Benefits of Seed Applied Insecticides to Canadian Farmers

A Summary Report Prepared for the Canadian Seed Trade Association

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In this document, we provide a brief overview on how and why Canadian crop farmers use neonicotinoids, with a goal of helping lay audiences better understand their value to farmers. We use a science-based approach, relying on a variety of data and research (some of it our own), as well as our own expertise from years of outreach programming for northern U.S. crop farmers. We first review insect management practices of Canadian crop farmers, and then explain how Canadian farmers use neonicotinoids, focusing on major crops uses. Finally, we overview some of the major reasons why Canadian farmers use neonicotinoids and some projections of how they would respond if neonicotinoids were not available.

Canadian farmers manage a range of both below ground and above ground insect pests throughout the growing season

Based on an extensive telephone survey of Canadian canola, corn and soybean farmers,[1] the list of most important and actively managed insect pests includes several above ground pests, many familiar to home gardeners. These above ground pests eat leaves and seeds, tunnel into stalks, and suck plant juices, and include armyworms and other moth larvae, various beetles and bugs such as flea beetles, Japanese beetles, bean leaf beetles and lygus bugs, plus aphids, leafhoppers, weevils and grasshoppers (Tables 1-3).

Canadian farmers also manage several below ground pests that may not be as familiar to home gardeners, such as wireworm larvae, various beetle grubs, seed maggots and corn rootworm, as well as early season pests such as cutworms and flea beetles (Tables 1-3). Wireworms, grubs, maggots and rootworm larvae live in the soil and eat seeds, seedlings and plant roots, often causing invisible damage that appears as stand reduction (too few plants growing in the field) or empty spots in fields, robbing yield as the season gets started.

About half of canola, corn and soybean farmers reported actively managing below ground and early season pests and identified them as them as among the most important to manage (Tables 1-3). Common below ground pests for these crops include wireworm, seed maggot, and grubs, plus corn rootworm in corn. Common early season pests for these crops include flea beetle in canola, cutworm in corn and soybean, and aphids and bean leaf beetle in soybean.

When making pest management decisions, farmers are concerned with human and environment safety about as much as they are with profits and product performance

When farmers were asked about how important various factors were to them when making their pest management decisions, human and environmental safety was among the most important concern, as was profitability and product performance (Table 4) (Hurley and Mitchell 2014). Convenience and saving time were of relatively less importance to farmers. Farmers' high level of concern for human and environmental safety is part of what drives their high adoption of neonicotinoid seed treatments.

Listening sessions conducted with Canadian and U.S. farmers in 2014 found that farmers preferred seed treatments partly because they are perceived as relatively safer to humans and the environment than returning to more frequent, less precise foliar applications of more broad-

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[1] Data and estimates for tables and figures based on telephone surveys of commercial-scale Canadian farmers conducted early in 2014 about the 2013 season, with responses from 500 canola farmers, 120 corn farmers and 120 soybean farmers (Hurley and Mitchell 2014).

spectrum insecticides such as pyrethroids and organophosphates (Shaw and Genskow 2014). Relative to these broad-spectrum insecticides, neonicotinoids have low toxicity to mammals (including humans), affect a narrower range of insects, require lower application rates and can be delivered in precise quantities where needed when applied as seed treatments (Health Canada 2016). Canola farmers mentioned not wanting to return to making more foliar sprays near their own homes or by towns and neighbors. Farmers perceive seed treatments as an unobtrusive way of delivering very effective, low-rate insecticides to a lot of acres compared to spray rigs or aerial application that the public can see. Ontario farmers emphasized how neonicotinoid seed treatments allow them to use environmentally friendly practices such as no till and cover crops, since these practices increase the prevalence of belowground pests targeted by neonicotinoid seed treatments (Shaw and Genskow 2014).[2]

When using insecticides, Canadian crop farmers rely primarily on seed-based delivery
Canadian crop farmers rely primarily on seed-based delivery of insecticides in canola, corn and soybean (Figures 1 and 2, Table 5). Based on average reported adoption rates in farmer surveys for the 2013 crop year (Hurley and Mitchell 2014), for these crops, seed-based delivery via seed treatments and Bt traits amount to 86% of insecticide treated acres, with foliar sprays and soil-applied insecticides constituting the remaining 14% of insecticide treated acres. An estimated 87% of the canola planted area, 75% of the corn planted area and 66% of the soybean planted area receives seed treatments, while 76% of the corn planted area uses Bt traits (Figure 1).

