 three-year average of GfK Kynetec data to reduce the impact of annual variations. In essence, the method allocates these neonicotinoid product acres to non-neonicotinoid AIs and practices for the non-neonicotinoid scenario, based on average market shares during 2010-2012 for each AI for each target pest, while controlling for the pest management system (soil-based or foliar-based). For both pest management systems and each major target pest group, neonicotinoid product acres are allocated to alternative non-neonicotinoid insecticides based on product acre shares for each insecticide and the frequency that different pest groups are targeted by insecticides. Because non-neonicotinoid alternatives are limited for some target pests managed in soil-based systems, these product acres are switched to appropriate foliar-based systems or to cultural practices. Differences in the duration of control and/or efficacies of insecticides are accounted for by varying the average number of applications. The final output from this part of the process is the estimated new product acres for each AI, the application method and other practice changes.

As for any analysis or model, this process is not without its limitations. For example, the analysis holds total crop acreage constant for the non-neonicotinoid scenario, even though the relative profitability of crops would change without neonicotinoid insecticides, so that farmers would adjust crop acreages. A different analysis uses the per acre cost changes estimated by this study and estimated yield changes from *An Economic Assessment of the Benefits of Nitroguanidine Neonicotinoid Insecticides in U.S. Crops* to project acreage shifts that would likely occur if neonicotinoid insecticides were not available. Furthermore, this analysis assumes that 2010-2012 market shares are accurate representations of the relative proportion of acres devoted to different non-neonicotinoid insecticides farmers would use without neonicotinoid insecticides by target pest. Similarly, the analysis holds the price of non-neonicotinoid insecticides and pest management practices constant, even though demand for some insecticides and practices are projected to increase substantially, so that price changes seem likely. Despite these and other limitations, this analysis provides some valuable results about the shifts in insecticides and practices that would likely occur without neonicotinoid insecticides.

The projected shifts in insecticide use patterns and in application methods imply changes in costs. These cost changes are estimated using the GfK Kynetec data on the cost of each AI and custom rate surveys and crop budgets from multiple states on the cost of different practices. The net effect on aggregate farmer costs is determined using a partial budget analysis that calculates the net change in costs by quantifying costs avoided and new costs added for the non-neonicotinoid scenario relative to the 2010-2012 base case scenario.

Summary of cotton data and results

The 2010-2012 average was 9.3 million neonicotinoid product acres in cotton, with two-thirds in soil-based systems using seed treatments and one-third using foliar systems. Thrips are the target of more than 75 percent of the neonicotinoid seed treatment product acres, while plant bugs are the target of almost 60 percent of the foliar neonicotinoid product acres. Aphids, fleahoppers, stink bugs and wireworms are the primary targets for the remaining seed treatment and foliar-applied neonicotinoid product acres. The 2010-2012 average for cotton is 12.6 million planted acres, with 9.3 million neonicotinoid product acres applied to 8.3 million base acres. Thus, about 65 percent of cotton planted acres are treated at least once with a neonicotinoid insecticide. Non-neonicotinoid insecticides are even more widely used in cotton, with an additional 21.9 million product acres, but substantial overlap occurs between neonicotinoid and non-neonicotinoid acres. Thus, though there is a total of 31.2 million insecticide product acres in cotton, there is only 8.6 million cotton base acres treated, so that 68 percent of cotton acres are treated at least once with an insecticide.

In general, the non-neonicotinoid scenario projects a slight increase in total insecticide product acres as farmers switch to non-neonicotinoid AIs, primarily organophosphates and pyrethroids, with a net increase in the total pounds of insecticide AIs applied and in the product acre shares for organophosphates and pyrethroids. Furthermore, a modest cost increase is projected, with a net decrease in expenditures on AIs as farmers switch to relatively lower cost organophosphate and pyrethroids AIs, but a larger net increase in application costs resulting from a substantial shift from seed treatments to foliar applications.

The analysis projects that the 9.3 million neonicotinoid product acres in cotton would be replaced with 7.7 million product acres of organophosphates and 1.4 million product acres of pyrethroids, respectively representing a 69 percent and 23 percent increase in the product acres of each class. In addition, almost 800,000 product acres of other insecticide classes would be added (e.g., benzoylureas, cyanoamidine neonicotinoids, flonicamid, carbamates). These increases in product acres imply an estimated 77 percent increase in the total pounds of organophosphates applied and a 27 percent increase in pounds of pyrethroids and of carbamates applied, with similar increases in the total AI applied for the other insecticide classes. The net effect of the non-neonicotinoid scenario is a 58 percent increase in total pounds of insecticide AIs applied to cotton.

These product acre shifts have a notable impact on the share of all cotton product acres devoted to organophosphates and pyrethroids. Based on the 2010-2012 average, 37 percent of cotton product acres receive organophosphates, 31 percent receive neonicotinoids and 21 percent receive pyrethroids; but for the non-neonicotinoid scenario, the share receiving organophosphates is estimated to increase to 62 percent and the pyrethroid share to 25 percent. These estimated shifts in product acres and increased reliance on these classes of insecticides raise concerns about increased potential for the development of insect resistance to these important modes of action. Furthermore, more than half of the 6.3 million product acres of neonicotinoid seed treatments would shift to foliar-based applications, most of which would be organophosphates and pyrethroids, so that total product acres of foliar-applied insecticides in cotton would increase by 30 percent. This projected shift to greater reliance on foliar applications of these non selective classes of insecticides raises concerns about negative impacts on beneficial insect populations that farmers rely on as part of an overall pest management strategy. With fewer beneficial insects, populations of current pests and secondary pests may increase and lead to additional insecticide use. This projected shift also removes other benefits of seed treatment in comparison to foliar treatments, such as reduced potential for spray drift and field runoff and fewer passes through the fields.

In terms of estimated cost changes, cotton growers would see a net decrease in expenditures for insecticide AIs by $22 million by switching to lower cost alternatives but see a net increase in application costs of $40 million, largely due to switching from seed treatments to foliar applications and to soil insecticides to manage above-ground early-season pests, such as thrips. No changes in scouting costs are assumed to occur for cotton growers since scouting would continue as part of management for the other cotton pests currently managed without neonicotinoid insecticides. The net effect is an estimated increase of $18.2 million in costs for cotton growers for the non-neonicotinoid scenario. Given the 12.6 million planted acres of cotton and 8.2 million base acres for neonicotinoids in cotton, the estimated average cost benefit of neonicotinoids is $1.44 per cotton planted acre or $2.21 per neonicotinoid treated base acre.

Summary of corn data and results

In terms of insecticide use, corn is dominated by soil-based insect management systems and neonicotinoid seed treatments. Based on the 2010-2012 averages, foliar-applied AIs only comprise 4.0 million of the total 96.6 million insecticide product acres in corn, with neonicotinoids comprising none of the foliar product acres. All of the 82.6 million neonicotinoid product acres in corn are seed treatments, while all other AIs constitute only 14.1 million product acres, of which 10.1 million are soil-applied insecticides. The 2010-2012 average for corn is 91.5 million planted acres, with 82.6 million neonicotinoid product acres applied to 81.4 million base acres, so that 89 percent of corn planted acres are treated at least once with a neonicotinoid insecticide. In terms of target pests, 33 percent of neonicotinoid seed treatments product acres are targeted at wireworms, with corn rootworms and seed corn maggots respectively comprising 24 percent and 21 percent of product acres. White grubs, cutworms and flea beetles are the remaining major pests targeted by neonicotinoid seed treatments.

In general, the non-neonicotinoid scenario projects a slight decrease in total insecticide product acres as farmers switch to pyrethroids and

organophosphates but a net increase in the total pounds of insecticide AIs applied and in the product acre shares for pyrethroids and organophosphates. Furthermore, a large cost increase is projected, as both expenditures on AIs and application costs increase because of a substantial switch from neonicotinoid seed treatments to soil-applied pyrethroid and organophosphate insecticides.

The analysis projects that the 2010-2012 average of 82.6 million neonicotinoid seed treatment product acres in corn would be replaced with 54.8 million product acres of pyrethroids and 25.8 million product acres of organophosphates, so that product acres of each class are about 10 times and 6.5 times greater respectively. Associated with these increases in product acres are increases in total pounds applied. The total pounds of organophosphates applied is 9.5 times greater for the non-neonicotinoid scenario, while the total pounds of pyrethroids applied is 8.5 times greater. The net effect of the non-neonicotinoid scenario is a 290 percent increase in total pounds of insecticide AIs applied to corn.

The impact that these product acre shifts have on the share of all corn product acres devoted to organophosphates and pyrethroids is substantial. Based on the 2010-2012 average, 87 percent of corn product acres receive neonicotinoids, 10 percent receive pyrethroids and 3 percent receive organophosphates, but for the non-neonicotinoid scenario, the share receiving pyrethroids is estimated to increase to 69 percent and the organophosphates share to 31 percent. These estimated product acres shifts and increased reliance on these classes of insecticides raise concerns about increased potential for the development of insect resistance to these important modes of action.

Most of the additional product acres of pyrethroids and organophosphates are applied as soil insecticides. However, the analysis also projects that 4.1 million of the 82.6 million product acres of neonicotinoid seed treatments would shift to foliar-based applications of pyrethroids and organophosphates to control above-ground pests, such as cutworms and flea beetles. This shift represents a doubling of foliar-applied insecticide product acres in corn, from their 2010-2012 average level of 4.0 million product acres. This projected shift to greater use of foliar applications of these non selective insecticides raises concerns about negative impacts on beneficial insect populations. If populations of these beneficial insects decline, populations of current pests and secondary pests may increase sufficiently to justify additional insecticide applications. This projected shift also removes other benefits of seed treatment compared to foliar treatments, such as reduced potential for spray drift and field runoff, and fewer passes through the fields.

In terms of estimated cost changes, corn growers would see a net increase in expenditures for insecticide AIs of $389 million by switching to non-neonicotinoid alternatives, plus see a net increase in application costs of $258 million, largely due to switching from seed treatments to soil insecticides and foliar applications. In addition, scouting costs would increase by $30 million as corn acres using foliar-based management systems roughly double. The net effect is an increase of $677 million in costs for corn growers for the non-neonicotinoid scenario. Given the 91.5 million planted acres of corn and 81.4 million neonicotinoid base acres in corn, the estimated average cost benefit of neonicotinoids is $7.40 per corn planted acre, or $8.32 per neonicotinoid-treated base acre.

Summary of soybean data and results

Neonicotinoid use in soybean is dominated by seed treatments – the 2010-2012 average is 50.7 million insecticide product acres in soybean, of which 29.1 million are in a soil-based insect management system exclusively using neonicotinoid seed treatments. Because no other insecticidal seed treatments or soil insecticides are registered for use in soybean, farmers do not have non-neonicotinoid insecticide alternatives available as replacements for neonicotinoid seed treatments to control soil-dwelling pests. However, of the 21.6 million foliar insecticide product acres in soybean, only 1.4 million are neonicotinoid foliar product acres, so that farmers have several non-neonicotinoid alternatives available for controlling above-ground pests.

The 2010-2012 average for soybean is 76.5 million planted acres, with 30.5 million neonicotinoid product acres applied to 30.4 million base acres, so that 40 percent of soybean planted acres are treated at least once with a neonicotinoid insecticide. Substantial overlap occurs between neonicotinoid seed treatment and non-neonicotinoid foliar application product acres. Though there are 30.5 million neonicotinoid product acres in soybean and 20.2 million non-neonicotinoid product acres, there are only 37.5 million insecticide base acres, so that 49 percent of soybean planted acres are treated with an insecticide.

In terms of target pests, neonicotinoid seed treatments in soybean primarily target above-ground pests, with almost two-thirds of neonicotinoid seed treatment product acres targeted at bean leaf beetles and aphids. Soil-dwelling insects targeted by neonicotinoid seed treatments include seed maggots, wireworms and white grubs, which are the target of one-third of the neonicotinoid seed treatment product acres. Japanese beetles and threecornered alfalfa hoppers are also significant insect pests targeted by neonicotinoid seed treatments. Almost three-fourths of foliar-applied neonicotinoid product acres are targeted at stink bugs and aphids, with threecornered alfalfa hoppers, bean leaf beetles and Japanese beetles comprising the targets for the remaining product acres.

In general, the non-neonicotinoid scenario projects that roughly two-thirds of neonicotinoid product acres would shift to foliar-based pest management and one-third would use cultural control (higher seeding densities and replanting). About half of the product acres shifting to foliar-based insect management would receive a pyrethroid or organophosphate application, so that total pounds of these insecticide AIs applied and their product acre shares would increase. As a result, a modest cost increase is projected, with total net expenditures on insecticide AIs decreasing but costs for insecticide applications and pest scouting increasing, as well as seeding costs for cultural control of soil-dwelling pests.

The analysis projects that the 2010-2012 average of 30.5 million neonicotinoid product acres in soybean would be replaced with 9.0 million product acres of pyrethroids and 2.5 million product acres of organophosphates, representing an increase of about 60 percent in the

product acres of each class. In terms of pounds of AI applied, the analysis projects a 60 percent increase in the total pounds of both pyrethroids and organophosphates for the non-neonicotinoid scenario. The impact that these product acre shifts have on the share of all soybean product acres devoted to organophosphates and pyrethroids is substantial. The 2010-2012 average shares for soybean insecticide product acres are 62 percent for neonicotinoids, 29 percent for pyrethroids and 9 percent for organophosphates; the non-neonicotinoid scenario projects that the pyrethroid share would increase to 78 percent and the organophosphate share to 22 percent. These estimated shifts and increased use of these insecticide classes raise concerns about increased potential for the development of insect resistance to these important modes of action.

The analysis also projects that 20.0 million product acres of neonicotinoid seed treatments would shift to foliar-based management to control above-ground pests, with roughly half of these product acres treated with pyrethroid and organophosphate insecticides and the other half scouted but not treated for the above-ground pests originally targeted by the neonicotinoid seed treatment. This shift represents almost a doubling of foliar-managed acres in soybean and nearly a 50 percent increase in foliar product acres, based on the 2010-2012 average of 21.6 million product acres treated with foliar insecticides. This projected shift to greater use of foliar applications of non selective insecticides raises concerns about negative impacts on beneficial insect populations. If populations of these beneficial insects decline, populations of current pests and secondary pests may increase sufficiently to justify additional insecticide applications. The analysis also projects that 9.6 million neonicotinoid product acres would switch to cultural control practices (higher seeding densities or replanting) to manage soil-dwelling insects such as wireworms, seed maggots and white grubs for the non-neonicotinoid scenario, since insecticidal options are currently not available.

In terms of estimated cost changes, soybean growers would see a net decrease in expenditures for insecticide AIs of $184 million by switching to non-neonicotinoid AIs but see a net increase in application costs of $73 million due to switching from seed treatments to foliar applications and a $63 million cost increase for cultural control (higher seeding densities or replanting). In addition, scouting costs would increase by $149 million as soybean acres using foliar-based management systems are projected to almost double. The net effect is an increase of $100 million in costs for soybean growers for the non-neonicotinoid scenario. Given the 76.5 million soybean planted acres and 30.4 million neonicotinoid base acres in soybean, the estimated average cost benefit of neonicotinoids is $1.31 per soybean planted acre or $3.30 per neonicotinoid treated base acre.

Summary of winter wheat data and results

The 2010-2012 average is 9.0 million insecticide product acres in winter wheat, with 6.9 million in a soil-based insect management system exclusively using neonicotinoid seed treatments and 2.1 million in foliar-applied non-neonicotinoids. The 2010-2012 average for winter wheat is 38.3 million planted acres, so that 18 percent of winter wheat planted acres are treated with a neonicotinoid seed treatment, with less than 22 percent of planted acres receiving an insecticide application of any type. In terms of target pests, wireworms, aphids and Hessian flies are the major targets of neonicotinoid seed treatments, with wireworms the target for 60 percent of the product acres. For the non-neonicotinoid scenario, aphid and Hessian fly product acres are allocated from neonicotinoid seed treatments to non-neonicotinoid foliar applications, while product acres targeted at wireworms use cultural control practices (higher seeding densities or replanting). The shift to cultural control occurs because non-neonicotinoid insecticide alternatives are not available and most of the target pests in winter wheat are soil-dwelling insects, primarily wireworms. As a result of this shift, total insecticide product acres decrease, but a significant increase is projected for foliar-applied pyrethroid and organophosphate product acres, with a commensurate increase in total pounds of these AIs applied. A small net cost increase is projected, with farmer expenditures on insecticide AIs decreasing but application costs, scouting costs, and seeding costs increasing.

For the non-neonicotinoid scenario, the analysis projects that the 2010-2012 average of 6.9 million neonicotinoid seed treatment product acres in winter wheat would be replaced by 4.1 million acres of cultural control (higher seeding densities or replanting) to manage wireworms. In addition, an estimated 500,000 product acres of pyrethroids and not quite 140,000 product acres of organophosphates would be added, representing an increase of 39 percent in pyrethroid product acres and a 17 percent increase of organophosphate product acres in winter wheat. Estimated increases in pounds of AI applied are similar in magnitude – a 37 percent increase in the total pounds of pyrethroids applied and a 19 percent increase in organophosphates is projected for the non-neonicotinoid scenario. Note that an estimated 2.2 million neonicotinoid product acres would be scouted and not treated for control of aphids or Hessian flies when switching from a seed treatment to a foliar-based pest management system. As a result, insecticide product acres decrease from 9.0 million to 2.7 million, even as product acres for pyrethroids and organophosphates increase 39 percent and 17 percent respectively, and the share of insecticide product acres for pyrethroids increases from 14 percent to 65 percent, while the organophosphate share increases from 9 percent to 35 percent. Furthermore, winter wheat acres in foliar-based insect management systems are projected to increase 132 percent, from the 2010-2012 average of 2.1 million product acres to 4.9 million product acres under the non-neonicotinoid scenario.

Winter wheat growers would see an estimated net decrease in expenditures for insecticide AIs of $24 million for the non-neonicotinoid, a net increase in application costs of almost $5 million due to switching from seed treatments to foliar applications and not quite an $18 million cost increase for cultural control (higher seeding densities or replanting). In addition, scouting costs would increase by almost $21 million as winter wheat acres using foliar-based management systems are projected to more than double. The net effect is an increase of $19 million in costs for winter wheat growers for the non-neonicotinoid scenario. With 38.3 million winter wheat planted acres and 6.9 million neonicotinoid base acres in winter wheat, the estimated average cost benefit of neonicotinoids is $0.50 per planted acre or $2.76 per neonicotinoid treated base acre.

Summary of spring wheat data and results

The 2010-2012 average is 5.9 million insecticide product acres in spring wheat, with 3.8 million in a soil-based insect management system exclusively using neonicotinoid seed treatments and 2.1 million in foliar-applied non-neonicotinoids. The 2010-2012 average for spring wheat is 14.9 million planted acres, so that 25 percent of spring wheat planted acres are treated with a neonicotinoid seed treatment, with almost 35 percent of planted acres receiving an insecticide application of some type. Wireworms are the target pest for 97 percent of neonicotinoid seed treatment product acres in spring wheat, with aphids and, to a very small extent Hessian flies, comprising the remaining target pests. Because non-neonicotinoid soil insecticide or seed treatments are not available for spring wheat in the non-neonicotinoid scenario, product acres targeted at wireworms are reallocated to cultural control practices (higher seeding densities or replanting), while the few aphid and Hessian fly product acres are reallocated to non-neonicotinoid foliar applications. As a result of this shift, total insecticide product acres decrease for the non-neonicotinoid scenario, but an increase is projected for foliar-applied pyrethroids and organophosphates, so that both product acres and total pounds of these AIs applied increase. Finally, a small net cost increase is projected, with farmer expenditures on insecticide AIs decreasing, but application costs, scouting costs and seeding costs increasing.

For the non-neonicotinoid scenario, the analysis projects that the 2010-2012 average of 3.8 million neonicotinoid seed treatment product acres in spring wheat would be replaced by 3.7 million acres of cultural control (higher seeding densities or replanting) to manage wireworms. In addition, an estimated 40,000 product acres of pyrethroids and organophosphates would be added, representing an increase of 2 percent in product acres and total pounds applied in spring wheat for each insecticide class. Finally, about 74,000 neonicotinoid product acres in spring wheat would be scouted and not treated for control of aphids or Hessian flies when switching from a seed treatment to a foliar-based pest management system for the non-neonicotinoid scenario. As a result, insecticide product acres decrease from 5.8 million to 2.1 million, but the share of insecticide product acres for pyrethroids increases from 20 percent to 57 percent, while the organophosphate share increases from 15 percent to 43 percent. Furthermore, spring wheat acres in foliar-based insect management systems are projected to increase 6 percent by adding almost 115,000 acres under the non-neonicotinoid scenario.

Spring wheat growers would see an estimated net decrease in expenditures for insecticide AIs of almost $10 million for the non-neonicotinoid, a net increase in application costs of almost $300,000 due to switching from seed treatments to foliar applications and almost a $16 million cost increase for cultural control (higher seeding densities or replanting). In addition, scouting costs would increase by about $850,000 as spring wheat acres using foliar-based management systems are projected to increase. The net effect is an increase of $7.4 million in costs for spring wheat growers for the non-neonicotinoid scenario. With 14.9 million spring wheat planted acres and 3.8 million neonicotinoid base acres in spring wheat, the estimated average cost benefit of neonicotinoids is $0.50 per planted acre or $1.97 per neonicotinoid treated base acre.

Summary of sorghum data and results

The 2010-2012 average is 3.2 million insecticide product acres for sorghum, with 2.5 million in a soil-based insect management system exclusively using neonicotinoid seed treatments and about 660,000 using foliar-applied non-neonicotinoids. The 2010-2012 average for sorghum is 5.8 million planted acres, so that 43 percent of sorghum planted acres are treated with a neonicotinoid seed treatment, with almost 48 percent of planted acres receiving at least one insecticide application. Aphids, chinch bugs and wireworms are the primary targets of the neonicotinoid seed treatments, with ants and seed maggots also significant major pest targets. For the non-neonicotinoid scenario, product acres targeting wireworms, seed maggots and ants are reallocated to a non-neonicotinoid soil insecticide, and those targeting aphids are reallocated to a foliar non-neonicotinoid; product acres targeting chinch bug are roughly evenly split between soil and foliar insecticides. As a result, insecticide product acres decrease slightly for the non-neonicotinoid scenario, but overall organophosphate and pyrethroid product acres and total pounds applied both increase. The estimated net increase in farm costs is relatively large for the crops analyzed here, with net expenditures on AIs, application and scouting projected to increase.

For the non-neonicotinoid scenario, the analysis projects that the 2010-2012 average of 2.5 million neonicotinoid seed treatment product acres in sorghum would be replaced by an estimated 1.4 million product acres of organophosphates and 0.4 million product acres of pyrethroids. This shift implies an increase in organophosphate product acres to almost 20 times their average level during 2010-2012, while total pounds of organophosphates increase almost 40 times. Pyrethroid product acres would increase almost 80 percent, with total pounds applied increasing almost 80 percent as well. Also, almost 670,000 neonicotinoid product acres in sorghum would be scouted and not treated for control of aphids or chinch bugs when switching from a seed treatment to a foliar-based pest management system for the non-neonicotinoid scenario. As a result, insecticide product acres decrease from 3.1 million to 2.4 million, with the share of insecticide product acres for organophosphates increases from 3 percent to 63 percent, while the pyrethroid share increases from 16 percent to 37 percent. Furthermore, sorghum acres in foliar-based insect management systems are projected to almost triple under the non-neonicotinoid scenario.

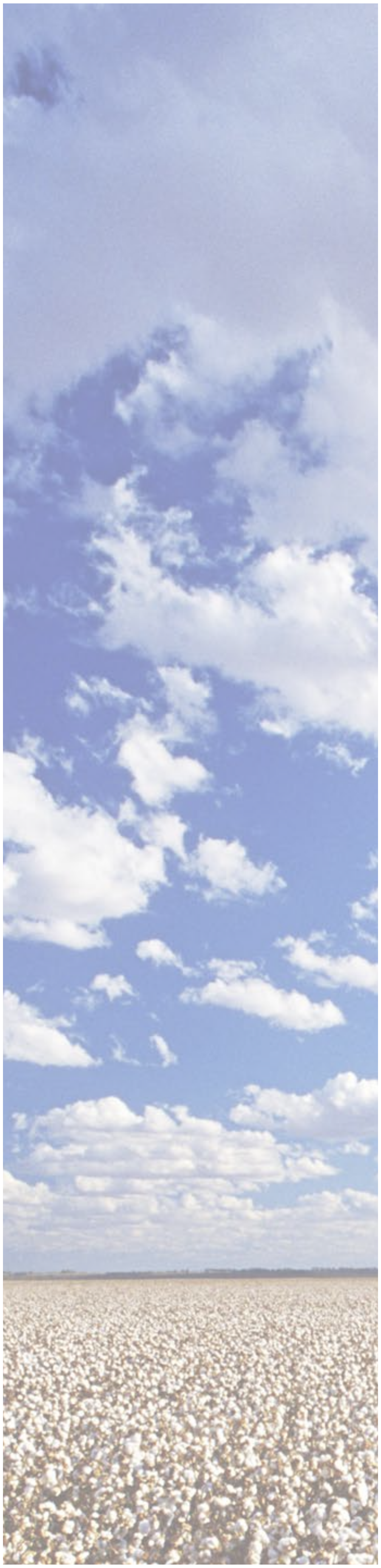
Sorghum growers would see an estimated increase in expenditures for insecticide AIs of more than $8.3 million for the non-neonicotinoid and a net increase in application costs of $8.1 due to switching from seed treatments to soil insecticides and foliar applications. In addition, scouting costs would increase by more than $9.5 million as sorghum acres using foliar-based management systems are projected to increase. The net effect is an increase of $26 million in costs for sorghum growers for the non-neonicotinoid scenario. With 5.8 million sorghum planted acres and 2.5 million neonicotinoid base acres, the estimated average cost benefit of neonicotinoids is $4.48 per planted acre or $10.39 per neonicotinoid treated base acre.

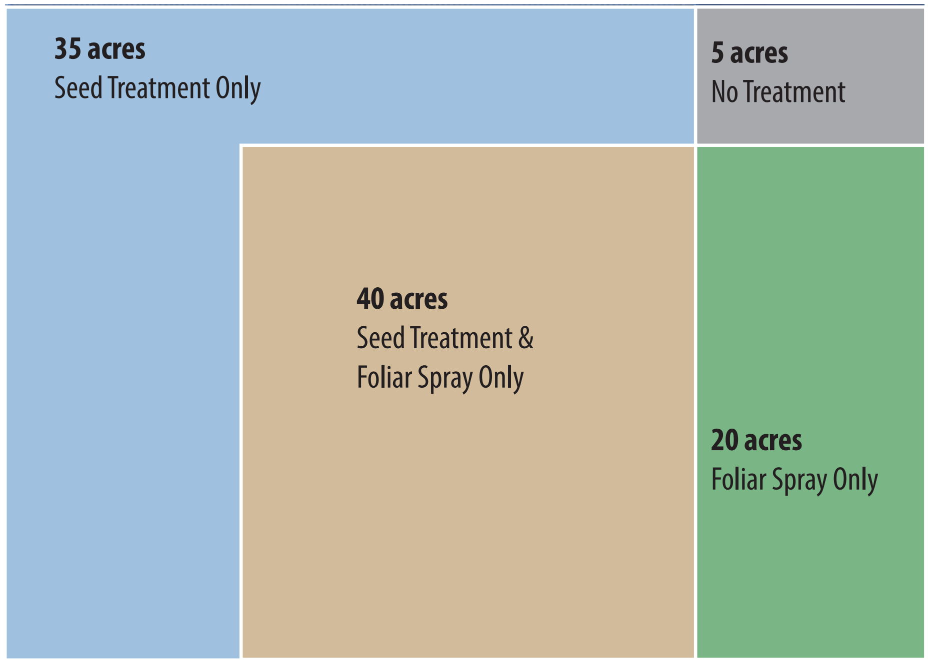
1.0 Introduction

This technical report is supporting documentation for an economic assessment of the benefits of the neonicotinoid insecticides. In this report, the term neonicotinoid is used for the following active ingredients (AIs): clothianidin, dinotefuran, imidacloprid and thiamethoxam, which are the nitroguanidine neonicotinoid insecticides, as opposed to the cyanoamidine neonicotinoid insecticides, such as acetamiprid, which have relatively minor usage. This technical report describes the process used to reallocate neonicotinoid product acres to non-neonicotinoid practices as part of developing a non-neonicotinoid scenario to estimate the benefits of neonicotinoid insecticides. These alternative practices include switching to non-neonicotinoid AIs, as well as accounting for the use of integrated pest management (IPM), including scouting costs, and the possibility to stop using any insect control. The process relies primarily on GfK Kynetec data for 2010-2012, using annual averages over these three years. For this technical report, cotton is used as the specific example to illustrate and describe the methodology, with an appendix reporting results for the other commodity crops examined: corn, soybean, winter wheat, spring wheat and sorghum.

The GfK Kynetec data are widely recognized as among the best survey-based data on agricultural chemical use and biotech seed adoption, having been collected annually for almost 50 years. Data collection covered 60 crops in the continental U.S. in 2013 and has been averaging about 20,000 farmgate level interviews per year in recent surveys. Data collection uses both in-person and telephone interviews, as well as mail and Web-based questionnaires, not only of the growers themselves but also processors, packing houses, crop consultants, custom applicators and retailers. In 2013, approximate sample sizes were 4,300 for corn, 4,300 for soybean, 3,200 for wheat, 1,350 for cotton, and 800 for sorghum – the five crops that are the focus of the analysis here. GfK Kynetec data collection includes a wide range of variables, but the specific variables used for this analysis include planted acres and base acres treated for each crop, plus the product acres, target pests, application method and grower expenditures for each AI used in each crop. Respondents are farmers, plus in some cases their agents, including pest control advisers, crop consultants, custom applicators and retailers, as long as the individuals have documented records of actual field applications, not intended treatments.

Understanding the differences between planted acres, base acres and product acres is important for this analysis. Planted acres are the number of acres planted, base acres are the unique number of these planted acres treated with an insecticide once or more, and product acres are the number of acres treated with insecticides, potentially the same acre more than once. A simple hypothetical example and a graphic aid illustrate these definitions (see next page for graphic). Suppose a farmer plants 100 acres of cotton (whole figure), with 75 of these acres using an insecticidal seed treatment. Later the farmer treats 60 acres with a foliar-applied insecticide: 20 of the acres that did not use a seed treatment and 40 of the acres that did. This farmer would generate 100 planted acres, 95 base acres and 135 product acres. This farmer would have 95/100 = 95 percent of planted acres treated, with an average of 135/95 = 1.42 applications per base acre and 135/100 = 1.35 applications per planted acre. In aggregate, the difference between cotton neonicotinoid base acres





and product acres is not this large. The 2010-2012 three-year average for cotton is 8.2 million cotton neonicotinoid base acres and 9.3 million product acres, or a 13 percent difference, which, among the crops analyzed here, is by far the largest difference between base acres and product acres. (Corn is the next largest with a 1.4 percent difference.)

For this analysis, insecticide product acres are categorized into soil-based systems or foliar-based systems as defined by GfK Kynetec based on target pest and the application method and timing. Soil-based systems use insecticides to manage below-ground pests and early-season pests, both above and below-ground, using methods such as seed treatments and in-furrow applications. Foliar-based systems use insecticides to manage above-ground pests, using application methods, such as broadcast and aerial application. These systems are analyzed separately for the neonicotinoid product acre reallocation process.

For cotton, the GfK Kynetec data indicate a three-year average planted area of 12.6 million acres, which is consistent with USDA-NASS data (USDA-NASS 2013). Of these planted acres, the three-year average base acres treated with insecticides is 8.6 million acres or 68 percent of the planted acres. Cotton Table 1 below summarizes the three-year average neonicotinoid product acres for cotton and their classification into either foliar-based or soil-based systems, with seed treatment and soil-applied insecticides reported separately.

Cotton Table 1. Product acres for all AIs and neonicotinoids (three-year average, 2010-2012).

		------------Soil-based System ---------		
	Foliar	**Seed Treatment**	**Soil-applied**	**Total**
Neonicotinoids	3,049,353	6,269,620	--	9,318,974
Non-Neonicotinoids	19,150,538	1,445,657	1,287,139	21,883,334
All AIs	22,199,891	7,715,277	1,287,139	31,202,308

The data show that for cotton, farmers using soil-based systems rely heavily on neonicotinoid seed treatments, as they constitute 70 percent of all insecticide product acres in soil-based systems and 81 percent of all seed treatments in cotton. However, neonicotinoids are a small component of foliar-based systems, constituting less than 14 percent of all foliar insecticide product acres in cotton. Because most insecticide use in cotton is foliar-applied, in total, over both of these systems, neonicotinoids constitute 30 percent of all cotton insecticide product acres, showing the relative significance of neonicotinoids for insect control in cotton.

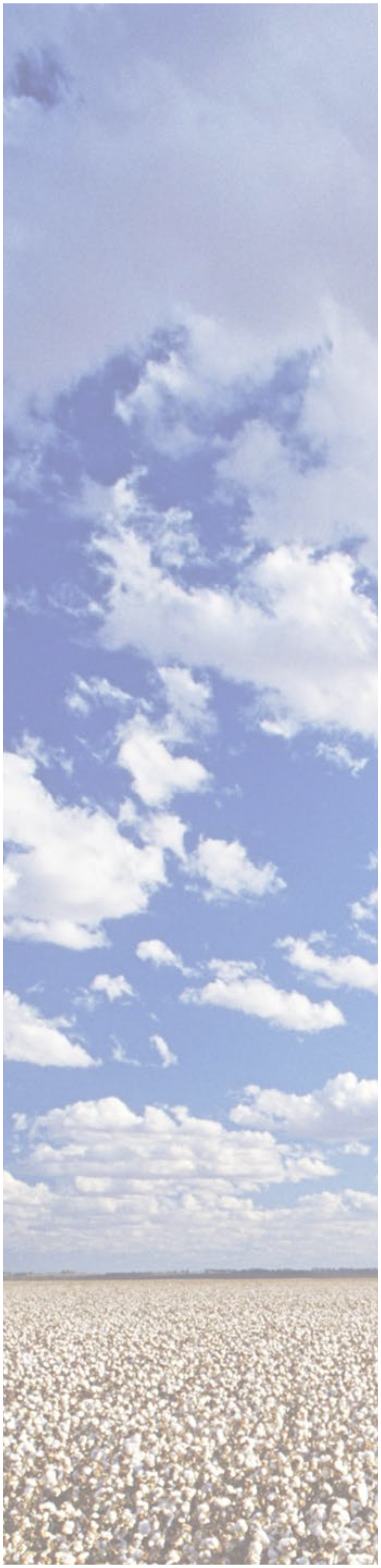
The distribution of insecticide product acres into these systems (foliar, seed treatment and soil-applied) results from the interaction of the primary insect pests of cotton and the activity of the different AIs. For example, plant bugs are problematic cotton pests, with neonicotinoid insecticides only recommended for early-season control and not for mid- to late-season control (Stewart and McClure, 2014). Similarly, lepidopteran pests, such as bollworms or budworms, are not controlled by neonicotinoids, but neonicotinoids provide control of multiple aphid species throughout the season. Thus, the observed use patterns in Table 1 result from these interactions: the types of pests that are present and when, plus the AIs active against these pests.

1.1 Foliar-based and soil-based insect management systems

For the purposes of this analysis, grower product acres are categorized into either a foliar-based or a soil-based insect management system as defined by GfK Kynetec based on the reported application method and target pests. Both systems are consistent with IPM, since growers in general choose pest management strategies that balance efficacy and cost to identify systems that provide effective pest control, while maintaining profitability and managing risk. Foliar-based systems exclusively target above-ground pests that are mostly mid- and late-season pests. A threshold-based IPM scouting program is used and when pest population densities exceed action thresholds, insecticide applications are made. Soil-based systems target both below-ground and above-ground pests that are almost exclusively early-season pests of seeds, seedlings and young plants. Because scouting of below-ground pests with timely delivery of insecticides is impractical, a protective IPM program is adopted that uses a seed treatment or soil-applied insecticides at planting time-based on historical occurrence of the pest in fields in the region, expert advice from various agricultural professionals, early-season scouting and/or other informative signals.

This analysis assumes that for the non-neonicotinoid scenario, growers would continue to use pest control on neonicotinoid product acres. The assumption is that since growers find neonicotinoid insecticide applications economical, they would, in most cases, also find non-neonicotinoid insecticide applications economical for the non-neonicotinoid scenario. But as explained below, when switching from a soil-based protective IPM program to a threshold-based IPM scouting program, this analysis assumes that growers would find it economical to scout and only make foliar insecticide application when supported by the scouting.

For the non-neonicotinoid scenario, neonicotinoid product acres in a foliar-based system remain in a foliar-based system for this analysis and simply switch to a non-neonicotinoid AI. Scouting costs do not change since



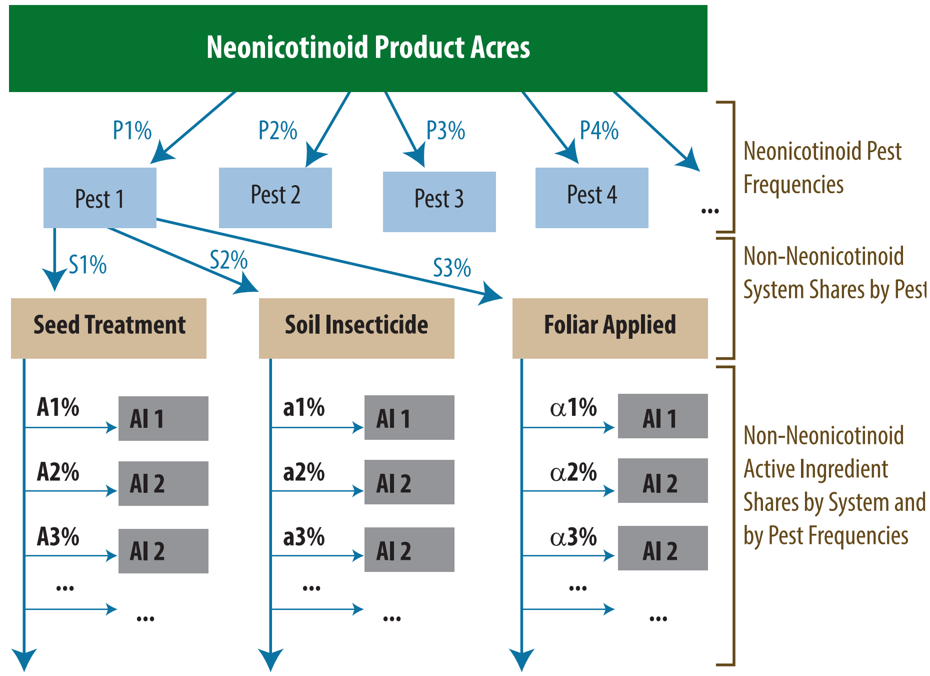
the grower is already scouting, and the insecticide application frequency is adjusted to reflect differences in field half-life and efficacy for the alternative AIs. As a result, grower costs change to reflect the net difference in AI costs and the net change in application costs due to changes in the average number of applications.

For the non-neonicotinoid scenario, neonicotinoid product acres in a soil-based (seed treatment) system either remain in a soil-based system or they switch to a foliar-based system. Those remaining in a soil-based system are allocated to either a non-neonicotinoid seed treatment or a non-neonicotinoid soil insecticide. These reallocations are based on the share of non-neonicotinoid product acres using seed treatments, soil insecticides and foliar insecticides for each pest targeted by the neonicotinoid seed treatment. In crops like cotton and corn, these neonicotinoid product acres simply switch to non-neonicotinoid AIs and may change application methods; but for crops like soybean and wheat, no alternative non-neonicotinoid seed treatments or soil insecticides are registered for use, and foliar-applied insecticides do not control many early-season below-ground insect pests targeted by neonicotinoid seed treatments. Since the impact of these early-season below-ground pests is to reduce stands, for this analysis, the non-neonicotinoid alternative is to increase the seeding rate for soybean and wheat or to replant field sections as needed. In terms of cost impacts, growers would have the net difference in AI costs, as well as changes in application costs, when switching from seed treatments to soil, or foliar-applied insecticides when applicable or the cost increase for using higher seeding rates or partial replanting.

2.0 Product Acre Analysis and Reallocation

This section describes the processing and analysis of the GfK Kynetec data and the use of this information to reallocate neonicotinoid product acres to non-neonicotinoid practices. The GfK Kynetec data include product acres by application method and target pest for 98 different AIs, including the four neonicotinoids (clothianidin, dinotefuran, imidacloprid and thiamethoxam). The 2010-2012 data for cotton include 72 different target pest species (including no answer and preventive program) and four different application methods (banded, broadcast, seed treatment and spot treatment). Data for other crops include other target pest species and additional application methods. Given this level of detail (target pest, application method, AI), a process was developed to allocate neonicotinoid product acres to non-neonicotinoid active ingredients while accounting for the target pest frequencies and application systems.

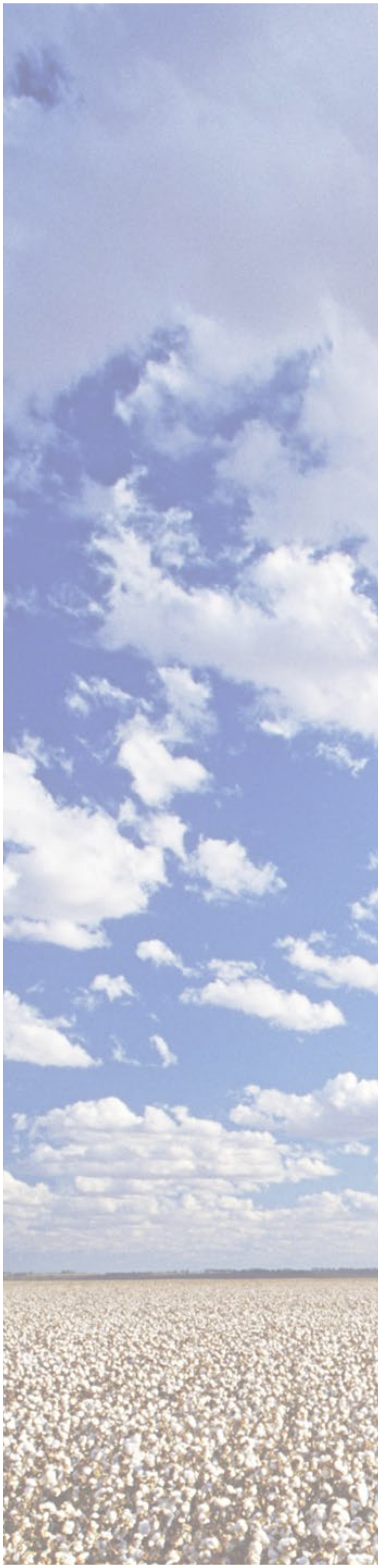
For this analysis, the data were first prepared by focusing on the major pests targeted by neonicotinoid use and the frequency each pest was targeted. Next, for each target pest, the data were analyzed to determine acreage shares of each application method (seed treatment, soil-applied, foliar application) used for non-neonicotinoid insecticides. Then finally, within each application system for each target pest, the product acre shares of each non-neonicotinoid active ingredient were determined. The figure on the following page illustrates this process.



This figure shows that the first step takes the neonicotinoid product acres of a certain type (e.g., cotton seed treatments) and determines the proportion targeted at each major pest. Next, for each of these neonicotinoid target pests, the process determines the non-neonicotinoid product acre system shares, i.e., the proportion of non-neonicotinoid product acres using each application method (seed treatment, soil insecticide, foliar-applied) when targeting that pest. Finally, for non-neonicotinoids targeted at that pest and using that application system, the process determines the proportion of product acres using each AI. The number of non-neonicotinoid AIs with non zero shares for this final step varies by crop, application method and target pest due to differences in product registrations and AI activity. These three steps create several tables and require various assumptions as described and reported in the sections below. Furthermore, after this part of the process, adjustments are made for differences in field efficacy of the different AIs and other factors, which are also described in the next sections, along with careful specification of the equations as used.