The total area treated with seed treatments is much larger than for Bt traits (Figure 2), largely because the canola seeded area is larger than for corn and soybean, and because Bt traits are only available for corn in Canada. For these three crops, seed treatments are used on 9.5 million ha, with more than 7.1 million in canola, while there are about 1.1 million ha of Bt traits used in corn (Table 5).

Foliar sprays are the remaining method of insecticide application. Foliar insecticides sprays are used on 18% of the canola seeded area, or more than 1.5 million ha (Figure 2). Foliar insecticide sprays are used on only 5% of the corn planted area and 7% of the soybean planted area, or 75,000 ha in corn and 138,000 ha in soybean (Figure 2). For these crops, soil-applied insecticides are a minor option only available in corn and used on less than 3% of the planted area.

Most farmers make seed and seed treatment purchases in December through February to ensure that they have the hybrids and varieties they want and that they are ready to plant as soon as the weather permits, since the growing season is short. Seed-based insect management means that farmers make insect management decisions months before planting in May and June and before insects can potentially cause economic losses. This type of decision is common for farmers – choosing how much of each crop and which varieties to plant months before crop prices and weather during the crop season are known. In this context, risk management is an important aspect of their decisions, including for managing risk from insects. If factors indicate that the risk is sufficiently high relative to the cost of the seed treatment or Bt trait, farmers will pay for the seed-based insecticide treatment. As a result, from a farmer's perspective, foliar sprays are for insect problems that cannot be addressed with seed-based treatments (e.g., grubs, wireworm and

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[2] To identify specific statements by Canadian farmers at the listening sessions, we recommend electronically searching Shaw and Genskow (2014) for "Ontario" and "canola".

maggots in soybean) and for rescue treatments when seed-based alternatives were not used (e.g., cutworms in corn and soybean) or when insect problems exceed the capacity of seed-based treatments (e.g., flea beetles in canola, aphids in soybean).

Neonicotinoid seed treatments are often the only or the most effective insecticide option for Canadian farmers to manage many below ground and early season pests

For soybean in Canada, neonicotinoid seed treatments are the only option for control of below ground insect pests such as wireworm, seed maggot, and grubs, since no soil-applied insecticides are registered for use in these crops. Corn also has these below ground pests, as well as corn rootworm, but also has soil-applied insecticides and Bt traits as available options. Bt corn hybrids are only sold with neonicotinoid seed treatments, not only to provide a second mode of a action, but also control of the full range below ground insects pests. Though available, few Canadian corn farmers use soil-applied insecticides (Hurley and Mitchell 2014). With below ground pests, rescue treatments are not possible and decisions to use seed treatments, Bt traits, and soil-applied insecticides are made before the early season below ground pest pressure is well known or easily quantifiable in a predictable manner. As a result, farmers base such decisions on risk factors, including history of damage, use of high risk crop management practices (agronomic practices can increase the risk of below ground insect pressure) such as cover crops, no till, and manure applications, and scouting of pest densities the previous season.

For early season pests, farmers (and particular canola farmers who identified these insects pests as the primary pest issue for this crop) generally have both seed treatment and foliar spray control options. The decision to use seed treatments is made at the time of seed purchase or just before planting, while foliar sprays can be based on field scouting. However, both Canadian and U.S. farmers in listening sessions emphasized the difficulty in scouting crop acres with sufficient reaction time to make foliar applications before economic losses occur early in the season (Shaw and Genskow 2014). Labor is also in short supply early in the season for both scouting and pesticide applications, even from off-farm sources. Using seed treatments slows pest population growth so that fewer foliar applications are needed and creates more time to identify where and when foliar applications are needed. Finally, many of these insect pests transmit pathogens to crops, such as Stewart’s wilt to corn by flea beetles, bean pod mottle virus to soybean by bean leaf beetles, and mosaic viruses to soybeans by aphids. As a result, even if the actual pest numbers are not sufficient to cause economic losses, they can do so indirectly by transmitting pathogens to the crop.

When using insecticides, Canadian crop farmers rely primarily on neonicotinoids

Neonicotinoids are the primary insecticide class used by Canadian famers for insect management in canola, corn and soybean (Table 6, Figures 3 and 4). At the time of the survey (Hurley and Mitchell 2014), all insecticidal seed treatments registered for use in Canada on these crops were neonicotinoids. Foliar application of neonicotinoids is approved for these crops, but in general, Canadian farmers rely on pyrethroids and organophosphates for foliar sprays in these crops.

An estimated 87% of the canola planted area, 75% of the corn planted area and 66% of the soybean planted area received neonicotinoids as seed treatments in 2013 based on average adoption rates from farmer surveys (Hurley and Mitchell 2014). For these crops, these percentages amount to 9.5 million ha, or 77% of the total 12.4 million ha treated with insecticides (Figure 3). The estimated use of pyrethroids and Bt traits each amount to about 9% of the insecticide treated area in these crops, or around 1.2 to 1.1 million ha each (Table 6, Figure 4). Organophosphates are the next most commonly used insecticide class, but only amount to an estimated share of 3% of the treated area in these crops, almost all of which are applied as foliar sprays in canola (Table 6, Figure 4). All other insecticide classes are estimated to amount to less than 2% of the treated area in these crops, or about 200,000 ha in total (Table 6, Figure 4).

Overall, Canadian farmers rely primarily on four insecticide classes for insect management in these crops, with neonicotinoids having by far the largest share. The other three class (Bt traits, pyrethroids and organophosphates) have a combined share of 22% of the treated area.

Why Canadian farmers use neonicotinoid seed treatments

Maximizing the planting window: Canadian farmers plant their respective cereal and oilseed crops earlier today than 15 years ago. The yield advantage to seeding earlier in northern climates has been widely documented (Hall 2013, Robinson et al. 2009, Rowntree et al. 2013). However, earlier planted seed takes longer to emerge because germination and emergence are temperature driven. As a result, the seed has a greater risk of disease and insect damage occurring during this time than later planted seed. Fungicide and neonicotinoid seed treatments reduce these risks and have been shown to increase early season plant growth (Gaspar and Conley 2015, Macedo and de Camargo eCastro 2011). Depending on the year and subsequent growing environment, this increase in early season crop health does not always translate to a measurable yield advantage, but these seed treatments do offer farmers an effective tool for mitigating these in-field risks.

Protection of seed and trait investment: Canadian farmers have experienced rising seed costs over the past 15 years for all crops they plant. Crops such a corn, soybean, and canola with herbicide or pest management traits have seen the greatest increase in cost, more than 100%. To protect the increased cost of their investment in seed, farmers have opted to invest in seed treatments as a means to mitigate stand failure from diseases and both belowground and early season pests. When compared to the total cost of seed, farmers often view seed treatments as a relatively small added cost to protect their seed investment.

Reduced seeding rates for some crops: Soybean is one of many crops that farmers have historically over seeded – planted more seeds than needed. Dramatic increases in seed costs, coupled with agronomic advancements such as early planting and independent data supporting lower seeding rates, have led Canadian farmers to systematically lower their seeding rates for soybean and canola and possibly in wheat where neonicotinoid treated seed had a greater percent germination and slightly improved freeze tolerance over untreated wheat (Larsen and Falk 2013). The cost saving from shifting to a lower seeding rate is often enough to pay for the seed treatment. Data also show that lower seeding rates coupled with seed treatments often can help mitigate grower risk and increase farmer returns (Gaspar et al. 2015, Gaspar et al. 2017).

Risk mitigation: Canadian farmers often operate on thin profit margins to remain solvent. Seed treatments provide farmers an additional tool to help offset downside production risk – the risk of crop failure. For example, in field corn, breeders have concentrated on selecting hybrids that yield better under increasingly dense plant populations (Hammer et al. 2009). As a result, agronomists have recommended that farmers annually increase their corn seeding rate as much as 750 seeds per hectare, depending on the field environment. In this scenario it is relatively easy to measure the impact of stand loss from disease and insect damage and the value of seed treatments. Crops such as soybean, canola or wheat can somewhat compensate for reduced stand, and so it is more difficult to accurately characterize the risk reduction provided by seed treatments (Gaspar and Conley 2015, Mourtzinis et al. 2016, Suhre et al. 2014). However recent work on soybean in Wisconsin has found that using a neonicotinoid increased yield 4% and 12% at 345,000 and 98,000 seeds per hectare, respectively, over using only a fungicide and untreated seed (Gaspar et al. 2015). Furthermore, the neonicotinoid seed treatment provided greater yield benefits the more severe the yield limiting situation was.