2.1 Preparing product acres for analysis

For this analysis, product acres were categorized as either a foliar-based or a soil-based insect management system as defined by GfK Kynetec based on the reported application method and target pests. Based on this classification, each system was analyzed separately to develop non-neonicotinoid alternatives for neonicotinoid product acres. The first step was to drop AIs with zero product acres for cotton, which left 39 AIs for foliar-based systems and 15 for soil-based systems. Because 71 unique target pests were reported for cotton, target pest groups were developed that combined multiple target pest species into a single group to reduce the number of target pests to a more manageable number. For example, the target pests – brown stink bugs, green stink bugs, redbanded stink bugs, rice stink bugs, Southern green stink bugs and stink bugs – were all categorized as simply stink bugs. Relative to the other crops, cotton is intermediate in terms of the number of



unique target pests reported; corn reported 80, soybean 75, winter wheat 54, sorghum 52 and spring wheat 39. Next, product acres were summed across all AIs to generate the total product acres for all AIs, and then these product acres were summed across all target pest species to generate total product acres for each of these target pest groups.

Next, target pest groups were dropped to focus on the main target pests of neonicotinoid insecticide use in cotton. Product acres for which the respondent provided no answer or reported a preventive program for the target pest were dropped. Why respondents did not always provide a target pest is unknown and likely varied among respondents (e.g., could not recall, followed an expert's advice or survey response burden). This analysis conservatively assumes no answer meant the farmer did not have a target pest, which likely over estimates this occurrence. After dropping these responses, the share of the total remaining product acres targeted for each insect group was then calculated. Any insect group with less than 1.5 percent of these product acres was dropped as a minor pest, as was any insect group not registered as a target pest for neonicotinoid insecticides. Next, product acres were then summed across the four neonicotinoid AIs to generate the total neonicotinoid product acres for each of the remaining insect groups. The share of the total neonicotinoid product acres for each insect group was then calculated and any insect group with less than 1 percent share of neonicotinoid product acres was dropped. For cotton, using either a foliar-based or a soil-based system, this process left six target insect groups: aphids, fleahoppers, plant bugs, stink bugs, thrips and wireworms. This list is not intended to imply that other cotton pests targeted by neonicotinoids are not important. These insects can be significant pests in some years and in some regions; but on a national level, these other pests become relatively minor targets and are dropped from this analysis. Relative to the other crops, cotton is intermediate in terms of the number of the major target pest groups remaining; soybean had eight, corn also had six, sorghum had five, and winter wheat and spring wheat each had three. These other crops had different major target pest groups.

Cotton Table 2 reports the initial product acres for all AIs and for neonicotinoids for both systems from Cotton Table 1 and then summarizes the aggregate results of this process. For the neonicotinoid product acres, 99 percent of the original 3 million product acres in foliar based systems are targeted at specific pests, while for product acres in soil-based systems almost 77 percent are. This process of focusing on major pests leaves 94 percent and 84 percent of neonicotinoid product acres targeted at specific pests respectively for the foliar-based and soil-based systems, and 93 percent and 65 percent of the initial neonicotinoid product acres respectively for the foliar-based and soil-based systems.

Cotton Table 2. Initial product acres for foliar-based and soil-based systems and remaining product acres after focusing on major pests targeted by neonicotinoids.

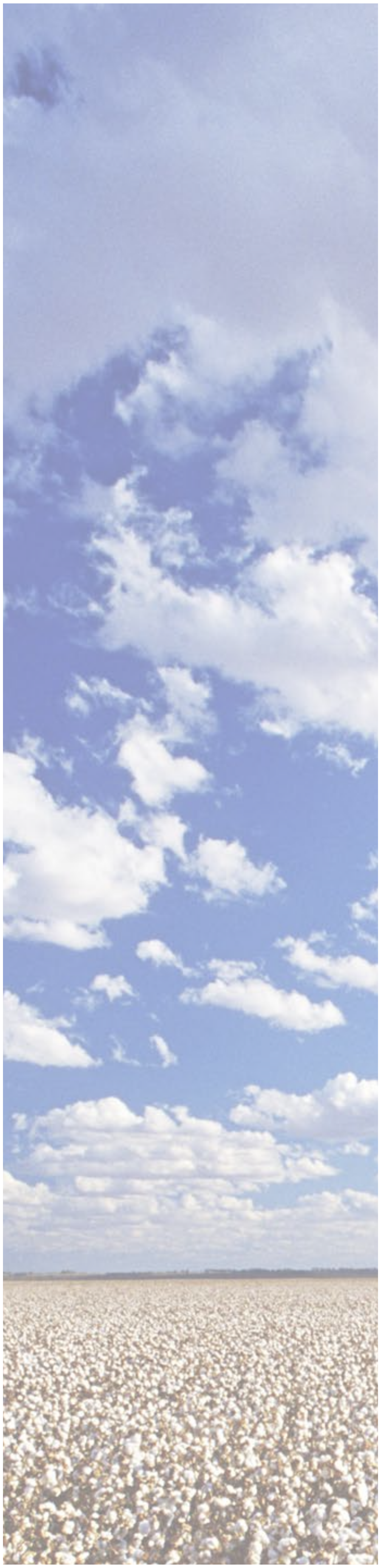
	--------Foliar-based Systems--------		---------Soil-based Systems---------	
	All AIs	Neonicotinoids	All AIs	Neonicotinoids
Initial Product Acres	22,199,891	3,049,353	9,002,416	6,269,620
No Answer	4.3%	1.0%	23.8%	23.2%
Targeted at Specific Pests	95.7%	99.0%	76.2%	76.8%
Remaining Product Acres				
% of Initial Product Acres	77.4%	93.0%	60.0%	64.6%
% Targeted at Specific Pests	80.8%	94.0%	78.8%	84.1%

2.2 Reallocating neonicotinoid product acres

Neonicotinoid product acres in the initial data are reallocated to non-neonicotinoid practices largely based on acreage shares of non-neonicotinoid insecticides for each major pest targeted by neonicotinoid insecticides. The reallocation process begins with the product acres remaining after the preparation process described above.

First, the share of non-neonicotinoid product acres treated with each non-neonicotinoid AI is calculated for each target insect group separately in order to identify the major non-neonicotinoid AIs used and their relative importance for controlling each target pest group. Any AI that has a maximum acreage share across all insect groups that is less than 2 percent is dropped in order to identify the main non-neonicotinoid alternatives in the foliar-based system and in the soil-based system. In addition, AIs, such as aldicarb, are dropped because they are no longer registered but were during 2010-2012 and so appear in the data. Also, AIs are dropped when the reported target pest is not a registered use of the AI, as this type of misreporting occurs rarely in the data due to imperfect recall or in some cases when pre-mixes or tank mixes of multiple AIs targeted at multiple pests are applied.

This process left 15 non-neonicotinoid AIs for foliar-based systems and four AIs for soil-based systems (both soil-applied insecticides and seed treatments), with some overlap in AIs between the systems. The relatively small number of AIs remaining for soil-based systems also occurs for some other crops due to the limited number of non-neonicotinoid alternatives that farmers have for controlling some types of soil insects in some crops. Indeed, the process left no AIs to control wireworms in cotton, since the only registered non-neonicotinoid AI in 2010-2012 for wireworms in cotton was aldicarb, which is no longer registered. Since chlorpyrifos is registered for wireworm control in corn and is registered for both foliar and soil application in cotton to control multiple pests (but not wireworms), this AI is used for wireworm control in cotton under the assumption that this registration would be sought and approved in a non-neonicotinoid scenario. This situation occurs for other crops as well. When no alternative non-neonicotinoid AIs are registered to control important target pests in these crops, this analysis explains the assumptions used to adjust the analysis process described here.



After dropping these AIs and making other adjustments as described, acreage shares for the remaining non-neonicotinoid AIs are renormalized for each target insect group separately so that they again add to 100 percent. Cotton Tables 3 and 4 report the resulting product acreage shares for the foliar-based system and both soil-based systems. In general, the spectrum of target pests is very similar for both the foliar-based and soil-based systems, which is not surprising, since most of the targets for neonicotinoid seed treatments are actually above-ground pests. The only difference in target pests is that the soil-based systems drop stink bugs and add wireworms.

Cotton Table 3. Non-neonicotinoid product acre shares by neonicotinoid target pest group for foliar-based systems.

Foliar-based System Active Ingredient	Aphid	Fleahopper	Plant Bug	Stink Bug	Thrips
Abamectin	0.0%	0.0%	0.8%	0.0%	0.0%
Acephate	29.1%	60.5%	31.2%	4.6%	70.8%
Acetamiprid	18.8%	6.1%	0.8%	0.0%	0.0%
Bifenthrin	9.6%	3.7%	18.0%	25.2%	3.8%
Chlorpyrifos	4.8%	0.3%	0.3%	0.0%	1.8%
Cyfluthrin	1.7%	2.7%	3.9%	10.3%	1.4%
Cypermethrin	1.1%	0.9%	4.4%	5.4%	1.1%
Dicrotophos	16.9%	16.5%	18.4%	37.5%	16.7%
Flonicamid	10.2%	0.7%	3.1%	0.0%	0.0%
Lambda-Cyhalothrin	2.4%	0.4%	4.1%	7.9%	0.4%
Naled	5.0%	0.0%	0.3%	0.0%	0.0%
Novaluron	0.1%	0.0%	9.1%	3.5%	0.1%
Oxamyl	0.0%	8.2%	4.3%	0.1%	0.8%
Spinetoram	0.0%	0.0%	0.0%	0.0%	3.1%
Zeta-Cypermethrin	0.3%	0.1%	1.2%	5.6%	0.0%

Cotton Tables 3 and 4 show the share of product acres for each AI by neonicotinoid target pest, so that each column for a target pest adds up to 100 percent within each system. In terms of interpretation, for example, the results for fleahoppers imply that 60.5 percent of all the non-neonicotinoid product acres targeted at fleahoppers use acephate and 16.5 percent use dicrotophos, with the remaining AIs having less than a 10 percent acreage share. Cotton Tables 3 and 4 also show that there are more non-neonicotinoid alternatives for foliar-based systems than for use in soil-based systems. Pests managed in foliar-based systems are also treated with a wider range of non-neonicotinoid insecticides (e.g., aphids, plant bugs, stink bugs), while soil-dwelling insects, such as wireworms, have a limited set of non-neonicotinoid alternatives available. Indeed, some mixes of pests would require two different AIs to replace the single neonicotinoid seed treatment, such as if the farmer wanted to control both thrips and fleahoppers with a seed treatment.

Cotton Table 4. Non-neonicotinoid active ingredient product acre shares by neonicotinoid target pest group for seed treatment and soil-applied insecticides.

Active Ingredient	Aphid	Fleahopper	Plant Bug	Thrips	Wireworm
	------------------------------------ Seed Treatment ------------------------------------				
Acephate	100.0%	0.0%	0.0%	100.0%	0.0%
Thiodicarb	0.0%	100.0%	100.0%	0.0%	0.0%
	-------------------------------------Soil-applied --------------------------------------				
Acephate	66.8%	0.0%	0.0%	60.3%	0.0%
Chlorpyrifos*	0.0%	0.0%	100.0%	0.0%	100.0%
Phorate	33.2%	0.0%	0.0%	39.7%	0.0%

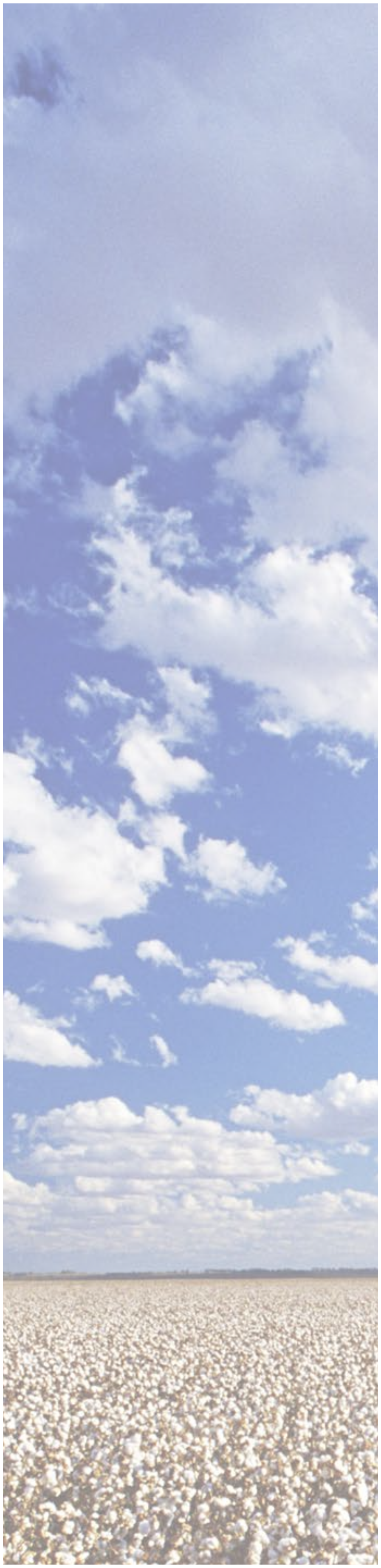
* Not registered as a soil-applied insecticide for control of wireworms in cotton, but this analysis assumes a registration would occur due to lack of alternatives (see text).

Cotton Tables 3 and 4 show which non-neonicotinoid AIs are used for each neonicotinoid target pest, but not how frequently growers target each pest group; Cotton Table 5 reports these frequencies. More specifically, for the foliar-based and the soil-based systems, the share of neonicotinoid product acres targeted to each pest group is calculated (i.e., the share of the neonicotinoid product acres in the last row of Cotton Table 2 targeted to each insect pest group listed in the row headings of Cotton Tables 3 and 4). Cotton Table 5 reports these shares, which can also be interpreted as the frequencies that each pest group is targeted by growers using neonicotinoids. As a result, each row adds up to 100 percent. The results in Cotton Table 5 show that plant bugs are overwhelmingly the primary target pest of neonicotinoid insecticides in foliar-based systems, with a 59 percent share of all foliar neonicotinoid product acres, while thrips are by far the primary target pests in soil-based systems, with a 75 percent product acre share.

Cotton Table 5. Share of neonicotinoid product acres targeted at each insect pest group for foliar-based and soil-based pest management systems.

Pest Control System	Aphid	Fleahopper	Plant Bug	Stink Bug	Thrips	Wireworm
Foliar-based	13.1%	9.4%	59.0%	11.8%	6.6%	0.0%
Soil-based	12.1%	5.7%	4.7%	0.0%	75.2%	2.3%

As Cotton Table 1 shows, neonicotinoid product acres in soil-based pest management systems use seed treatments, while Cotton Table 4 shows that many of the target pests of these seed treatments are actually above-ground pests. For the non-neonicotinoid scenario, these seed treatment neonicotinoid product acres either remain in a soil-based system or they switch to a foliar-based system, with those remaining in a soil-based system allocated to either a non-neonicotinoid seed treatment or a non-neonicotinoid soil insecticide. These reallocations are based on the share of non-neonicotinoid product acres using seed treatments, soil insecticides and foliar insecticides for each pest group targeted by the neonicotinoid seed treatments. Cotton Table 6 reports these shares for the pests targeted by neonicotinoid seed treatments used in cotton.



Cotton Table 6. Share of non-neonicotinoid product acres from foliar-based and from soil-based systems allocated to seed treatments, soil insecticides and foliar systems by target pest.

	Aphid	Leafhopper	Plant Bug	Stink Bug	Thrips	Wireworm
Foliar-based Treatment	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Soil-based						
Seed Treatment	5.4%	6.8%	0.7%	0.0%	13.1%	0.0%
Soil-applied	8.8%	6.0%	0.9%	0.0%	14.8%	100.0%
Foliar-applied	85.8%	87.2%	98.4%	0.0%	72.2%	0.0%

Results in Cotton Table 6 confirm that the pests targeted by neonicotinoid seed treatments in cotton are also often the targets of foliar applications of non-neonicotinoid insecticides, except for wireworms, which are only targeted by soil-applied insecticides. As a result, most of the neonicotinoid product acres in soil-based systems will be reallocated to foliar-based systems for the non-neonicotinoid scenario. For example, Cotton Table 6 implies that for the neonicotinoid seed treatment product acres targeted at aphids, 85.8 percent will be reallocated to a foliar-based system, 8.8 percent to a soil-based system using soil insecticides and 5.4 percent to a soil-based system using a non-neonicotinoid seed treatment. The only exception to this major shift from soil-based neonicotinoid seed treatments to non-neonicotinoid foliar applications is for wireworm control; these product acres will remain in a soil-based system, as foliar-based control is not an option.

For completeness, Cotton Table 6 also includes the foliar shares, which are all 100 percent since foliar neonicotinoid product acres all remain in a foliar-based system for this analysis. Also, stink bugs are included, which for the soil-based systems, will always have a 0 percent share since stink bugs are not targeted by neonicotinoid seed treatments.

2.3 Basic neonicotinoid reallocation equation

Based on these results, the neonicotinoid product acres in Cotton Table 1 can be allocated to non-neonicotinoid AIs using the neonicotinoid acreage shares for each target pest group in Cotton Table 6 and the non-neonicotinoid acreage shares for each AI by target pest group in Cotton Tables 4 and 5. To express this process mathematically, let $NonNeonicProdAcres^{t}_{i,j,s}$ be the neonicotinoid product acres currently in pest management system, with s allocated to non-neonicotinoid AI j, which is targeted at pest group i in pest control system t. Here i indexes the pest groups listed in Cotton Tables 3-6, j indexes the AIs listed in Cotton Tables 3 or 4, and s and t are ***foliar***, ***seed*** or ***soil*** for the foliar-based, the soil-based seed treatment or the soil-based soil insecticide pest control systems respectively. Let $NeonicProdAcres_{s}$ be the neonicotinoid product acres in Cotton Table 1 for pest control system s. Let $SystemShare^{t}_{i,s}$ be share for target pest group i in Cotton Table 6 currently in pest control system s to be allocated to pest control system t. Let $PestFreq_{i,s}$ be the neonicotinoid acreage share for target pest group i in Cotton Table 5 for pest control system s, and let $AIShare_{i,j,s}$ be the non-neonicotinoid acreage targeted of AI j targeted at pest group i in Cotton Table 3 or 4 for pest control systems s.

Based on these definitions, the general equation for allocating neonicotinoid product acres currently in pest control system s to non-neonicotinoid pest control system t, to each AI j targeted at pest group i ($Non\text{-}NeonicProdAcres^{t}_{i,j,s}$) is the product of neonicotinoid product acres to be allocated ($NeonicProdAcres_{s}$), the share of these product acres currently in system s to be allocated to system t ($SystemShare^{t}_{i,s}$), the frequency that these neonicotinoid acres targeted at pest group i ($PestFreq_{i,s}$), and the share of non-neonicotinoid acres for AI j targeted at pest group i in the system t to which they are being allocated ($AIShare^{t}_{i,j}$):

(1) $$Non\text{-}NeonicProdAcres^{t}_{i,j,s} = NeonicProdAcres_{s} \times SystemShare^{t}_{i,s} \times PestFreq_{i,s} \times AIShare^{t}_{i,j}$$

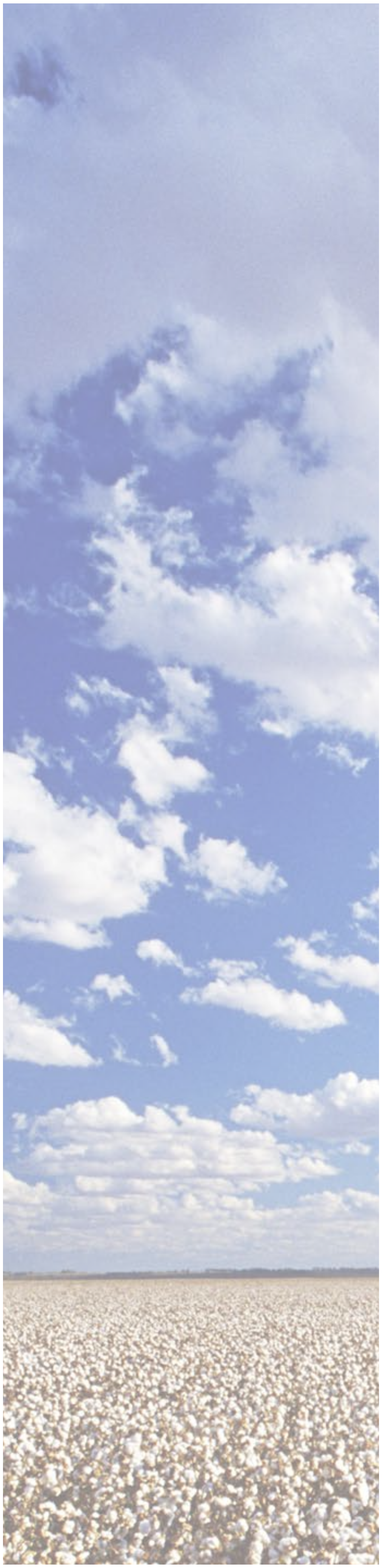
Note that $AIShare^{t}_{i,j}$ has a superscript t since it is the AI product acre shares for the system to which the neonicotinoid product acres are being allocated to, not the shares for the system they currently use. Also note that equation (1) is a general equation that still requires some adjustments before implementing, with the results reported in Cotton Tables 1-6.

2.4 Adjusting the neonicotinoid reallocation equation

This section describes two adjustments to the basic neonicotinoid reallocation equation. First, the reallocation equations must be adjusted to reflect that some of the soil-based protective IPM acres switching to a foliar-based threshold IPM program would remain untreated for the pests originally targeted by the neonicotinoid application based on the scouting results (though they may still be treated for other pests). This adjustment is made by multiplying by the expected insecticide treatment rate for a foliar-based threshold IPM program in that crop. For this analysis, this treatment rate is the ratio of base acres treated to total planted acres for the crop (A_{base}/A_{pltd}). For cotton, this ratio is 8.6 million base acres treated divided by 12.6 million planted acres or 68.3 percent, based on the 2010-2012 average. Finally, the neonicotinoid product acres that go untreated for the original neonicotinoid target pest as a result of this switch from a soil-based protective IPM program to a foliar-based threshold IPM program are also calculated.

Second, insecticides differ in the duration of control in the field, as well as in the efficacy and range of species controlled, so that switching AIs can require using a different number of applications. For example, switching from a neonicotinoid that provides 30 days of control to a non-neonicotinoid that provides 15 days of control will require an additional application in some cases, depending on the pest pressure, the efficacy of control and various environmental factors. The average number of applications used for each AI captures the impact of these differences in the duration of control and performance in different environments. For the GfK Kynetec data, the average number of applications for each AI is the ratio of product acres to base acres, which is tracked separately for soil-based and foliar-based systems for each crop, but not by target pest. Thus, for AI j in system s, the average number of applications is $AvgApps_{js} = ProductAcres_{js} / BaseAcres_{js}$.

The basic neonicotinoid reallocation equation is a one-to-one mapping of neonicotinoid product acres to non-neonicotinoid alternatives. This ratio is used to proportionally increase or decrease the number of non-neonicotinoid product acres to reflect these differences in product efficacy and field half-life. For example, 100 neonicotinoid product



acres would be reallocated to 110 non-neonicotinoid product acres if the non-neonicotinoid AI had an average number of applications 10 percent greater than for the neonicotinoids. The key to note is that insecticide product acres could increase for the non-neonicotinoid scenario if the 2010-2012 data show that non-neonicotinoid AIs on average used more applications than used for the neonicotinoids.

Cotton Table 7 reports the average number of applications for each non-neonicotinoid AI in Cotton Tables 3 and 4, as well as the ratios to adjust for differences in the number of applications for non-neonicotinoids relative to neonicotinoids. Note that both seed treatments and soil insecticides are combined in Cotton Table 7 as a soil-based application. Results in Cotton Table 7 show that soil-based systems use a single application for most AIs, likely as a seed treatment or as a soil-applied insecticide at the time of planting. Foliar-based systems use multiple applications for all AIs, ranging from 1.012 for spinetoram to 1.765 for novaluron. Because the average number of applications is 1.001 for neonicotinoid AIs in the soil-based systems, the soil-to-soil and foliar-to-soil ratios all essentially equal the average number of applications. However, because the average number of applications for neonicotinoids used in foliar-based systems is 1.547, the foliar-to-foliar ratios vary substantially, ranging from 0.655 for spinetoram to 1.141 for novaluron.

2.5 Neonicotinoid reallocation equations

Based on these definitions, equations (2)-(6) report the neonicotinoid product acres allocated to each non-neonicotinoid AI to control each target pest in foliar-based and both soil-based pest management systems for the non-neonicotinoid scenario.

$$(2)\ \textit{Non-NeonicProdAcres}_{i,j,foliar}^{foliar} = \textit{NeonicProdAcres}_{foliar} \times \textit{SystemShare}_{i,foliar}^{foliar} \times \textit{PestFreq}_{i,foliar} \times \textit{AIShare}_{i,j}^{foliar} \times \frac{\textit{AvgApps}_{j,foliar}}{\textit{AvgApps}_{neo,foliar}}$$

$$(3)\ \textit{Non-NeonicProdAcres}_{i,j,seed}^{seed} = \textit{NeonicProdAcres}_{seed} \times \textit{SystemShare}_{i,seed}^{seed} \times \textit{PestFreq}_{i,seed} \times \textit{AIShare}_{i,j}^{seed} \times \frac{\textit{AvgApps}_{j,seed}}{\textit{AvgApps}_{neo,seed}},$$

$$(4)\ \textit{Non-NeonicProdAcres}_{i,j,seed}^{soil} = \textit{NeonicProdAcres}_{seed} \times \textit{SystemShare}_{i,seed}^{soil} \times \textit{PestFreq}_{i,seed} \times \textit{AIShare}_{i,j}^{soil} \times \frac{\textit{AvgApps}_{j,soil}}{\textit{AvgApps}_{neo,seed}}$$

$$(5)\ \textit{Non-NeonicProdAcres}_{i,j,seed}^{foliar} = \textit{NeonicProdAcres}_{seed} \times \textit{SystemShare}_{i,seed}^{foliar} \times \textit{PestFreq}_{i,seed} \times \textit{AIShare}_{i,j}^{foliar} \times \frac{A_{base}}{A_{pltd}} \times \frac{\textit{AvgApps}_{j,foliar}}{\textit{AvgApps}_{neo,seed}}$$

$$(6)\ \textit{Non-NeonicProdAcres}_{0,0,seed}^{foliar} = \textit{NeonicProtAcres}_{seed} \times \textit{SystemShare}_{i,seed}^{foliar} \times \textit{PestFreq}_{i,seed} \times \left(1-\frac{A_{base}}{A_{pltd}}\right),$$

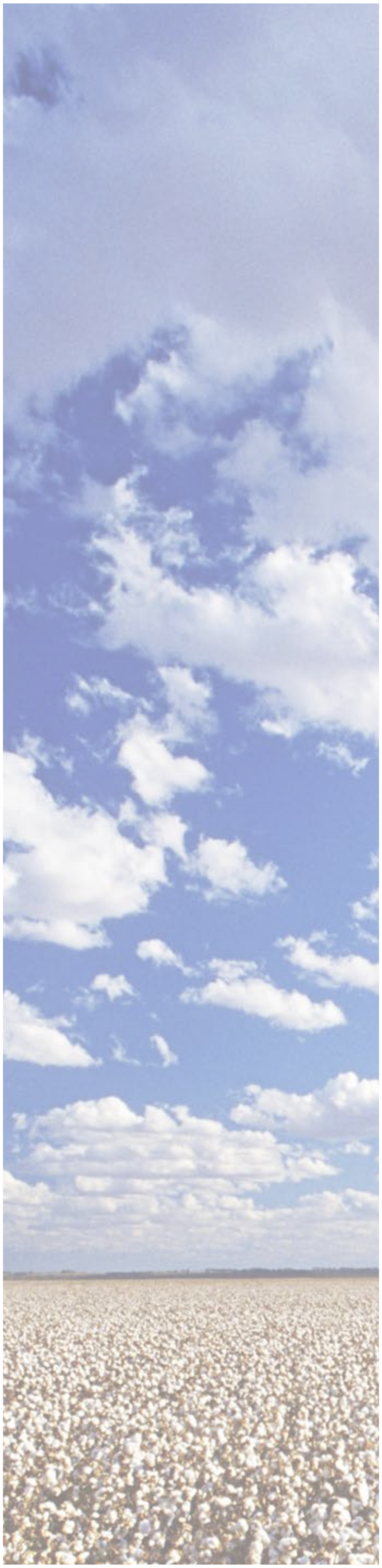
Equation (2) is the same as the basic reallocation equation (1), with ***s*** and ***t*** replaced with ***foliar*** to denote neonicotinoid product acres in a foliar system remain in a foliar-based system for the non-neonicotinoid scenario and the ratio to adjust for the average number of applications at the end.

Cotton Table 7. Average number of applications for each AI and ratios of these averages.

	Average Number of Applications		Ratio of Average Non-Neonicotinoid Applications to Neonicotinoid Applications		
Active Ingredient	Soil-based	Foliar-based	Soil:Soil	Foliar:Foliar	Foliar:Soil
Abamectin		1.248		0.807	1.247
Acephate	1.029	1.679	1.028	1.085	1.678
Acetamiprid		1.377		0.890	1.376
Bifenthrin		1.741		1.126	1.740
Chlorpyrifos	1.000	1.505	0.999	0.973	1.504
Cyfluthrin		1.478		0.956	1.477
Cypermethrin		1.694		1.095	1.693
Dicrotophos		1.603		1.037	1.602
Flonicamid		1.243		0.804	1.242
Lambda-Cyhalothrin		1.422		0.919	1.421
Naled		1.052		0.680	1.052
Novaluron		1.765		1.141	1.764
Oxamyl		1.345		0.870	1.345
Phorate	1.000		0.999		
Spinetoram		1.012		0.655	1.012
Thiodicarb	1.000		0.999		
Zeta-Cypermethrin		1.513		0.978	1.513
Neonicotinoids	1.001	1.547			

$NeonicProdAcres_{foliar}$ is from Cotton Table 1 (i.e., 3,049,353). The $SystemShare_{i,foliar}^{foliar}$ is from Cotton Table 6 (i.e., 100 percent for aphids). The $\text{PestFreq}_{i,foliar}$ for each target pest i is from Cotton Table 5 (i.e., 13.1 percent for aphids). The $\text{AIShare}_{i,j}^{foliar}$ for each AI j for each target pest group i is in Cotton Table 3 (i.e., 29.1 percent for acephate targeted at aphids) and the ratio for each AI j is in Table 7 (i.e., 1.085 for acephate). The calculation gives 126,125 product acres of acephate as a foliar application to control aphids, reallocated from the 116,244 neonicotinoid seed treatment product acres currently targeted to control aphids. The remaining equations follow a similar logic.

Note that equation (6) calculates the product acres that remain untreated for the neonicotinoid target pest when switching from using a neonicotinoid seed treatment in a soil-based protective IPM program to a non-neonicotinoid in a foliar-based threshold IPM program. Equation (6) is the same as equation (5), except that the AI shares ($\text{AIShare}_{i,j}^{foliar}$) and average application ratio are dropped since no AIs are applied for these pests, and one minus the expected treatment rate is used, since these acres remain untreated for the same pests as targeted by the original neonicotinoid application (though they may be treated for other pests).



Several possible combinations of neonicotinoid and new non-neonicotinoid pest management systems are not represented in equations (2)-(6) because the combinations do not occur in this analysis based on the 2010-2012 data. For example, no soil insecticide uses of neonicotinoids need to be reallocated (see Cotton Table 1), and so the combinations of ***s*** = ***soil*** and ***t*** = ***soil***, ***seed*** or ***foliar***, does not occur. Similarly, none of the foliar neonicotinoid product acres are allocated to a soil-based system, so these combinations do not occur.

Cotton Tables 8-11 report the non-neonicotinoid product acres by AI and target pest reallocated from the neonicotinoid product acres calculated using equations (2)-(6) and the appropriate values from the other tables. Cotton Table 8 shows that for the non-neonicotinoid scenario, most of the neonicotinoid product acres in foliar-based systems would switch to acephate, dicrotophos and bifenthrin, mostly to manage plant bugs. For the non-neonicotinoid scenario, Cotton Table 9 shows that the product acres allocated from a neonicotinoid seed treatment to a non-neonicotinoid seed treatment would use acephate mostly to manage thrips, while Cotton Table 10 shows that those allocated to a non-neonicotinoid soil insecticide would use acephate and phorate mostly to manage thrips. Also, Cotton Table 10 shows a small amount of chlorpyrifos used to manage wireworms. The analysis assumes chlorpyrifos would be registered for wireworm control in cotton as a non-neonicotinoid soil insecticide, even though it currently is not (though it is in corn). Finally, Cotton Table 11 shows that neonicotinoid seed treatment product acres allocated to a foliar system for the non-neonicotinoid scenario would mostly use acephate and dicrotophos to manage thrips.

Cotton Table 8. Non-neonicotinoid product acres in a foliar-based pest management system by AI and target pest group reallocated from neonicotinoid product acres in a foliar-based pest management system.

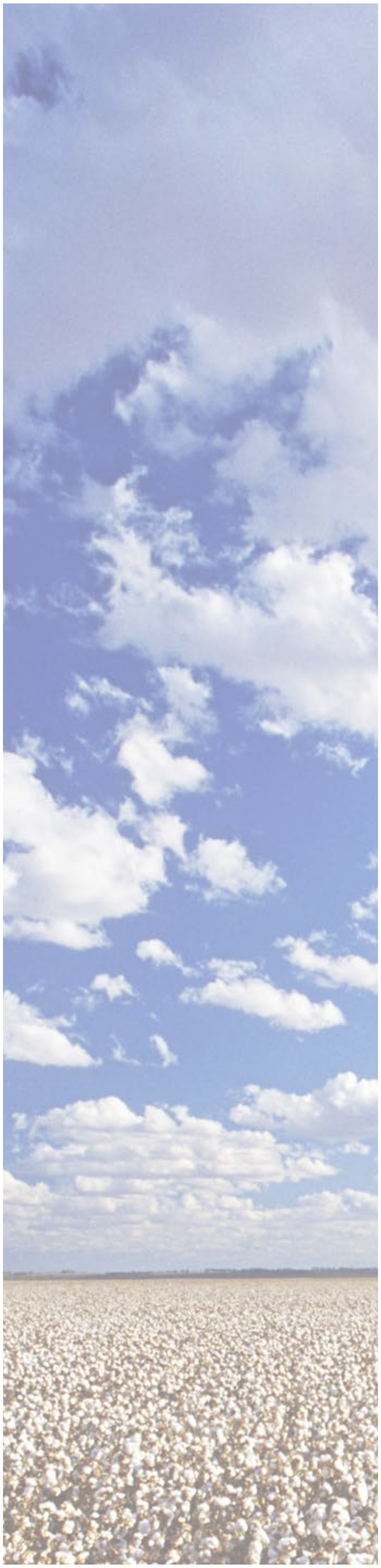
Active Ingredient	Aphid	Fleahopper	Plant Bug	Stink Bug	Thrips	Total	AI Weights
Abamectin	0	0	11,615	0	0	11,615	0.4%
Acephate	126,125	188,157	609,038	17,959	154,602	1,095,881	34.5%
Acetamiprid	66,839	15,562	12,810	0	0	95,210	3.0%
Bifenthrin	43,181	11,942	364,645	102,101	8,611	530,480	16.7%
Chlorpyrifos	18,657	837	5,252	0	3,525	28,270	0.9%
Cyfluthrin	6,492	7,399	67,078	35,431	2,694	119,094	3.8%
Cypermethrin	4,812	2,825	86,682	21,276	2,424	118,018	3.7%
Dicrotophos	70,007	49,045	343,286	139,926	34,854	637,119	20.1%
Flonicamid	32,759	1,613	44,841	0	0	79,214	2.5%
Lambda-Cyhalothrin	8,811	1,054	67,789	26,124	740	104,517	3.3%
Naled	13,582	0	3,670	0	0	17,252	0.5%
Novaluron	456	0	186,804	14,370	230	201,859	6.4%
Oxamyl	0	20,449	67,305	313	1,401	89,468	2.8%
Spinetoram	0	0	0	0	4,087	4,087	0.1%
Zeta-Cypermethrin	1,172	280	21,114	19,707	0	42,274	1.3%
Total	**392,892**	**299,162**	**1,891,930**	**377,206**	**213,166**	**3,174,356**	**100.0%**

Cotton Table 9. Non-neonicotinoid product acres in a seed treatment pest management system by AI and target pest group reallocated from neonicotinoid product acres in a seed treatment pest management system.

Active Ingredient	Aphid	Fleahopper	Plant Bug	Thrips	Wireworm	Total	AI Weights
Acephate	42,113	0	0	634,927	0w	677,039	96.3%
Thiodicarb	0	24,277	2,061	0	0	26,337	3.7%
Total	**42,113**	**24,277**	**2,061**	**634,927**	**0**	**703,377**	**100.0%**

Cotton Table 10. Non-neonicotinoid product acres in a soil insecticide pest management system by AI and target pest group reallocated from neonicotinoid product acres in a seed treatment pest management system.

Active Ingredient	Aphid	Fleahopper	Plant Bug	Thrips	Wireworm	Total	AI Weights
Acephate	45,844	0	0	432,545	0	478,389	51.8%
Chlorpyrifos	0	0	2,649	0	144,057	146,706	15.9%
Phorate	22,142	0	0	276,743	0	298,885	32.3%
Total	**67,985**	**0**	**2,649**	**709,288**	**144,057**	**923,980**	**100.0%**



Cotton Table 11. Non-neonicotinoid product acres in a foliar-based pest management system by AI and target pest group reallocated from neonicotinoid product acres in a seed treatment pest management system.

Active Ingredient	Aphid	Fleahopper	Plant Bug	Stink Bug	Thrips	Total	AI Weights
Abamectin	0	0	1,973	0	0	1,973	0.0%
Acephate	216,828	215,823	103,561	0	2,758,917	3,295,130	65.0%
Acetamiprid	114,870	17,844	2,178	0	0	134,892	2.7%
Bifenthrin	74,174	13,687	61,955	0	153,549	303,364	6.0%
Chlorpyrifos	32,057	959	893	0	62,869	96,777	1.9%
Cyfluthrin	11,150	8,478	11,395	0	48,020	79,042	1.6%
Cypermethrin	8,270	3,239	14,735	0	43,248	69,492	1.4%
Dicrotophos	120,221	56,195	58,308	0	621,287	856,012	16.9%
Flonicamid	56,254	1,848	7,616	0	0	65,718	1.3%
Lambda-Cyhalothrin	15,144	1,208	11,525	0	13,200	41,077	0.8%
Naled	23,357	0	624	0	0	23,981	0.5%
Novaluron	783	0	31,753	0	4,096	36,633	0.7%
Oxamyl	0	23,447	11,440	0	24,988	59,875	1.2%
Spinetoram	0	0	0	0	0	0	0.0%
Zeta-Cypermethrin	1,348	215	2,402	0	0	3,965	0.1%
Total Treated With These AIs	674,456	342,944	320,359	0	3,730,173	5,067,932	100.0%
Scouted, Not Treated for These Pests	206,850	99,032	92,146	0	1,081,779	1,479,807	
Total	**881,306**	**441,976**	**412,505**	**0**	**4,811,952**	**6,547,739**	

3.0 Results: Impacts of the Non-Neonicotinoid Scenario on Pest Management

3.1 Changes in AI product acres and product acre shares

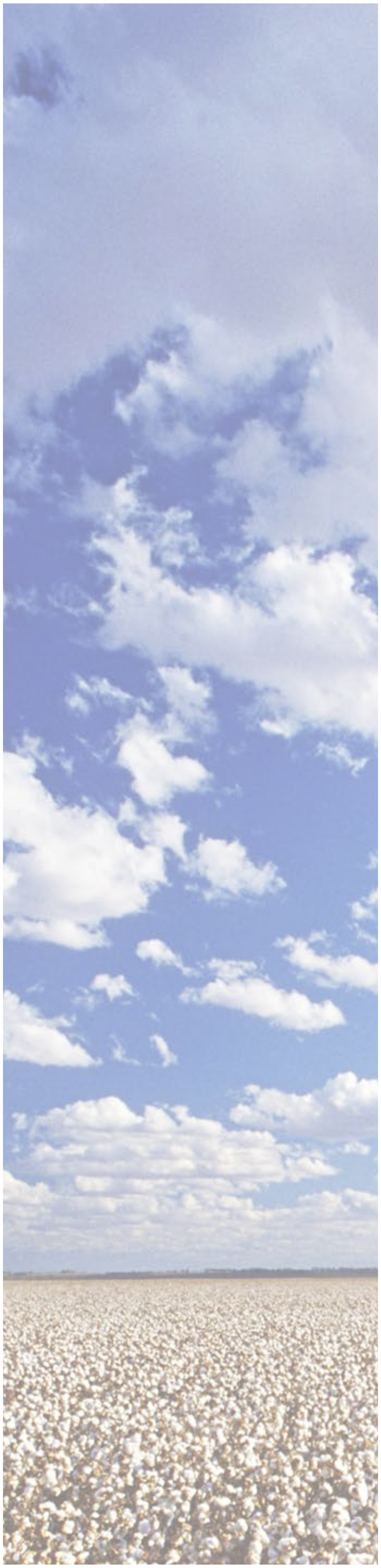
Cotton Table 12 summarizes the results of this process for cotton. For the non-neonicotinoid scenario, the 2010-2012 average neonicotinoid product acres are allocated to several non-neonicotinoid AIs, and Cotton Table 12 lists these 17 specific AIs and their Insecticide Resistance Action Committee (IRAC) mode of action (MOA) classification (IRAC, 2014). Cotton Table 12 then lists the 2010-2012 annual average product acres for each of these AIs for their use in cotton, targeted at any pest. Cotton Table 12 does not list all AIs used for cotton, only those non-neonicotinoid AIs to which neonicotinoid product acres are reallocated using the process described above. Minor use AIs were dropped (if their maximum product acre share was less than 2 percent across all target pest groups), as were AIs no longer registered for use or otherwise misreported (see Section 2.2), and so totals in Cotton Table 12 do not match those in Cotton Table 1. Cotton Table 12 then lists the neonicotinoid product acres added to each non-neonicotinoid

Cotton Table 12. Impact of the non-neonicotinoid scenario on non-neonicotinoid product acres by individual active ingredients and by insecticide class.

		------------------------------ Product Acres ------------------------------			
MOA	**Active Ingredient**	**2010-2012 Average**	**Added**	**New Total**	**Change**
6	Abamectin	574,461	13,588	588,049	2%
1B	Acephate	6,691,995	5,546,438	12,238,433	83%
4A	Acetamiprid	291,568	230,102	521,670	79%
3A	Bifenthrin	2,754,234	833,844	3,588,078	30%
1B	Chlorpyrifos	679,484	271,753	951,238	40%
3A	Cyfluthrin	1,022,844	198,136	1,220,980	19%
3A	Cypermethrin	847,166	187,510	1,034,676	22%
1B	Dicrotophos	3,583,520	1,493,131	5,076,650	42%
9C	Flonicamid	282,223	144,932	427,155	51%
3A	Lambda-Cyhalothrin	1,213,532	145,593	1,359,126	12%
1B	Naled	53,577	41,233	94,810	77%
4A	Neonicotinoids	9,318,974	-9,318,974	0	-100%
15	Novaluron	881,554	238,493	1,120,047	27%
1A	Oxamyl	493,871	149,343	643,213	30%
1B	Phorate	98,880	298,885	397,765	302%
5	Spinetoram	99,439	4,087	103,525	4%
1A	Thiodicarb	537,638	26,337	563,975	5%
3A	Zeta-Cypermethrin	402,762	46,239	449,001	11%
Total Treated With These AIs*		**29,827,722**	**550,671**	**30,378,392**	**2%**
Non-Neonicotinoids*		20,508,747	9,869,645	30,378,392	48%
Neonicotinoids		9,318,974	-9,318,974	0	-100%
Scouted but Not Treated for These Pests			**1,479,807**	**1,479,807**	

		------------------------------ Product Acres ------------------------------			
MOA	**Insecticide Class**	**2010-2012 Average**	**Added**	**New Total**	**Change**
6	Avermectins	574,461	13,588	588,049	2%
15	Benzoylureas	881,554	238,493	1,120,047	27%
1A	Carbamates	1,031,509	175,680	1,207,189	17%
9C	Flonicamids	282,223	144,932	427,155	51%
4A	Neonicotinoids	9,318,974	-9,318,974	0	-100%
4A	Other Neonicotinoids**	291,568	230,102	521,670	79%
1B	Organophosphates	11,107,456	7,651,440	18,758,896	69%
3A	Pyrethroids	6,240,538	1,411,323	7,651,861	23%
5	Spinosyns	99,439	4,087	103,525	4%
Total Treated With These AIs*		**29,827,722**	**550,671**	**30,378,392**	**2%**
Non-Neonicotinoids*		20,508,747	9,869,645	30,378,392	48%
Neonicotinoids		9,318,974	-9,318,974	0	-100%
Scouted but Not Treated for These Pests			**1,479,807**	**1,479,807**	

*Does not match Cotton Table 1 totals because totals here do not include minor use AIs.
**The cyanoamidine neonicotinoid insecticide acetamiprid.



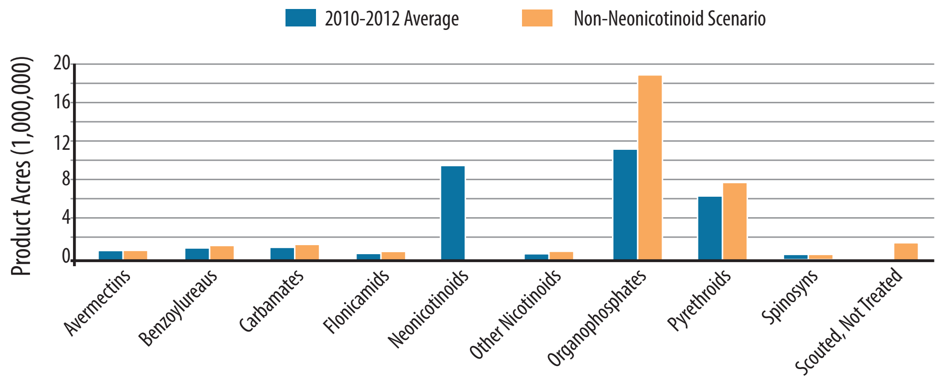
AI for the non-neonicotinoid scenario, which is the sum of the product acres reallocated to each AI as reported in Cotton Tables 8-11. Next, Cotton Table 12 reports the new updated total product acres for each non-neonicotinoid AI implied by the non-neonicotinoid scenario and the associated percentage increase in product acres that this updated total represents relative to average use in 2010-2012. Finally, Cotton Table 12 reports the same data (2010-2012 average, added and new total product acres), but aggregated by insecticide class using the IRAC MOA classifications. Cotton Figure 1 graphically reports the 2010-2012 average product acres and the new total product acres for the non-neonicotinoid scenario by insecticide class as reported in Cotton Table 12.

In terms of net increases in product acres, the results in Cotton Table 12 show large increases for acephate, dicrotophos and bifenthrin. By far, the largest increase is estimated for acephate, which adds more than 5.5 million product acres, while dicrotophos adds almost 1.5 million product acres and bifenthrin adds 833,000; all other AIs add less than 300,000 product acres. The insecticide class results in the lower portion of Cotton Table 12 show large increases for organophosphates and pyrethroids, which add an estimated 7.7 million and 1.4 million product acres respectively; the next largest increase is for the benzoylureas, which add less than 240,000 product acres. The overall increase in total product acres treated with these AIs increases to almost 9.9 million acres, or almost 50 percent, with an additional 1.5 million product acres scouted but not treated with these AIs for the pests originally targeted by neonicotinoids. Cotton Figure 1 graphically shows these same results. The importance of neonicotinoids, organophosphates and pyrethroids, as insecticide classes for insect management in cotton during 2010-2012 is clear in Cotton Figure 1, as are the large increases in organophosphates that are estimated under the non-neonicotinoid scenario; the other insecticide classes and their changes seem relatively minor in comparison.

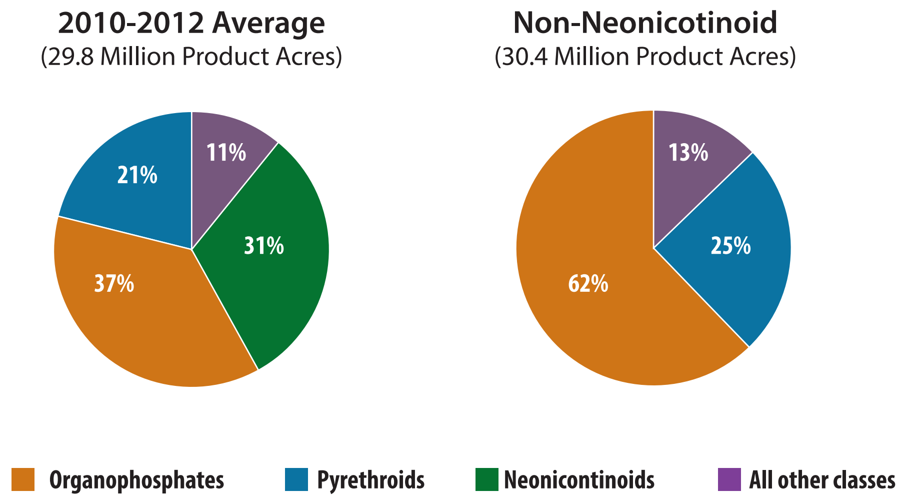
Cotton Figure 1 also highlights how cotton growers rely heavily on these three insecticide modes of action (organophosphates, neonicotinoids and pyrethroids) and shift to even heavier reliance on only two modes of action for the non-neonicotinoid scenario. As Cotton Table 1 indicates, there were annually 31.2 million product acres for all insecticide AIs applied to cotton on average for 2010-2012. For these three modes of action, Cotton Figure 2 shows the 2010-2012 average shares of these product acres devoted to each mode of action and the estimated shares for the non-neonicotinoid scenario. The data show that more than 37 percent of all cotton product acres received organophosphates, more than 31 percent received neonicotinoids, almost 21 percent received pyrethroids and the remaining 11 percent received one or more of all other modes of action. The non-neonicotinoid scenario eliminates the 31 percent share for neonicotinoids, reallocating most of it to organophosphates and to some extent pyrethroids so that their shares increase to almost 62 percent for organophosphates and more than 25 percent for pyrethroids, with the variety of remaining modes of action increasing to 13 percent.

In terms of relative increases, the percentage changes in Cotton Table 12 show the largest increases for phorate, acephate, acetamiprid and naled, which all increase more than 50 percent. In terms of relative increas-

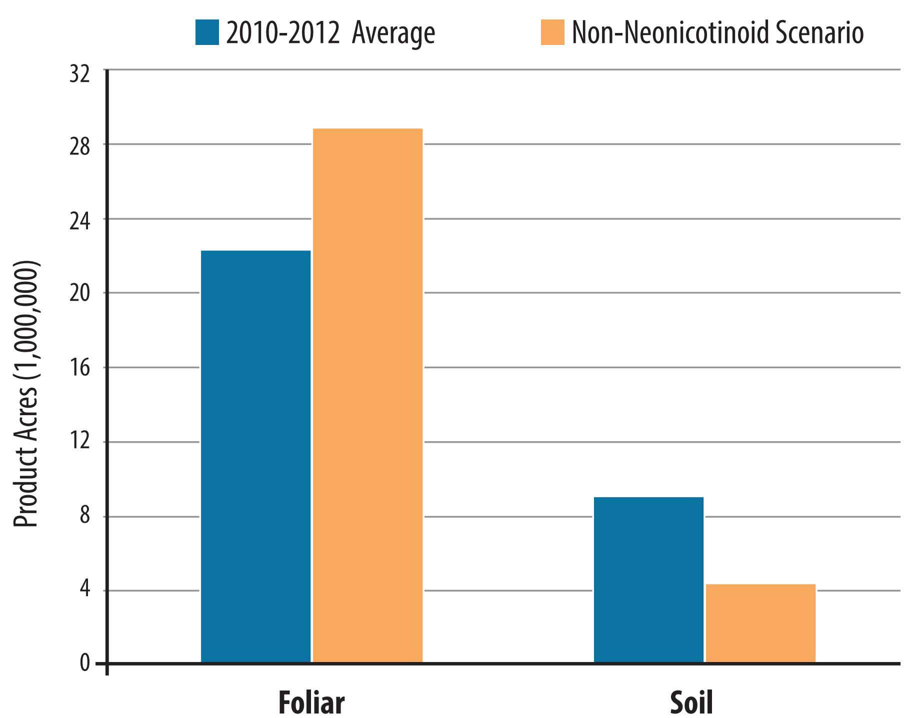
Cotton Figure 1. 2010-2012 average product acres and new total product acres for the non-neonicotinoid scenario by insecticide class.

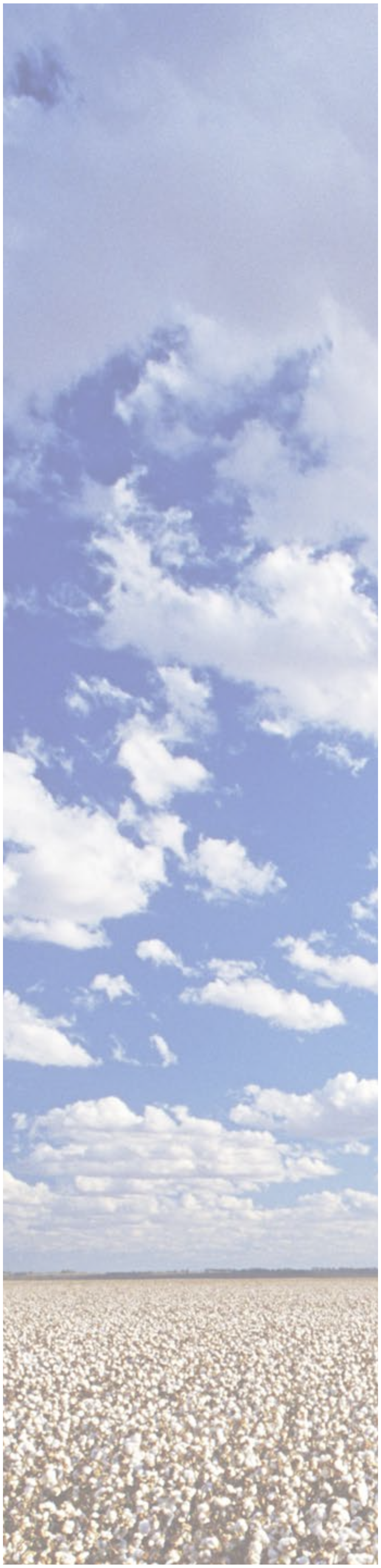


Cotton Figure 2. 2010-2012 average shares of total insecticide product acres allocated to major insecticide modes of action and estimated shares for the non-neonicotinoid scenario. (Shares are based on product acres data in Cotton Table 12 and do not include product acres reallocated to "scouted but not treated" or to "cultural control".)



Cotton Figure 3. 2010-2012 annual average product acres and new total product acres for the non-neonicotinoid scenario using foliar-based and soil-based pest management systems. (Foliar-based includes both acres "scouted and treated" as well as "scouted and not treated"; soil-based includes "seed treatments" and "soil insecticides.")





es in the different insecticide classes, such as the other neonicotinoids (acetamiprid), flonicamid and benzoylureas, increase substantially because they started from relatively small initial product acres. Organophosphate product acres show the second largest percentage increase (70 percent), with carbamates increasing more than 27 percent and pyrethroids increasing almost 23 percent.

These estimated shifts in insecticide use in Cotton Table 12 and Cotton Figures 1 and 2 raise additional concerns that this analysis does not capture. Over-reliance on only a few modes of action contributes to the development of insect resistance to these modes of action, and the shifts in product acreage shares indicated by these results would seem to be a concern. This contribution of neonicotinoids to improved insect resistance management is a benefit missing from this analysis. Furthermore, unlike neonicotinoids, organophosphates and pyrethroids are non selective insecticides that can reduce beneficial insect populations when applied, and so reduce the efficacy of natural pest control mechanisms. As a result, populations of the target pest or secondary pests are more likely to reach levels triggering additional insecticide applications. This contribution of neonicotinoids to increased populations of beneficial insects is also a benefit missing from this analysis.

Cotton Table 13. Average application rate (pounds per product acre) for each active ingredient by method of application (foliar-applied, soil-applied, seed treatment).

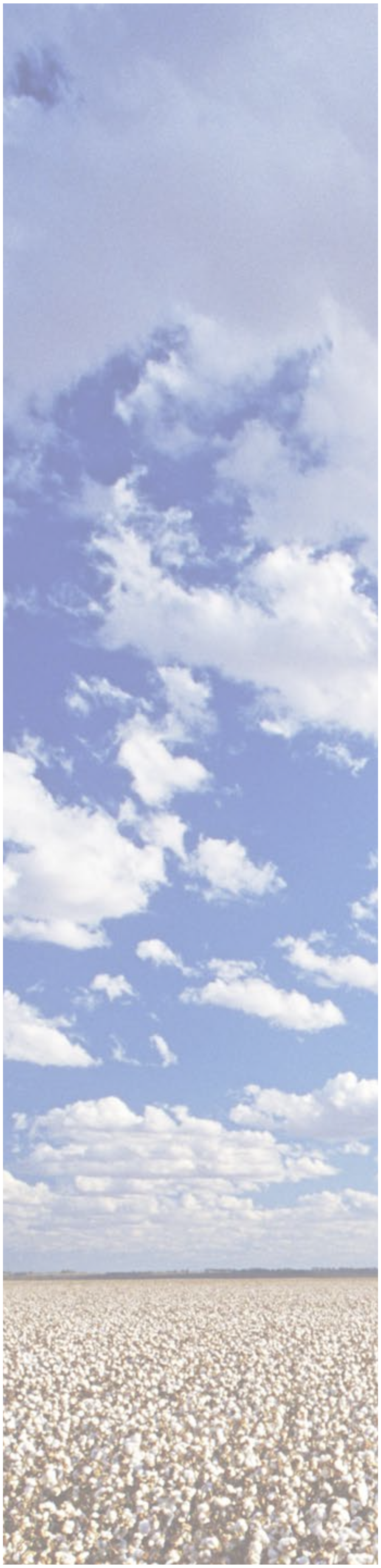
		---Average Application Rate (Pounds per Product Acre) **---**		
MOA	**Active Ingredient**	**Foliar**	**Seed Treatment**	**Soil Insecticide**
6	Abamectin	0.0085		
1B	Acephate	0.4397	0.1402	0.4464
4A	Acetamiprid	0.0458		
3A	Bifenthrin	0.0695		
1B	Chlorpyrifos	0.4665		0.5001
3A	Cyfluthrin	0.0244		
3A	Cypermethrin	0.0653		
1B	Dicrotophos	0.2980		
9C	Flonicamid	0.0741		
3A	Lambda-Cyhalothrin	0.0307		
1B	Naled	0.9375		
4A	Neonicotinoids	0.0544	0.0391	
15	Novaluron	0.0423		
1A	Oxamyl	0.3935		
1B	Phorate			1.1141
5	Spinetoram	0.0210		
1A	Thiodicarb		0.0541	
3A	Zeta-Cypermethrin	0.0194		

Cotton Table 14. Impact of the non-neonicotinoid scenario on pounds of AI applied by insecticide class.

MOA	Active Ingredient	-----------------Pounds of Active Ingredient Applied----------------- 2010-2012 Average	Added	New Total	Change
6	Abamectin	4,881	116	4,997	2%
1B	Acephate	2,835,524	2,239,216	5,074,740	79%
4A	Acetamiprid	13,356	10,540	23,896	79%
3A	Bifenthrin	190,806	57,973	248,779	30%
1B	Chlorpyrifos	62,773	131,701	194,474	210%
3A	Cyfluthrin	24,218	4,841	29,059	20%
3A	Cypermethrin	41,313	12,238	53,551	30%
1B	Dicrotophos	1,059,923	444,909	1,504,831	42%
9C	Flonicamid	20,910	10,738	31,648	51%
3A	Lambda-Cyhalothrin	35,721	4,464	40,185	12%
1B	Naled	50,229	38,656	88,885	77%
4A	Neonicotinoids	408,734	-408,734	0	-100%
15	Novaluron	37,325	10,098	47,423	27%
1A	Oxamyl	194,073	58,770	252,843	30%
1B	Phorate	110,166	332,998	443,164	302%
5	Spinetoram	2,090	86	2,176	4%
1A	Thiodicarb	29,086	1,425	30,510	5%
3A	Zeta-Cypermethrin	7,694	896	8,590	12%
	Total	**5,128,821**	**2,950,931**	**8,079,752**	**58%**

MOA	Insecticide Class	-----------------Pounds of Active Ingredient Applied----------------- 2010-2012 Average	Added	New Total	Change
6	Avermectins	4,881	116	4,997	2%
15	Benzoylureas	37,325	10,098	47,423	27%
1A	Carbamates	223,159	60,194	283,353	27%
9C	Flonicamids	20,910	10,738	31,648	51%
4A	Neonicotinoids	408,734	-408,734	0	-100%
4A	Other Neonicotinoids*	13,356	10,540	23,896	79%
1B	Organophosphates	4,118,614	3,187,480	7,306,095	77%
3A	Pyrethroids	299,752	80,412	380,164	27%
5	Spinosyns	2,090	86	2,176	4%
	Total	**5,128,821**	**2,950,931**	**8,079,752**	**58%**

*The cyanoamidine neonicotinoid insecticide acetamiprid.



3.2 Changes in total pounds of AIs applied

Cotton Table 13 reports the average application rate in pounds per product acre for each active ingredient by method of application (foliar, soil, seed treatment). These are calculated separately for each AI and each application method as total pounds of the AI applied divided by the total product acres, and so average across all the different pests targeted by that AI, the different formulations and the years 2010-2012. Cotton Table 13 shows that most AIs are used at relatively low rates per acre, except for the organophosphates and carbamates. Multiplying these average application rates by the product acres for each AI for each application method gives the total pounds applied. Cotton Table 14 reports the total pounds of each AI and for each insecticide class using this method.

In Cotton Table 14, the observed differences between the 2010-2012 averages and the non-neonicotinoid scenario generally match the trends evident in Cotton Table 12 product acres, but with small variations since some AIs are used at different rates for different application methods. The only exception is chlorpyrifos, which has a projected 210 percent increase in pounds of AI applied for the non-neonicotinoid scenario, but a 40 percent increase in product acres. This difference exists because 80 percent of chlorpyrifos product acres in cotton during 2010-2012 were applied as seed treatments, while the non-neonicotinoid scenario adds more than 270,000 product acres as foliar and soil applications. Cotton Table 13 shows that the average application rate for the foliar- and soil-applied chlorpyrifos is much greater than the application rate as a seed treatment.

The results in Cotton Table 14 show that the non-neonicotinoid scenario increases the total application of insecticide active ingredients by almost 3 million pounds, increasing it from 5.1 million pounds to 8.0 million pounds, or about 58 percent. Most of this increase comes from replacing more than 400,000 pounds of neonicotinoids with almost 3.2 million pounds of organophosphates, which as Cotton Table 13 shows, are used at higher application rates than most other insecticides. Total pounds applied increases 77 percent for organophosphates, the largest increase, except for the 79 percent increase for the cyanoamidine neonicotinoid insecticide acetamiprid.

3.3 Changes in pest management systems used

Cotton Table 15 focuses on product acres managing pests using foliar-based and soil-based systems and how they change for the non-neonicotinoid scenario. The 2010-2012 annual average product acres in each system and the neonicotinoid product acres in each system to be reallocated (removed) for the non-neonicotinoid scenario can be gleaned from Cotton Tables 1 and 2, while the product acres added to each system are from Cotton Tables 8-11. In general, a shift from soil-based management to foliar-based management occurs for the non-neonicotinoid scenario as cotton growers switch from seed treatments to foliar applications to manage thrips and other above-ground pests. The estimated net increase in product acres using foliar-based system is 6.7 million, more than a 30 percent increase, while product acres in a soil-based system decrease almost 4.6 million, more than a 50 percent decrease. Cotton Figure 3 illustrates this change graphically, showing the shift to foliar-based pest management in cotton. About 71 percent of insecticide product acres during 2010-2012

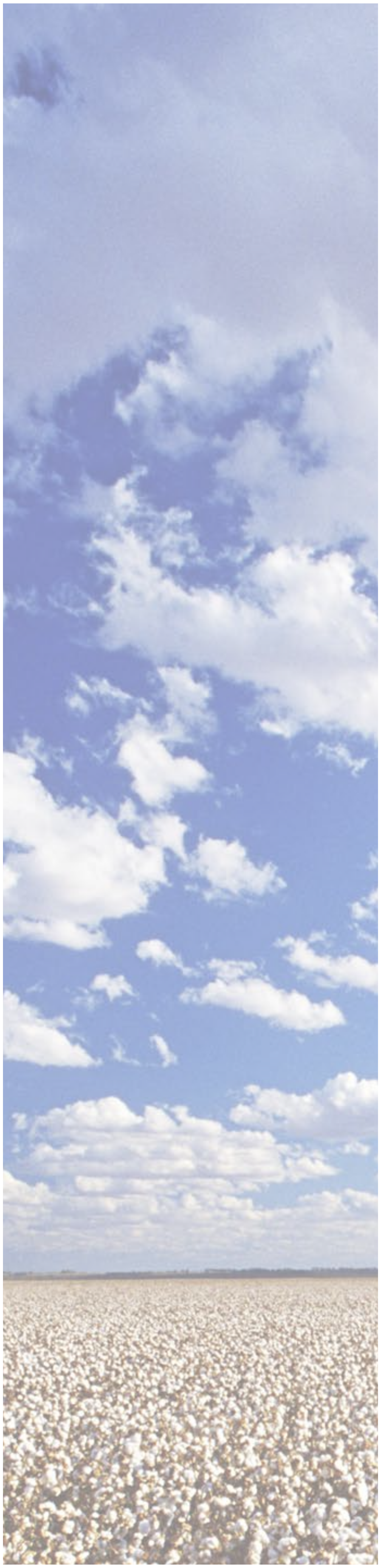
Cotton Table 15. Impact of the non-neonicotinoid scenario on product acres using foliar-based and soil-based pest management systems.

Category	Foliar-based	Soil-based	Total
2010-2012 Average Product Acres (All AIs)	22,199,891	9,002,416	31,202,308
Neonicotinoid Product Acres to be Reallocated	3,049,353	6,269,620	9,318,974
Total Non-Neonicotinoid Product Acres Added	9,722,095	1,627,357	11,349,452
Scouted and Treated	8,242,288	1,627,357	9,869,645
Scouted Only	1,479,807	0	1,479,807
New Total Product Acres (including Scouted Only)	28,872,633	4,360,153	33,232,786
Net Change (Product Acres)	**6,672,742**	**-4,642,264**	**2,030,478**
Net Change (%)	**30.1%**	**-51.6%**	**6.5%**

were in a foliar-based pest management system and 29 percent in a soil-based system; but for the non-neonicotinoid scenario, this shifts so that 87 percent of product acres are in a foliar-based system and 13 percent in a soil-based system.

These shifts to alternative AIs for the non-neonicotinoid scenario are based on use patterns as indicated by the three-year average use for 2010-2012. The reallocation process assumes farmers will continue to target the same insect pests over the same number of acres but switch to non-neonicotinoid practices. The reallocation to these alternative non-neonicotinoid practices was determined by the average 2010-2012 market shares for non-neonicotinoid AIs that farmers used then to target these same insect pests. A key assumption of this reallocation process is that the past is an accurate indication of what farmers would do without neonicotinoid insecticides. More specifically, if neonicotinoids were no longer available, the process assumes that relative insecticide prices would remain unchanged, that new technologies would not emerge, and that pest population dynamics and geographic ranges would not change. For example, the increase in demand for insecticides, such as acephate, dicrotophos and bifenthrin, could lead to price increases relative to other insecticides, and so moderate to some extent the projected product acre increases in Cotton Table 12. This type of adjustment is not accounted for by this analysis. Similarly, companies would likely seek ways to make other insecticides applied as seed treatments and explore new AIs and new modes of action, which could substantially increase demand for these AIs beyond their historical market share used for this process. Finally, the target pest data used for this process could shift as new pests emerge or invade cropping regions, or pests develop resistance to existing modes of action. Again, accounting for these types of adjustments is beyond the scope of this analysis. Finally, this projected shift to foliar-based pest management systems also removes some of the other benefits of seed treatments in comparison to foliar treatments, such as reduced potential for spray drift and field runoff, and fewer passes through the fields. These benefits and cost impacts are also not accounted for in this analysis.

Nevertheless, with these caveats, this data-driven analysis quantifies the changes that would likely occur if neonicotinoids were not available – cot-



ton farmers would substantially increase their use of organophosphates and rely even more heavily on foliar applications to manage pests, such as thrips, which are currently managed using neonicotinoid seed treatments. Overall, 9.3 million product acres of cotton are currently treated with neonicotinoids, about 3 million foliar-applied and 6.3 million as seed treatments. These product acres would be replaced with an estimated 7.7 million product acres of organophosphates (almost a 70 percent increase), 1.4 million product acres of pyrethroids (almost a 23 percent increase) and more than 800,000 product acres of other non-neonicotinoid active ingredients (a 26 percent increase). Furthermore, product acres using foliar-based pest management would increase by an estimated 6.8 million acres, including more than 1.5 million acres scouted and not treated with a non-neonicotinoid alternative for the pests currently targeted by a neonicotinoid. As a result, the current 6.3 million product acres of neonicotinoid seed treatments in cotton would be replaced with an estimated 5.2 million product acres of foliar-applied non-neonicotinoid insecticides and 1.6 million product acres of non-neonicotinoid seed treatments and soil insecticides, for an increase of 0.5 million insecticide product acres. The current 3.0 million product acres of foliar-applied neonicotinoids would be replaced by an estimated 3.2 million product acres of foliar-applied non-neonicotinoid alternatives. This net increase in product acres occurs because the average number of applications is larger for the non-neonicotinoid alternatives relative to neonicotinoids.

3.4 Impact on grower costs

This section describes the partial budget analysis used to estimate the impact of the reallocation of neonicotinoid product acres to non-neonicotinoid insecticides on grower costs. The cost analysis for the non-neonicotinoid scenario focuses on three costs: AI costs, application costs and scouting costs. AI costs depend on the per acre cost for each alternative non-neonicotinoid AI relative to the neonicotinoid AI cost, with GfK Kynetec data providing estimates of the per acre costs for each AI. Application and scouting costs for this analysis vary depending on whether the neonicotinoid product acre is in a foliar-based system and remains in a foliar-based system, is in a soil-based system and switches to a foliar-based system, or is in a soil-based system and remains in a soil-based system. Information from custom rate surveys and crop budgets are collected and analyzed to estimate application and scouting costs. Furthermore, the impacts of the non-neonicotinoid scenario on application and scouting costs vary for each crop, since crops differ in terms of their pest management practices. For example, most cotton acres are already scouted for insects, so that switching from soil-based management to foliar-based management of insects for the non-neonicotinoid scenario would not entail changes in crop scouting costs. Cotton growers already scouting would continue to do so and those who do not scout would not start as a result of the non-neonicotinoid scenario. Specific assumptions regarding changes in application and scouting costs are explained for each crop.

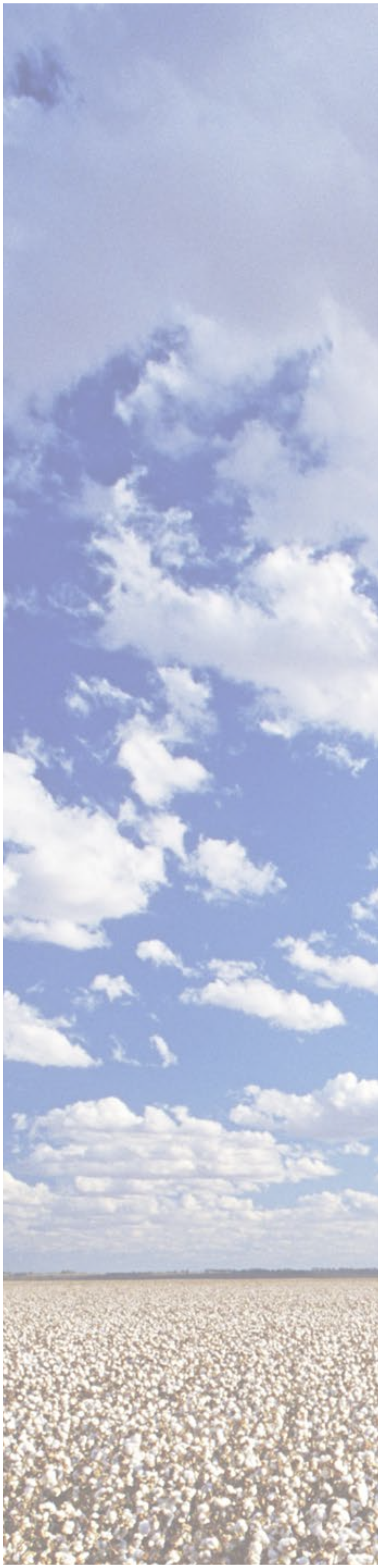
3.4.1 Cost data

GfK Kynetec data are used to determine the average cost of each AI per product acre. Specifically, the GfK Kynetec data include total grower expenditures on each AI in Cotton Tables 8-11. Dividing these expenditures by the product acres of each AI gives the average grower cost per product acre for each AI. Note that these AI costs do not include any application costs, just the cost for the AI. Also, this average cost estimate averages over the different application rates that farmers use for a specific AI and, furthermore, weights costs by the product acres, so that the final cost estimate used for this analysis is an acreage-weighted average of per acre expenditures for each AI during 2010-2012. For the non-neonicotinoid scenario, Cotton Tables 8 and 11 report all the AIs that would be used in a foliar-based system, while Cotton Tables 9 and 10 report the AIs that would be used in a soil-based system. Cotton Table 16 reports the 2010 to 2012 average grower cost per acre for each AI listed in Cotton Tables 8-11, as well as for the neonicotinoid insecticides. The average costs in Cotton Table 16 range from $2.00/A for foliar-applied cypermethrin to $12.99/A for foliar-applied spinetoram. Cotton Table 16 shows that neonicotinoids are in the middle of the cost per acre range among the foliar and soil insecticides in Cotton Tables 8-11.

Cotton Table 16 also reports per acre costs for both foliar and in-furrow application and for scouting fields for insect management purposes. Costs for foliar applications are based on custom rate surveys from several states. Custom rate surveys for 15 states were available on line, with Cotton Table

Cotton Table 16. Average cost for each AI ($/Product Acre) for 2010-2012 for foliar and soil use (not including application costs), plus application and scouting costs.

Active Ingredient	Foliar ($/Product Acre)	Seed Treatment ($/Product Acre)	Soil Insecticide ($/Product Acre)
Abamectin	8.73		
Acephate	3.46	1.97	3.62
Acetamiprid	10.83		
Bifenthrin	3.58		
Chlorpyrifos	5.26		5.25
Cyfluthrin	3.64		
Cypermethrin	2.00		
Dicrotophos	3.54		
Flonicamid	10.06		
Lambda-Cyhalothrin	4.44		
Naled	11.52		
Novaluron	6.63		
Oxamyl	7.18		
Phorate			15.71
Spinetoram	12.99		
Thiodicarb		0.81	
Zeta-Cypermethrin	3.83		
Neonicotinoid Average	**5.60**	**7.45**	
Application Costs	**7.20**		**3.00**
Scouting Costs	**7.44**		



17 summarizing the pertinent data from these surveys. Surveys were from different years, so reported costs were adjusted for inflation using the USDA NASS annual prices paid index for custom rates (USDA-NASS 2014, p. 78.) Specific index values were 98 for 2010, 100 for 2011, 102 for 2012 and 106 for 2013. These indexes were used to convert the reported cost from each the survey's base year to costs for 2010, 2011 and 2012. The average of these costs was calculated for each state, and then the average was calculated over all the states. If a range of costs was reported for a state, the midpoint was used; and if costs were reported for multiple regions in a state, the average was used. If different values were reported for different sizes of equipment,

Cotton Table 17. Reported costs ($/A) for foliar applications and insect scouting based on custom rates and budgets from multiple states.

State	Year	Apply ($/A)	Scout ($/A)	Source
AR	2013	6.50	9.00	http://www.uaex.edu/depts/ag_economics/budgets/2013/Bud-gets2013.pdf
AL	2013	9.00	8.00	http://www.aces.edu/agriculture/business-management/budgets/2013/rowcrops.php
CO	2012	7.27		http://www.coopext.colostate.edu/abm/custrates12.pdf
GA	2013		10.00	http://www.ugacotton.com/vault/file/2013BUDGETS.pdf
IA	2013	7.30	4.95	http://www.extension.iastate.edu/agdm/crops/pdf/a3-10.pdf
ID	2011	7.11		http://www.cals.uidaho.edu/edcomm/pdf/BUL/BUL0729.pdf
KS	2013	6.03		http://www.kingman.ksu.edu/doc46174.ashx
KY	2013	7.00		http://www2.ca.uky.edu/cmspubsclass/files/ghalich/CustomMachin-eryRatesKentucky2013.pdf
MI	2012	7.55	5.00	https://www.msu.edu/~steind/1_2012%20Cust_MachineWrk%20 10_31_11.pdf
MN	2013	5.14		http://faculty.apec.umn.edu/wlazarus/documents/machdata.pdf
MO	2012	7.59	8.00	http://extension.missouri.edu/explorepdf/agguides/agecon/g00302.pdf http://extension.missouri.edu/seregion/Crop_Budgets_PDF.htm
MS	2013		7.00	http://www.agecon.msstate.edu/whatwedo/budgets/docs/MSUCOT14.pdf
ND	2010	6.00		http://www.nass.usda.gov/Statistics_by_State/North_Dakota/Publica-tions/Custom_Rates/index.asp
NE	2012	7.42		http://ianrpubs.unl.edu/epublic/live/ec823/build/ec823.pdf
NY	2011	10.00		http://blogs.cornell.edu/ccefranklin//files/2010/04/2011-Custom-Rates.pdf
OK	2011	6.17		http://oces.okstate.edu/kay/ag/CustomRates%202011-2012.pdf/at_download/file
PA	2013	11.30		http://farmprogress.com/mdfm/Faress1/author/198/2013%20Custom-Rates.pdf
SC	2013		9.00	http://www.clemson.edu/extension/aes/budgets/
TN	2013	8.46	9.50	http://economics.ag.utk.edu/extension/pubs/CustomRates2013-rev.pdf http://economics.ag.utk.edu/budgets/2014/2014RowCropBudgets.pdf
TX	2013	6.22		http://agecoext.tamu.edu/files/2012/05/CustomRateSurveyMay2013.pdf
WI	2010	7.70		http://www.nass.usda.gov/Statistics_by_State/Wisconsin/Publications/custom_rates_2010.pdf

ranges of application rates or different types of applicators (i.e., spray, aerial), the average was used. Few custom rate guides were available for Southern cotton-producing regions, so crop budgets were examined and values used when available. The Cotton Table 17 data show that the reported application costs range from $5.14 in Minnesota to $11.30 in Pennsylvania, both for 2013. Following the described process to convert reported costs to 2010-2012 averages (not reported) gives application costs ranging from $4.85 in Minnesota to $10.66 in Pennsylvania, and then averaging over all the states gives an average application cost of $7.20/A for 2010-2012 as reported in Cotton Table 16. Similarly, the Cotton Table 17 data show reported insect scouting costs ranging from $4.95 in Iowa to $10.00 in Georgia, both for 2013. Again, converting reported costs to 2010-2012 averages (not reported) gives scouting costs ranging from $4.67 in Iowa to $9.43 in Georgia, and the average over all the states gives an average scouting cost of $7.44/A for 2010-2012 as reported in Cotton Table 16.

For in-furrow and similar types of soil application of insecticides (not seed treatments), no estimates of annual machinery costs were found for any cropping system (e.g., Edwards, 2009; Lazarus, 2013). Thus, the spreadsheet machinery cost estimator developed by Edwards (2009) was used to estimate the cost, based on assumptions for the initial cost, useful life, annual use and an interest rate. Soil insecticides are applied during the planting operation with an insecticide delivery system either built in or added on to an existing row crop planter. The little cost information that could be found for such systems for row crop planters was for Midwestern corn planters. As a result, this information is used to develop an application cost for soil-applied insecticides and used in this analysis not only for corn, but also for cotton and sorghum. (No soil-applied insecticides are registered for soybean and wheat, so no application cost estimate is needed for this analysis.).

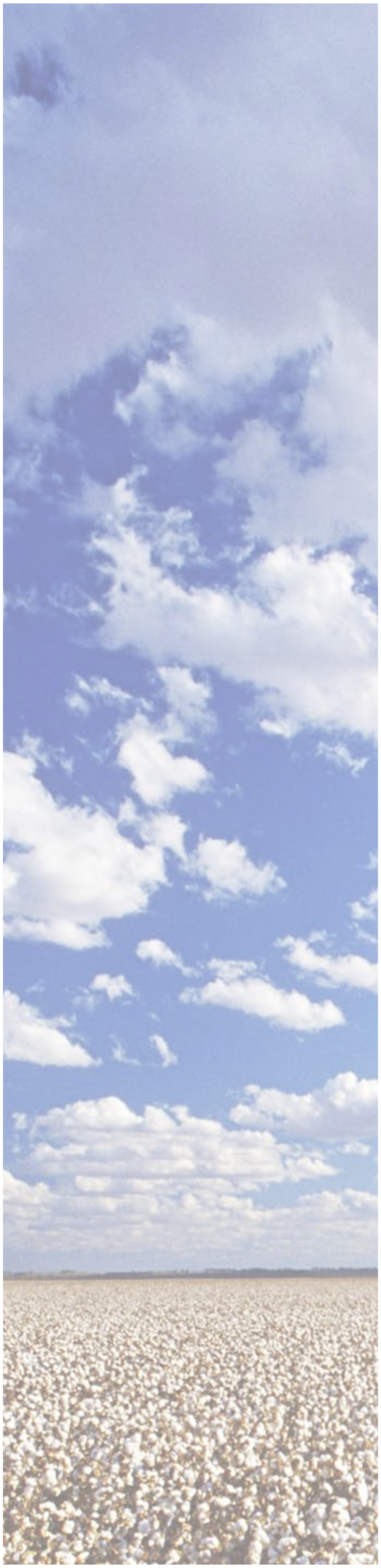
The machinery cost estimator developed by Edwards (2009) requires the following information: initial cost, years of useful life, annual use measured in acres covered and an interest rate. The pertinent purchase price is the extra cost to buy a new planter, which includes an insecticide delivery system (either liquid or granular), such as John Deere's Central Insecticide System[1], or to retrofit an existing planter, such as by adding AmVac's SmartBox or Gandy's hopper systems[2]. Online price lists were not available, but anecdotal information was found in a recent Farm Journal article[3], which indicates that for a 24-row planter, SmartBox system costs $15,300 plus installation, while retrofitting a planter with a liquid insecticide system would run in the "low 20s" plus installation. This estimation assumes a 1,000 acre operation based on the average reported for the Illinois Farm Business Farm Management Association report (Raab and Zwilling, 2013). The analysis assumes a 16-row planter would allow a 1000-acre farm to plant its crops in Illinois in most years (Schnitkey. 2004, Table 2). Based on this information and these assumptions, the analysis assumes an initial cost of $20,000, including installation for a soil insecticide delivery system on a row crop planter. Following IRS tax rules, the analysis assumes a seven-year useful life for the sys-

---

[1] http://salesmanual.deere.com/sales/salesmanual/en_NA/seeding/attachments/herbicide_insecticide/planters/central_insecticide_system.html

[2] http://www.amvac-chemical.com/products/documents/SmartBox_Brochure.pdf or http://www.gandy.net/categories.asp

[3] http://www.agweb.com/article/soil_insecticide_use_in_corn_to_top_15_million_acres/default.aspx?print=y.



tem[4]. Finally, a 4 percent interest rate is used for the analysis. Using these assumptions, the spreadsheet machinery cost estimator of Edwards (2009) gives an application cost of $3.00/A for soil-applied insecticides, which is the cost reported in Table 16. For sensitivity analysis, adding $1,000 to the purchase price increases the cost by $0.15/A, increasing the interest rate 1 percentage point increases the cost by $0.27/A, increasing the farm size by 100 acres decreases the cost by $0.24/A, and adding an additional year to the useful life decreases the cost by $0.09/A. Note that this machinery-based application cost estimate is not the only cost that would result from switching to a soil-applied insecticide from a seed treatment. Beyond this machinery cost would be increased labor and time to handle insecticides, fill the application equipment and maintain the equipment, increasing the average planting time needed at a crucial time for crop production. This analysis does not estimate these and similar costs.

3.4.2 Cost analysis

Based on this information, multiplying the new product acres from Cotton Tables 8-11 by the average cost for each AI from Cotton Table 16 gives the total expenditures by growers for the alternative insecticides that would be used for the non-neonicotinoid scenario. Cotton Table 18 reports the results of these calculations for the product acres reallocated from either a foliar-based neonicotinoid system or from a neonicotinoid seed treatment to a foliar-based non-neonicotinoid system. Cotton Table 19 reports similar results but for product acres reallocated from a neonicotinoid seed treatment and reallocated to either a non-neonicotinoid seed treatment or a non-neonicotinoid soil insecticide. Cotton Tables 18 and 19 report the new product acres for each AI from Cotton Tables 8-11, per acre costs for these AIs from Cotton Table 12, and then the total cost to growers for these AIs. The final rows of Cotton Tables 18 and 19 report the application (and scouting) costs for these AIs. For cotton, scouting costs do not change, so these costs are not applicable, but this is not necessarily the case for other crops.

Results in Cotton Table18 show a cost of $13.5 million for non-neonicotinoid AIs used in foliar systems after reallocation from foliar-applied neonicotinoids and $19.7 million for non-neonicotinoid AIs used in foliar systems after reallocation from neonicotinoid seed treatments. Costs mostly track product acres, so acephate, dicrotophos and bifenthrin each have more than $1 million in grower AI costs; but some AIs like acetamipriod and novaluron are relatively expensive, so even moderate increases in product acres have grower AI costs exceeding $1 million. Results in Cotton Table 19 show AI costs to replace neonicotinoid seed treatments – a $1.4 million AI cost for non-neonicotinoid seed treatments, which are relatively low cost on a per acre basis and a $7.2 million cost for non-neonicotinoid soil insecticides, with most of these costs for phorate, which has by far the highest per acre cost of any AI in Cotton Table 16.

Cotton Tables 18 and 19 also report total costs for insecticide application and for scouting. These costs are the appropriate product acres multiplied by the appropriate cost per acre. Following the convention for partial budget analysis, these costs are only reported if they change. Thus, for instance, since scouting costs are not assumed to change (cotton farmers who already scout

[4] IRS Pub. 225, Ch. 7: Depreciation, Depletion and Amortization, http://www.irs.gov/publications/p225/ch07.html

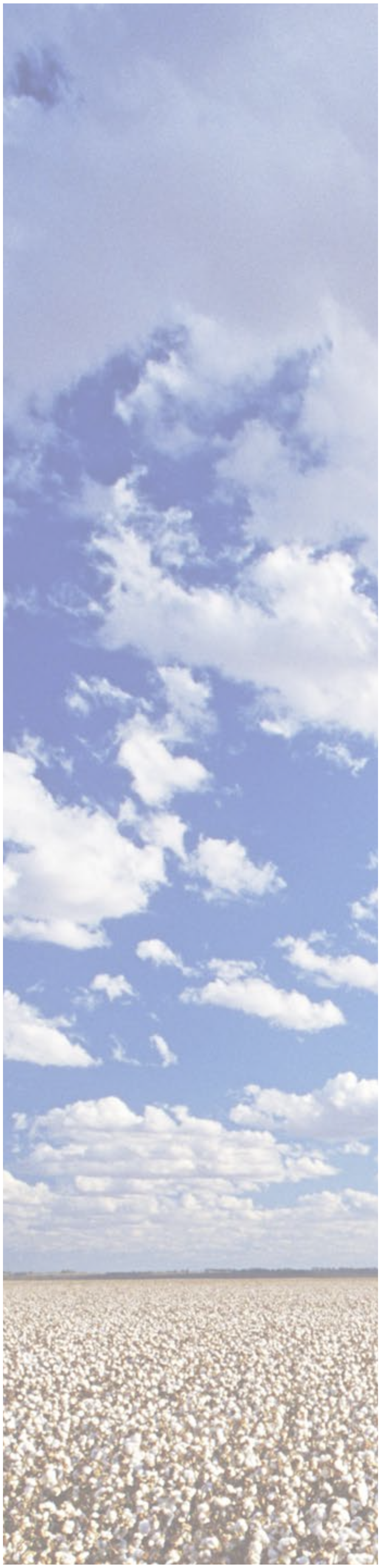
would continue to do so, and those who do not scout would not start scouting under the non-neonicotinoid scenario), none of these costs are listed in Cotton Tables 18 and 19.