Climate change and increased weather unpredictability: Canadian farmers are facing the impacts of climate change (Qian et al. 2013). Over the past 20 years, monthly precipitation and temperature trends have varied greatly among and within provinces. These results point to spatial variations in climate change variability, which drive increases in yield variably. The estimated climate change contribution to total annual variation in U.S. soybean yields ranged from –22% to +9% of total annual yield variation from 1994 to 2013, with U.S. soybean yields declining on average by 2.2% due to climate change over this period (Mourtzinis et al. 2015). Similar results have been reported at the global scale for the major cereal and oilseed crops grown in Canada.

Pest unpredictability: Increased weather variability induced by climate change also plays a significant role in driving unpredictable disease and insect outbreaks (Rosenzweig et al. 2001). Pest cycles are largely governed by temperature and precipitation. Given the unpredictability of accurately knowing the upcoming environment and thus the pest pressure, coupled with the continued increase in the size of Canadian farms, farmers use seed treatments to offset risk. Furthermore, pre-planting scouting for below ground and early season pests such as flea beetles, wireworm, and cutworm is simply impractical due not only to the patchiness and unpredictable nature of their presence, but also increased farm size.

Save labor and management time: The size of Canadian crop farms continues to increase even as the available labor decreases (Statistics Canada 2017). As a result, farmers simply cannot scout all of their crops in a timely manner and make treatments when needed. Based on the 2016 Census of Canadian Agriculture, between 2011 and 2016, the number of farms decreased 5.9% and the number of farmers declined by 7.5%, while the total area of cropland increased by 6.9%. As a result, the average size of a Canadian farm increase 13.6% between 2011 and 2016. Furthermore, for farms reporting at least $1 million in gross receipts in 2015, 73% of the farmers already worked more than 40 hours per week on their farm. In 2015, the total number of agricultural employees was down 5.8% compared to 2010, though a shift has occurred toward hiring year-round employees (full time and part time) in place of seasonal and temporary employees.

Ease of application: Neonicotinoids can be applied to the seed prior to farm delivery and easily partnered with many seed applied fungicides and biologicals, such as microbial inoculants. Neonicotinoids are applied at a low use rates per hectare, and so uniform application is required. Canadian farmer concern for human and environmental safety led to the rapid adoption of neonicotinoid seed treatments to control belowground and early season insect pests. Farmers can now purchases their seed with the fungicide and insecticide treatments already applied to the seed, which lessens worker exposure to pesticides and reduces farm labor needs.

Yield increases leading to positive return on investment: Yield increases from using neonicotinoid seed treatments are the foundation for a positive return on investment for Canadian farmers. A summary of small-plot experimental data from field studies conducted in Canada found yield gains of 18.9% for canola when using a neonicotinoid seed treatment relative to using a foliar insecticide (Mitchell 2014b). Such a large average yield gain drives the high levels of seed treatment adoption among Canadian canola farmers, since it pays for the cost of the seed treatment relative to the cost of scouting and making foliar applications and the risk for a foliar-based system.

A similar summary of small-plot data from field studies conducted in Ontario by University of Guelph faculty estimated the average yield benefits for neonicotinoid seed treatments when used in corn and soybean. Relative to using no insect control, the average yield increase when using a neonicotinoid seed treatment was 11% for corn and 8.5% for soybean. Relative to using alternative insecticides, either soil-applied or foliar sprays, the average yield increase when using a neonicotinoid seed treatment was 9.8% for corn and 1.6% for soybean. These yield benefits drive the adoption of seed treatments, as they generate a positive return on investment, even the smallest gain of 1.6%. A soybean budget analysis using average farmer yields and prices and typical costs for applications and scouting show net gains in the range of $35 per hectare for Canadian soybean growers with the 1.6% yield advantage relative to using foliar spays to manage pests (Mitchell 2015a).