The analysis assumes no application cost for seed treatments (neonicotinoid and non-neonicotinoid), and so any neonicotinoid seed treatment acres allocated to foliar and soil insecticide use will have changes in application costs. Also, because of differences in the average number of applications for each AI [see equation (2)-(5)], the total number of foliar product acres can change even for neonicotinoid foliar acres that remain in a foliar system for the non-neonicotinoid scenario. Cotton Table 18 shows application costs of almost $22.9 million for neonicotinoid product acres remaining in foliar systems for the non-neonicotinoid scenario and almost $36.5 million in application costs for neonicotinoid seed treatment product acres reallocated to foliar systems. Cotton Table 19 shows no application costs for product acres con-

Cotton Table 18. Estimated grower costs for alternative AIs, application and scouting for foliar-based systems in the non-neonicotinoid scenario.

	------------ Foliar to Foliar -----------			---------Seed Treatment to Foliar-------		
Active Ingredient	**Added Acres**	**Cost** ($/A)	**Total Cost**	**Added Acres**	**Cost** ($/A)	**Total Cost**
Abamectin	11,615	8.73	101,411	1,973	8.73	17,229
Acephate	1,095,881	3.46	3,791,569	3,295,130	3.46	11,400,614
Acetamiprid	95,210	10.83	1,030,668	134,892	10.83	1,460,235
Bifenthrin	530,480	3.58	1,896,987	303,364	3.58	1,084,824
Chlorpyrifos	28,270	5.26	148,720	96,777	5.26	509,118
Cyfluthrin	119,094	3.64	433,580	79,042	3.64	287,766
Cypermethrin	118,018	2.00	235,566	69,492	2.00	138,707
Dicrotophos	637,119	3.54	2,254,105	856,012	3.54	3,028,538
Flonicamid	79,214	10.06	796,657	65,718	10.06	660,933
Lambda-Cyhalothrin	104,517	4.44	464,573	41,077	4.44	182,584
Naled	17,252	11.52	198,805	23,981	11.52	276,351
Novaluron	201,859	6.63	1,337,475	36,633	6.63	242,724
Oxamyl	89,468	7.18	642,692	59,875	7.18	430,113
Phorate						
Spinetoram	4,087	12.99	53,073	0	12.99	0
Thiodicarb						
Zeta-Cypermethrin	42,274	3.83	162,048	3,965	3.83	15,201
Scouted & Treated	**3,174,356**	**4.27**	**13,547,928**	**5,067,932**	**3.89**	**19,734,937**
Scouted Only				**1,479,807**		
Application	**3,174,356**	**7.20**	**22,855,365**	**5,067,932**	**7.20**	**36,489,109**
Scouting*						

*Not applicable for this crop as it does not change for the non-neonicotinoid scenario.



tinuing to use seed treatments for the non-neonicotinoid scenario and $2.8 million in application costs for product acres switching to non-neonicotinoid soil insecticides from neonicotinoid seed treatments.

Cotton Table 19. Estimated grower costs for alternative AIs, application and scouting for soil-based systems in the non-neonicotinoid scenario.

	Seed Treatment to Seed Treatment			Seed Treatment to Soil Insecticide		
Active Ingredient	**Added Acres**	**Cost** ($/A)	**Total Cost**	**Added Acres**	**Cost** ($/A)	**Total Cost**
Acephate	677,039	1.97	1,336,469	478,389	3.62	1,729,860
Chlorpyrifos				146,706	5.25	770,202
Phorate				298,885	15.71	4,695,645
Thiodicarb	26,337	0.81	21,449			
Scouted & Treated	**703,377**	**1.93**	**1,357,918**	**923,980**	**7.79**	**7,195,708**
Scouted Only						
Application				**923,980**	**3.00**	**2,771,940**
Scouting*						

*Not applicable for this crop as it does not change for the non-neonicotinoid scenario.

Cotton Table 20 reports costs for neonicotinoid active ingredients for both foliar- and soil-based seed treatment systems, as well as application costs for the foliar insecticides. A line for scouting costs is listed but left blank since cotton scouting costs do not change, but this assumption may not hold for other crops. AI costs are $17.1 million for the foliar neonicotinoids and $46.7 million for the neonicotinoid seed treatments, with almost $22 million in application costs for the foliar neonicotinoids.

Cotton Table 20. Estimated grower costs for neonicotinoid AIs, application and scouting for the 2010-2012 average neonicotinoid use.

	------------- Foliar Use -------------			------- Seed Treatment Use -------		
Cost Category	**Original Acres**	**Cost** ($/A)	**Total Cost**	**Original Acres**	**Cost** ($/A)	**Total Cost**
Active Ingredients	3,049,353	5.60	17,091,263	6,269,620	7.45	46,723,028
Application	3,049,353	7.20	21,955,344			
Scouting*						

*Does not change for the non-neonicotinoid scenario.

Cotton Table 21 reports the results of the partial budget analysis by combining all the costs from Cotton Tables 18-20 and calculating the estimated net change in grower expenditures. For the non-neonicotinoid scenario, cotton growers would avoid almost $86 million in expenditures for neonicotinoid AIs and foliar applications, with almost $64 million of the savings due to not purchasing neonicotinoid insecticides and seed treatments. However, cotton growers would have a variety of new expenditures for the

Cotton Table 21. Estimated net change in grower expenditures for the non-neonicotinoid scenario.

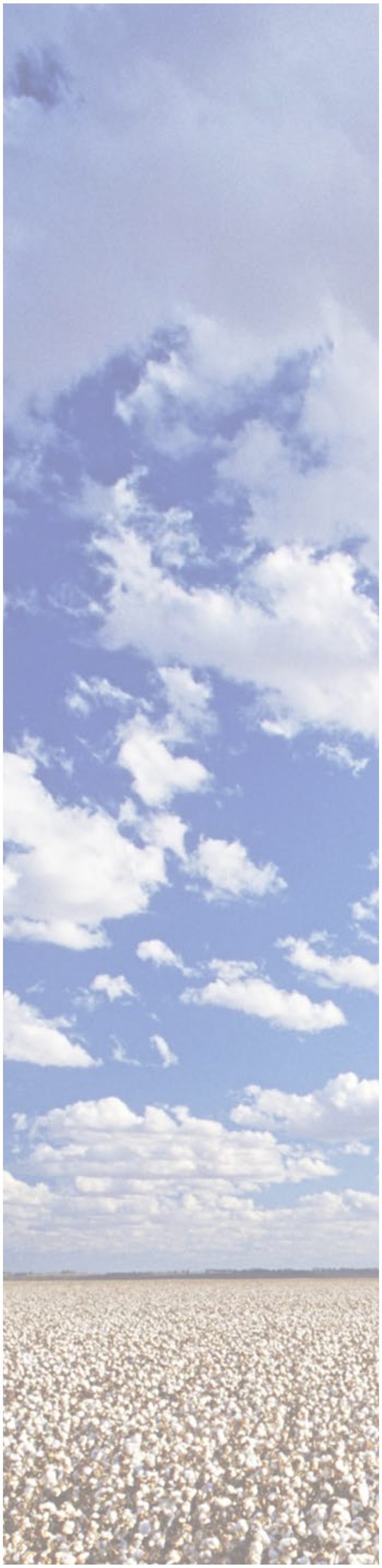
	Avoided Expenditures From the Current System	New Expenditures for the Non-Neonicotinoid Scenario	Net Change in Grower Expenditures
Soil AI Costs	46,723,028	8,553,626	-38,169,402
Foliar AI Costs	17,091,263	33,282,865	16,191,602
Soil Application Costs		2,771,940	2,771,940
Foliar Application Costs	21,955,344	59,344,474	37,389,130
Soil Scouting Costs			0
Foliar Scouting Costs			0
Total Costs	85,769,635	103,952,905	18,183,269

Net Change in Grower Expenditures	Acres	$/Acre
Neonicotinoid Base Acres Treated	8,237,402	2.21
Planted Acres	12,610,329	1.44

non-neonicotinoid scenario totaling almost $104 million, with almost $42 million for non-neonicotinoid AIs and more than $62 million for application costs. The estimated net effect of these changes is a $22 million decrease in spending on AIs, because on average, the chosen non-neonicotinoid AIs are lower cost per acre than neonicotinoid insecticides, but the changes would also result in more than a $40 million increase in application costs due to switching from seed treatment to soil insecticides and more foliar applications. There are no scouting cost changes for either the soil-based or foliar-based systems, so these entries are left blank. Aggregating all cost changes gives an estimated net increase of $18.2 million in grower costs. Based on the 2010-2012 average of more than 8.6 million neonicotinoid base acres for cotton and about 12.6 million cotton planted acres, the average cost increase is $2.21 per neonicotinoid base acre and $1.44 per planted acre of cotton. The implication is that neonicotinoid insecticides are priced to be fairly cost competitive relative to their substitutes, as the analysis shows little net cost difference between neonicotinoids and non-neonicotinoids once application costs are accounted for. The fact that neonicotinoid insecticides are used on such a large portion of cotton acres is evidence that the source of their value is something other than simply being slightly less costly than the non-neonicotinoid alternatives.

3.4.3 Caveats

This cost analysis has several caveats, some of which are described here. First, the per acre costs for each AI reported in Cotton Table 16 are accurate for the 2010-2012 market structure. If neonicotinoids were not available, farmer demand for the non-neonicotinoid AIs would increase sharply and likely increase the costs in Cotton Table 16, which would then increase the net change in grower expenditures on AIs in Cotton Tables 18 and 19. In addition, the increased demand for soil insecticide applications and for foliar applications, as well as scouting services would have a similar effect – the prices for each of these would likely increase beyond those reported in Cotton Table 17. The regional panels of growers and other experts conduct-



ed as part of this research have made this point: It would take some time for the industry to adapt to higher demand for applications and scouting, and the prices would likely be higher than assumed for this analysis. The impact of these demand increases would increase the net change in grower expenditures on applications and scouting in Cotton Tables 18 and 19.

Additionally, the cost analysis depends on the assumptions used for how farmers would adjust their soil-based pest management practices. This analysis assumed a substantial shift to foliar-based management for many of the above-ground pests managed with neonicotinoid seed treatments. This shift increased aggregate application costs by more than $41 million for the non-neonicotinoid scenario. Potentially cotton farmers could find lower cost ways to manage these pests to reduce these costs but have no incentive to do so at this time, since they find neonicotinoid seed treatments sufficient. The impact of this adaptation would decrease the net change in grower expenditures on applications in Cotton Tables 18 and 19.

4.0 Appendix: Results for Other Crops

This appendix briefly reports the tables and figures summarizing the analysis process and results for corn, soybeans, winter wheat, spring wheat and sorghum. Since the process for each crop is essentially the same, little additional explanation is given for each crop, except to explain and/or justify changes in the process used for that crop that differ from what is reported for cotton in the main text. To make finding information easier, the same table and figure numbers used for cotton in the main text are used for all crops, and an effort is made to have each table and figure look the same across crops. Thus, rather than number tables consecutively across crops, tables are numbered consecutively within each crop, with the crop added to the title. As a result, Corn Table 1 looks the same and reports the same type of data for corn as Cotton Table 1 does for cotton and similarly for the remaining crops.

4.1 Corn analysis and results

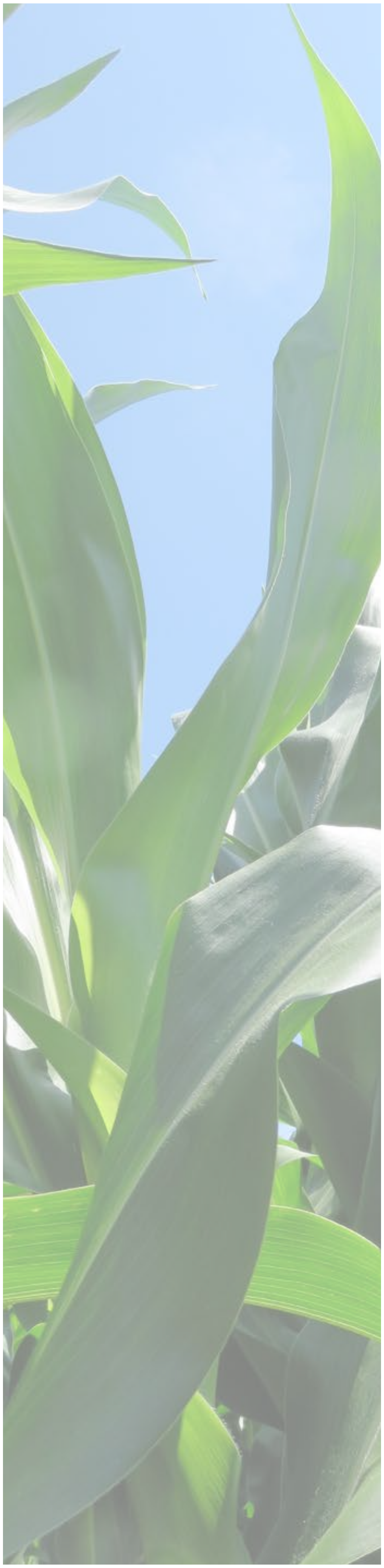
The most significant difference for the corn analysis relative to the cotton analysis is that the only significant use of neonicotinoids in corn is as seed treatments (i.e., no significant foliar use of neonicotinoid occurs in corn) and use of non-neonicotinoid seed treatments is minimal. As a result, sections of several tables concerning reallocation of foliar neonicotinoid applications are empty, and Corn Tables 8 and 9 are not needed.

In terms of insecticide use, corn is dominated by soil-based insect management systems and neonicotinoid seed treatments. Based on the 2010-2012 averages, foliar-applied AIs only comprise 4.0 million of the total 96.6 million insecticide product acres in corn. All of the 82.6 million neonicotinoid product acres in corn are seed treatments, while all other AIs constitute only 14.1 million product acres, of which 10.1 million are soil-applied insecticides. The 2010-2012 three-year average for corn is 91.5 million planted acres, with 82.6 million neonicotinoid product acres applied to 81.4 million base acres, so that 89 percent of corn planted acres are treated at least once with a neonicotinoid insecticide. In terms of target pests, 33 percent of neonicotinoid seed treatments product acres are targeted at wireworms, with corn rootworms and seed corn maggots each comprising 24 percent and 21 percent of product acres respectively. White grubs, cutworms and flea beetles are the remaining major pests targeted by neonicotinoid seed treatments.

The analysis projects that the 2010-2012 annual average of 82.6 million neonicotinoid seed treatment product acres in corn would be replaced with 54.8 million product acres of pyrethroids and 25.8 million product acres of organophosphates, so that product acres of each class increase about 10 times and 6.5 times respectively for the non-neonicotinoid scenario. Associated with these increases in product acres are increases in total pounds applied. The total pounds of organophosphates applied is more than 9.5 times greater for the non-neonicotinoid scenario and more than 8.5 times greater for the total pounds of pyrethroids applied. The net effect of the non-neonicotinoid scenario is a 290 percent increase in total pounds of insecticide AIs applied to corn.

The impact that these product acre shifts has on the share of all corn product acres devoted to organophosphates and pyrethroids is substantial. Based on the 2010-0212 average, 87 percent of corn product acres receive neonicotinoids, 10 percent receive pyrethroids and 3 percent receive organophosphates; but for the non-neonicotinoid scenario, the share receiving pyrethroids is estimated to increase to 69 percent and the organophosphates share to 31 percent. These estimated product acres shifts and increased reliance on these classes of insecticides raise concerns about increased potential for the development of insect resistance to these important modes of action.

The analysis also projects that 4.1 million product acres of neonicotinoid seed treatments would shift to foliar-based applications of pyrethroids and organophosphates to control cutworms and flea beetles. This shift represents a doubling of foliar-applied insecticide product acres in corn from their 2010-2012 level of 4.0 million product acres. This projected shift to greater use of foliar applications of these non selective insecticides raises concerns about negative impacts on beneficial insect populations. If popu-



lations of these beneficial insects decline, populations of current pests and secondary pests may increase sufficiently to justify additional insecticide applications. Furthermore, these additional 4.1 million acres of foliar applications lose some of the other benefits of seed treatments, which are not captured in this analysis, such as reduced potential for spray drift and field runoff and fewer passes through the field.

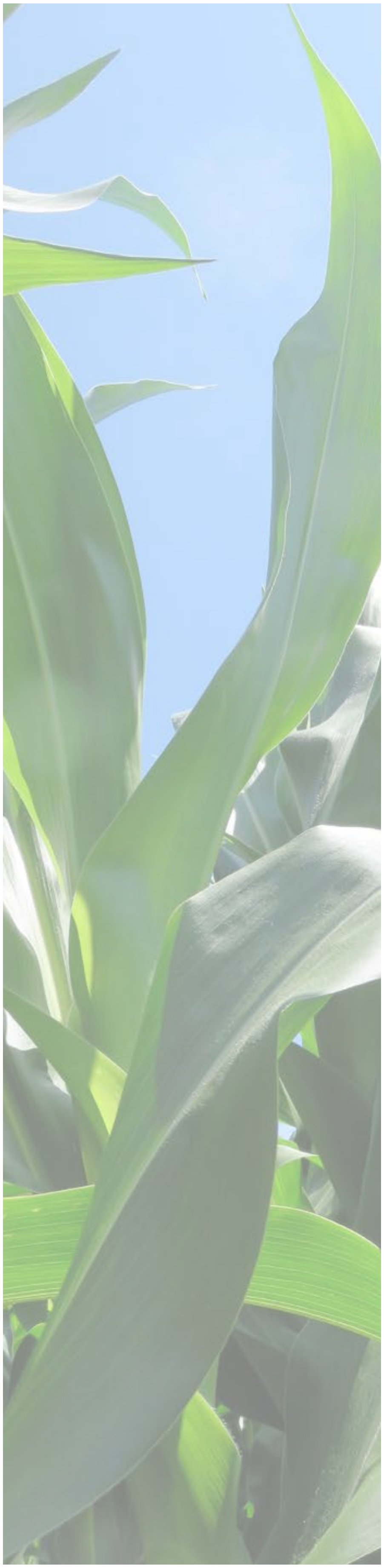
In terms of estimated cost changes, corn growers would see a net increase in expenditures for insecticide AIs of $389 million by switching to non-neonicotinoid alternatives, plus see a net increase in application costs of $258 million, largely due to switching from seed treatments to soil insecticides and foliar applications. Application costs for soil insecticides are conservatively estimated at $3 per acre for this analysis, even though many farmers have abandoned use of soil insecticide application equipment. In addition, scouting costs would increase by $30 million, as corn acres using foliar-based management systems roughly double. The net effect is an increase of $677 million in costs for corn growers for the non-neonicotinoid scenario. Given the 91.5 million planted acres of corn and 81.4 million neonicotinoid base acres in corn, the estimated average cost benefit of neonicotinoids is $7.40 per corn planted acre or $8.32 per neonicotinoid treated base acre.

Corn Table 1. Product acres for all AIs and neonicotinoids (three-year average, 2010-2012).

		---------- Soil-based System -----------		
	Foliar	**Seed Treatment**	**Soil-applied**	**Total**
Neonicotinoids	---	82,550,924	---	82,550,924
Non-Neonicotinoids	3,976,739	---	10,117,491	14,094,230
All AIs	3,976,739	82,550,924	10,117,491	96,645,154

Corn Table 2. Initial product acres for foliar-based and soil-based systems and remaining product acres after focusing on major pests targeted by neonicotinoids.

	-------Foliar-based Systems------		-------Soil-based Systems-------	
	All AIs	**Neonicotinoids**	**All AIs**	**Neonicotinoids**
Initial Product Acres	3,976,739	---	92,668,415	82,550,924
No Answer	6.8%	---	34.7%	38.7%
Targeted at Specific Pests	93.2%	---	65.3%	61.3%
Remaining Product Acres				
% of Initial Product Acres	4.4%	---	47.4%	45.6%
% Targeted at Specific Pests	4.7%	---	72.5%	74.5%

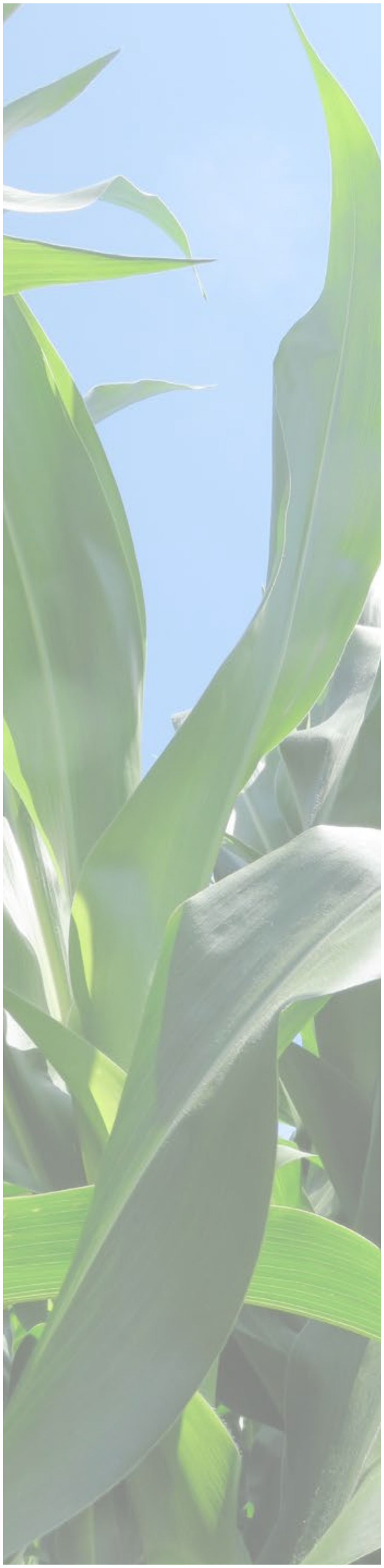


Corn Table 3. Non-neonicotinoid product acre shares by neonicotinoid target pest group for foliar-based systems.

Active Ingredient	Cutworm	Flea Beetle
Bifenthrin	5.2%	30.5%
Chlorpyrifos	3.3%	6.5%
Cyfluthrin	21.4%	1.1%
Deltamethrin	1.4%	
Esfenvalerate	6.7%	7.0%
Gamma-Cyhalothrin	1.3%	
Lambda-Cyhalothrin	37.7%	15.2%
Methomyl		4.2%
Methyl Parathion		9.5%
Permethrin	8.1%	9.2%
Tefluthrin	1.3%	
Zeta-Cypermethrin	13.7%	17.0%

Corn Table 4. Non-neonicotinoid AI product acre shares by neonicotinoid target pest group for seed treatment and soil-applied insecticides.

	--Soil Insecticide ------------------------------------					
Active Ingredient	Corn Rootworm	Cutworm	Flea Beetle	Seed Corn Maggot	White Grub	Wireworm
Bifenthrin	18.6%	39.0%		27.0%	28.2%	24.0%
Chlorethoxyfos	1.7%	3.1%		3.9%	1.4%	2.8%
Chlorpyrifos	7.3%	7.3%	32.7%	9.5%	5.3%	6.2%
Cyfluthrin				17.9%	25.1%	26.9%
Lambda-Cyhalothrin		2.6%		2.9%	4.6%	4.0%
Permethrin		1.8%		1.3%	1.5%	
Tebupirimphos	33.4%	23.8%	43.8%	13.6%	16.8%	17.2%
Tefluthrin	35.8%	15.8%	23.6%	21.0%	15.6%	16.1%
Terbufos	3.2%	3.8%		3.0%	1.4%	2.9%
Zeta-Cypermethrin		2.9%				



Corn Table 5. Share of neonicotinoid product acres targeted at each insect pest group for foliar-based and soil-based pest management systems.

Pest Control System	Corn Rootworm	Cutworm	Flea Beetle	Seed Corn Maggot	White Grub	Wireworm
Foliar-based*	-----	-----	-----	-----	-----	-----
Soil-based	23.9%	5.6%	1.6%	21.0%	15.1%	32.8%

*No significant foliar use of neonicotinoids occurs in corn, so data not relevant.

Corn Table 6. Share of non-neonicotinoid product acres from foliar-based and from soil-based systems allocated to seed treatments, soil insecticides and foliar systems by target pest.

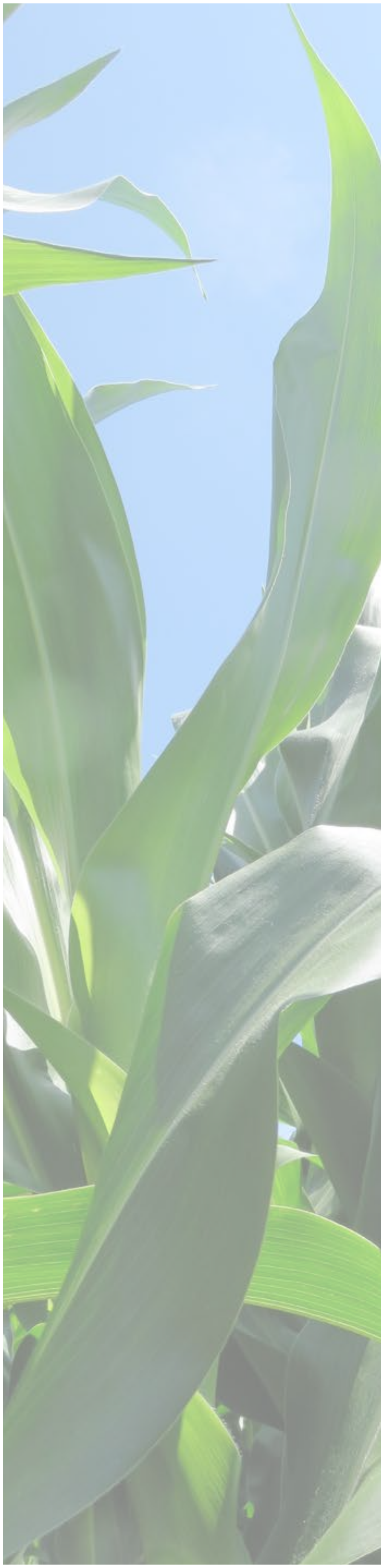
	Corn Rootworm	Cutworm	Flea Beetle	Seed Corn Maggot	White Grub	Wireworm
Foliar-based*	-----	-----	-----	-----	-----	-----
Soil-based						
To Seed Treatment**	-----	-----	-----	-----	-----	-----
To Soil-applied	100.0%	35.8%	16.2%	100.0%	100.0%	100.0%
To Foliar-based	0.0%	64.2%	83.8%	0.0%	0.0%	0.0%

*No significant foliar use of neonicotinoids occurs in corn, so data not relevant.
**No significant non-neonicotinoid seed treatments use occurs in corn, so data not relevant.

Corn Table 7. Average number of applications for each AI and ratios of these averages.

	Average Number of Applications		Ratio of Average Non-Neonicotinoid Applications to Neonicotinoid Applications		
Active Ingredient	Soil-based	Foliar-based	Soil:Soil	Foliar:Foliar	Foliar:Soil
Bifenthrin	1.000	1.053	0.986	---	1.038
Chlorethoxyfos	1.000		0.986		
Chlorpyrifos	1.000	1.000	0.986	---	0.986
Cyfluthrin	1.004	1.009	0.990	---	0.995
Deltamethrin		1.000		---	0.986
Esfenvalerate		1.139		---	1.123
Gamma-Cyhalothrin		1.000		---	0.986
Lambda-Cyhalothrin	1.000	1.000	0.986	---	0.986
Methomyl		1.000		---	0.986
Methyl Parathion		1.000		---	0.986
Permethrin		1.000		---	0.986
Tebupirimphos	1.000		0.986		
Tefluthrin	1.000	1.000	0.986	---	0.986
Terbufos	1.000		0.986		
Zeta-Cypermethrin	1.000	1.000	0.986	---	0.986
Neonicotinoids	1.014	*			

*No significant foliar use of neonicotinoids occurs in corn.

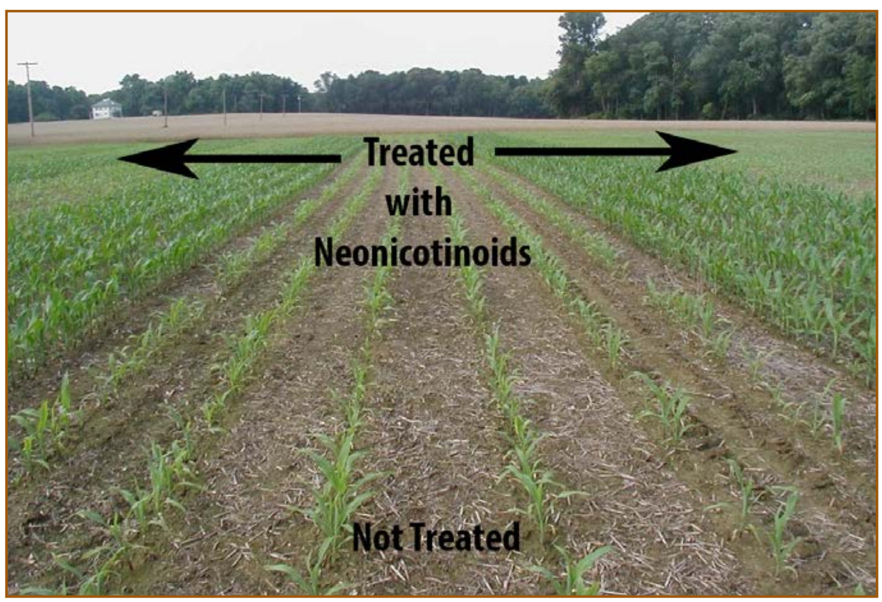


Corn Table 8. Non-neonicotinoid product acres in a foliar-based pest management system by AI and target pest group reallocated from neonicotinoid product acres in a foliar-based pest management system.

Table not needed as no significant foliar use of neonicotinoids occurs in corn.

Corn Table 9. Non-neonicotinoid product acres in a seed treatment pest management system by AI and target pest group reallocated from neonicotinoid product acres in a seed treatment pest management system.

Table not needed as no significant use of non-neonicotinoids seed treatments occurs in corn for these pests.

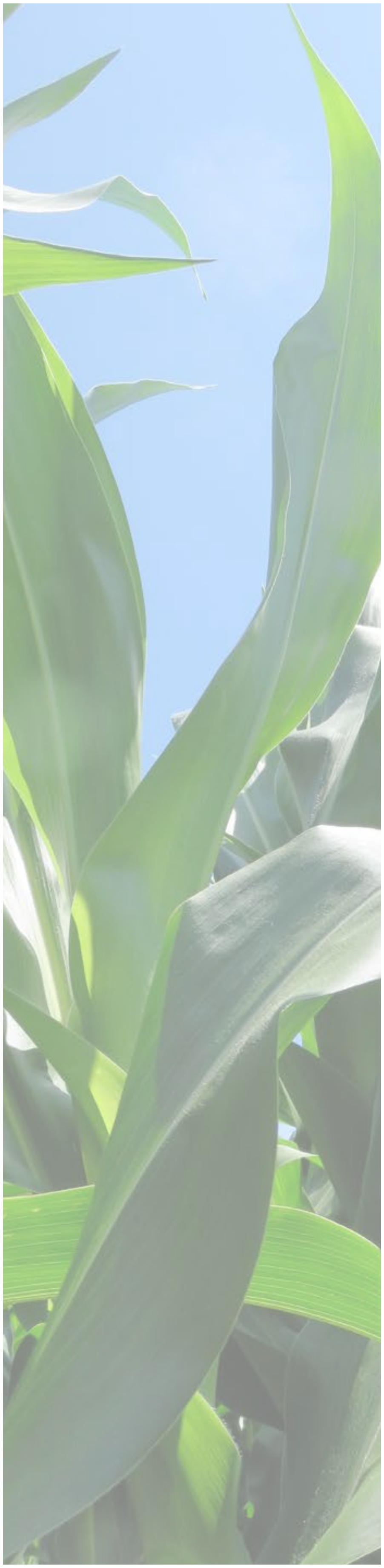


Corn Table 10. Non-neonicotinoid product acres in a soil insecticide pest management system by AI and target pest group reallocated from neonicotinoid product acres in a seed treatment pest management system.

Active Ingredient	Corn Rootworm	Cutworm	Flea Beetle	Seed Corn Maggot	White Grub	Wireworm	Total	AI Weights
Bifenthrin	3,609,684	635,098	0	4,609,208	3,471,354	6,402,172	18,727,517	24.3%
Chlorethoxyfos	332,703	50,247	0	674,713	177,070	742,698	1,977,431	2.6%
Chlorpyrifos	1,424,053	118,452	68,970	1,629,464	653,007	1,649,952	5,543,898	7.2%
Cyfluthrin	0	0	0	3,064,707	3,103,829	7,199,278	13,367,814	17.4%
Lambda-Cyhalothrin	0	42,797	0	495,941	567,444	1,080,160	2,186,341	2.8%
Permethrin	0	0	0	0	0	0	0	0.0%
Tebupirimphos	6,496,975	388,381	92,352	2,316,677	2,062,221	4,586,215	15,942,822	20.7%
Tefluthrin	6,968,594	256,807	49,760	3,595,991	1,911,672	4,297,231	17,080,055	22.2%
Terbufos	625,260	61,635	0	505,067	171,946	773,838	2,137,746	2.8%
Zeta-Cypermethrin	0	47,672	0	0	0	0	47,672	0.1%
Total	**19,457,269**	**1,601,089**	**211,082**	**16,891,768**	**12,118,542**	**26,731,545**	**77,011,296**	**100.0%**

Corn Table 11. Non-neonicotinoid product acres in a foliar-based pest management system by AI and target pest group reallocated from neonicotinoid product acres in a seed treatment pest management system.

Active Ingredient	Corn Rootworm	Cutworm	Flea Beetle	Seed Corn Maggot	White Grub	Wireworm	Total	AI Weights
Bifenthrin		143,609	316,597				460,206	12.4%
Chlorpyrifos		86,265	63,722				149,987	4.1%
Cyfluthrin		571,424	10,642				582,067	15.7%
Deltamethrin		36,806	0				36,806	1.0%
Esfenvalerate		203,471	78,479				281,949	7.6%
Gamma-Cyhalothrin		34,141	0				34,141	0.9%
Lambda-Cyhalothrin		998,273	149,768				1,148,041	31.0%
Methomyl		0	41,531				41,531	1.1%
Methyl Parathion		0	93,505				93,505	2.5%
Permethrin		214,298	90,556				304,853	8.2%
Tefluthrin		33,600	0				33,600	0.9%
Zeta-Cypermethrin		363,050	167,665				530,715	14.4%
Total Treated with These AIs		2,684,938	1,012,464				3,697,402	100.0%
Scouted, Not Treated for These Pests		284,684	106,105				390,789	
Total		**2,969,622**	**1,118,569**				**4,088,191**	

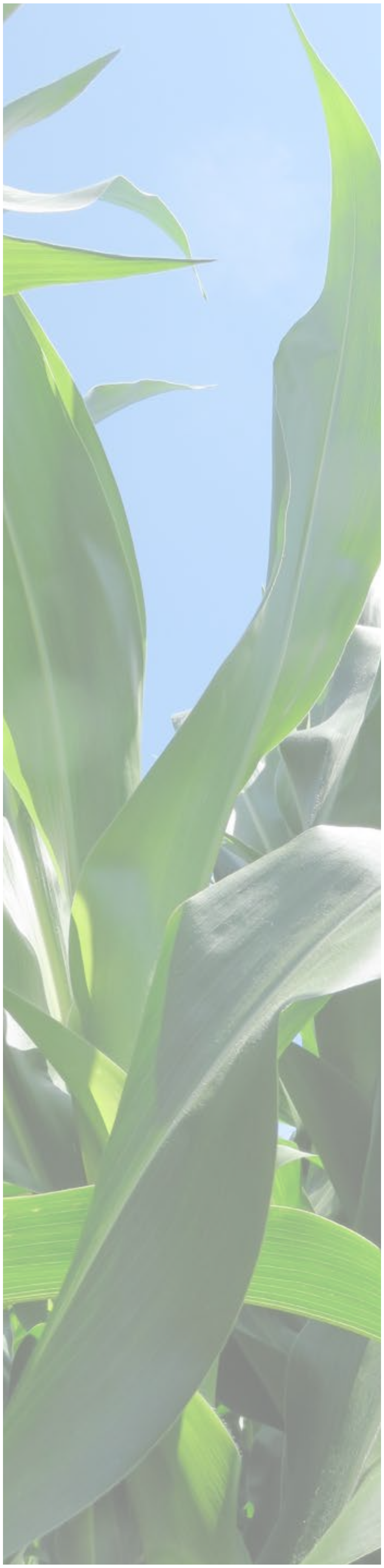


Corn Table 12. Impact of the non-neonicotinoid scenario on non-neonicotinoid product acres by individual AIs and by insecticide class.

		------------------------------ Product Acres ------------------------------			
MOA	**Active Ingredient**	**2010-2012 Average**	**Added**	**New Total**	**Change**
3A	Bifenthrin	2,613,174	19,187,722	21,800,896	734%
1B	Chlorethoxyfos	93,042	1,977,431	2,070,473	2125%
1B	Chlorpyrifos	774,920	5,693,885	6,468,805	735%
3A	Cyfluthrin	2,481,646	13,949,881	16,431,527	562%
3A	Deltamethrin	40,486	36,806	77,292	91%
3A	Esfenvalerate	177,877	281,949	459,826	159%
3A	Gamma-Cyhalothrin	67,784	34,141	101,925	50%
3A	Lambda-Cyhalothrin	1,546,186	3,334,382	4,880,568	216%
1A	Methomyl	22,494	41,531	64,025	185%
1B	Methyl Parathion	112,078	93,505	205,583	83%
4A	Neonicotinoids	82,550,924	-82,550,924	0	-100%
3A	Permethrin	319,484	304,853	624,337	95%
1B	Tebupirimphos	1,694,722	15,942,822	17,637,544	941%
3A	Tefluthrin	1,895,057	17,113,655	19,008,712	903%
1B	Terbufos	213,886	2,137,746	2,351,632	999%
3A	Zeta-Cypermethrin	699,845	578,387	1,278,232	83%
Total Treated With These AIs*		**95,303,605**	**-1,842,226**	**93,461,379**	**-2%**
Non-Neonicotinoids*		12,752,681	80,708,698	93,461,379	633%
Neonicotinoids		82,550,924	-82,550,924	0	-100%
Scouted but Not Treated for These Pests			**390,789**	**390,789**	

		--------------------------------Product Acres ------------------------------			
MOA	**Insecticide Class**	**2010-2012 Average**	**Added**	**New Total**	**Change**
1A	Carbamates	22,494	41,531	64,025	185%
4A	Neonicotinoids	82,550,924	-82,550,924	0	-100%
1B	Organophosphates	2,888,648	25,839,202	28,727,850	895%
3A	Pyrethroids	9,841,539	54,828,885	64,670,424	557%
Total Treated With These AIs*		**95,303,605**	**-1,841,306**	**93,462,299**	**-2%**
Non-Neonicotinoids*		12,752,681	80,709,618	93,462,299	633%
Neonicotinoids		82,550,924	-82,550,924	0	-100%
Scouted but Not Treated for These Pests			**390,789**	**390,789**	

*Does not match Corn Table 1 totals because totals here do not include minor-use AIs.

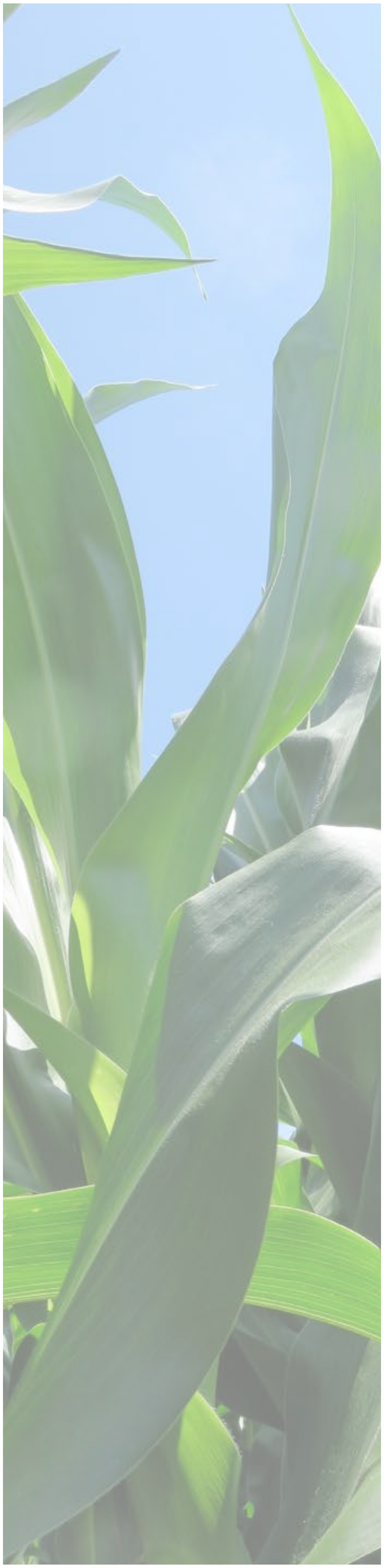


Corn Table 13. Average application rate (pounds per product acre) for each AI by method of application (foliar-applied, soil-applied, seed treatment).

		---**Average Application Rate** (Pounds per Product Acre)----		
MOA	**Active Ingredient**	**Foliar**	**Seed Treatment**	**Soil Insecticide**
3A	Bifenthrin	0.0735		0.0542
1B	Chlorethoxyfos			0.1843
1B	Chlorpyrifos	0.5966		0.9037
3A	Cyfluthrin	0.0197		0.0093
3A	Deltamethrin	0.0106		
3A	Esfenvalerate	0.0283		
3A	Gamma-Cyhalothrin	0.0102		
3A	Lambda-Cyhalothrin	0.0228		0.0250
1A	Methomyl	0.3600		
1B	Methyl Parathion	0.4233		
4A	Neonicotinoids		0.0261	
3A	Permethrin	0.1218		
1B	Tebupirimphos			0.1280
3A	Tefluthrin	0.1302		0.1220
1B	Terbufos			1.0189
3A	Zeta-Cypermethrin	0.0120		0.0138

Neonicotinoid insecticides target a wide range of insects specific to the geographic location where the seed is planted. Corn growers in North Carolina use a seed treatment insecticide at planting rather than a granular insecticide to control Southern corn billbug. In the South, growers need to control Southern green and brown stink bugs and sugarcane beetles. Southwest corn growers may need to control chinch bugs or early-season aphids. Growers in the Midwest may use seed treatment insecticides for corn rootworm control.

Page 39, Crop Life Foundation. November 2013. *The Role of Seed Treatment in Modern U.S. Crop Production: A Review of Benefits*. Washington, DC. Retrieved from: http://www.croplifeamerica.org/sites/default/files/SeedTreatment.pdf



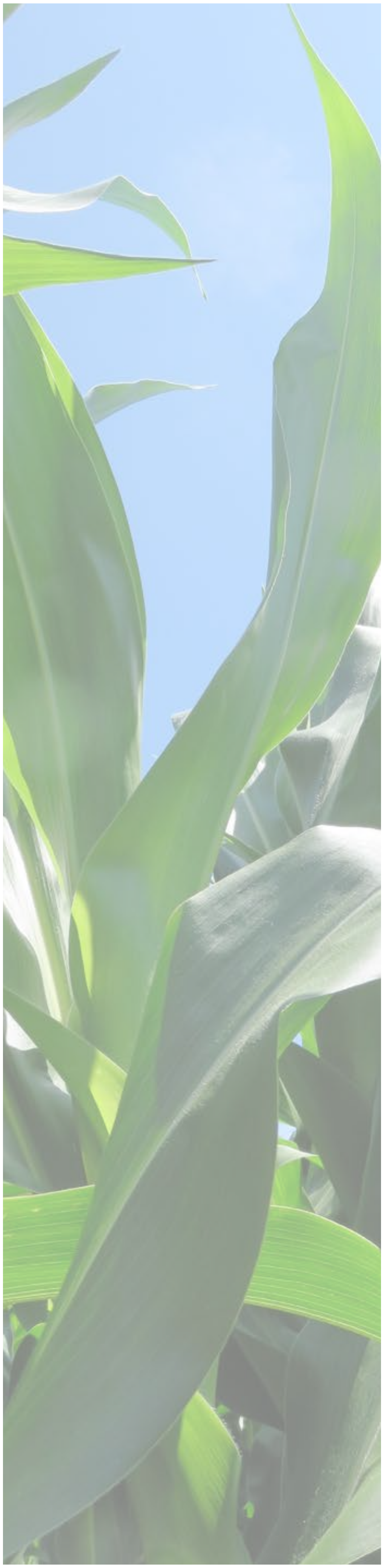
Corn Table 14. Impact of the non-neonicotinoid scenario on pounds of AI applied by insecticide class.

		Pounds of Active Ingredient Applied			
MOA	Active Ingredient	2010-2012 Average	Added	New Total	Change
3A	Bifenthrin	161,504	1,048,782	1,210,286	649%
1B	Chlorethoxyfos	17,146	364,413	381,559	2125%
1B	Chlorpyrifos	641,543	5,099,882	5,741,425	795%
3A	Cyfluthrin	25,264	136,154	161,418	539%
3A	Deltamethrin	162	390	552	240%
3A	Esfenvalerate	1,838	7,972	9,810	434%
3A	Gamma-Cyhalothrin	503	350	852	70%
3A	Lambda-Cyhalothrin	37,234	80,956	118,190	217%
1A	Methomyl	7,929	14,951	22,881	189%
1B	Methyl Parathion	47,447	39,584	87,031	83%
4A	Neonicotinoids	2,157,221	-2,157,221	0	-100%
3A	Permethrin	14,856	37,134	51,989	250%
1B	Tebupirimphos	216,883	2,040,295	2,257,178	941%
3A	Tefluthrin	229,949	2,088,139	2,317,779	909%
1B	Terbufos	214,671	2,178,115	2,392,786	1015%
3A	Zeta-Cypermethrin	9,045	7,035	16,080	78%
	Total	**3,782,887**	**10,986,930**	**14,769,817**	**290%**

		Pounds of Active Ingredient Applied			
MOA	Insecticide Class	2010-2012 Average	Added	New Total	Change
1A	Carbamates	7,929	14,951	22,881	189%
4A	Neonicotinoids	2,157,221	-2,157,221	0	-100%
1B	Organophosphates	1,137,690	9,722,289	10,859,979	855%
3A	Pyrethroids	480,047	3,406,910	3,886,957	710%
	Total	**3,782,887**	**10,986,930**	**14,769,817**	**290%**

Another success factor is the ability of neonicotinoids to control pests that had developed resistance against a wide range of insecticides … A prominent example is the widespread metabolic resistance in aphids to [organophosphates], and to some extent to carbamates and pyrethroids

Pages 1100-1101, Elbert, A., Haas, M., Springer, B., Thielert, W., & Nauen, R. (2008). *Applied aspects of neonicotinoid uses in crop protection*. Pest Management Science, 64(11), 1099–1105. doi:10.1002/ps.1616.



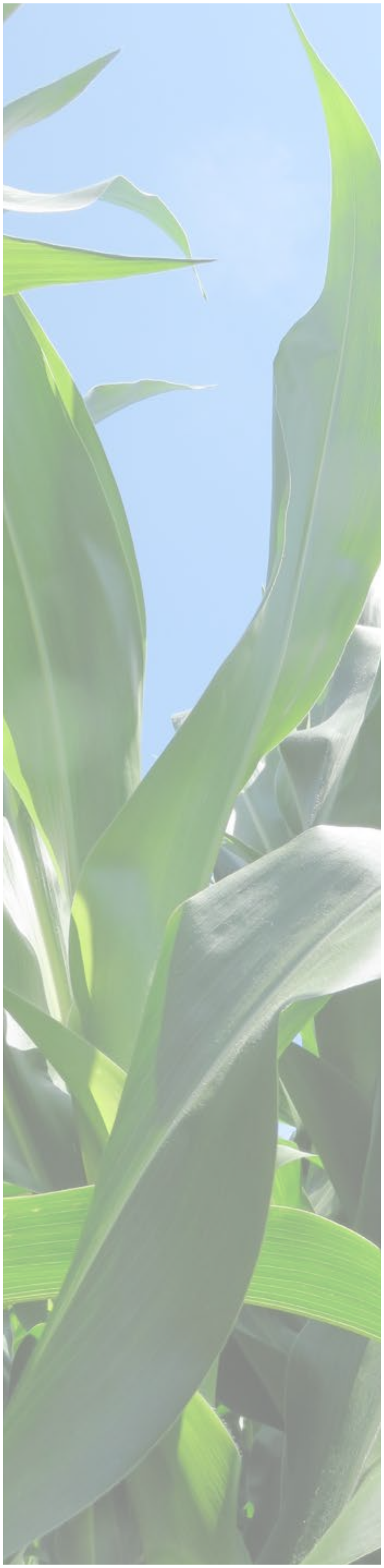
Corn Table 15. Impact of the non-neonicotinoid scenario on product acres using foliar-based and soil-based pest management systems.

Category	Foliar-based	Soil-based	Total
2010-2012 Average Product Acres (All AIs)	3,976,739	92,668,415	96,645,154
Neonicotinoid Product Acres to be Reallocated	0	82,550,924	82,550,924
Total Non-Neonicotinoid Product Acres Added	4,088,191	77,011,296	81,099,487
Scouted and Treated	3,697,402	77,011,296	80,708,698
Scouted Only	390,789	0	390,789
New Total Product Acres	**8,064,930**	**87,128,787**	**95,193,717**
Net Change (Product Acres)	**4,088,191**	**-5,539,628**	**-1,451,437**
Net Change (%)	**103%**	**-6%**	**-2%**

Corn Table 16. Average cost for each AI ($/Product Acre) for 2010-2012 for foliar and soil use (not including application costs), plus application and scouting costs.

Active Ingredient	Foliar ($/Product Acre)	Seed Treatment ($/Product Acre)	Soil Insecticide ($/Product Acre)
Bifenthrin	6.02		7.13
Chlorethoxyfos			8.49
Chlorpyrifos	5.24		9.42
Cyfluthrin	3.36		1.47
Deltamethrin	2.91		
Esfenvalerate	3.93		
Gamma-Cyhalothrin	4.29		
Lambda-Cyhalothrin	4.94		5.57
Methomyl	9.00		
Methyl Parathion	4.58		
Permethrin	3.32		3.00
Tebupirimphos			14.26
Tefluthrin	18.70		16.18
Terbufos			14.45
Zeta-Cypermethrin	2.51		3.00
Neonicotinoid Average	*	**4.80**	
Application Costs	**7.20**		**3.00**
Scouting Costs	**7.44**		

*No significant foliar use of neonicotinoids occurs in corn.

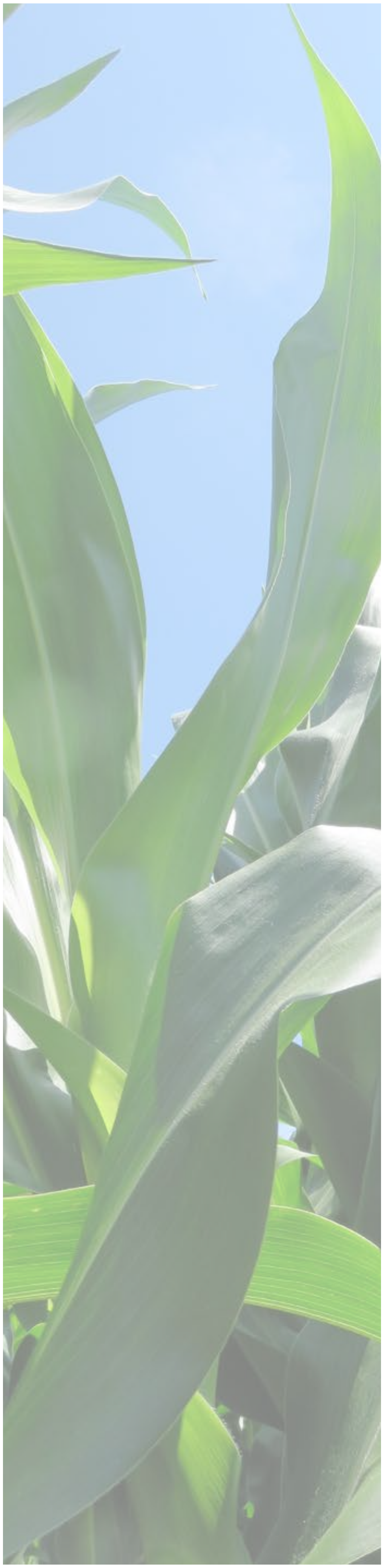


Corn Table 17. Reported cost ($/A) for foliar applications and insect scouting based on custom rates and budgets from multiple states.

State	Year	Apply ($/A)	Scout ($/A)	Source
AR	2013	6.50	9.00	http://www.uaex.edu/depts/ag_economics/budgets/2013/Budgets2013.pdf
AL	2013	9.00	8.00	http://www.aces.edu/agriculture/business-management/budgets/2013/rowcrops.php
CO	2012	7.27		http://www.coopext.colostate.edu/abm/custrates12.pdf
GA	2013		10.00	http://www.ugacotton.com/vault/file/2013BUDGETS.pdf
IA	2013	7.30	4.95	http://www.extension.iastate.edu/agdm/crops/pdf/a3-10.pdf
ID	2011	7.11		http://www.cals.uidaho.edu/edcomm/pdf/BUL/BUL0729.pdf
KS	2013	6.03		http://www.kingman.ksu.edu/doc46174.ashx
KY	2013	7.00		http://www2.ca.uky.edu/cmspubsclass/files/ghalich/CustomMachineryRatesKentucky2013.pdf
MI	2012	7.55	5.00	https://www.msu.edu/~steind/1_2012%20Cust_MachineWrk%20 10_31_11.pdf
MN	2013	5.14		http://faculty.apec.umn.edu/wlazarus/documents/machdata.pdf
MO	2012	7.59	8.00	http://extension.missouri.edu/explorepdf/agguides/agecon/g00302.pdf http://extension.missouri.edu/seregion/Crop_Budgets_PDF.htm
MS	2013		7.00	http://www.agecon.msstate.edu/whatwedo/budgets/docs/MSUCOT14.pdf
ND	2010	6.00		http://www.nass.usda.gov/Statistics_by_State/North_Dakota/Publications/Custom_Rates/index.asp
NE	2012	7.42		http://ianrpubs.unl.edu/epublic/live/ec823/build/ec823.pdf
NY	2011	10.00		http://blogs.cornell.edu/ccefranklin//files/2010/04/2011-Custom-Rates.pdf
OK	2011	6.17		http://oces.okstate.edu/kay/ag/CustomRates%202011-2012.pdf/at_download/file
PA	2013	11.30		http://farmprogress.com/mdfm/Faress1/author/198/2013%20Custom-Rates.pdf
SC	2013		9.00	http://www.clemson.edu/extension/aes/budgets/
TN	2013	8.46	9.50	http://economics.ag.utk.edu/extension/pubs/CustomRates2013-rev.pdf http://economics.ag.utk.edu/budgets/2014/2014RowCropBudgets.pdf
TX	2013	6.22		http://agecoext.tamu.edu/files/2012/05/CustomRateSurveyMay2013.pdf
WI	2010	7.70		http://www.nass.usda.gov/Statistics_by_State/Wisconsin/Publications/custom_rates_2010.pdf

Neonicotinoid insecticides control early-season insect pests in the critical phase of seedling emergence and during the vulnerable, early-growth stages of plant development.

Page 13, Crop Life Foundation. November 2013. *The Role of Seed Treatment in Modern U.S. Crop Production: A Review of Benefits*. Washington, D.C. Retrieved from: http://www.croplifeamerica.org/sites/default/files/SeedTreatment.pdf.



Corn Table 18. Estimated grower costs for alternative AIs, application and scouting for foliar-based systems in the non-neonicotinoid scenario.

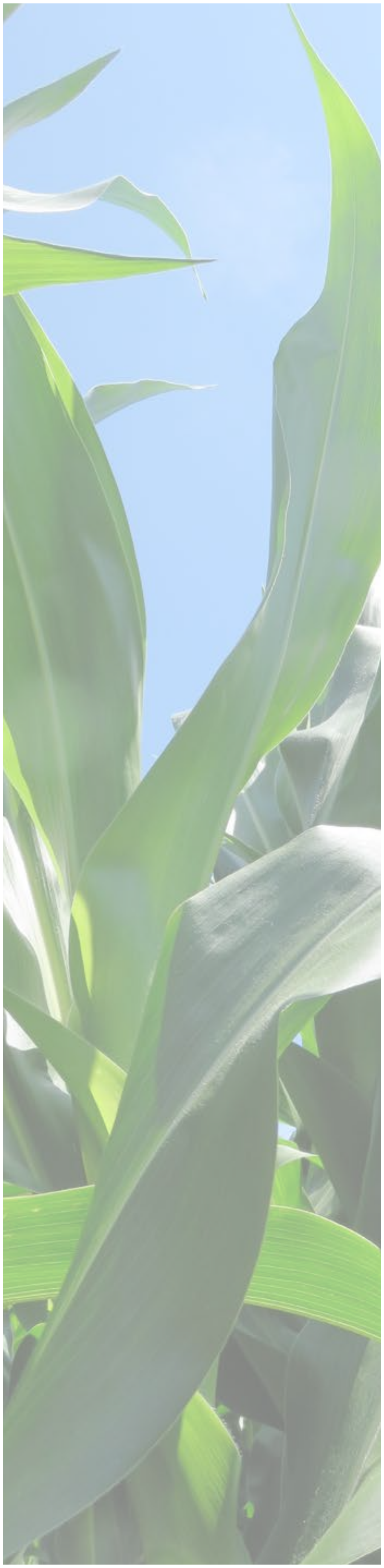
	------------ Foliar to Foliar ----------			----------Seed Treatment to Foliar---------		
Active Ingredient	**Added Acres**	**Cost** ($/A)	**Total Cost**	**Added Acres**	**Cost** ($/A)	**Total Cost**
Bifenthrin				460,206	6.02	2,770,799
Chlorpyrifos				149,987	5.24	785,396
Cyfluthrin				582,067	3.36	1,957,043
Deltamethrin				36,806	2.91	106,973
Esfenvalerate				281,949	3.93	1,107,866
Gamma-Cyhalothrin				34,141	4.29	146,479
Lambda-Cyhalothrin				1,148,041	4.94	5,667,319
Methomyl				41,531	9.00	373,785
Methyl Parathion				93,505	4.58	428,522
Permethrin				304,853	3.32	1,012,280
Tefluthrin				33,600	18.70	628,477
Zeta-Cypermethrin				530,715	2.51	1,333,199
Scouted & Treated				**3,697,402**	**4.41**	**16,318,138**
Scouted Only				**390,789**		
Application				**3,697,402**	**7.20**	**26,621,295**
Scouting*				**4,088,191**	**7.44**	**30,416,143**

*No significant foliar use of neonicotinoids occurs in corn.

Corn Table 19. Estimated grower costs for alternative AIs, application and scouting for soil-based systems in the non-neonicotinoid scenario.

	Seed Treatment to Seed Treatment*			Seed Treatment to Soil Insecticide		
Active Ingredient	**Added Acres**	**Cost** ($/A)	**Total Cost**	**Added Acres**	**Cost** ($/A)	**Total Cost**
Bifenthrin				18,727,517	7.13	133,482,664
Chlorethoxyfos				1,977,431	8.49	16,783,882
Chlorpyrifos				5,543,898	9.42	52,244,477
Cyfluthrin				13,367,814	1.47	19,599,125
Lambda-Cyhalothrin				2,186,341	5.57	12,179,253
Tebupirimphos				15,942,822	14.26	227,393,333
Tefluthrin				17,080,055	16.18	276,393,259
Terbufos				2,137,746	14.45	30,882,902
Zeta-Cypermethrin				47,672	3.00	142,972
Scouted & Treated				**77,011,296**	**9.99**	**769,101,868**
Application				**77,011,296**	**3.00**	**231,033,888**
Scouting**						

*No significant non-neonicotinoid seed treatment use occurs in corn.
*Not applicable as scouting does not change for the non-neonicotinoid scenario.



Corn Table 20. Estimated grower costs for neonicotinoid AIs, application and scouting for the 2010-2012 average neonicotinoid use.

	Foliar Use*			Seed Treatment Use		
Cost Category	Original Acres	Cost ($/A)	Total Cost	Original Acres	Cost ($/A)	Total Cost
Active Ingredients				82,550,924	4.80	396,637,854
Application						
Scouting**						

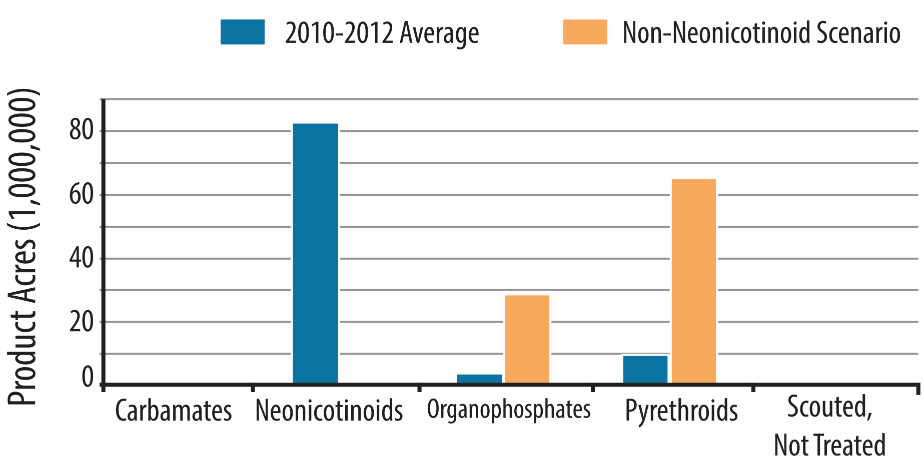
*No significant foliar use of neonicotinoids occurs in corn.
**Does not change for the non-neonicotinoid scenario.

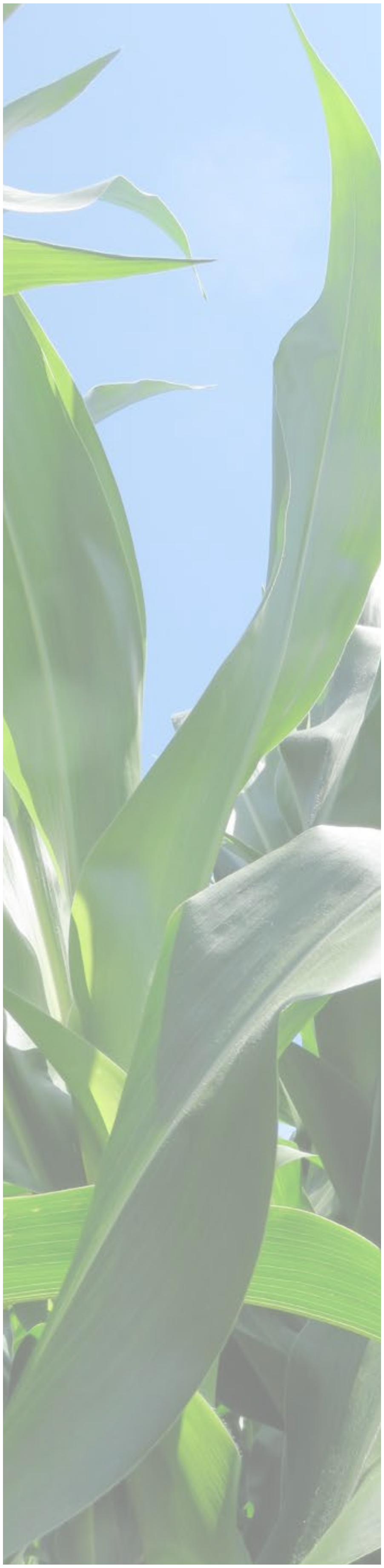
Corn Table 21. Estimated net change in grower expenditures for the non-neonicotinoid scenario.

	Avoided Expenditures From the Current System	New Expenditures for the Non-Neonicotinoid Scenario	Net Change in Grower Expenditures
Soil AI Costs	396,637,854	769,101,868	372,464,015
Foliar AI Costs		16,318,138	16,318,138
Soil Application Costs		231,033,888	231,033,888
Foliar Application Costs		26,621,295	26,621,295
Soil Scouting Costs			0
Foliar Scouting Costs		30,416,143	30,416,143
Total Costs	**396,637,854**	**1,073,491,333**	**676,853,479**

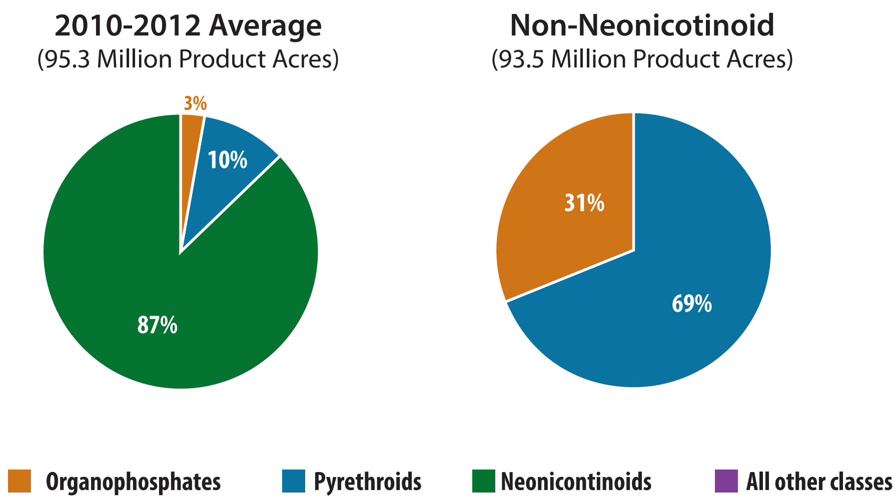
Net Change in Grower Expenditures	Acres	$/Acre
Neonicotinoid Base Acres Treated	81,373,939	8.32
Planted Acres	91,505,014	7.40

Corn Figure 1. 2010-2012 average product acres and new total product acres for the non-neonicotinoid scenario by insecticide class.

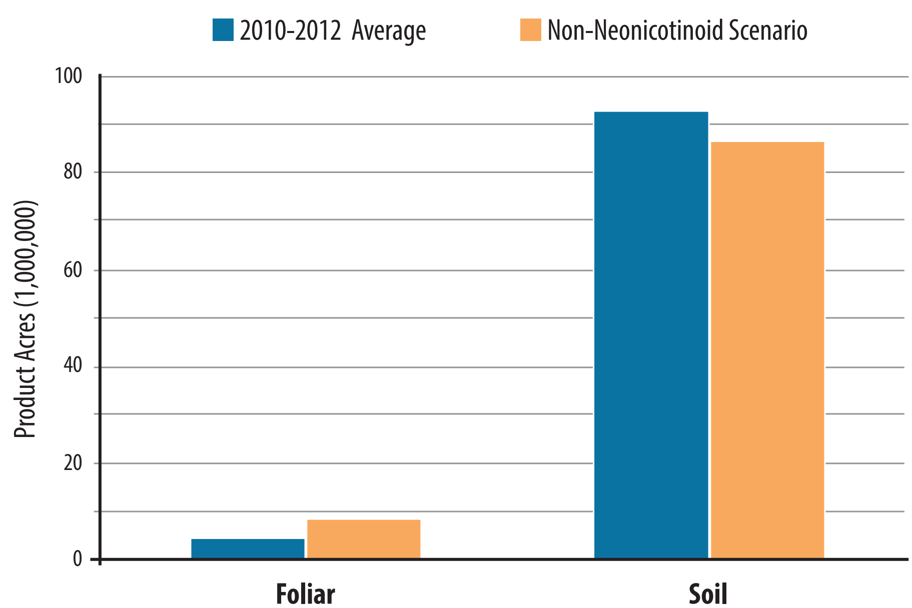




Corn Figure 2. 2010-2012 average shares of total insecticide product acres allocated to major insecticide modes of action and estimated shares for the non-neonicotinoid scenario. (Shares are based on product acres in Corn Table 12 and do not include product acres reallocated to "scouted but not treated.")



Corn Figure 3. 2010-2012 annual average product acres and new total product acres for the non-neonicotinoid scenario using foliar-based and soil-based pest management systems. (Foliar-based includes both acres "scouted and treated" as well as "scouted and not treated"; soil-based includes "seed treatments" and "soil insecticides.")



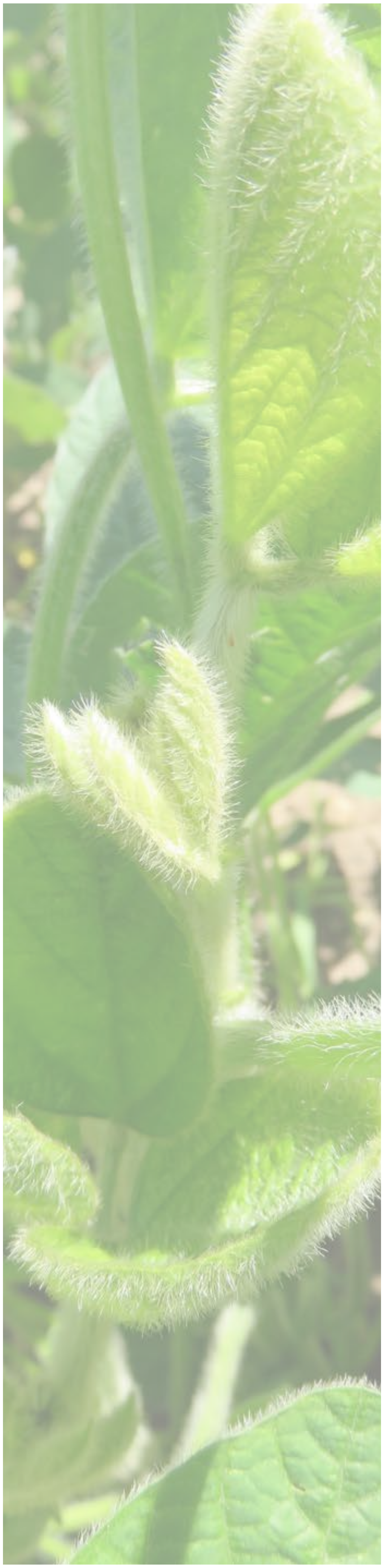
4.2 Soybean analysis and results

The most significant difference for the soybean analysis relative to the cotton analysis is that no non-neonicotinoid soil insecticides or seed treatments have been registered for use in soybeans. Foliar non-neonicotinoid alternatives are available and used for above-ground pests, but no insecticidal alternatives to neonicotinoid insecticides are registered to manage below-ground insect pests in soybean. Thus, all soil-dwelling insect pests of soybean are controlled with neonicotinoid seed treatments or culturally. Since the primary impact of below-ground insect pests is stand reduction, the analysis assumes cultural control is used for the non-neonicotinoid scenario – namely planting higher seed densities or replanting. The analysis adds this cultural practice as an alternative for the non-neonicotinoid scenario, which changes some of the tables.

Cotton Table 4 reports target pest acreage shares using seed treatments and soil insecticides for the non-neonicotinoid scenario, but Soybean Table 4 is exclusively acreage shares using cultural control, since non-neonicotinoid soil insecticides or seed treatments are not available. Also, for soil-based insect management systems, Soybean Table 6 only reports acreage shares allocated to cultural practices and Soybean Table 9 reports new product acres allocated to higher seeding densities, since seed treatments and soil insecticides are not registered for soybean. Also, Soybean Table 10 is dropped since it is no longer relevant.

The partial budget analysis to estimate the cost benefit of neonicotinoids requires a per acre cost for all non-neonicotinoid alternatives, including cultural practices. Soybean Table 16 reports the average cost for each AI, including an average cost of $6.56/A for higher seeding densities. This cost is based on the results of Gaspar et al. (2014), who used field data from nine sites in Wisconsin over two years to estimate a general function describing how the optimal soybean seeding rate varies with and without a neonicotinoid seed treatment. Their Table 2 shows that the optimal seeding rate for untreated seed or fungicide-only treated seed ranges from 17,400 to 19,800 more than for neonicotinoid treated seed, depending on the soybean price. Assuming a seed price of $51 for 140,000 seeds, which is the 2010-2012 average reported by Duffy (2014), and assuming seeding rates are increased by 18,000 seeds per acre, the additional cost is 18,000 seeds/A x $51/140,000 seeds = $6.56/A, the value reported in Soybean Table 12. Note that this cost estimate only focuses on the cost of additional seed and does not include any extra costs for the time needed to refill planters more frequently and the associated impact on profitability due to increased time needed for planting, a time-critical component of yield.

Of the 2010-2012 annual average of 50.7 million insecticide product acres in soybean, 29.1 million are in a soil-based insect management system exclusively using neonicotinoid seed treatments. However, of the 21.6 million foliar insecticide product acres in soybean, only 1.4 million are neonicotinoid foliar product acres. The implication is that neonicotinoid use in soybean is dominated by seed treatments, with non-neonicotinoid insecticide alternatives not available. However, a substantial proportion of soybean acres use foliar-applied non-neonicotinoid insecticides, providing several non-neonicotinoid alternatives for controlling above-ground pests.

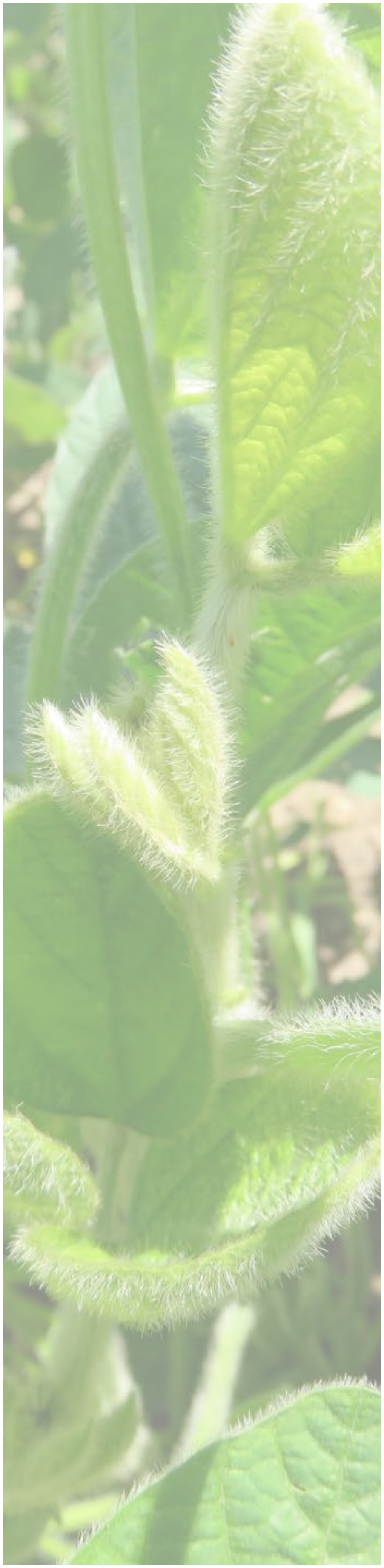


The 2010-2012 three-year average for soybean is 76.5 million planted acres, with 30.5 million neonicotinoid product acres applied to 30.4 million base acres, so that 40 percent of soybean planted acres are treated at least once with a neonicotinoid insecticide. Substantial overlap occurs between neonicotinoid seed treatment and non-neonicotinoid foliar application product acres. Though there are 30.5 million neonicotinoid product acres in soybean and 20.2 million non-neonicotinoid product acres, there are only 37.5 million insecticide base acres, so that 49 percent of soybean planted acres are treated with an insecticide.

In terms of target pests, neonicotinoid seed treatments in soybean primarily target above-ground pests, with 37percent and 25 percent of neonicotinoid seed treatment product acres respectively targeted at bean leaf beetle and aphids. Soil-dwelling insects targeted by neonicotinoid seed treatments include seed maggots, wireworms and white grubs, each comprising 14 percent, 13 percent and 6 percent of neonicotinoid seed treatment product acres respectively. The remaining product acres are targeted at Japanese beetles and threecornered alfalfa hoppers. Almost three-fourths of foliar-applied neonicotinoid product acres are targeted at stink bugs and aphids, with threecornered alfalfa hoppers, bean leaf beetles and Japanese beetles comprising the targets for the remaining product acres.

The analysis projects that the 2010-2012 average of 30.5 million neonicotinoid product acres in soybean would be replaced with 9.0 million product acres of pyrethroids and 2.5 million product acres of organophosphates, representing an increase of about 60 percent in the product acres of each class. In terms of pounds of AI applied, the analysis projects a 60 percent increase in the total pounds of both pyrethroids and organophosphates for the non-neonicotinoid scenario. The impact that these product acre shifts have on the share of all soybean product acres devoted to organophosphates and pyrethroids is substantial. Based on 2010-2012 data, 62 percent of soybean insecticide product acres are neonicotinoids, 29 percent are pyrethroids and 9 percent are organophosphates; but the non-neonicotinoid scenario projects that the pyrethroid share increases to 78 percent and the organophosphate share to 22 percent. These estimated shifts and increased use of these insecticide classes raise concerns about increased potential for the development of insect resistance to these important modes of action.

The analysis also projects that 20.0 million product acres of neonicotinoid seed treatments would shift to foliar-based applications of pyrethroids and organophosphates to control above-ground pests. This represents almost a doubling of foliar-applied insecticide product acres in soybean from their 2010-2012 average level of 21.6 million product acres. The projected shift to greater use of foliar applications of non selective insecticides raises concerns about negative impacts on beneficial insect populations. If populations of these beneficial insects decline, populations of current pests and secondary pests may increase sufficiently to justify additional insecticide applications. The analysis also projects that 9.6 million neonicotinoid product acres would switch to cultural control practices (higher seeding densities or replanting) to manage soil-dwelling insects, such as wireworms, seed maggots and white grubs for the non-neonicotinoid scenario, since insecticidal options are currently not available. Finally, another 9.9 million neonicotinoid product



acres would be scouted but not treated for the above-ground pests originally targeted by the neonicotinoid seed treatment.

In terms of estimated cost changes, soybean growers would see a net decrease in expenditures for insecticide AIs of $184 million by switching to non-neonicotinoid AIs, but see a net increase in application costs of $73 million due to switching from seed treatments to foliar applications and a $63 million cost increase for cultural control (higher seeding densities or replanting). In addition, scouting costs would increase by $149 million, as soybean acres using foliar-based management systems are projected to almost double. The net effect is an increase of $100 million in costs for soybean growers for the non-neonicotinoid scenario. Given the 76.5 million soybean planted acres and 30.4 million neonicotinoid base acres in soybeans, the estimated average cost benefit of neonicotinoids is $1.31 per soybean planted acre or $3.30 per neonicotinoid treated base acre.

Soybean Table 1. Product acres for all AIs and neonicotinoids (three-year average, 2010-2012).

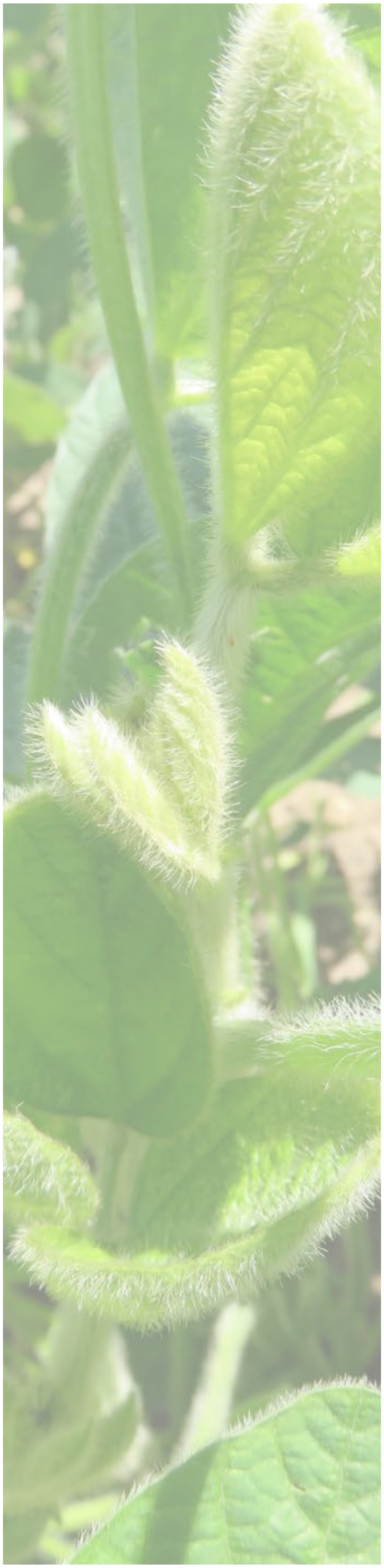
		-------- Soil-based System --------		
	Foliar	Seed Treatment	Soil-applied	Total
Neonicotinoids	1,431,635	29,054,840	---	30,486,475
Non-Neonicotinoids	20,184,335	---	---	20,184,335
All AIs	21,615,970	29,054,840	---	50,670,810

Crop protection products applied as seed treatments are placed directly on the seed, and can reduce potential soil surface exposure by up to 90 percent.

The Role of Seed Treatment in Modern Agriculture. (2013). CropLife Foundation. http://tellmemore.croplifeamerica.org/wp-content/uploads/2013/12/SeedTreatmentModernAg.jpg.

Soybean Table 2. Initial product acres for foliar-based and soil-based systems and remaining product acres after focusing on major pests targeted by neonicotinoids.

	-------Foliar-based Systems------		-------Soil-based Systems-------	
	All AIs	Neonicotinoids	All AIs	Neonicotinoids
Initial Product Acres	21,615,970	1,431,635	29,054,840	29,054,840
No Answer	6.2%	8.1%	46.7%	46.7%
Targeted at Specific Pests	93.8%	91.9%	53.3%	53.3%
Remaining Product Acres				
% of Initial Product Acres	56.7%	71.4%	42.6%	42.6%
% Targeted at Specific Pests	60.4%	77.7%	79.8%	79.8%



Soybean Table 3. Non-neonicotinoid product acre shares by neonicotinoid target pest group for foliar-based systems.

Active Ingredient	Aphid	Bean Leaf Beetle	Japanese Beetle	Stink Bug	Three-cornered Alfalfa Hopper
Acephate		5.8%		14.1%	9.5%
Bifenthrin	10.8%	11.6%	17.2%	27.5%	
Chlorpyrifos	25.6%	16.9%			
Cyfluthrin	5.9%	5.4%	16.4%	22.9%	61.2%
Esfenvalerate	6.4%	3.3%	4.9%	1.6%	12.2%
Gamma-Cyhalothrin	7.8%	11.6%	9.3%	1.6%	8.5%
Lambda-Cyhalothrin	39.2%	36.2%	34.6%	27.1%	8.5%
Permethrin		1.1%	2.3%		
Zeta-Cypermethrin	4.3%	8.0%	15.3%	5.2%	

Soybean seed treated with neonicotinoid product | Untreated soybean

Soybean Table 4. Non-neonicotinoid cultural practice shares by neonicotinoid target pest group for soil-dwelling pests.

Practice	Aphid	Bean Leaf Beetle	Japanese Beetle	Seed Maggot	Stink Bug	Three-cornered Alfalfa Hopper	White Grub	Wireworm
Higher Seeding Rate*	0%	0%	0%	100%	0%	0%	100%	100%

* No non-neonicotinoid seed treatments or soil insecticides labelled for soybeans, so these are product acre shares allocated to higher seeding rates to compensate for losses due to soil-dwelling pests.

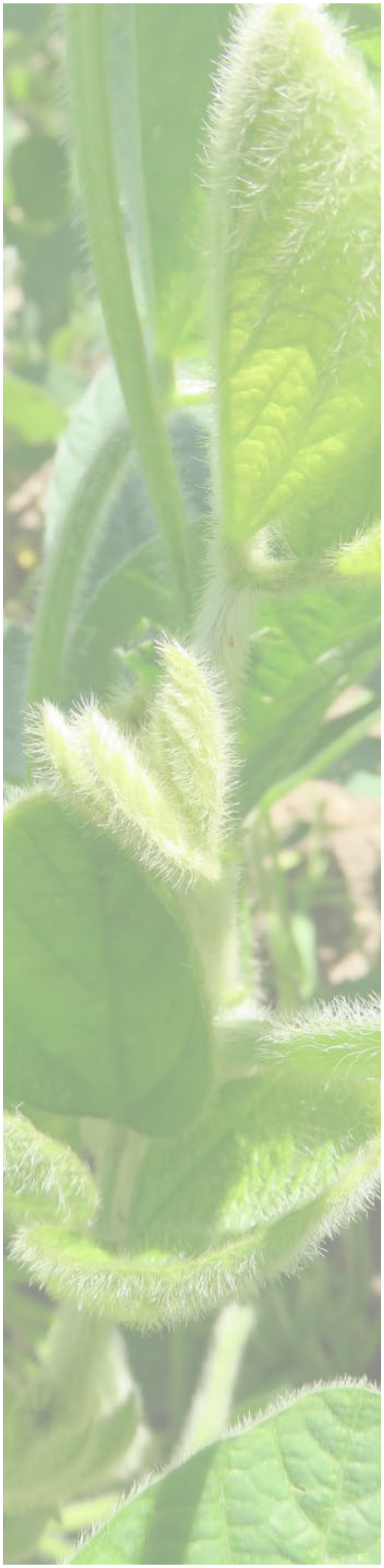
Soybean Table 5. Share of neonicotinoid product acres targeted at each insect pest group for foliar-based and soil-based pest management systems.

Pest Control System	Aphid	Bean Leaf Beetle	Japanese Beetle	Seed Maggot	Stink Bug	Three-cornered Alfalfa Hopper	White Grub	Wireworm
Foliar-based	29.7%	7.1%	7.0%		41.8%	14.3%		
Soil-based	24.9%	36.7%	1.0%	14.0%	1.5%	2.8%	5.9%	13.2%

Soybean Table 6. Share of non-neonicotinoid product acres from foliar-based and from soil-based systems allocated to seed treatments, soil insecticides and foliar systems by target pest.

Pest Control System	Aphid	Bean Leaf Beetle	Japanese Beetle	Seed Maggot	Stink Bug	Three-cornered Alfalfa Hopper	White Grub	Wireworm
Foliar-based								
To Foliar-based	100%	100%	100%	0%	100%	100%	0%	0%
Soil-based								
To Foliar-based	100%	100%	100%	0%	100%	100%	0%	0%
To Cultural Practices*	0%	0%	0%	100%	0%	0%	100%	100%

*No non-neonicotinoid seed treatments or soil-applied insecticides labelled for use in soybean, so neonicotinoid product acres allocated to higher seeding densities or replanting to compensate for uncontrolled soil pests.



Soybean Table 7. Average number of applications for each AI and ratios of these averages.

	Average Number of Applications		Ratio of Average Non-Neonicotinoid Applications to Neonicotinoid Applications		
Active Ingredient	Soil-based	Foliar-based	Soil:Soil	Foliar:Foliar	Foliar:Soil
Acephate		1.105		1.044	1.105
Bifenthrin		1.155		1.091	1.155
Chlorpyrifos		1.041		0.984	1.041
Cyfluthrin		1.073		1.014	1.073
Esfenvalerate		1.015		0.959	1.015
Gamma-Cyhalothrin		1.040		0.983	1.040
Lambda-Cyhalothrin		1.036		0.979	1.036
Permethrin		1.041		0.984	1.041
Zeta-Cypermethrin		1.045		0.987	1.045
Neonicotinoids	1.000	1.058			

*No non-neonicotinoid seed treatments or soil-applied insecticides labelled for use in soybeans.