Field research has found similar yield responses and positive returns on investment for soybean in several states in the northern U.S. (Esker and Conley 2012, Gaspar et al. 2014, Orlowski et al. 2016). Based on small plot studies in Wisconsin, the probability of a positive net return from neonicotinoid treated seed relative to untreated seed at common soybean seeding rates was 71% (Gaspar et al. 2015). A similar response was noted for soybean across Ontario, Wisconsin, Iowa, Indiana, and Michigan where the combined fungicide and neonicotinoid seed treatment delivered an average profit increase of almost $10 per ha, with a 70% probability of a positive net return (Gaspar et al. 2017). Farmer surveys conducted in the same manner of those of Canadian farmers found similar result in the U.S., with average yields more than 4% higher for soybean farmers using neonicotinoid seed treatments (Hurley and Mitchell 2016).

In their own words

Several listening sessions of farmers and agricultural professionals were held from November 2013 through March 2014, focusing on pest management and neonicotinoids. Two sessions were held on Canada, one in Regina, SK focused on canola and one in London, ON focused on soybeans and corn (Shaw and Genskow 2014). As additional evidence of the relevancy of the general points noted above, here we use direct quotes from the Canadian listening session that re-state some of these points, but in the farmers' own words. Many more statements from the

Canadian listening sessions are available than these given below.[3] All page numbers are from Shaw and Genskow (2014).

A canola farmer explaining the crucial role neonicotinoid seed treatment play in extending the reaction time they have to find and to address flea beetle problems (p. 6):

> *Neonicotinoids isn't maybe the magic bullet, but it buys me time, so I can get to those fields; and sometimes the flea beetle pressure is high enough that we've got to go out and spray, but, like I said, it just extends that because it's such a tight window because in all reality, you've just got two weeks to get a crop on and off.*

Another canola farmer's perspective on why foliar applications cannot effectively replace neonicotinoid seed treatments due to a variety of factors (p. 6):

> *It's all well and good to say that the crop scout costs $5 per acre and then after you seed your crop, the crop scout shows up on the day that you want him, that the weather is good and that he can see exactly what he needs to see and that you're not losing a population already before he gets there, and that's not what happens. So you have to be aware that when that plant comes out of the ground, if there's a high population of flea beetles that the plant is already suffering from the effects of the insects, then you have to get it sprayed and you have to get it sprayed on a day that's not windy. So there's several days wait off, and especially if you have any amount of acres, before you can get it sprayed. So you may lose a crop before you can even get a chance to spray it. So it's not just a matter of what you can do, but it's a matter of living in the real world. When you seed with a seed treatment, that seed is treated from the moment that you get it into the ground.*

A canola farmer's statement that neonicotinoid seed treatments are the only option in canola for flea beetles and his likely response if he did not have them (p. 17):

> *In the canola industry – if someone were to come along and tell me 'seed treatments are out,' I mean, we've got no option. My first thought is I mean I would cancel 50 to 75 percent of my canola seed because I cannot manage the alternative effectively.*

An Ontario farmer expressing frustration at the potential of reintroducing human safety risks by not having neonicotinoid seed treatments (p. 15):

> *On the other side of it, we have the neonics, we eliminated all of those [human safety] problems we just talked about for the last 10 minutes, and we don't have those problems because of the neonics.*

An Ontario farmer's thoughts on how the amount of spraying would increase if neonicotinoid seed treatments were not available (p. 13):

> *Would spraying increase? Yes. Astronomically. Because if we go back to what was happening in 2003 with aphids as an example, we had a major infestation, I mean there was hundreds of thousands of acres sprayed, and if we go into last year where you had aphid sprays … the guys that had CruiserMaxx® treatment on their soybeans they didn't have to spray but everyone else did. So the volume of spray would go way up. If I had to look at my own farm, I'm going to have to budget two leafhopper sprays minimum, right off the bat, guaranteed. Compared to none today. Soybeans, I'm going to have to, guarantee, probably put a spray in my aphids, which I don't today, because ladybugs build their population and away they go. So, astronomical impact.*

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[3] To identify specific statements by Canadian farmers at the listening sessions, we recommend electronically searching Shaw and Genskow (2014) for "Ontario" and "canola".

Canadian crop farmers find value in neonicotinoid seed treatments

Overall, Canadian farmers find neonicotinoid seed treatments valuable. An econometric analysis of farmer survey data estimated that the average value of neonicotinoid seed treatments in 2013 for Canadian farmer using them was $34.51/ha for canola, $32.28/ha for corn and $39.03/ha for soybean, net of the seed treatment cost (Hurley and Mitchell 2014). Adding these values over all the seeded area using them in 2013 in these three crops gives a total value of $242 million for canola farmers, $36 million for corn farmers and $48 million for soybean farmers, for a total of $326 million.