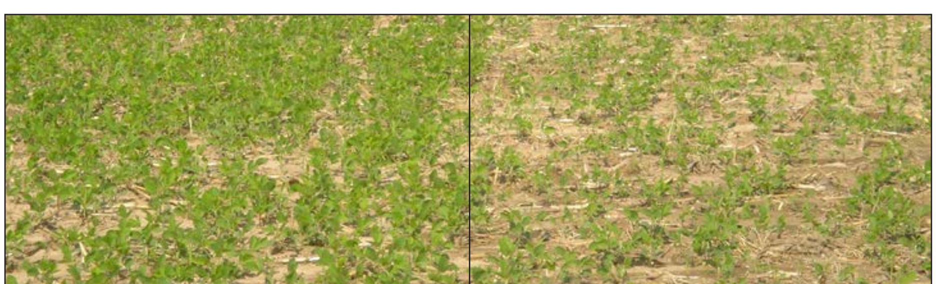
See next page for Soybean Table 8

Soybean Table 9. Neonicotinoid product acres in a soil-based pest control system reallocated to cultural practices by target pest group.

Practice	White Grub	Seed Maggot	Wireworm	All Other Target Pests	Total
Adjust Seeding Rate*	4,064,425	1,705,365	3,845,606	0	9,615,397
Total	**4,064,425**	**1,705,365**	**3,845,606**	**0**	**9,615,397**

Soybean Table 10. Non-neonicotinoid product acres in a soil insecticide pest management system by AI and target pest group reallocated from neonicotinoid product acres in a seed treatment pest management system.

Table not relevant for soybeans.



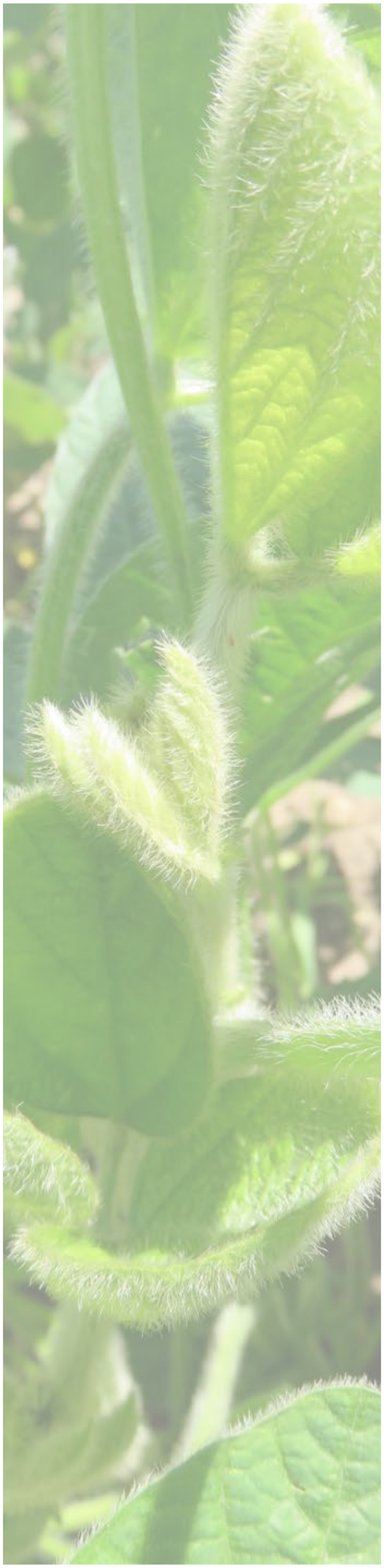
Soybean seed treated with neonicotinoid product | Untreated soybean

Soybean Table 8. Neonicotinoid product acres in a foliar-based pest control system reallocated to each AI and target pest group in a foliar-based pest control system.

Active Ingredient	Aphid	Bean Leaf Beetle	Japanese Beetle	Stink Bug	Threecornered Alfalfa Hopper	Total	AI Weights
Acephate	0	6,169	0	88,452	20,416	115,037	8.0%
Bifenthrin	50,136	12,850	18,961	179,933	0	261,881	18.1%
Chlorpyrifos	107,027	16,796	0	0	0	123,823	8.6%
Cyfluthrin	25,297	5,548	16,769	139,042	127,480	314,136	21.7%
Esfenvalerate	26,293	3,250	4,725	9,194	24,096	67,558	4.7%
Gamma-Cyhalothrin	32,645	11,581	9,178	9,290	17,082	79,776	5.5%
Lambda-Cyhalothrin	163,147	35,902	34,178	158,970	17,171	409,368	28.3%
Permethrin	0	1,134	2,290	0	0	3,424	0.2%
Zeta-Cypermethrin	17,994	7,996	15,205	30,677	0	71,871	5.0%
Total	**422,539**	**101,226**	**101,306**	**615,557**	**206,246**	**1,446,874**	**100.0%**

Soybean Table 11. Non-neonicotinoid product acres in a foliar-based pest management system by AI and target pest group reallocated from neonicotinoid product acres in a seed treatment pest management system.

Active Ingredient	Aphid	Bean Leaf Beetle	Japanese Beetle	Stink Bug	Threecornered Alfalfa Hopper	Total	AI Weights
Acephate	0	336,978	0	32,951	41,575	411,504	4.1%
Bifenthrin	443,105	701,918	28,875	67,031	0	1,240,929	12.3%
Chlorpyrifos	945,900	917,487	0	0	0	1,863,387	18.5%
Cyfluthrin	223,570	303,081	25,537	51,798	259,599	863,585	8.6%
Esfenvalerate	232,378	177,534	7,195	3,425	49,070	469,602	4.7%
Gamma-Cyhalothrin	288,516	632,605	13,976	3,461	34,786	973,344	9.7%
Lambda-Cyhalothrin	1,441,886	1,961,145	52,048	59,221	34,967	3,549,268	35.3%
Permethrin	0	61,967	3,487	0	0	65,454	0.7%
Zeta-Cypermethrin	159,032	436,760	23,155	11,428	0	630,375	6.3%
Total Treated With These AIs	3,734,389	5,529,475	154,272	229,315	419,997	10,067,448	100.0%
Scouted, Not Treated for These Pests	3,691,251	5,436,891	150,813	219,288	410,761	9,909,004	
Total	**7,425,640**	**10,966,366**	**305,085**	**448,603**	**830,757**	**19,976,452**	



Soybean Table 12. Impact of the non-neonicotinoid scenario on non-neonicotinoid product acres by individual AIs and by insecticide class.

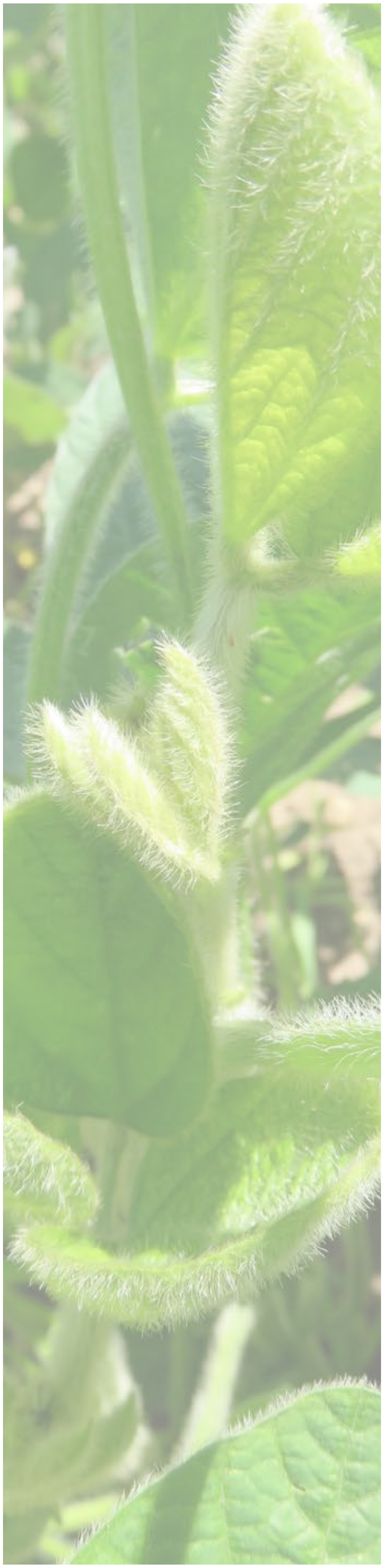
		---- Product Acres ----			
MOA	**Active Ingredient**	**2010-2012 Average**	**Added**	**New Total**	**Change**
1B	Acephate	911,508	526,540	1,438,049	58%
3A	Bifenthrin	2,855,432	1,502,810	4,358,242	53%
1B	Chlorpyrifos	3,282,809	1,987,210	5,270,019	61%
3A	Cyfluthrin	2,002,144	1,177,721	3,179,865	59%
3A	Esfenvalerate	812,666	537,160	1,349,826	66%
3A	Gamma-Cyhalothrin	977,000	1,053,120	2,030,120	108%
3A	Lambda-Cyhalothrin	6,324,197	3,958,636	10,282,833	63%
4A	Neonicotinoids	30,486,475	-30,486,475	0	-100%
3A	Permethrin	212,817	68,879	281,696	32%
3A	Zeta-Cypermethrin	1,095,251	702,246	1,797,497	64%
Total Treated With These AIs*		**48,960,300**	**-18,972,154**	**29,988,147**	**-39%**
Non-Neonicotinoids*		18,473,825	11,514,321	29,988,147	62%
Neonicotinoids		30,486,475	-30,486,475	0	-100%
Scouted but Not Treated for These Pests			**9,909,004**	**9,909,004**	
Cultural Control			**9,615,397**	**9,615,397**	

		---- Product Acres ----			
MOA	**Insecticide Class**	**2010-2012 Average**	**Added**	**New Total**	**Change**
4A	Neonicotinoids	30,486,475	-30,486,475	0	-100%
1B	Organophosphates	4,194,318	2,513,750	6,708,068	60%
3A	Pyrethroids	14,279,508	9,000,571	23,280,079	63%
Total Treated with These AIs*		**48,960,300**	**-18,972,154**	**29,988,147**	**-39%**
Non-Neonicotinoids*		18,473,825	11,514,321	29,988,147	62%
Neonicotinoids		30,486,475	-30,486,475	0	-100%
Scouted but Not Treated for These Pests			**9,909,004**	**9,909,004**	
Cultural Control			**9,615,397**	**9,615,397**	

*Does not match Soybean Table 1 totals because totals here do not include minor-use AIs.

The discovery of neonicotinoids can be considered a milestone in insecticide research and greatly facilitated the understanding of the functional properties of insect nicotinic receptors.

p. 2884, Tomizawa, M., & Casida, J. E. (2010). *Neonicotinoid insecticides: highlights of a symposium on strategic molecular designs*. Journal of agricultural and food chemistry, 59(7), 2883-2886.



Soybean Table 13. Average application rate (pounds per product acre) for each AI by method of application (foliar-applied, soil-applied, seed treatment).

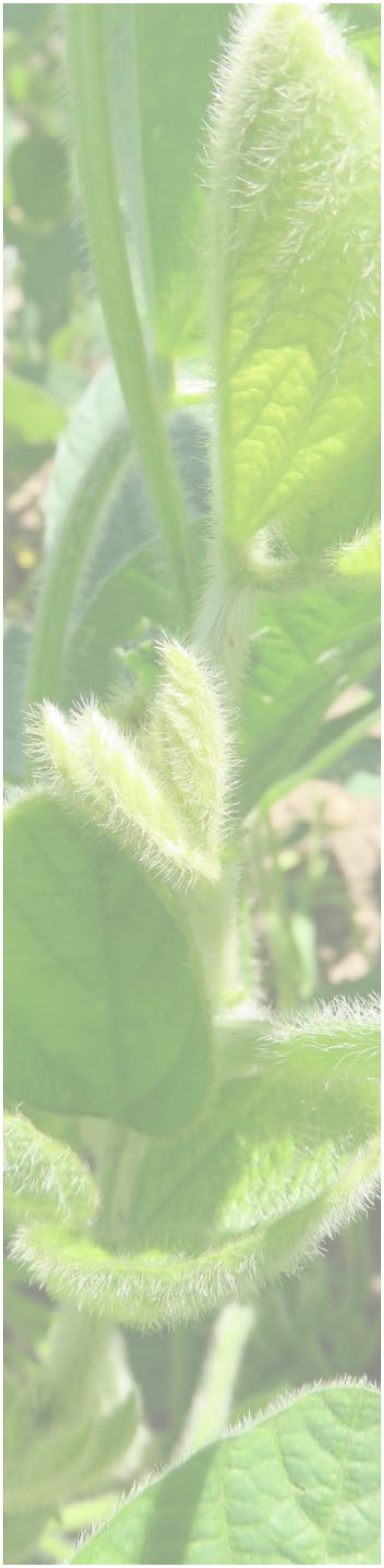
		-----Average Application Rate (Pounds per Product Acre)-----		
MOA	Active Ingredient	Foliar	Seed Treatment*	Soil Insecticide*
1B	Acephate	0.5684		
3A	Bifenthrin	0.0544		
1B	Chlorpyrifos	0.3389		
3A	Cyfluthrin	0.0225		
3A	Esfenvalerate	0.0323		
3A	Gamma-Cyhalothrin	0.0070		
3A	Lambda-Cyhalothrin	0.0229		
4A	Neonicotinoids	0.0378	0.0410	
3A	Permethrin	0.0959		
3A	Zeta-Cypermethrin	0.0142		

*No soil insecticides or non-neonicotinoid seed treatments registered for use in soybean.

Soybean Table 14. Impact of the non-neonicotinoid scenario on pounds of AI applied by insecticide class.

		----------------Pounds of Active Ingredient Applied----------------			
MOA	Active Ingredient	2010-2012 Average	Added	New Total	Change
1B	Acephate	518,059	299,261	817,320	58%
3A	Bifenthrin	153,132	81,754	234,886	53%
1B	Chlorpyrifos	1,092,492	673,537	1,766,029	62%
3A	Cyfluthrin	44,787	26,447	71,235	59%
3A	Esfenvalerate	24,439	17,350	41,789	71%
3A	Gamma-Cyhalothrin	6,868	7,403	14,271	108%
3A	Lambda-Cyhalothrin	143,821	90,512	234,333	63%
4A	Neonicotinoids	1,244,874	-1,244,874	0	-100%
3A	Permethrin	19,458	6,603	26,060	34%
3A	Zeta-Cypermethrin	14,714	9,966	24,680	68%
	Total	**3,262,643**	**-32,040**	**3,230,604**	**-1%**

		Pounds of Active Ingredient Applied			
MOA	Insecticide Class	2010-2012 Average	Added	New Total	Change
4A	Neonicotinoids	1,244,874	-1,244,874	0	-100%
1B	Organophosphates	1,610,550	972,798	2,583,348	60%
3A	Pyrethroids	407,219	240,036	647,255	59%
	Total	**3,262,643**	**-32,040**	**3,230,604**	**-1%**



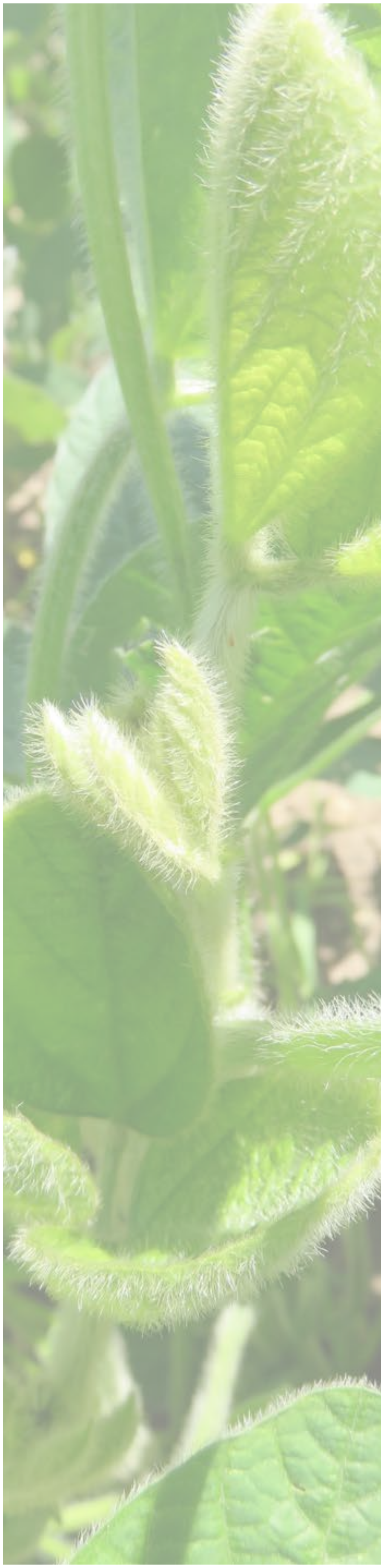
Soybean Table 15. Impact of the non-neonicotinoid scenario on product acres using foliar-based and soil-based pest management systems.

Category	Foliar-based	Soil-based	Total
2010-2012 Average Product Acres (All AIs)	21,615,970	29,054,840	50,670,810
Neonicotinoid Product Acres to be Reallocated	1,431,635	29,054,840	30,486,475
Total Non-Neonicotinoid Product Acres Added	21,423,325	9,615,397	31,038,722
Scouted and Treated	11,514,321	0	21,129,718
Scouted Only	9,909,004	0	9,909,004
Cultural Control	0	9,615,397	9,615,397
New Total Product Acres	**41,607,661**	**19,230,793**	**51,223,057**
Net Change (Product Acres)	**19,991,691**	**-9,824,047**	**552,247**
Net Change (%)	**92%**	**-34%**	**1%**

Soybean Table 16. Average cost for each AI ($/Product Acre) for 2010-2012 for foliar and soil use (not including application costs), plus application and scouting costs.

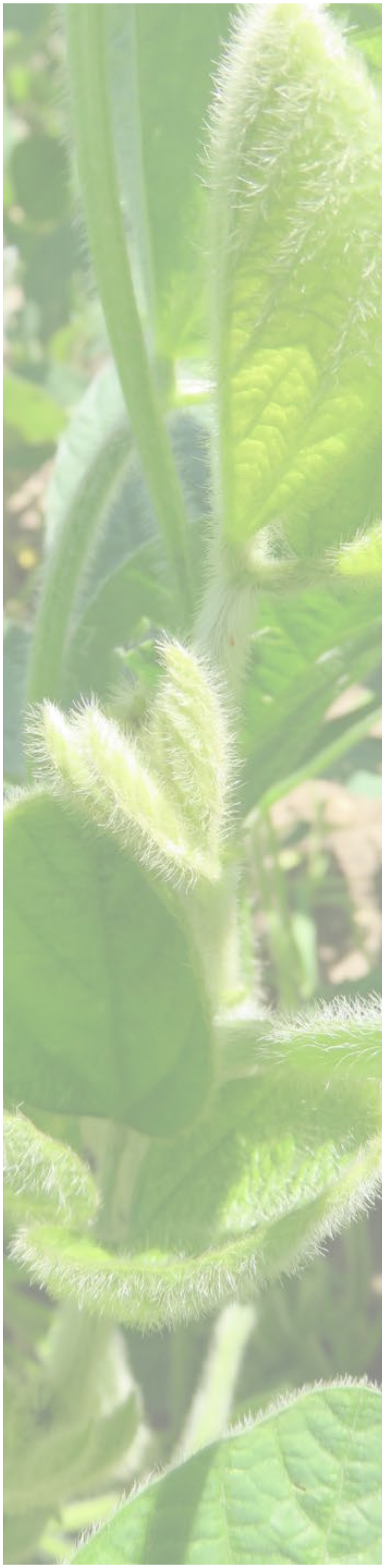
Active Ingredient	Foliar ($/Product Acre)	Seed Treatment ($/Product Acre)
Acephate	4.61	
Bifenthrin	3.65	
Chlorpyrifos	3.22	
Cyfluthrin	2.96	
Esfenvalerate	4.55	
Gamma-Cyhalothrin	3.07	
Lambda-Cyhalothrin	4.43	
Permethrin	2.31	
Zeta-Cypermethrin	2.81	
Neonicotinoid Average	**3.07**	**7.67**
Application Costs	**7.20**	
Scouting Costs	**7.44**	
Adjust Seeding Rate*		**6.56**

*See introductory text for explanation..



Soybean Table 17. Reported cost ($/A) for foliar applications and insect scouting based on custom rates and budgets from multiple states.

State	Year	Apply ($/A)	Scout ($/A)	Source
AR	2013	6.50	9.00	http://www.uaex.edu/depts/ag_economics/budgets/2013/Budgets2013.pdf
AL	2013	9.00	8.00	http://www.aces.edu/agriculture/business-management/budgets/2013/rowcrops.php
CO	2012	7.27		http://www.coopext.colostate.edu/abm/custrates12.pdf
GA	2013		10.00	http://www.ugacotton.com/vault/file/2013BUDGETS.pdf
IA	2013	7.30	4.95	http://www.extension.iastate.edu/agdm/crops/pdf/a3-10.pdf
ID	2011	7.11		http://www.cals.uidaho.edu/edcomm/pdf/BUL/BUL0729.pdf
KS	2013	6.03		http://www.kingman.ksu.edu/doc46174.ashx
KY	2013	7.00		http://www2.ca.uky.edu/cmspubsclass/files/ghalich/CustomMachineryRatesKentucky2013.pdf
MI	2012	7.55	5.00	https://www.msu.edu/~steind/1_2012%20Cust_MachineWrk%20 10_31_11.pdf
MN	2013	5.14		http://faculty.apec.umn.edu/wlazarus/documents/machdata.pdf
MO	2012	7.59	8.00	http://extension.missouri.edu/explorepdf/agguides/agecon/g00302.pdf http://extension.missouri.edu/seregion/Crop_Budgets_PDF.htm
MS	2013		7.00	http://www.agecon.msstate.edu/whatwedo/budgets/docs/MSUCOT14.pdf
ND	2010	6.00		http://www.nass.usda.gov/Statistics_by_State/North_Dakota/Publications/Custom_Rates/index.asp
NE	2012	7.42		http://ianrpubs.unl.edu/epublic/live/ec823/build/ec823.pdf
NY	2011	10.00		http://blogs.cornell.edu/ccefranklin//files/2010/04/2011-Custom-Rates.pdf
OK	2011	6.17		http://oces.okstate.edu/kay/ag/CustomRates%202011-2012.pdf/at_download/file
PA	2013	11.30		http://farmprogress.com/mdfm/Faress1/author/198/2013%20CustomRates.pdf
SC	2013		9.00	http://www.clemson.edu/extension/aes/budgets/
TN	2013	8.46	9.50	http://economics.ag.utk.edu/extension/pubs/CustomRates2013-rev.pdf http://economics.ag.utk.edu/budgets/2014/2014RowCropBudgets.pdf
TX	2013	6.22		http://agecoext.tamu.edu/files/2012/05/CustomRateSurveyMay2013.pdf
WI	2010	7.70		http://www.nass.usda.gov/Statistics_by_State/Wisconsin/Publications/custom_rates_2010.pdf



Soybean Table 18. Estimated grower costs for alternative AIs, application and scouting for foliar-based systems in the non-neonicotinoid scenario.

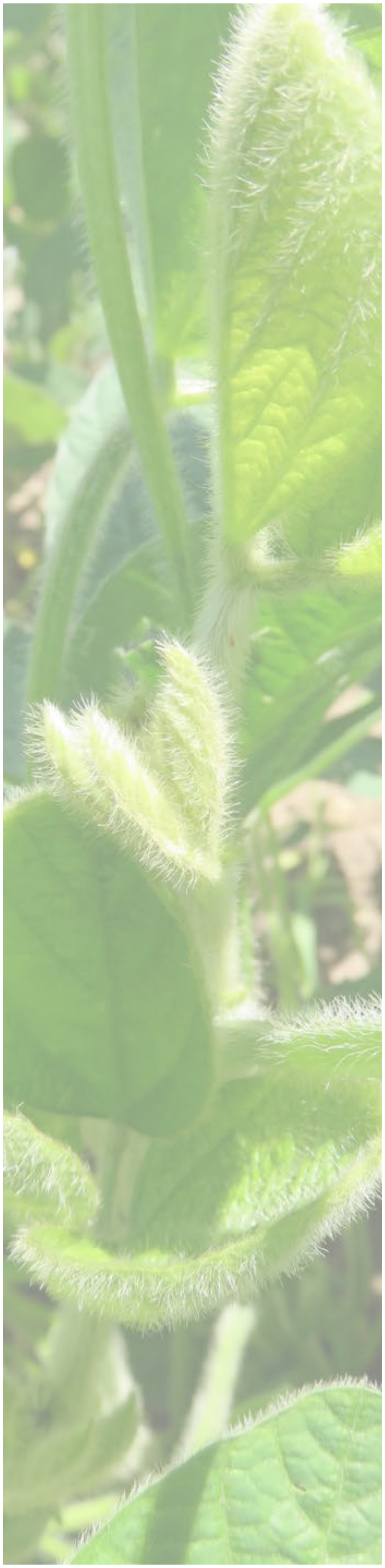
	------------ Foliar to Foliar ---------			---------Seed Treatment to Foliar--------		
Active Ingredient	**Added Acres**	**Cost** ($/A)	**Total Cost**	**Added Acres**	**Cost** ($/A)	**Total Cost**
Acephate	115,037	4.61	529,984	411,504	4.61	1,895,831
Bifenthrin	261,881	3.65	955,314	1,240,929	3.65	4,526,784
Chlorpyrifos	123,823	3.22	398,468	1,863,387	3.22	5,996,477
Cyfluthrin	314,136	2.96	930,427	863,585	2.96	2,557,814
Esfenvalerate	67,558	4.55	307,628	469,602	4.55	2,138,347
Gamma-Cyhalothrin	79,776	3.07	245,156	973,344	3.07	2,991,154
Lambda-Cyhalothrin	409,368	4.43	1,814,931	3,549,268	4.43	15,735,676
Permethrin	3,424	2.31	7,918	65,454	2.31	151,348
Zeta-Cypermethrin	71,871	2.81	202,206	630,375	2.81	1,773,525
Scouted & Treated	**1,446,874**	**3.73**	**5,392,033**	**10,067,448**	**3.75**	**37,766,956**
Scouted Only				**9,909,004**		
Application	**1,446,874**	**7.20**	**10,417,491**	**10,067,448**	**7.20**	**72,485,623**
Scouting	**1,446,874**	**7.44**	**10,764,741**	**19,976,452**	**7.44**	**148,624,800**

Soybean Table 19. Estimated grower costs for alternative AIs, application and scouting for soil-based systems in the non-neonicotinoid scenario.

Cultural Practice	**Added Acres**	**Cost** ($/A)	**Total Cost**
Adjust Seeding Rate	9,615,397	6.56	63,077,002
Total	**9,615,397**	**6.56**	**63,077,002**

Soybean Table 20. Estimated grower costs for neonicotinoid AIs, application and scouting for the 2010-2012 average neonicotinoid use.

	-------------- Foliar Use---------------			--------- Seed Treatment Use -------		
Cost Category	**Original Acres**	**Cost** ($/A)	**Total Cost**	**Original Acres**	**Cost** ($/A)	**Total Cost**
Active Ingredients	1,431,635	3.07	4,402,104	29,054,840	7.67	222,781,343
Application	1,431,635	7.20	10,307,770	29,054,840	0	0
Scouting	1,431,635	7.44	10,651,362			

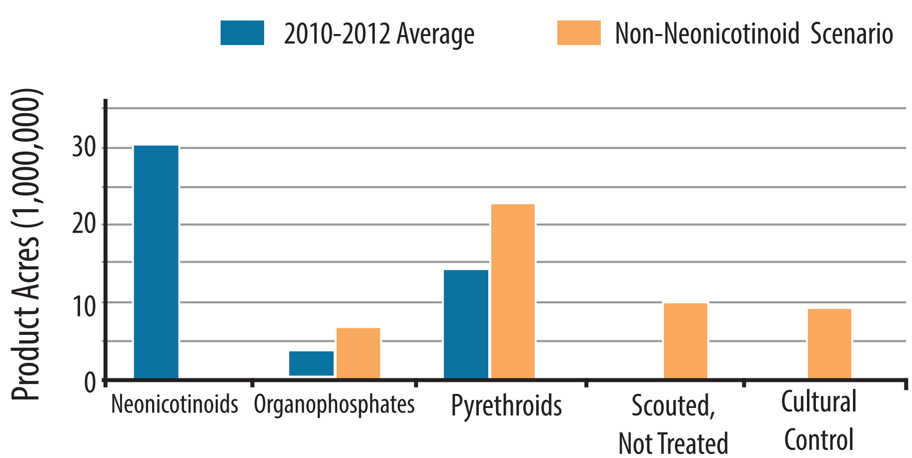


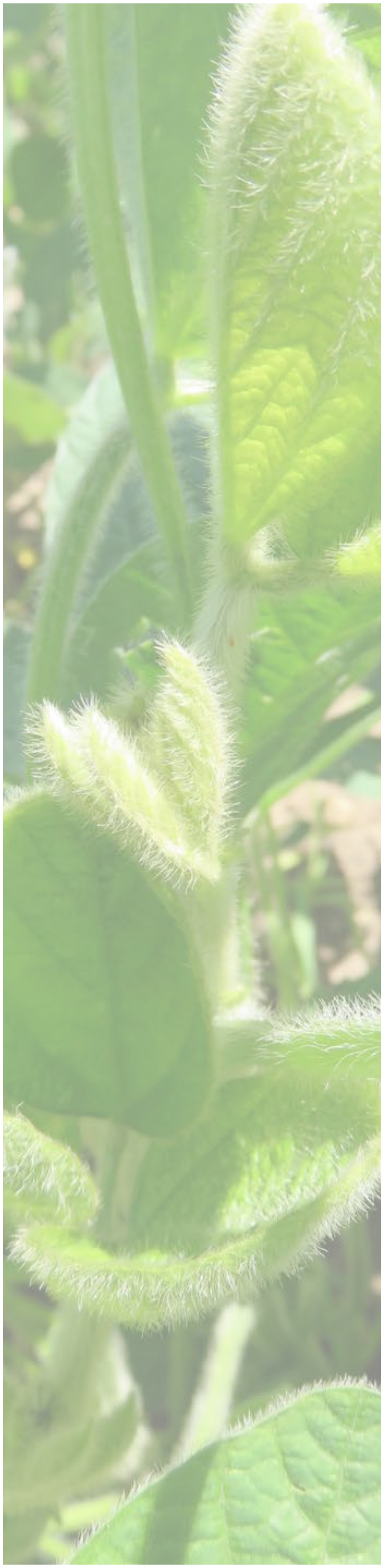
Soybean Table 21. Estimated net change in grower expenditures for the non-neonicotinoid scenario.

	Avoided Expenditures From the Current System	New Expenditures for the Non-Neonicotinoid Scenario	Net Change in Grower Expenditures
Soil AI Costs	222,781,343	---	-222,781,343
Foliar AI Costs	4,402,104	43,158,989	38,756,885
Soil Application Costs	---	---	---
Foliar Application Costs	10,307,770	82,903,114	72,595,345
Soil Scouting Costs	---	---	---
Foliar Scouting Costs	10,651,362	159,389,541	148,738,179
Cultural Control	---	63,077,002	63,077,002
Total Costs	**248,142,578**	**348,528,646**	**100,386,068**

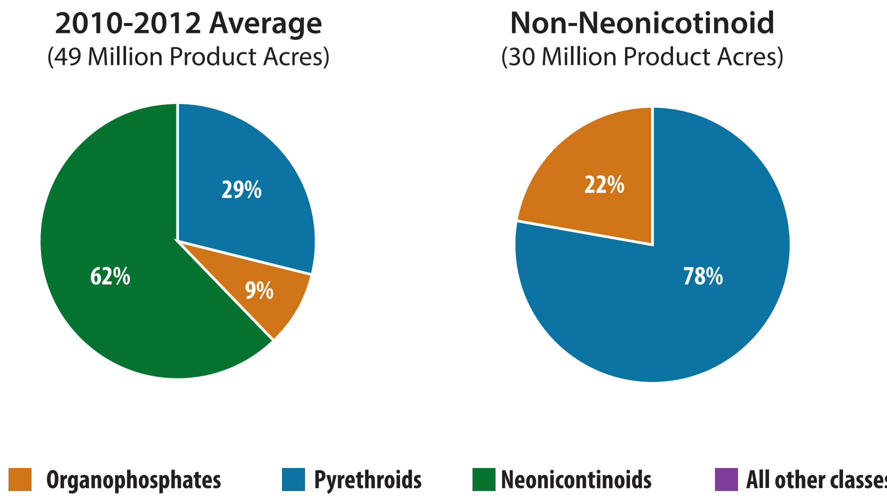
Net Change in Grower Expenditures	Acres	$/Acre
Neonicotinoid Base Acres Treated	30,411,223	3.30
Planted Acres	76,500,003	1.31

Soybean Figure 1. 2010-2012 average product acres and new total product acres for the non-neonicotinoid scenario by insecticide class.

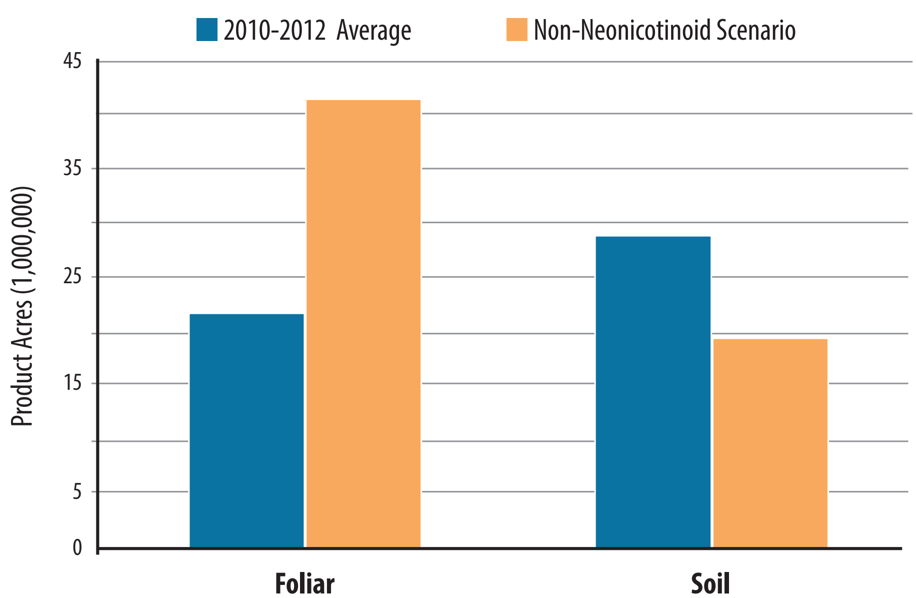




Soybean Figure 2. 2010-2012 average shares of total insecticide product acres allocated to major insecticide modes of action and estimated shares for the non-neonicotinoid scenario. (Shares are based on product acres in Soybean Table 12 and do not include product acres reallocated to "scouted but not treated" or to "cultural control.")



Soybean Figure 3. 2010-2012 annual average product acres and new total product acres for the non-neonicotinoid scenario using foliar-based and soil-based pest management systems. (Foliar-based includes both acres "scouted and treated" as well as "scouted and not treated"; soil-based includes "seed treatments" and "higher seeding density.")



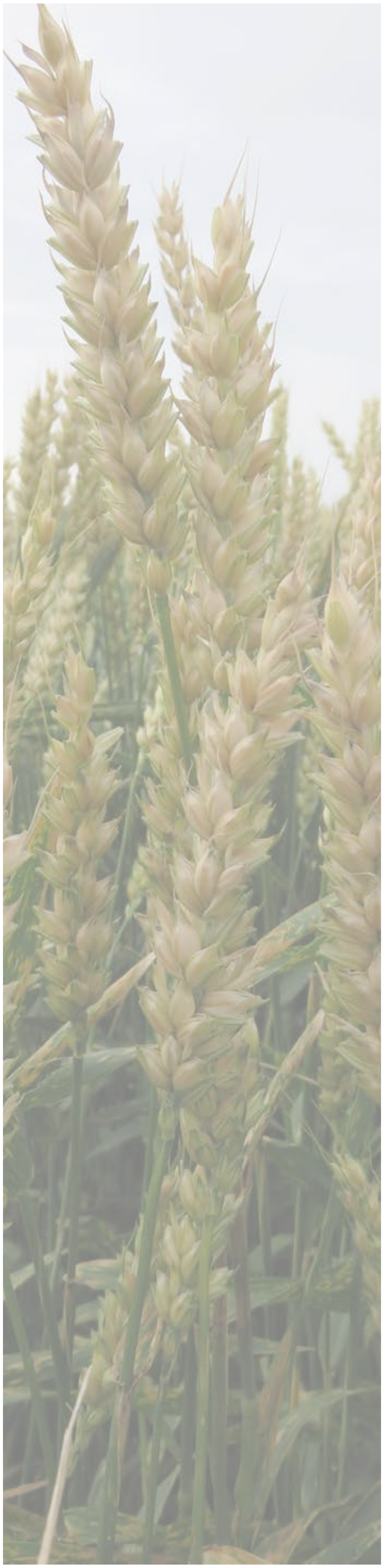
4.3 Winter wheat analysis and results

Winter wheat has two key differences relative to cotton. First, like soybean, soil insecticides and non-neonicotinoid seed treatments are not available as alternatives to neonicotinoid seed treatments in winter wheat. So again, as with soybean, cultural control practices (higher seeding densities or replanting) are used as the non-neonicotinoid control option for soil-dwelling pests, such as wireworms, targeted by neonicotinoid seed treatments in winter wheat. As a result, just as for soybean, Winter Wheat Tables 4, 6 and 9 report shares and acres allocated to cultural control, not soil insecticides or seed treatments, and Winter Wheat Table 10 is dropped. Second, like corn, no significant foliar applications of neonicotinoid insecticides occur in winter wheat. As a result, sections of several tables concerning reallocation of foliar neonicotinoid applications are empty and Winter Wheat Table 8 is not needed. However, because aphids are an above-ground pest targeted by neonicotinoid seed treatments that can be controlled with foliar applications, the analysis reallocates neonicotinoid product acres targeted at aphids to a foliar-based system for the non-neonicotinoid scenario.

No paper comparable to Gaspar et al. (2014) was available for wheat. As a result, the percentage seeding rate increase estimated by Gaspar et al. (2014) for soybean (almost 16 percent) is used here as a guide for wheat. Examining a variety of crop budgets for wheat showed a range of seeding rates from 50 to 150 lbs/A, with seed costs in 2014 ranging from $0.17/lb in Kansas to $0.37/lb in Nebraska, with $0.23 reported in Minnesota, $0.28 in Wisconsin, and $0.30 in South Carolina.[5] Based on these ranges, the analysis he used $0.30/lb as the cost for wheat seed. The final calculation to estimate the cost for increasing wheat seeding rates by 15 percent as a cultural practice to compensate for uncontrolled soil pests is 15% x 90 lbs/A x $0.30/lb = $4.32, the value reported in Winter Wheat Table 16. This cost is intended to be an average, with actual farmer costs varying substantially with local seeding rates and seed costs.

Of the 2010-2012 annual average of 9.0 million insecticide product acres in winter wheat, 6.9 million are in a soil-based insect management system exclusively using neonicotinoid seed treatments and 2.1 million are foliar-applied non-neonicotinoids. The 2010-2012 three-year average for winter wheat is 38.3 million planted acres, so that 18 percent of winter wheat planted acres are treated with a neonicotinoid seed treatment, with less than 22 percent of planted acres receiving an insecticide application of any type. In terms of target pests, wireworms, aphids and Hessian flies are the major targets of neonicotinoid seed treatments, with wireworms the target for 60 percent of the product acres. For the non-neonicotinoid scenario, aphid and Hessian fly product acres are allocated from neonicotinoid seed treatments to non-neonicotinoid foliar applications, while product acres targeted at wireworms use cultural control practices (higher seeding densities or replanting).

[5] The following wheat budgets were used (accessed August 12, 2014):
Kansas: http://www.agmanager.info/crops/budgets/proj_budget/FM-Guides--Crops--(2014).xls,
Minnesota: http://faculty.apec.umn.edu/wlazarus/documents/Cropbud.xlsm,
Nebraska: http://www.ianrpubs.unl.edu/epublic/live/ec872/build/ec872.pdf,
South Carolina: http://www.clemson.edu/extension/aes/budgets/files/wheat65.pdf, and
Wisconsin: http://www.uwex.edu/ces/farmteam/budgets/documents/2014CropBudgetCostofProductionCalculator-forWisconsin.xls.

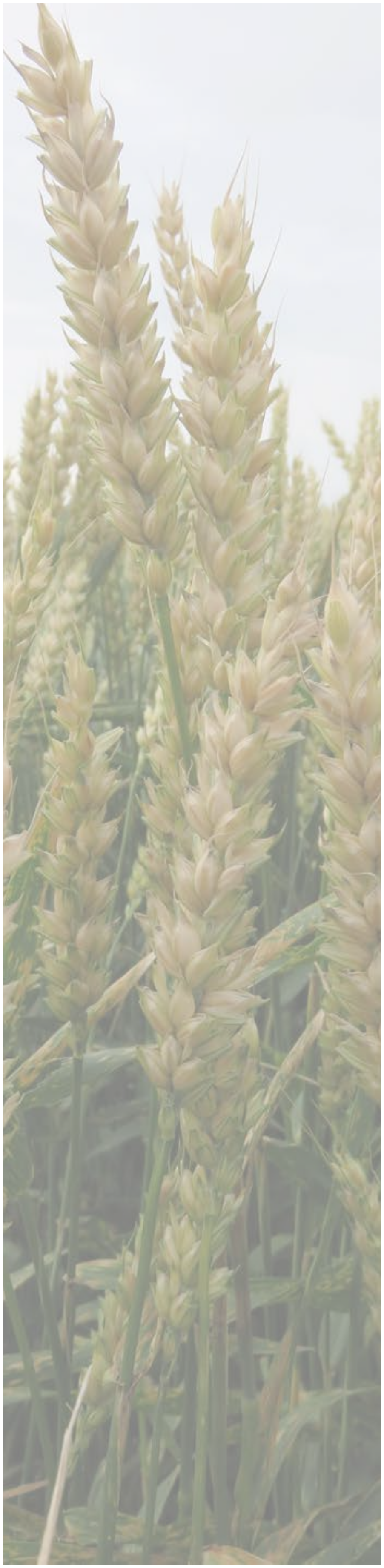


For the non-neonicotinoid scenario, the analysis projects that the 2010-2012 average of 6.9 million neonicotinoid seed treatment product acres in winter wheat would be replaced by 4.1 million acres of cultural control (higher seeding densities or replanting) to manage wireworms. In addition, an estimated 500,000 product acres of pyrethroids and not quite 140,000 product acres of organophosphates would be added, representing an increase of 39 percent in pyrethroid product acres and a 17 percent increase of organophosphate product acres in winter wheat. Estimated increases in pounds of AI applied are similar in magnitude – a 37 percent increase in the total pounds of pyrethroids applied and a 19 percent increase in organophosphates is projected for the non-neonicotinoid scenario. Note than an estimated 2.2 million neonicotinoid product acres would be scouted and not treated for control of aphids or Hessian fly when switching from a seed treatment to a foliar-based pest management system. As a result, insecticide product acres decrease from 9.0 million to 2.7 million, even as product acres for pyrethroids and organophosphates increase 39 percent and 17 percent respectively, and the share of insecticide product acres for pyrethroids increases from 14 percent to 65 percent, while the organophosphate share increases from 9 percent to 35 percent. Furthermore, winter wheat acres in foliar-based insect management systems are projected to increase 132 percent, from the 2010-2012 average of 2.1 million product acres per year to 4.9 million product acres under the non-neonicotinoid scenario.

Winter wheat growers would see an estimated net decrease in expenditures for insecticide AIs of $24 million for the non-neonicotinoid, a net increase in application costs of almost $5 million due to switching from seed treatments to foliar applications, and not quite an $18 million cost increase for cultural control (higher seeding densities or replanting). In addition, scouting costs would increase by almost $21 million, as winter wheat acres using foliar-based management systems are projected to more than double. The net effect is an increase of $19 million in costs for winter wheat growers for the non-neonicotinoid scenario. With 38.3 million winter wheat planted acres and 6.9 million neonicotinoid base acres in winter wheat, the estimated average cost benefit of neonicotinoids is $0.50 per planted acre or $2.76 per neonicotinoid treated base acre.

Winter Wheat Table 1. Product acres for all AIs and neonicotinoids (2010-2012 average).

		-------- Soil-based System --------		
	Foliar	**Seed Treatment**	**Soil-applied**	**Total**
Neonicotinoids	---	6,879,669	---	6,879,669
Non-Neonicotinoids	2,112,390	---	---	2,112,390
All AIs	2,112,390	6,879,669	---	8,992,059



Winter Wheat Table 2. Initial product acres for foliar-based and soil-based systems and remaining product acres after focusing on major pests targeted by neonicotinoids.

	-------Foliar-based Systems------		-------Soil-based Systems-------	
	All AIs	**Neonicotinoids**	**All AIs**	**Neonicotinoids**
Initial Product Acres	2,112,390	---	6,879,669	6,879,669
No Answer	9.4%	---	20.2%	20.2%
Targeted at Specific Pests	90.6%	---	79.8%	79.8%
Remaining Product Acres				
% of Initial Product Acres	26.9%	---	49.3%	49.3%
% Targeted at Specific Pests	29.7%	---	61.9%	61.9%

Winter Wheat Table 3. Non-neonicotinoid product acre shares by neonicotinoid target pest group for foliar-based systems.

Active Ingredient	Aphid	Hessian Fly
Chlorpyrifos	37.1%	
Cyfluthrin	7.4%	
Dimethoate	4.4%	
Gamma-Cyhalothrin	2.6%	40.0%
Lambda-Cyhalothrin	46.8%	60.0%
Zeta-Cypermethrin	1.7%	

Winter Wheat Table 4. Non-neonicotinoid cultural practice shares by neonicotinoid target pest group for soil-dwelling pests.

Practice	Aphid	Hessian Fly	Wireworm
Higher Seeding Rate*	0%	0%	100%

* No non-neonicotinoid seed treatments or soil insecticides labelled for wheat, so these are product acre shares allocated to higher seeding rates to compensate for losses due to soil-dwelling pests. See introductory text.

Winter Wheat Table 5. Share of neonicotinoid product acres targeted at each insect pest group for foliar-based and soil-based pest management systems.

Pest Control System	Aphid	Hessian Fly	Wireworm
Foliar-based	---	---	---
Soil-based	21.6%	18.4%	59.9%

Winter Wheat Table 6. Share of non-neonicotinoid product acres from foliar-based and from soil-based systems allocated to seed treatments, soil insecticides and foliar systems by target pest.

Pest Control System	Aphids	Hessian Fly	Wireworm
Foliar-based			
To Foliar-based	100%	100%	0%
Soil-based			
To Foliar-based	100%	100%	0%
To Cultural Practices*	0%	0%	100%

*No non-neonicotinoid seed treatments or soil-applied insecticides labeled for use in wheat, so neonicotinoid product acres allocated to higher seeding densities or replanting to compensate for uncontrolled soil pests.

Winter Wheat Table 7. Average number of applications for each AI and ratios of these averages.

	Average Number of Applications		Ratio of Average Non-Neonicotinoid Applications to Neonicotinoid Applications		
Active Ingredient	Soil-based*	Foliar-based	Soil:Soil	Foliar:Foliar**	Foliar:Soil
Chlorpyrifos		1.031		1.031	1.029
Cyfluthrin		1.027		1.027	1.025
Dimethoate		1.000		1.000	0.998
Gamma-Cyhalothrin		1.000		1.000	0.998
Lambda-Cyhalothrin		1.106		1.106	1.104
Zeta-Cypermethrin		1.014		1.014	1.012
Neonicotinoids	1.002	1.000**			

*No non-neonicotinoid seed treatments or soil-applied insecticides labeled for use in wheat.
**Foliar to foliar average application ratio calculated assuming the foliar neonicotinoid average number of applications is 1.000.

Winter Wheat Table 8. Neonicotinoid product acres in a foliar-based pest control system reallocated to each AI and target pest group in a foliar-based pest control system.

Table not relevant for winter wheat since no significant foliar use of neonicotinoid insecticides occurs.

Winter Wheat Table 9. Neonicotinoid product acres in a soil-based pest control system reallocated to cultural practices by target pest group.

Practice	Aphid	Hessian Fly	Wireworm	Total
Adjust Seeding Rate*	0	0	4,121,377	4,121,377
Total	**0**	**0**	**4,121,377**	**4,121,377**

*No non-neonicotinoid seed treatments or soil-applied insecticides labeled for use in wheat, so neonicotinoid product acres allocated to higher seeding densities or replanting to compensate for uncontrolled soil pests.

Winter Wheat Table 10. Non-neonicotinoid product acres in a soil insecticide pest management system by AI and target pest group reallocated from neonicotinoid product acres in a seed treatment pest management system.

Table not relevant for winter wheat.

Winter Wheat Table 11. Non-neonicotinoid product acres in a foliar-based pest management system by AI and target pest group reallocated from neonicotinoid product acres in a seed treatment pest management system.

Active Ingredient	Aphid	Hessian Fly	Wireworm	Total	AI Weights
Chlorpyrifos	123,797	0	0	123,797	19.4%
Cyfluthrin	24,631	0	0	24,631	3.9%
Dimethoate	14,284	0	0	14,284	2.2%
Gamma-Cyhalothrin	8,323	110,118	0	118,441	18.6%
Lambda-Cyhalothrin	167,370	182,914	0	350,284	55.0%
Zeta-Cypermethrin	5,483	0	0	5,483	0.9%
Total Treated with These AIs	343,888	293,032	0	636,920	100.0%
Scouted, Not Treated for These Pests	1,165,499	992,940	0	2,158,439	
Total	**1,509,387**	**1,285,972**	**0**	**2,795,359**	

Winter Wheat Table 12. Impact of the non-neonicotinoid scenario on non-neonicotinoid product acres by individual AIs and by insecticide class.

		Product Acres			
MOA	**Active Ingredient**	**2010-2012 Average**	**Added**	**New Total**	**Change**
1B	Chlorpyrifos	562,041	123,797	685,837	22%
3A	Cyfluthrin	274,839	24,631	299,470	9%
1B	Dimethoate	263,360	14,284	277,645	5%
3A	Gamma-Cyhalothrin	53,041	118,441	171,482	223%
3A	Lambda-Cyhalothrin	848,951	350,284	1,199,235	41%
4A	Neonicotinoids	6,879,669	-6,879,669	0	-100%
3A	Zeta-Cypermethrin	97,004	5,483	102,487	6%
Total Treated With These AIs*		**8,978,904**	**-6,242,749**	**2,736,155**	**-70%**
Non-Neonicotinoids*		2,099,235	636,920	2,736,155	30%
Neonicotinoids		6,879,669	-6,879,669	0	-100%
Scouted but Not Treated for These Pests			**2,158,439**	**2,158,439**	
Cultural Control			**4,121,377**	**4,121,377**	

		Product Acres			
MOA	**Insecticide Class**	**2010-2012 Average**	**Added**	**New Total**	**Change**
4A	Neonicotinoids	6,879,669	-6,879,669	0	-100%
1B	Organophosphates	825,401	138,081	963,482	17%
3A	Pyrethroids	1,273,834	498,839	1,772,673	39%
Total Treated With These AIs*		**8,978,904**	**-6,242,749**	**2,736,155**	**-70%**
Non-Neonicotinoids*		2,099,235	636,920	2,736,155	30%
Neonicotinoids		6,879,669	-6,879,669	0	-100%
Scouted but Not Treated for These Pests			**2,158,439**	**2,158,439**	
Cultural Control			**4,121,377**	**4,121,377**	

*Does not match Winter Wheat Table 1 totals because totals here do not include minor-use AIs.

Farmers must meet an array of demands and challenges every day: growing crops that have minimal disease and insect damage, protecting the environment, and providing food, feed, fiber and fuel for communities across the globe. Seed treatment is a precise mode of applying crop protection products directly to the surface of a seed, providing protection during a plant's most vulnerable developmental stages.

Infographic: *The Role of Seed Treatment in Modern Agriculture.* (2013). CropLife Foundation. http://tellmemore.croplifeamerica.org/wp-content/uploads/2013/12/SeedTreatmentModernAg.jpg.

Winter Wheat Table 13. Average application rate (pounds per product acre) for each AI by method of application (foliar-applied, soil-applied, seed treatment).

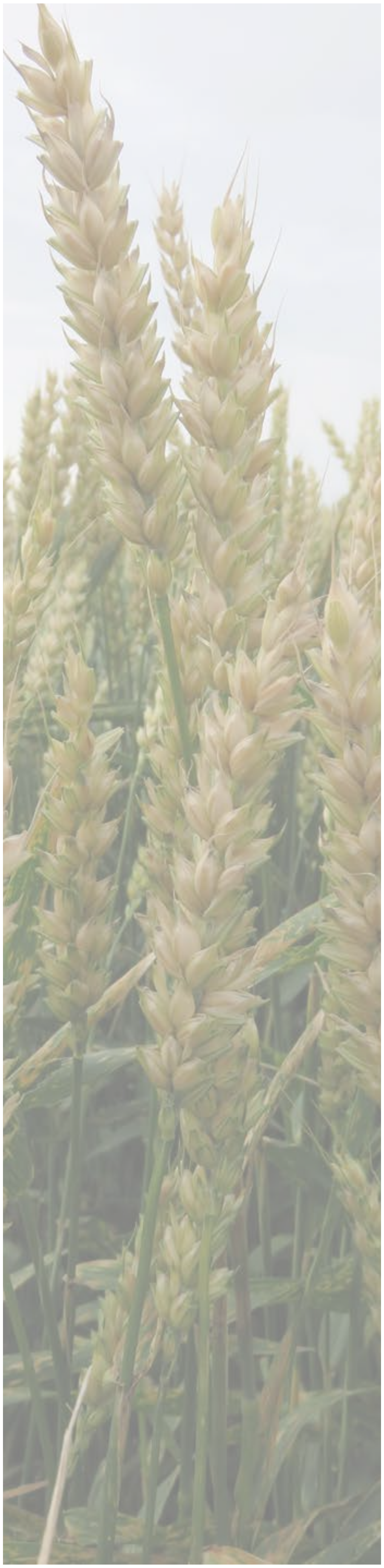
		---Average Application Rate (Pounds per Product Acre)---		
MOA	**Active Ingredient**	**Foliar**	**Seed Treatment***	**Soil Insecticide***
1B	Chlorpyrifos	0.4842		
3A	Cyfluthrin	0.0176		
1B	Dimethoate	0.2974		
3A	Gamma-Cyhalothrin	0.0076		
3A	Lambda-Cyhalothrin	0.0195		
4A	Neonicotinoids		0.0180	
3A	Zeta-Cypermethrin	0.0200		

*No soil insecticides or non-neonicotinoid seed treatments registered for use in wheat.

Winter Wheat Table 14. Impact of the non-neonicotinoid scenario on pounds of AI applied by insecticide class.

		---------Average Application Rate (Pounds per Product Acre)-------			
MOA	**Active Ingredient**	**2010-2012 Average**	**Added**	**New Total**	**Change**
1B	Chlorpyrifos	265,778	59,944	325,722	23%
3A	Cyfluthrin	4,838	434	5,272	9%
1B	Dimethoate	78,312	4,248	82,560	5%
3A	Gamma-Cyhalothrin	383	905	1,288	236%
3A	Lambda-Cyhalothrin	15,479	6,834	22,314	44%
4A	Neonicotinoids	124,108	-124,108	0	-100%
3A	Zeta-Cypermethrin	1,943	110	2,052	6%
	Total	**490,841**	**-51,633**	**439,208**	**-11%**

		Pounds of Active Ingredient Applied			
MOA	Insecticide Class	**2010-2012 Average**	**Added**	**New Total**	**Change**
4A	Neonicotinoids	124,108	-124,108	0	-100%
1B	Organophosphates	344,090	64,192	408,282	19%
3A	Pyrethroids	22,643	8,283	30,926	37%
	Total	**490,841**	**-51,633**	**439,208**	**-11%**



Winter Wheat Table 15. Impact of the non-neonicotinoid scenario on product acres using foliar-based and soil-based pest management systems.

Category	Foliar-based	Soil-based	Total
2010-2012 Average Product Acres (All AIs)	2,112,390	6,879,669	8,992,059
Neonicotinoid Product Acres to be Reallocated	0	6,879,669	6,879,669
Total Non-Neonicotinoid Product Acres Added	2,795,359	4,121,377	6,916,736
Scouted and Treated	636,920	0	636,920
Scouted Only	2,158,439	0	2,158,439
Cultural Control	0	4,121,377	
New Total Product Acres	4,907,749	4,121,377	9,029,125
Net Change (Product Acres)	**2,795,359**	**-2,758,292**	**37,067**
Net Change (%)	**132%**	**-40%**	**0.4%**

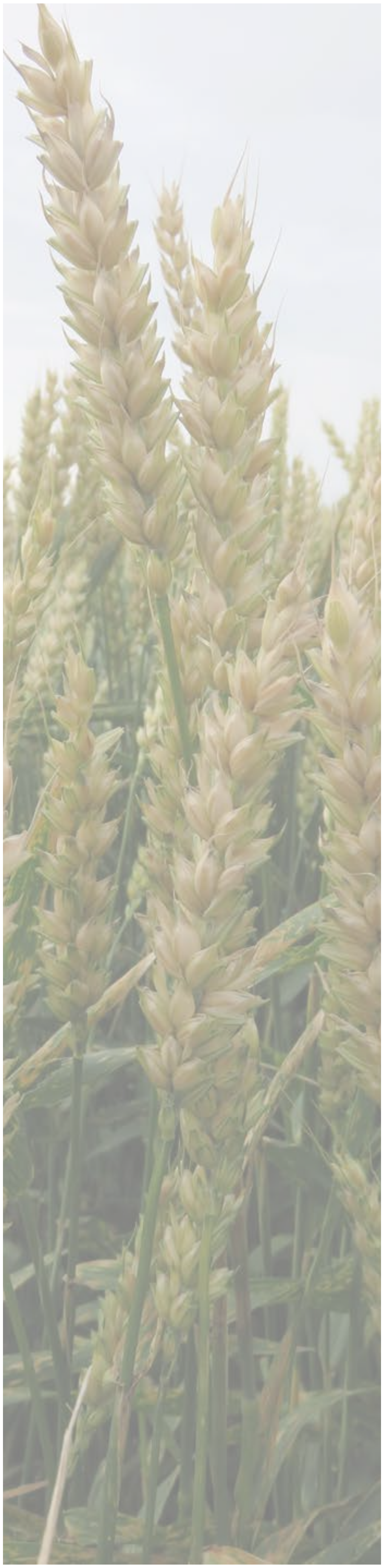
Winter Wheat Table 16. Average cost for each AI ($/Product Acre) for 2010-2012 for foliar and soil use (not including application costs), plus application and scouting costs.

Active Ingredient	Foliar ($/Product Acre)	Seed Treatment ($/Product Acre)
Chlorpyrifos	5.79	
Cyfluthrin	3.28	
Dimethoate	2.86	
Gamma-Cyhalothrin	2.94	
Lambda-Cyhalothrin	3.69	
Zeta-Cypermethrin	4.71	
Neonicotinoid Average		**3.88**
Application Costs	**7.20**	
Scouting Costs	**7.44**	
Adjust Seeding Rate*		**4.32**

*See introductory text for explanation.

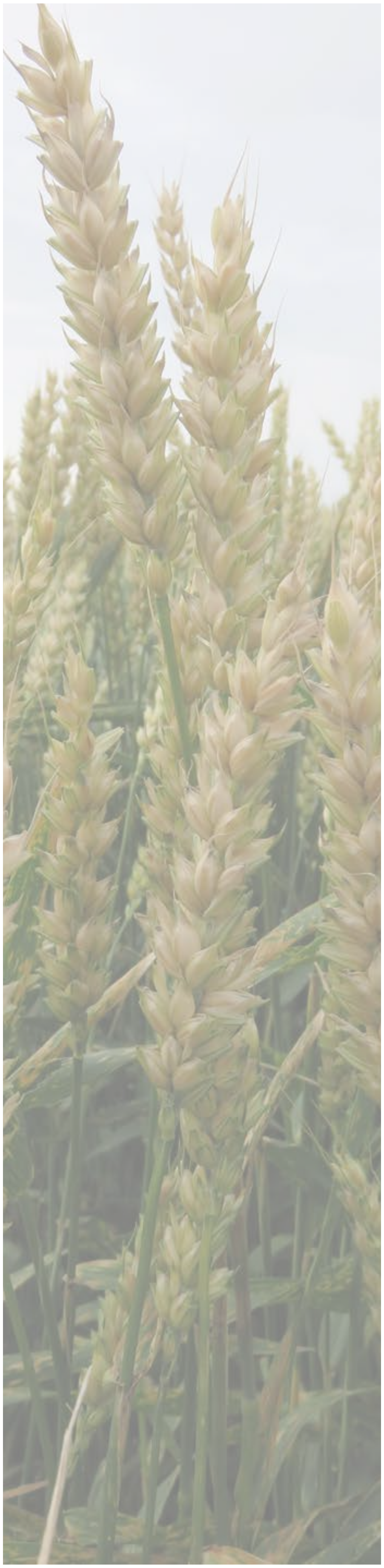
[Neonicotinoids] control pest populations resistant to conventional insecticides and exhibit long-lasting residual effects, especially in seed treatment and soil application. [They also have] excellent plant virus vector control, high systemicity and versatile application methods, combined with high operator and consumer safety.

Page 1103. Elbert, A., Haas, M., Springer, B., Thielert, W., & Nauen, R. (2008). *Applied aspects of neonicotinoid uses in crop protection*. Pest Management Science, 64(11), 1099–1105. doi:10.1002/ps.1616.



Winter Wheat Table 17. Reported cost ($/A) for foliar applications and insect scouting based on custom rates and budgets from multiple states.

State	Year	Apply ($/A)	Scout ($/A)	Source
AR	2013	6.50	9.00	http://www.uaex.edu/depts/ag_economics/budgets/2013/Budgets2013.pdf
AL	2013	9.00	8.00	http://www.aces.edu/agriculture/business-management/budgets/2013/rowcrops.php
CO	2012	7.27		http://www.coopext.colostate.edu/abm/custrates12.pdf
GA	2013		10.00	http://www.ugacotton.com/vault/file/2013BUDGETS.pdf
IA	2013	7.30	4.95	http://www.extension.iastate.edu/agdm/crops/pdf/a3-10.pdf
ID	2011	7.11		http://www.cals.uidaho.edu/edcomm/pdf/BUL/BUL0729.pdf
KS	2013	6.03		http://www.kingman.ksu.edu/doc46174.ashx
KY	2013	7.00		http://www2.ca.uky.edu/cmspubsclass/files/ghalich/CustomMachineryRatesKentucky2013.pdf
MI	2012	7.55	5.00	https://www.msu.edu/~steind/1_2012%20Cust_MachineWrk%20 10_31_11.pdf
MN	2013	5.14		http://faculty.apec.umn.edu/wlazarus/documents/machdata.pdf
MO	2012	7.59	8.00	http://extension.missouri.edu/explorepdf/agguides/agecon/g00302.pdf http://extension.missouri.edu/seregion/Crop_Budgets_PDF.htm
MS	2013		7.00	http://www.agecon.msstate.edu/whatwedo/budgets/docs/MSUCOT14.pdf
ND	2010	6.00		http://www.nass.usda.gov/Statistics_by_State/North_Dakota/Publications/Custom_Rates/index.asp
NE	2012	7.42		http://ianrpubs.unl.edu/epublic/live/ec823/build/ec823.pdf
NY	2011	10.00		http://blogs.cornell.edu/ccefranklin//files/2010/04/2011-Custom-Rates.pdf
OK	2011	6.17		http://oces.okstate.edu/kay/ag/CustomRates%202011-2012.pdf/at_download/file
PA	2013	11.30		http://farmprogress.com/mdfm/Faress1/author/198/2013%20Custom-Rates.pdf
SC	2013		9.00	http://www.clemson.edu/extension/aes/budgets/
TN	2013	8.46	9.50	http://economics.ag.utk.edu/extension/pubs/CustomRates2013-rev.pdf http://economics.ag.utk.edu/budgets/2014/2014RowCropBudgets.pdf
TX	2013	6.22		http://agecoext.tamu.edu/files/2012/05/CustomRateSurveyMay2013.pdf
WI	2010	7.70		http://www.nass.usda.gov/Statistics_by_State/Wisconsin/Publications/custom_rates_2010.pdf



Winter Wheat Table 18. Estimated grower costs for alternative AIs, application and scouting for foliar-based systems in the non-neonicotinoid scenario.

	------------ Foliar to Foliar ----------			----------Seed Treatment to Foliar---------		
Active Ingredient	**Added Acres**	**Cost ($/A)**	**Total Cost**	**Added Acres**	**Cost ($/A)**	**Total Cost**
Chlorpyrifos				123,797	5.79	716,513
Cyfluthrin				24,631	3.28	80,795
Dimethoate				14,284	2.86	40,843
Gamma-Cyhalothrin				118,441	2.94	348,226
Lambda-Cyhalothrin				350,284	3.69	1,293,524
Zeta-Cypermethrin				5,483	4.71	25,820
Scouted & Treated				**636,920**	**3.93**	**2,505,721**
Scouted Only				**2,158,439**		
Application				**636,920**	**7.20**	**4,585,822**
Scouting*				**2,795,359**	**7.44**	**20,797,470**

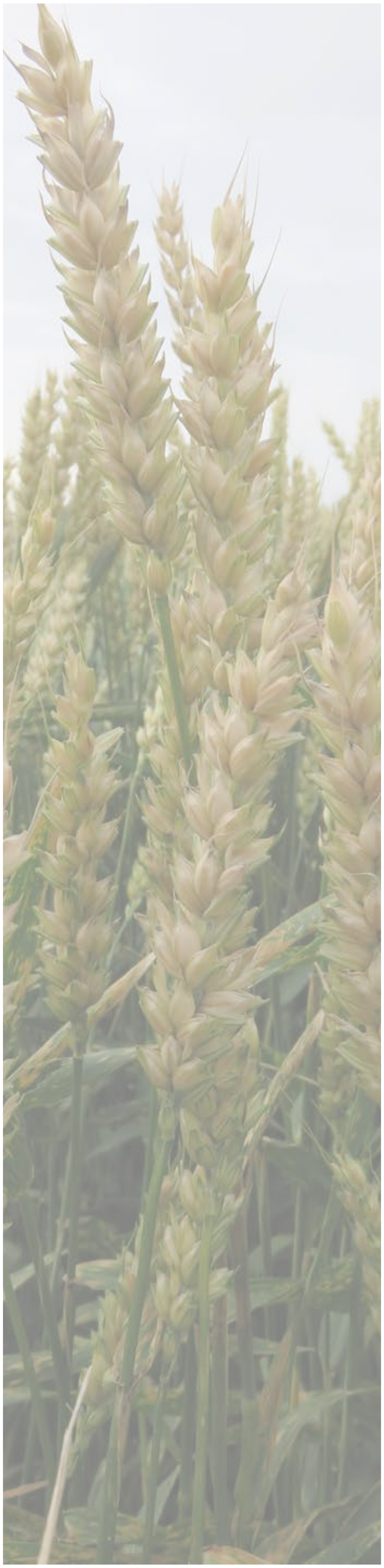
Winter Wheat Table 19. Estimated grower costs for alternative AIs, application and scouting for soil-based systems in the non-neonicotinoid scenario.

Cultural Practice	**Added Acres**	**Cost** ($/A)	**Total Cost**
Adjust Seeding Rate	4,121,377	4.32	17,804,348
Total	**4,121,377**	**4.32**	**17,804,348**

Winter Wheat Table 20. Estimated grower costs for neonicotinoid AIs, application and scouting for the 2010-2012 average neonicotinoid use.

	------------- Foliar Use-------------			------- Seed Treatment Use -------		
Cost Category	**Original Acres**	**Cost ($/A)**	**Total Cost**	**Original Acres**	**Cost ($/A)**	**Total Cost**
Active Ingredients				6,879,669	3.88	26,707,249
Application*						
Scouting*						

*Does not change for the non-neonicotinoid scenario.

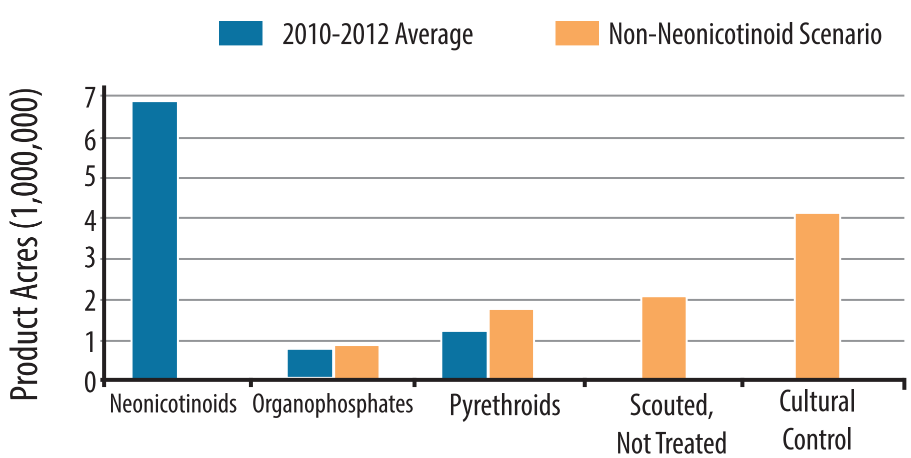


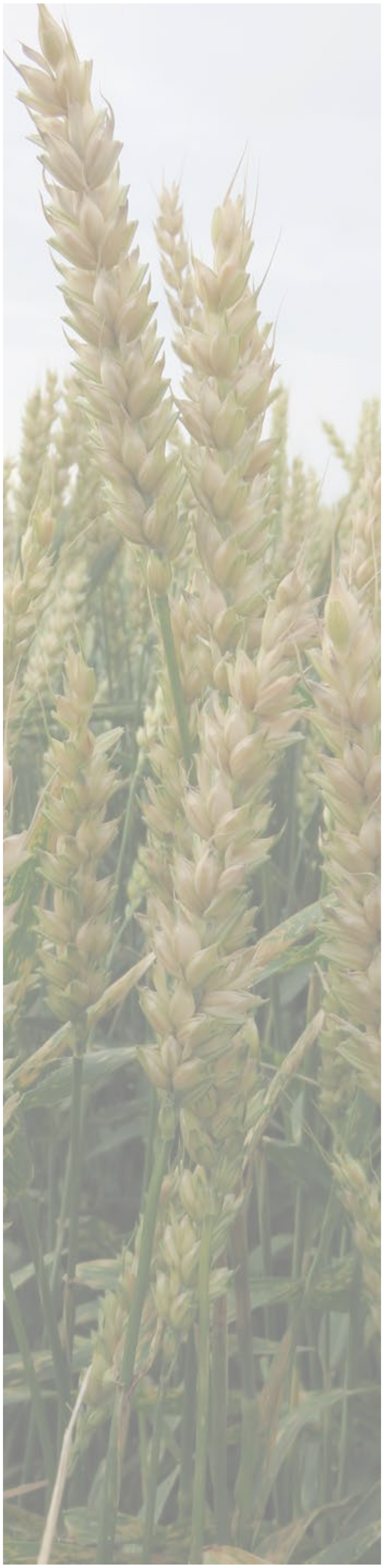
Winter Wheat Table 21. Estimated net change in grower expenditures for the non-neonicotinoid scenario.

	Avoided Expenditures From the Current System	New Expenditures for the Non-Neonicotinoid Scenario	Net Change in Grower Expenditures
Soil AI Costs	26,707,249	---	-26,707,249
Foliar AI Costs	---	2,505,721	2,505,721
Soil Application Costs	---	---	---
Foliar Application Costs	---	4,585,822	4,585,822
Soil Scouting Costs	---	---	---
Foliar Scouting Costs	---	20,797,470	20,797,470
Cultural Control	---	17,804,348	17,804,348
Total Costs	**26,707,249**	**45,693,360**	**18,986,112**

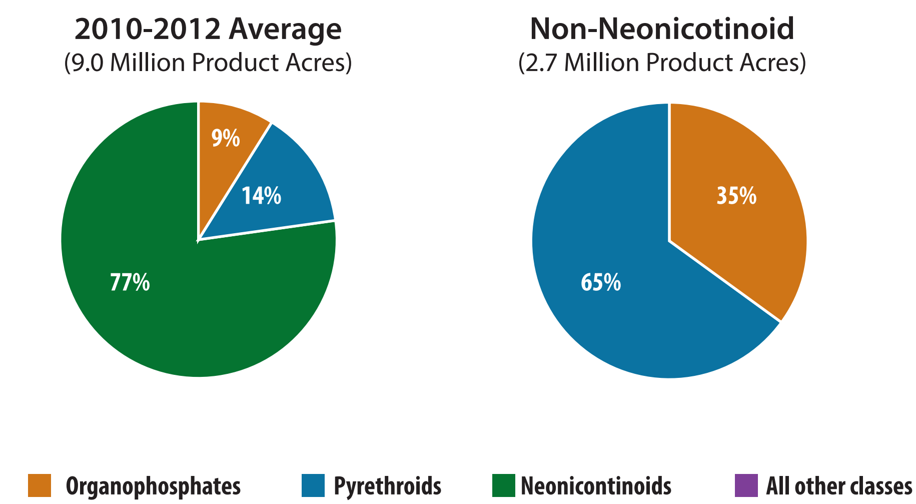
Net Change in Grower Expenditures	Acres	$/Acre
Neonicotinoid Base Acres Treated	6,873,437	2.76
Planted Acres	38,269,999	0.50

Winter Wheat Figure 1. 2010-2012 average product acres and new total product acres for the non-neonicotinoid scenario by insecticide class.

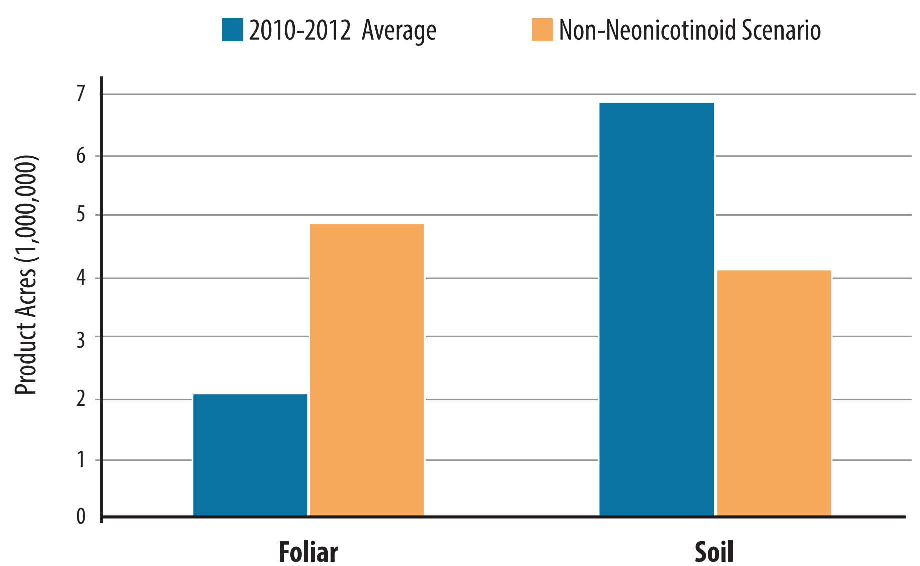




Winter Wheat Figure 2. 2010-2012 average shares of total insecticide product acres allocated to major insecticide modes of action and estimated shares for the non-neonicotinoid scenario. (Shares are based on product acres in Winter Wheat Table 12 and do not include product acres reallocated to "scouted but not treated" or to "cultural control.")



Winter Wheat Figure 3. 2010-2012 annual average product acres and new total product acres for the non-neonicotinoid scenario using foliar-based and soil-based pest management systems. (Foliar-based includes both acres "scouted and treated" as well as "scouted and not treated"; soil-based includes "seed treatments" and "higher seeding density".)



4.4 Spring wheat analysis and results

Spring wheat is very similar to winter wheat in terms of this analysis. First, like winter wheat and soybean, non-neonicotinoid soil insecticides and seed treatments are not available as alternatives to neonicotinoid seed treatments. Thus again, cultural control practices (higher seeding densities or replanting) are used as the non-neonicotinoid control option for soil-dwelling pests, such as wireworms, targeted by neonicotinoid seed treatments in spring wheat. As a result, just as for winter wheat and soybean, Spring Wheat Tables 4, 6 and 9 report shares and acres allocated to cultural control, not soil insecticides or seed treatments, and Spring Wheat Table 10 is dropped. Second, just like winter wheat and corn, no significant foliar applications of neonicotinoid insecticides occur in spring wheat. As a result, sections of several tables concerning reallocation of foliar neonicotinoid applications are empty and Spring Wheat Table 8 is not needed. However, because aphids are an above-ground pest targeted by neonicotinoid seed treatments that can be controlled with foliar applications, the analysis reallocates neonicotinoid product acres targeted at aphids to a foliar-based system for the non-neonicotinoid scenario.

Just as for winter wheat, no paper comparable to Gaspar et al. (2014) was available, and so spring wheat used the same average cost estimate for higher seeding densities and replanting as used for winter wheat. Thus, the final calculation to estimate the cost for increasing wheat seeding rates by 15 percent as a cultural practice to compensate for uncontrolled soil pests is 15% x 90 lbs/A x \$0.30/lb = \$4.32, the value reported in Spring Wheat Table 16. This cost is intended to be an average, with actual farmer costs varying substantially with local seeding rates and seed costs.

Of the 2010-2012 annual average of 5.9 million insecticide product acres in spring wheat, 3.8 million are in a soil-based insect management system exclusively using neonicotinoid seed treatments and 2.1 million are foliar-applied non-neonicotinoids. The 2010-2012 three-year average for spring wheat is 14.9 million planted acres, so that 25 percent of spring wheat planted acres are treated with a neonicotinoid seed treatment, with almost 35 percent of planted acres receiving an insecticide application of some type. Wireworms are the target pest for 97 percent of neonicotinoid seed treatment product acres in spring wheat, with aphids and, to a very small extent, Hessian flies comprising the remaining target pests. Because non-neonicotinoid soil insecticide or seed treatments are not available for spring wheat, for the non-neonicotinoid scenario, product acres targeted at wireworms are reallocated to cultural control practices (higher seeding densities or replanting), while the few aphid and Hessian fly product acres are reallocated to non-neonicotinoid foliar applications.

For the non-neonicotinoid scenario, the analysis projects that the 2010-2012 average of 3.8 million neonicotinoid seed treatment product acres in spring wheat would be replaced by 3.7 million acres of cultural control (higher seeding densities or replanting) to manage wireworms. In addition, an estimated 40,000 product acres of pyrethroids and organophosphates would be added, representing an increase of 2 percent in product acres and total pounds applied in winter wheat for each insecticide class. Finally, about 74,000 neonicotinoid product acres in spring wheat would be scouted and not treated for control of aphids or Hessian flies when

switching from a seed treatment to a foliar-based pest management system for the non-neonicotinoid scenario. As a result, insecticide product acres decrease from 5.8 million to 2.1 million, but the share of insecticide product acres for pyrethroids increases from 20 percent to 57 percent, while the organophosphate share increases from 15 percent to 43 percent. Furthermore, spring wheat acres in foliar-based insect management systems are projected to increase 6 percent by adding almost 115,000 acres under the non-neonicotinoid scenario.

Spring wheat growers would see an estimated net decrease in expenditures for insecticide AIs of almost $10 million for the non-neonicotinoid, a net increase in application costs of almost $300,000 due to switching from seed treatments to foliar applications, and almost a $16 million cost increase for cultural control (higher seeding densities or replanting). In addition, scouting costs would increase by about $850,000, as spring wheat acres using foliar-based management systems are projected to increase. The net effect is an increase of $7.4 million in costs for spring wheat growers for the non-neonicotinoid scenario. With 14.9 million spring wheat planted acres and 3.8 million neonicotinoid base acres in spring wheat, the estimated average cost benefit of neonicotinoids is $0.50 per planted acre or $1.97 per neonicotinoid treated base acre.

Spring Wheat Table 1. Product acres for all AIs and neonicotinoids (2010-2012 average).

		-------- Soil-based System --------		
	Foliar	**Seed Treatment**	**Soil-applied**	**Total**
Neonicotinoids	---	3,782,494	---	3,782,494
Non-Neonicotinoids	2,071,111	---	---	2,071,111
All AIs	2,071,111	3,782,494	---	5,853,605

Spring Wheat Table 2. Initial product acres for foliar-based and soil-based systems and remaining product acres after focusing on major pests targeted by neonicotinoids.

	-------Foliar-based Systems------		-------Soil-based Systems-------	
	All AIs	**Neonicotinoids**	**All AIs**	**Neonicotinoids**
Initial Product Acres	2,071,111	---	3,782,494	3,782,494
No Answer	5.4%	---	26.6%	26.6%
Targeted at Specific Pests	94.6%	---	73.4%	73.4%
Remaining Product Acres				
% of Initial Product Acres	41.7%	---	51.7%	51.7%
% Targeted at Specific Pests	44.1%	---	70.4%	70.4%

Spring Wheat Table 3. Non-neonicotinoid product acre shares by neonicotinoid target pest group for foliar-based systems.

Active Ingredient	Aphid	Hessian Fly
Chlorpyrifos	40.2%	
Cyfluthrin	5.2%	
Dimethoate	2.4%	
Lambda-Cyhalothrin	34.4%	100.0%
Methyl Parathion	7.6%	
Zeta-Cypermethrin	10.3%	

Spring Wheat Table 4. Non-neonicotinoid cultural practice shares by neonicotinoid target pest group for soil-dwelling pests.

Practice	Aphid	Hessian Fly	Wireworm
Higher Seeding Rate*	0%	0%	100.0%

* No non-neonicotinoid seed treatments or soil insecticides labeled for wheat, so these are product acre shares allocated to higher seeding rates to compensate for losses due to soil-dwelling pests. See introductory text.

Spring Wheat Table 5. Share of neonicotinoid product acres targeted at each insect pest group for foliar-based and soil-based pest management systems.

Pest Control System	Aphid	Hessian Fly	Wireworm
Foliar-based	---	---	---
Soil-based	2.9%	0.1%	97.0%

Systemic neonicotinoid insecticide seed-piece treatments are effective against adults and larvae but are ineffective when summer adults emerge from pupation. Growers use insecticides with a different mode of action against summer adults and their offspring, helping to slow the beetle's resistance to insecticides.

Page 48, Crop Life Foundation. November 2013. *The Role of Seed Treatment in Modern U.S. Crop Production: A Review of Benefits.* Washington, D.C. Retrieved from: http://www.croplifeamerica.org/sites/default/files/SeedTreatment.pdf.

Spring Wheat Table 6. Share of non-neonicotinoid product acres from foliar-based and from soil-based systems allocated to seed treatments, soil insecticides and foliar systems by target pest.

Pest Control System	Aphid	Hessian Fly	Wireworm
Foliar-based			
To Foliar-based	100%	100%	0%
Soil-based			
To Foliar-based	100%	100%	0%
To Cultural Practices*	0%	0%	100%

*No non-neonicotinoid seed treatments or soil-applied insecticides labeled for use in wheat, so neonicotinoid product acres allocated to higher seeding densities or replanting to compensate for uncontrolled soil pests.

Spring Wheat Table 7. Average number of applications for each AI and ratios of these averages.

	Average Number of Applications		Ratio of Average Number of Applications to Neonicotinoid Average		
Active Ingredient	Soil-based	Foliar-based	Soil-based*	Foliar-based**	Soil-based
Chlorpyrifos		1.005		1.005	1.005
Cyfluthrin		1.000		1.000	1.000
Dimethoate		1.000		1.000	1.000
Lambda-Cyhalothrin		1.113		1.113	1.113
Methyl Parathion		1.000		1.000	1.000
Zeta-Cypermethrin		1.000		1.000	1.000
Neonicotinoids	1.000	1.000**			

*No non-neonicotinoid seed treatments or soil-applied insecticides labeled for use in wheat.
**Foliar to foliar average application ratio calculated assuming the foliar neonicotinoid average number of applications is 1.000.

Spring Wheat Table 8. Neonicotinoid product acres in a foliar-based pest control system reallocated to each AI and target pest group in a foliar-based pest control system.

Table not relevant for spring wheat since no significant foliar use of neonicotinoid insecticides occurs.

Spring Wheat Table 9. Neonicotinoid product acres in a soil-based pest control system reallocated to cultural practices by target pest group.

Practice	Aphid	Hessian Fly	Wireworm	Total
Adjust Seeding Rate*	0	0	3,669,775	3,669,775
Total	**0**	**0**	**3,669,775**	**3,669,775**

*No non-neonicotinoid seed treatments or soil-applied insecticides labeled for use in wheat, so neonicotinoid product acres allocated to higher seeding densities or replanting to compensate for uncontrolled soil pests.

Spring Wheat Table 10. Non-neonicotinoid product acres in a soil insecticide pest management system by AI and target pest group reallocated from neonicotinoid product acres in a seed treatment pest management system.

Table not relevant for spring wheat.

Spring Wheat Table 11. Non-neonicotinoid product acres in a foliar-based pest management system by AI and target pest group reallocated from neonicotinoid product acres in a seed treatment pest management system.

Active Ingredient	Aphid	Hessian Fly	Wireworm	Total	AI Weights
Chlorpyrifos	15,167	0	0	15,167	37.1%
Cyfluthrin	1,933	0	0	1,933	4.7%
Dimethoate	905	0	0	905	2.2%
Lambda-Cyhalothrin	14,345	1,802	0	16,148	39.5%
Methyl Parathion	2,852	0	0	2,852	7.0%
Zeta-Cypermethrin	3,850	0	0	3,850	9.4%
Total Treated With These AIs	39,053	1,802	0	40,855	100.0%
Scouted, Not Treated for These Pests	70,533	3,045	0	73,578	
Total	**109,586**	**4,847**	**0**	**114,433**	

Since the market introduction of IMI [imidacloprid] , neonicotinoids have become the fastest-growing class of chemical insecticides. This tremendous success can be explained by their unique chemical and biological properties, such as broad-spectrum insecticidal activity, low application rates and their versatility in application methods, excellent systemic characteristics … and their favorable safety profile. However, they have also profited from the withdrawal of older compounds owing to increased regulatory hurdles, for example for organophosphates.

Page 1087, Jeschke, P., & Nauen, R. (2008). *Neonicotinoids—from zero to hero in insecticide chemistry*. Pest Management Science, 64(11), 1084–1098. doi:10.1002/ps.1631.

Spring Wheat Table 12. Impact of the non-neonicotinoid scenario on non-neonicotinoid product acres by individualAIs and by insecticide class.

		Product Acres			
MOA	**Active Ingredient**	**2010-2012 Average**	**Added**	**New Total**	**Change**
1B	Chlorpyrifos	745,971	15,167	761,138	2%
3A	Cyfluthrin	121,611	1,933	123,544	2%
1B	Dimethoate	27,204	905	28,109	3%
3A	Lambda-Cyhalothrin	905,292	16,148	921,440	2%
1B	Methyl Parathion	131,808	2,852	134,660	2%
4A	Neonicotinoids	3,782,494	-3,782,494	0	-100%
3A	Zeta-Cypermethrin	126,452	3,850	130,302	3%
Total Treated With These AIs*		**5,840,832**	**-3,741,639**	**2,099,193**	**-64%**
Non-Neonicotinoids*		2,058,338	40,855	2,099,193	2%
Neonicotinoids		3,782,494	-3,782,494	0	-100%
Scouted but Not Treated for These Pests			**73,578**	**73,578**	
Cultural Control			**3,669,775**	**3,669,775**	

		Product Acres			
MOA	**Insecticide Class**	**2010-2012 Average**	**Added**	**New Total**	**Change**
4A	Neonicotinoids	3,782,494	-3,782,494	0	-100%
1B	Organophosphates	904,983	18,924	923,907	2%
3A	Pyrethroids	1,153,355	21,931	1,175,286	2%
Total Treated With These AIs*		**5,840,832**	**-3,741,639**	**2,099,193**	**-64%**
Non-Neonicotinoids*		2,058,338	40,855	2,099,193	2%
Neonicotinoids		3,782,494	-3,782,494	0	-100%
Scouted but Not Treated for These Pests			**73,578**	**73,578**	
Cultural Control			**3,669,775**	**3,669,775**	

*Does not match Spring Wheat Table 1 totals because totals here do not include minor-use AIs.

EPA approved the use of a neonicotinoid called imidacloprid in 1994, and it has since become the most widespread insecticide in the world. Approved for use in about 140 crops and numerous garden and horticultural products, sales topped $1 billion in 2009.

Page 674, Stokstad, E. (2013). *Pesticides under fire for risks to pollinators.* Science, 340, 674-676.

Spring Wheat Table 13. Average application rate (pounds per product acre) for each AI by method of application (foliar-applied, soil-applied, seed treatment).

		---Average Application Rate (Pounds per Product Acre)---		
MOA	**Active Ingredient**	**Foliar**	**Seed Treatment***	**Soil Insecticide***
1B	Chlorpyrifos	0.2934		
3A	Cyfluthrin	0.0112		
1B	Dimethoate	0.2719		
3A	Lambda-Cyhalothrin	0.0185		
1B	Methyl Parathion	0.2258		
4A	Neonicotinoids		0.0104	
3A	Zeta-Cypermethrin	0.0113		

*No soil insecticides or non-neonicotinoid seed treatments registered for use in wheat.

Spring Wheat Table 14. Impact of the non-neonicotinoid scenario on pounds of AI applied by insecticide class.

		---------------Pounds of Active Ingredient Applied---------------			
MOA	**Active Ingredient**	**2010-2012 Average**	**Added**	**New Total**	**Change**
1B	Chlorpyrifos	210,623	4,450	215,073	2%
3A	Cyfluthrin	1,367	22	1,389	2%
1B	Dimethoate	7,397	246	7,643	3%
3A	Lambda-Cyhalothrin	16,724	298	17,022	2%
1B	Methyl Parathion	29,760	644	30,404	2%
3A	Zeta-Cypermethrin	1,433	44	1,477	3%
4A	Neonicotinoids	39,236	-39,236	0	-100%
	Total	**306,540**	**-33,533**	**273,008**	**-11%**

		---------------Pounds of Active Ingredient Applied---------------			
MOA	**Insecticide Class**	**2010-2012 Average**	**Added**	**New Total**	**Change**
4A	Neonicotinoids	39,236	-39,236	0	-100%
1B	Organophosphates	247,780	5,340	253,120	2%
3A	Pyrethroids	19,524	364	19,888	2%
	Total	**306,540**	**-33,533**	**273,008**	**-11%**

Spring Wheat Table 15. Impact of the non-neonicotinoid scenario on product acres using foliar-based and soil-based pest management systems.

Category	Foliar-based	Soil-based	Total
2010-2012 Average Product Acres (All AIs)	2,071,111	3,782,494	5,853,605
Neonicotinoid Product Acres to be Reallocated	0	3,782,494	3,782,494
Total Non-Neonicotinoid Product Acres Added	114,433	3,669,775	3,784,207
Scouted and Treated	40,855	0	40,855
Scouted Only	73,578	0	73,578
Cultural Control	0	3,669,775	
New Total Product Acres	2,185,544	3,669,775	5,855,319
Net Change (Product Acres)	**114,433**	**-112,719**	**1,713**
Net Change (%)	**6%**	**-3%**	**0%**

Spring Wheat Table 16. Average cost for each AI ($/Product Acre) for 2010-2012 for foliar and soil use (not including application costs), plus application and scouting costs.

Active Ingredient	Foliar ($/Product Acre)	Seed Treatment ($/Product Acre)
Chlorpyrifos	2.99	
Cyfluthrin	2.52	
Dimethoate	4.12	
Lambda-Cyhalothrin	3.24	
Methyl Parathion	3.17	
Zeta-Cypermethrin	2.12	
Neonicotinoid Average		**2.56**
Application Costs	**7.20**	
Scouting Costs	**7.44**	
Adjust Seeding Rate*		**4.32**

*See introductory text for explanation.

If neonicotinoids are not available, then farmers will have to choose alternative pest-management strategies, alternative crops or accept greater losses.

Page 3, Godfray, H. C. J., Blacquière, T., Field, L. M., Hails, R. S., Petrokofsky, G., Potts, S. G., ... & McLean, A. R. (2014). *A restatement of the natural science evidence base concerning neonicotinoid insecticides and insect pollinators.* Proceedings of the Royal Society B: Biological Sciences, 281(1786), 20140558.

Spring Wheat Table 17. Reported cost ($/A) for foliar applications and insect scouting based on custom rates and budgets from multiple states.

State	Year	Apply ($/A)	Scout ($/A)	Source
AR	2013	6.50	9.00	http://www.uaex.edu/depts/ag_economics/budgets/2013/Budgets2013.pdf
AL	2013	9.00	8.00	http://www.aces.edu/agriculture/business-management/budgets/2013/rowcrops.php
CO	2012	7.27		http://www.coopext.colostate.edu/abm/custrates12.pdf
GA	2013		10.00	http://www.ugacotton.com/vault/file/2013BUDGETS.pdf
IA	2013	7.30	4.95	http://www.extension.iastate.edu/agdm/crops/pdf/a3-10.pdf
ID	2011	7.11		http://www.cals.uidaho.edu/edcomm/pdf/BUL/BUL0729.pdf
KS	2013	6.03		http://www.kingman.ksu.edu/doc46174.ashx
KY	2013	7.00		http://www2.ca.uky.edu/cmspubsclass/files/ghalich/CustomMachineryRatesKentucky2013.pdf
MI	2012	7.55	5.00	https://www.msu.edu/~steind/1_2012%20Cust_MachineWrk%20 10_31_11.pdf
MN	2013	5.14		http://faculty.apec.umn.edu/wlazarus/documents/machdata.pdf
MO	2012	7.59	8.00	http://extension.missouri.edu/explorepdf/agguides/agecon/g00302.pdf http://extension.missouri.edu/seregion/Crop_Budgets_PDF.htm
MS	2013		7.00	http://www.agecon.msstate.edu/whatwedo/budgets/docs/MSUCOT14.pdf
ND	2010	6.00		http://www.nass.usda.gov/Statistics_by_State/North_Dakota/Publications/Custom_Rates/index.asp
NE	2012	7.42		http://ianrpubs.unl.edu/epublic/live/ec823/build/ec823.pdf
NY	2011	10.00		http://blogs.cornell.edu/ccefranklin//files/2010/04/2011-Custom-Rates.pdf
OK	2011	6.17		http://oces.okstate.edu/kay/ag/CustomRates%202011-2012.pdf/at_download/file
PA	2013	11.30		http://farmprogress.com/mdfm/Faress1/author/198/2013%20Custom-Rates.pdf
SC	2013		9.00	http://www.clemson.edu/extension/aes/budgets/
TN	2013	8.46	9.50	http://economics.ag.utk.edu/extension/pubs/CustomRates2013-rev.pdf http://economics.ag.utk.edu/budgets/2014/2014RowCropBudgets.pdf
TX	2013	6.22		http://agecoext.tamu.edu/files/2012/05/CustomRateSurveyMay2013.pdf
WI	2010	7.70		http://www.nass.usda.gov/Statistics_by_State/Wisconsin/Publications/custom_rates_2010.pdf

Spring Wheat Table 18. Estimated grower costs for alternative AIs, application and scouting for foliar-based systems in the non-neonicotinoid scenario.

	------------ Foliar to Foliar ----------			---------Seed Treatment to Foliar--------		
Active Ingredient	**Added Acres**	**Cost** ($/A)	**Total Cost**	**Added Acres**	**Cost** ($/A)	**Total Cost**
Chlorpyrifos				15,167	2.99	45,335
Cyfluthrin				1,933	2.52	4,868
Dimethoate				905	4.12	3,729
Lambda-Cyhalothrin				16,148	3.24	52,322
Methyl Parathion				2,852	3.17	9,031
Zeta-Cypermethrin				3,850	2.12	8,156
Scouted & Treated				**40,855**	**3.02**	**123,441**
Scouted Only				**73,578**		
Application				**40,855**	**7.20**	**294,156**
Scouting				**114,433**	**7.44**	**851,378**

Spring Wheat Table 19. Estimated grower costs for alternative AIs, application and scouting for soil-based systems in the non-neonicotinoid scenario.

Cultural Practice	**Added Acres**	**Cost** ($/A)	**Total Cost**
Adjust Seeding Rate	3,669,775	4.32	15,853,427
Total	**3,669,775**	**4.32**	**15,853,427**

Spring Wheat Table 20. Estimated grower costs for neonicotinoid AIs, application and scouting for the 2010-2012 average neonicotinoid use.

	------------- Foliar Use* -------------			------- Seed Treatment Use -------		
Cost Category	**Original Acres**	**Cost** ($/A)	**Total Cost**	**Original Acres**	**Cost** ($/A)	**Total Cost**
Active Ingredients				3,782,494	2.56	9,689,363
Application*						
Scouting*						

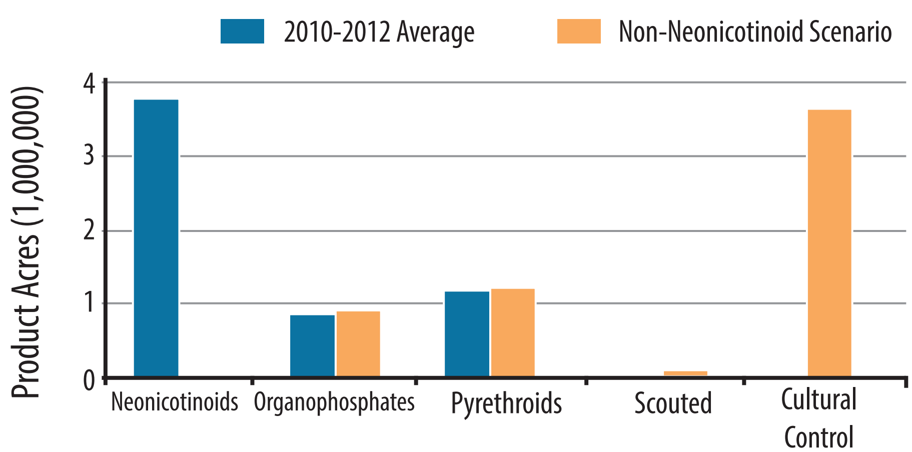
*Does not change for the non-neonicotinoid scenario.

Spring Wheat Table 21. Estimated net change in grower expenditures for the non-neonicotinoid scenario.

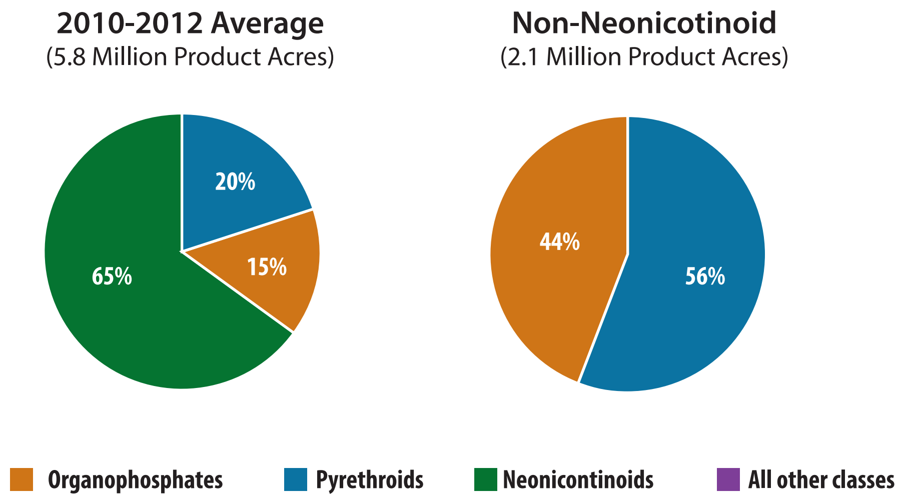
	Avoided Expenditures From the Current System	New Expenditures for the Non-Neonicotinoid Scenario	Net Change in Grower Expenditures
Soil AI Costs	9,689,363	---	-9,689,363
Foliar AI Costs	---	123,441	123,441
Soil Application Costs	---	---	---
Foliar Application Costs	---	294,156	294,156
Soil Scouting Costs	---	---	---
Foliar Scouting Costs	---	851,378	851,378
Cultural Control	---	15,853,427	15,853,427
Total Costs	**9,689,363**	**17,122,403**	**7,433,040**

Net Change in Grower Expenditures	Acres	$/Acre
Neonicotinoid Base Acres Treated	3,782,494	1.97
Planted Acres	14,897,013	0.50

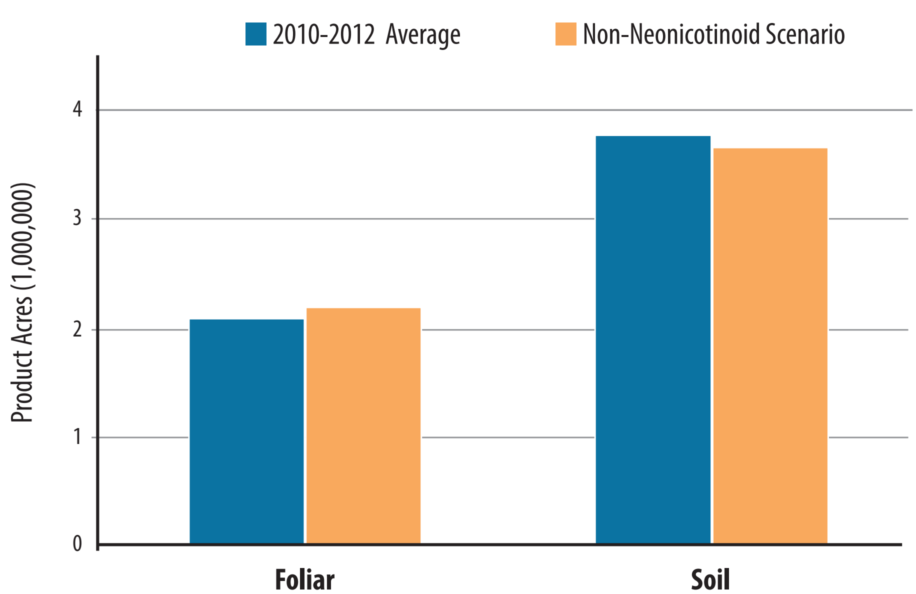
Spring Wheat Figure 1. 2010-2012 average product acres and new total product acres for the non-neonicotinoid scenario by insecticide class.



Spring Wheat Figure 2. 2010-2012 average shares of total insecticide product acres allocated to major insecticide modes of action and estimated shares for the non-neonicotinoid scenario. (Shares are based on product acres in Spring Wheat Table 12 and do not include product acres reallocated to "scouted but not treated" or to "cultural control.")



Spring Wheat Figure 3. 2010-2012 annual average product acres and new total product acres for the non-neonicotinoid scenario using foliar-based and soil-based pest management systems. (Foliar-based includes both acres "scouted and treated" as well as "scouted and not treated"; soil-based includes "seed treatments" and "higher seeding density.")



4.5 Sorghum analysis and results

The sorghum analysis is similar to the corn analysis in terms of differences relative to the cotton analysis. Seed treatments are the only use of neonicotinoids in sorghum, with no significant foliar use of neonicotinoid occurring. As a result, sections of several tables concerning reallocation of foliar neonicotinoid applications are empty, Sorghum Table 8 is not needed, and because sorghum has no registered non-neonicotinoid seed treatments, Sorghum Table 9 is also not needed.

Of the 2010-2012 annual average of 3.2 million insecticide product acres in sorghum, 2.5 million are in a soil-based insect management system exclusively using neonicotinoid seed treatments and about 660,000 are foliar-applied non-neonicotinoids. The 2010-2012 three-year average for sorghum is 5.8 million planted acres, so that 43 percent of sorghum planted acres are treated with a neonicotinoid seed treatment, with almost 48 percent of planted acres receiving at least one insecticide application. Aphids, chinch bugs and wireworms are the primary targets of the neonicotinoid seed treatments, with ants and seed maggots also significant pest targets. For the non-neonicotinoid scenario, product acres targeting wireworms, seed maggots and ants are reallocated to a non-neonicotinoid soil insecticide, and those targeting aphids are reallocated to a foliar non-neonicotinoid; product acres targeting chinch bugs are roughly evenly split between soil and foliar insecticides.

For the non-neonicotinoid scenario, the analysis projects that the 2010-2012 average of 2.5 million neonicotinoid seed treatment product acres in sorghum would be replaced by an estimated 1.4 million product acres of organophosphates and 0.4 million product acres of pyrethroids. This shift implies an increase in organophosphate product acres to almost 20 times their 2010-2012 average level, while total pounds of organophosphates increases almost 40 times. Pyrethroids product acres would increase almost 80 percent, with an increase in total pounds applied of almost 80 percent as well. Also, almost 670,000 neonicotinoid product acres in sorghum would be scouted and not treated for control of aphids or chinch bug when switching from a seed treatment to a foliar-based pest management system for the non-neonicotinoid scenario. As a result, insecticide product acres decrease from 3.1 million to 2.4 million, with the share of insecticide product acres for organophosphates increases from 3 percent to 63 percent, while the pyrethroid share increases from 16 percent to 37 percent. Furthermore, sorghum acres in foliar-based insect management systems are projected to almost triple under the non-neonicotinoid scenario.

Sorghum growers would see an estimated increase in expenditures for insecticide AIs of more than $8.3 million for the non-neonicotinoid and a net increase in application costs of $8.1 due to switching from seed treatments to soil insecticides and foliar applications. In addition, scouting costs would increase by more than $9.5 million, as sorghum acres using foliar-based management systems are projected to increase. The net effect is an increase of $26 million in costs for sorghum growers for the non-neonicotinoid scenario. With 5.8 million sorghum planted acres and 2.5 million neonicotinoid base acres, the estimated average cost benefit of neonicotinoids is $4.48 per planted acre or $10.39 per neonicotinoid treated base acre.

Sorghum Table 1. Product acres for all AIs and neonicotinoids (2010-2012 average).

		-------- Soil-based System --------		
	Foliar	Seed Treatment	Soil-applied	Total
Neonicotinoids	---	2,500,588	---	2,500,588
Non-Neonicotinoids	661,358	28,476	---	689,833
All AIs	661,358	2,529,063	20,459	3,210,880

Sorghum Table 2. Initial product acres for foliar-based and soil-based systems and remaining product acres after focusing on major pests targeted by neonicotinoids.

	-------Foliar-based Systems------		-------Soil-based Systems-------	
	All AIs	Neonicotinoids	All AIs	Neonicotinoids
Initial Product Acres	661,358	---	2,549,523	2,500,588
No Answer	3.7%	---	15.7%	16.0%
Targeted at Specific Pests	96.3%	---	84.3%	84.0%
Remaining Product Acres				
% of Initial Product Acres	3.3%	---	81.7%	81.8%
% Targeted at Specific Pests	3.4%	---	97.0%	97.4%

Sorghum Table 3. Non-neonicotinoid product acre shares by neonicotinoid target pest group for foliar-based systems.

Active Ingredient	Aphid	Chinch Bug
Chlorpyrifos	46.7%	
Cyfluthrin		11.5%
Lambda-Cyhalothrin		5.3%
Zeta-Cypermethrin	53.3%	83.2%

Like the naturally occurring alkaloid nicotine, all neonicotinoids act selectively on the insect central nervous system.

Page 1087. Jeschke, P., & Nauen, R. (2008). *Neonicotinoids—from zero to hero in insecticide chemistry*. Pest Management Science, 64(11), 1084–1098. doi:10.1002/ps.1631

Sorghum Table 4. Non-neonicotinoid cultural practice shares by neonicotinoid target pest group for soil-dwelling pests.

	Soil Insecticide				
Practice	**Ant**	**Aphid**	**Chinch Bug**	**Seed Maggot**	**Wirewom**
Chlorpyrifos	100.0%*				
Terbufos			100.0%	100.0%**	100.0%*

*Labeled for use in sorghum for these pests, but did not appear in the GfK Kynetec data.
**Not labeled for use in sorghum for seed maggot, but labeled for use in corn.

Sorghum Table 5. Share of neonicotinoid product acres targeted at each insect pest group for foliar-based and soil-based pest management systems.

Pest Control System	Ant	Aphid	Chinch Bug	Seed Maggot	Wirewom
Foliar-based*					
Soil-based	3.5%	38.7%	27.6%	2.0%	28.2%

*No significant foliar use of neonicotinoids occurs in sorghum, so data not relevant.

Sorghum Table 6. Share of non-neonicotinoid product acres from foliar-based and from soil-based systems allocated to seed treatments, soil insecticides and foliar systems by target pest.

Pest Control System	Ant	Aphid	Chinch Bug	Seed Maggot	Wirewom
Foliar-based*					
To Foliar-based					
Soil-based					
To Seed Treatment**					
To Soil-applied	100%	0%	55.3%	100%	100%
To Foliar-based	0%	100%	44.7%	0%	0%

*No significant foliar use of neonicotinoids occurs in sorghum, so data not relevant.
**No non-neonicotinoid seed treatments registered for use in sorghum for these pests.

Sorghum Table 7. Average number of applications for each AI and ratios of these averages.

	Average Number of Applications		Ratio of Average Number of Applications to Neonicotinoid Average		
Active Ingredient	Soil-based	Foliar-based	Soil-based	Foliar-based*	Soil-based
Chlorpyrifos	1.000	1.000	1.000	---	1.000
Cyfluthrin		1.345		---	1.345
Lambda-Cyhalothrin		1.169		---	1.169
Terbufos	1.000		1.000		
Zeta-Cypermethrin		1.000		---	1.000
Neonicotinoids	1.000	*			

*No significant foliar use of neonicotinoids occurs in sorghum, so data not relevant.

Sorghum Table 8. Neonicotinoid product acres in a foliar-based pest control system reallocated to each AI and target pest group in a foliar-based pest control system.

Table not needed as there is no significant foliar use of neonicotinoids occurs in sorghum.

Sorghum Table 9. Neonicotinoid product acres in a soil-based pest control system reallocated to cultural practices by target pest group.

Table not needed as no non-neonicotinoids seed treatments registered for use in sorghum for these pests.

Sorghum Table 10. Non-neonicotinoid product acres in a soil insecticide pest management system by AI and target pest group reallocated from neonicotinoid product acres in a seed treatment pest management system.

Active Ingredient	Ant	Aphid	Chinch Bug	Seed Maggot	Wireworm	Total	AI Weights
Chlorpyrifos	87,565	0	0	0	0	87,565	7.2%
Terbufos	0	0	381,462	49,201	706,078	1,136,740	92.8%
Total Treated with These AIs	**87,565**	**0**	**381,462**	**49,201**	**706,078**	**1,224,305**	**100%**

Another success factor is the ability of neonicotinoids to control pests that had developed resistance against a wide range of insecticides … A prominent example is the widespread metabolic resistance in aphids to [organophosphates] and, to some extent, to carbamates and pyrethroids.

Pages1100-1101. Elbert, A., Haas, M., Springer, B., Thielert, W., & Nauen, R. (2008). *Applied aspects of neonicotinoid uses in crop protection.* Pest Management Science, 64(11), 1099–1105. doi:10.1002/ps.1616

Sorghum Table 11. Non-neonicotinoid product acres in a foliar-based pest management system by AI and target pest group reallocated from neonicotinoid product acres in a seed treatment pest management system.

Active Ingredient	Aphid	Chinch Bug	Total	AI Weights
Chlorpyrifos	215,540	0	215,540	35.0%
Cyfluthrin	0	22,752	22,752	3.7%
Lambda-Cyhalothrin	0	9,053	9,053	1.5%
Zeta-Cypermethrin	245,980	122,519	368,499	59.8%
Total Treated With These AIs	461,520	154,324	615,843	100%
Scouted, Not Treated for These Pests	506,153	161,422	667,575	
Total	**967,673**	**315,745**	**1,283,419**	

Sorghum Table 12. Impact of the non-neonicotinoid scenario on non-neonicotinoid product acres by individual AIs and by insecticide class.

		------------------------------- Product Acres -------------------------------			
MOA	**Active Ingredient**	**2010-2012 Average**	**Added**	**New Total**	**Change**
1B	Chlorpyrifos	62,241	303,105	365,346	487%
3A	Cyfluthrin	175,629	22,752	198,381	13%
3A	Lambda-Cyhalothrin	199,266	9,053	208,319	5%
4A	Neonicotinoids	2,500,588	-2,500,588	0	-100%
1B	Terbufos	15,778	1,136,740	1,152,518	7205%
3A	Zeta-Cypermethrin	130,736	368,499	499,235	282%
Total Treated With These AIs*		**3,084,237**	**-660,439**	**2,423,798**	**-21%**
Non-Neonicotinoids*		583,650	1,840,149	2,423,798	315%
Neonicotinoids		2,500,588	-2,500,588	0	-100%
Scouted but Not Treated for These Pests			**667,575**	**667,575**	

		--------------------------------Product Acres ------------------------------			
MOA	**Insecticide Class**	**2010-2012 Average**	**Added**	**New Total**	**Change**
4A	Neonicotinoids	2,500,588	-2,500,588	0	-100%
1B	Organophosphates	78,018	1,439,845	1,517,863	1846%
3A	Pyrethroids	505,631	400,304	905,935	79%
Total Treated With These AIs*		**3,084,237**	**-660,439**	**2,423,798**	**-21%**
Non-Neonicotinoids*		583,650	1,840,149	2,423,798	315%
Neonicotinoids		2,500,588	-2,500,588	0	-100%
Scouted but Not Treated for These Pests			**667,575**	**667,575**	

**Does not match Sorghum Table 1 totals because totals here do not include minor-use AIs.

Sorghum Table 13. Average application rate (pounds per product acre) for each AI by method of application (foliar-applied, soil-applied, seed treatment).

		---Average Application Rate (Pounds per Product Acre)---		
MOA	**Active Ingredient**	**Foliar**	**Seed Treatment**	**Soil Insecticide**
1B	Chlorpyrifos	0.3944		0.7500
3A	Cyfluthrin	0.0246		
3A	Lambda-Cyhalothrin	0.0242		
4A	Neonicotinoids		0.0120	
1B	Terbufos			1.0350
3A	Zeta-Cypermethrin	0.0231		

Sorghum Table 14. Impact of the non-neonicotinoid scenario on pounds of AI applied by insecticide class.

		-------------------Pounds of Active Ingredient Applied------------------			
MOA	**Active Ingredient**	**2010-2012 Average**	**Added**	**New Total**	**Change**
1B	Chlorpyrifos	18,243	150,689	168,932	826%
3A	Cyfluthrin	4,327	561	4,888	13%
3A	Lambda-Cyhalothrin	4,824	219	5,043	5%
4A	Neonicotinoids	29,962	-29,962	0	-100%
1B	Terbufos	16,330	1,176,558	1,192,888	7205%
3A	Zeta-Cypermethrin	2,929	8,506	11,435	290%
	Total	**76,615**	**1,306,571**	**1,383,186**	**1705%**

		-----------------Pounds of Active Ingredient Applied-----------------			
MOA	**Insecticide Class**	**2010-2012 Average**	**Added**	**New Total**	**Change**
4A	Neonicotinoids	29,962	-29,962	0	-100%
1B	Organophosphates	34,574	1,327,247	1,361,820	3839%
3A	Pyrethroids	12,080	9,286	21,365	77%
	Total	**76,615**	**1,306,571**	**1,383,186**	**1705%**

Sorghum Table 15. Impact of the non-neonicotinoid scenario on product acres using foliar-based and soil-based pest management systems.

Category	Foliar-based	Soil-based	Total
2010-2012 Average Product Acres (All AIs)	661,358	2,549,523	3,210,880
Neonicotinoid Product Acres to be Reallocated	0	2,500,588	2,500,588
Total Non-Neonicotinoid Product Acres Added	1,283,419	1,224,305	2,507,724
Scouted and Treated	615,843	1,224,305	1,840,149
Scouted Only	667,575	0	667,575
New Total Product Acres	**1,944,776**	**1,273,240**	**3,218,017**
Net Change (Product Acres)	**1,283,419**	**-1,276,282**	**7,136**
Net Change (%)	**194%**	**-50%**	**0%**

Sorghum Table 16. Average cost for each AI ($/Product Acre) for 2010-2012 for foliar and soil use (not including application costs), plus application and scouting costs.

Active Ingredient	Foliar Use ($/Product Acre)	Soil Insecticide ($/Product Acre)
Chlorpyrifos	3.99	1.54
Cyfluthrin	3.80	
Lambda-Cyhalothrin	3.94	
Terbufos		17.87
Zeta-Cypermethrin	5.08	
Neonicotinoid Average	*	**5.98**
Application Costs	**7.20**	**3.00**
Scouting Costs	**7.44**	

*No significant foliar use of neonicotinoids occurs in sorghum, so data not relevant.

When neonicotinoid insecticides were introduced as seed treatments in 1994, they ushered in a new era of farming practices and market growth. Prior to the introduction of neonicotinoid insecticides, seed treatments were generally sold as low cost insurance products. The seed industry considered seed treatments a "cost of goods" that reduced their net profit for the sale of a bag of seed. The marketing team at Gustafson LLC, anticipating the value of imidacloprid for sorghum, designed a program prior to its introduction in 1994 that made seed treatment a profit center for the seed industry… This new profit stream began the industry's conversion from considering seed treatments as "cost of goods" to value-added products.

Page 38, Crop Life Foundation. November 2013. T*he Role of Seed Treatment in Modern U.S. Crop Production: A Review of Benefits.* Washington, D.C. Retrieved from: http://www.croplifeamerica.org/sites/default/files/SeedTreatment.pdf.

Sorghum Table 17. Reported cost ($/A) for foliar applications and insect scouting based on custom rates and budgets from multiple states.

State	Year	Apply ($/A)	Scout ($/A)	Source
AR	2013	6.50	9.00	http://www.uaex.edu/depts/ag_economics/budgets/2013/Budgets2013.pdf
AL	2013	9.00	8.00	http://www.aces.edu/agriculture/business-management/budgets/2013/rowcrops.php
CO	2012	7.27		http://www.coopext.colostate.edu/abm/custrates12.pdf
GA	2013		10.00	http://www.ugacotton.com/vault/file/2013BUDGETS.pdf
IA	2013	7.30	4.95	http://www.extension.iastate.edu/agdm/crops/pdf/a3-10.pdf
ID	2011	7.11		http://www.cals.uidaho.edu/edcomm/pdf/BUL/BUL0729.pdf
KS	2013	6.03		http://www.kingman.ksu.edu/doc46174.ashx
KY	2013	7.00		http://www2.ca.uky.edu/cmspubsclass/files/ghalich/CustomMachineryRatesKentucky2013.pdf
MI	2012	7.55	5.00	https://www.msu.edu/~steind/1_2012%20Cust_MachineWrk%20 10_31_11.pdf
MN	2013	5.14		http://faculty.apec.umn.edu/wlazarus/documents/machdata.pdf
MO	2012	7.59	8.00	http://extension.missouri.edu/explorepdf/agguides/agecon/g00302.pdf http://extension.missouri.edu/seregion/Crop_Budgets_PDF.htm
MS	2013		7.00	http://www.agecon.msstate.edu/whatwedo/budgets/docs/MSUCOT14.pdf
ND	2010	6.00		http://www.nass.usda.gov/Statistics_by_State/North_Dakota/Publications/Custom_Rates/index.asp
NE	2012	7.42		http://ianrpubs.unl.edu/epublic/live/ec823/build/ec823.pdf
NY	2011	10.00		http://blogs.cornell.edu/ccefranklin//files/2010/04/2011-Custom-Rates.pdf
OK	2011	6.17		http://oces.okstate.edu/kay/ag/CustomRates%202011-2012.pdf/at_download/file
PA	2013	11.30		http://farmprogress.com/mdfm/Faress1/author/198/2013%20Custom-Rates.pdf
SC	2013		9.00	http://www.clemson.edu/extension/aes/budgets/
TN	2013	8.46	9.50	http://economics.ag.utk.edu/extension/pubs/CustomRates2013-rev.pdf http://economics.ag.utk.edu/budgets/2014/2014RowCropBudgets.pdf
TX	2013	6.22		http://agecoext.tamu.edu/files/2012/05/CustomRateSurveyMay2013.pdf
WI	2010	7.70		http://www.nass.usda.gov/Statistics_by_State/Wisconsin/Publications/custom_rates_2010.pdf

The most common use [of neonicotinoids] in agriculture is to coat seeds to protect them from soil pests. As the seed grows, it readily incorporates the compounds so that tender young plants are guarded as well. That means less pesticide is applied than if it was sprayed onto the plants.

Pages 674-5, Stokstad, E. (2013). Pesticides under fire for risks to pollinators. Science, 340, 674-676.

Sorghum Table 18. Estimated grower costs for alternative AIs, application and scouting for foliar-based systems in the non-neonicotinoid scenario.

	------------- Foliar to Foliar *----------			----------Seed Treatment to Foliar---------		
Active Ingredient	**Added Acres**	**Cost ($/A)**	**Total Cost**	**Added Acres**	**Cost ($/A)**	**Total Cost**
Chlorpyrifos				215,540	3.99	859,845
Cyfluthrin				22,752	3.80	86,413
Lambda-Cyhalothrin				9,053	3.94	35,645
Zeta-Cypermethrin				368,499	5.08	1,873,637
Scouted & Treated				**615,843**	**4.64**	**2,855,540**
Scouted Only				**667,575**		
Application				**615,843**	**7.20**	**4,434,072**
Scouting				**1,283,419**	**7.44**	**9,548,634**

*No significant foliar use of neonicotinoids occurs in sorghum.

Sorghum Table 19. Estimated grower costs for alternative AIs, application and scouting for soil-based systems in the non-neonicotinoid scenario.

	Seed Treatment to Seed Treatment*			Seed Treatment to Soil Insecticide		
Active Ingredient	**Added Acres**	**Cost ($/A)**	**Total Cost**	**Added Acres**	**Cost ($/A)**	**Total Cost**
Chlorpyrifos				87,565	1.54	134,548
Terbufos				1,136,740	17.87	20,315,639
Scouted & Treated				**1,224,305**	**16.70**	**20,450,188**
Application				**1,224,305**	**3.00**	**3,672,916**
Scouting*						

*Not applicable as it does not change for the non-neonicotinoid scenario.

Sorghum Table 20. Estimated grower costs for neonicotinoid AIs, application and scouting for the 2010-2012 average neonicotinoid use.

	------------- Foliar Use* -------------			------- Seed Treatment Use -------		
Cost Category	**Original Acres**	**Cost ($/A)**	**Total Cost**	**Original Acres**	**Cost ($/A)**	**Total Cost**
Active Ingredients				2,500,588	5.98	14,956,586
Application						
Scouting**						

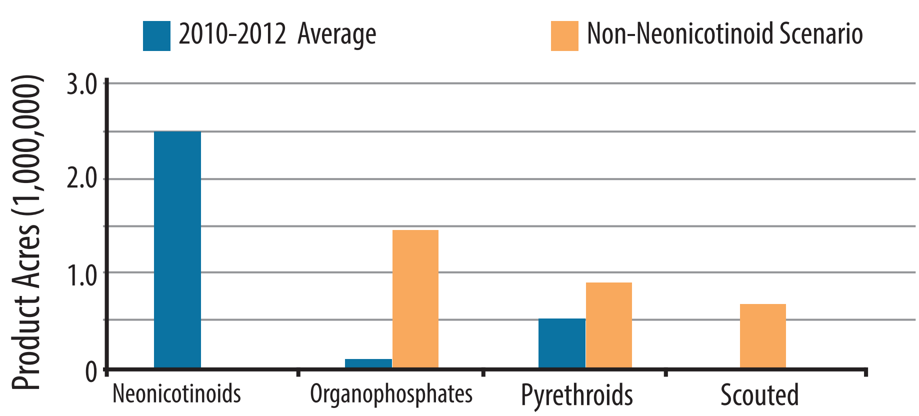
*No significant foliar use of neonicotinoids occurs in sorghum, so data not relevant.
**Does not change for the non-neonicotinoid scenario.

Sorghum Table 21. Estimated net change in grower expenditures for the non-neonicotinoid scenario.

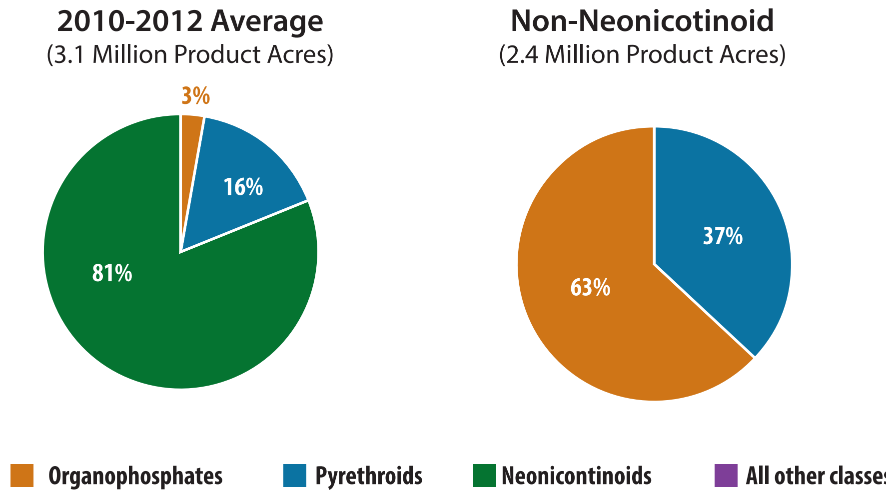
	Avoided Expenditures From the Current System	New Expenditures for the Non-Neonicotinoid Scenario	Net Change in Grower Expenditures
Soil AI Costs	14,956,586	20,450,188	5,493,602
Foliar AI Costs		2,855,540	2,855,540
Soil Application Costs		3,672,916	3,672,916
Foliar Application Costs		4,434,072	4,434,072
Soil Scouting Costs			
Foliar Scouting Costs		9,548,634	9,548,634
Total Costs	**14,956,586**	**40,961,350**	**26,004,764**

Net Change in Grower Expenditures	Acres	$/Acre
Neonicotinoid Base Acres Treated	2,770,211	10.39
Planted Acres	5,808,329	4.48

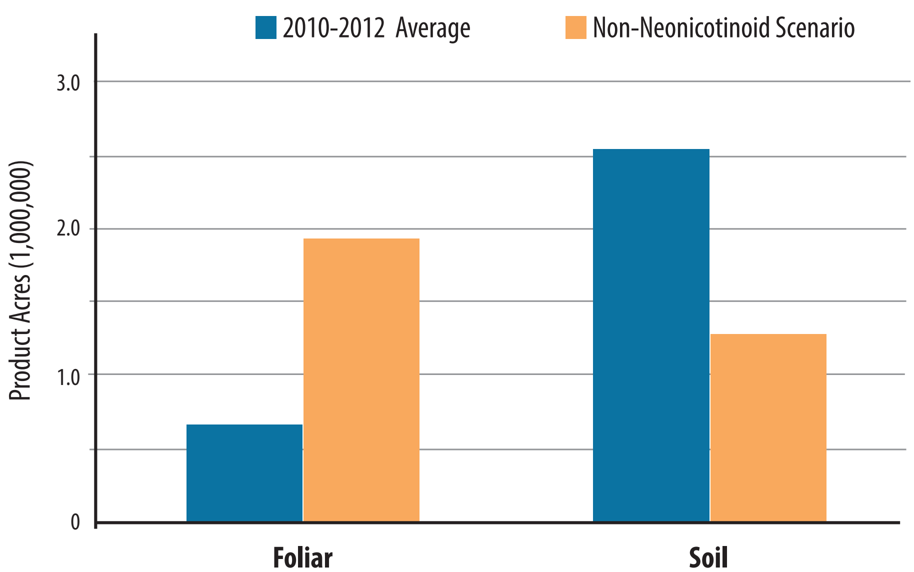
Sorghum Figure 1. 2010-2012 average product acres and new total product acres for the non-neonicotinoid scenario by insecticide class.



Sorghum Figure 2. 2010-2012 average shares of total insecticide product acres allocated to major insecticide modes of action and estimated shares for the non-neonicotinoid scenario. (Shares are based on product acres in Sorghum Table 12 and do not include product acres reallocated to "scouted but not treated.")



Sorghum Figure 3. 2010-2012 annual average product acres and new total product acres for the non-neonicotinoid scenario using foliar-based and soil-based pest management systems. (Foliar-based includes both acres "scouted and treated" as well as "scouted and not treated"; soil-based includes "seed treatments" and "soil insecticides.")



5.0 References

Duffy, M. 2014. *Estimated Costs of Crop Production in Iowa*. Iowa State University Extension, Ames, IA. Online: http://www2.econ.iastate.edu/faculty/duffy/extensionnew.html (Accessed February 9, 2014).

Edwards, W. 2009. *Estimating Farm Machinery Costs*. Iowa State University Extension Publication A3-29, Ames IA. Online: https://www.extension.iastate.edu/agdm/crops/pdf/a3-29.pdf. (Accessed February 9, 2014).

Gaspar, A, S.P. Conley, and P.D. Mitchell. 2014. *Economic Risk and Profitability of Soybean Seed Treatments at Reduced Seeding Rates.* Crop Science (forthcoming).

Insecticide Resistance Action Committee (IRAC). 2014. *Mode of Action Classification Scheme*, Version 7.3. IRAC, Washington, DC. Online: http://www.irac-online.org/documents/moa-classification/?ext=pdf. (Accessed June 27, 2014).

Lazarus, W. 2013. *Machinery Cost Estimates.* University of Minnesota Extension, St. Paul, MN. Online: http://faculty.apec.umn.edu/wlazarus/documents/machdata.pdf. (Accessed February 9, 2014).

Raab, D., and B. Zwilling. 2013. *Farm Income and Production Costs for 2012: Advance Report*. University of Illinois Extension Publication AE-4566, Urbana-Champaign, IL. Online: http://fbfm.ace.uiuc.edu/pdf%20files/Advance%20Report/AdvanceReport12.pdf. (Accessed February 9, 2014).

Schnitkey, G. 2004. *Planter Costs for Alternative Farm Sizes*. University of Illinois Extension Publication FEFO 04-05, Urbana-Champaign, IL. Online: http://farmdoc.illinois.edu/manage/newsletters/fefo04_05/fefo04_05.pdf. (Accessed February 9, 2014).

Stewart, S., and A. McClure. 2014. *2014 Insect Control Recommendations for Field Crops*. The University of Tennessee Institute of Agriculture, Knoxville, TN. Online: https://utextension.tennessee.edu/publications/documents/PB1768.pdf. (Accessed June 26, 2014).

Taylor C.R. 1993. *AGSIM: An econometric-simulation model of regional crop and national livestock production in the United States. In Agricultural Sector Models for the United States: Description and Selected Policy Applications, ed*. by C.R. Taylor, K. Reichelderfer and S. Johnson. Ames, IA: Iowa State University Press.

U.S. Department of Agriculture, National Agricultural Statistics Service (USDA-NASS). 2014. *Agricultural Prices* (January 2014). USDA-NASS, Washington, DC. Online: http://usda.mannlib.cornell.edu/usda/nass/AgriPric//2010s/2014/AgriPric-01-31-2014_revision.pdf. (Accessed August 14, 2014).

U.S. Department of Agriculture, National Agricultural Statistics Service (USDA-NASS). *2013. Quick Stats Lite*. USDA-NASS, Washington, DC. Online: http://www.nass.usda.gov/Quick_Stats/index.php. (Accessed December 23, 2013).