Health Canada's Pest Management Regulatory Agency (PMRA) similarly found that neonicotinoid seed treatments in the Canadian corn industry add approximately $74.2 to $83.3 million, or about 3.2% to 3.6% of the national farm gate value for corn in 2013, with Ontario reaping a majority of these benefits. In soybean, neonicotinoid seed treatments results in an estimated economic benefit of about 1.5% to 2.1% of the national farm gate value for 2013 (about $37.3 to $51 million) with Manitoba and Ontario soybean industries experiencing much of this value (PMRA 2016).

The loss of neonicotinoid seed treatments would likely put Canadian farmers at an economic disadvantage. In Ontario alone it was estimated that the loss of this technology would likely lead to fewer farmers (tighter margins and reduced farm profitability) and smaller farms (inability to scout and effectively manage current farm size). This would cost Ontario farmers more than $630 million annually and reduce Ontario's GDP by nearly $440 million (Grant et al. 2014).

The economic loss of neonicotinoid seed treatments is compounded by the lack of alternative seed treatments for Canadian farmers. In four case studies in the European Union where farmers lost the ability to use neonicotinoid seed treatments and no other seed treatment options existed farmers often altered their pest management practices by: increasing their seeding rate (higher seed cost), through increased scouting, and/or altered planting date. The farmers perceived that these changes led to increased management time, cost and insecticide applications (Kathage et al. 2017). They also surmised that the lack of this mode of action may lead to greater pressure on fewer insecticide classes (such as pyrethroids) and increased risk of pest resistance.

Potential impacts of Canadian crop farmers lost access to neonicotinoid seed treatments

As explained in the previous sections, neonicotinoid seed treatments are an integral part of insect management for Canadian crop farmers. Should these technologies no longer be available, it is anticipated that farmers would make substantial changes in their pest management practices. A detailed assessment on the value of neonicotinoid seed treatments was made for the U.S. agricultural industry. Though the relative importance of crops and the product registrations in Canada differ from the U.S., the general situation is the same: neonicotinoid seed treatments are also an integral part of insect management for U.S. crop farmers. Based on this information, a general extrapolation to the Canadian market (with a specific focus on canola, corn, and soybeans) can be made.

Estimated U.S. impacts

U.S. crop farmers rely on the same four insecticide classes as their Canadian counterparts: neonicotinoids, Bt traits, pyrethroids, and organophosphates, with seed-based delivery by far the dominate method of application. For U.S. farmers growing corn, soybeans, wheat, cotton and sorghum, the 2010-2012 average use for neonicotinoids amounted to 52% of the insecticide treated area, Bt amounted to almost 27%, while pyrethroids and organophosphates amounted to 13% and 8% respectively, with all other classes only amounting to 1.2% of the treated area (Mitchell 2014a). Because almost all of the neonicotinoids are applied as seed treatments, 78% of the insecticide treated area uses seed-based delivery. Though the crops, climate and pests vary to some degree, U.S. famers rely on seed-based delivery and neonicotinoids for many of the same reasons as Canadian crop farmers.

A U.S. study projected the changes in pest management practices among U.S. farmers if neonicotinoids were not available, based on detailed U.S. data on insecticide use that is not available for Canada (Mitchell 2014a). Based on the general similarity of Canadian and U.S. cropping systems, we anticipate that the projected impacts among Canadian crop farmers would be generally similar as among U.S crop farmers if neonicotinoids were no longer available.

The following projections are based on the average insecticide market shares for 2010-2012, the projected impact to the U.S to a complete ban of neonicotinoid seed treatments and the resulting shift to more foliar and soil applied pyrethroids and organophosphates to manage insect pests (Mitchell 2014a). The projected area treated with pyrethroids tripled and the area treated with organophosphates increased 2.9 times. Most of this new projected treated area was foliar applied based on field scouting. Furthermore, no alternatives to neonicotinoids were available for some pests in some crops, such as for below ground pests of soybean and wheat, and so large areas were projected to remain untreated and to suffer stand reduction and yield loss. In addition, farmer costs increased as these alternative active ingredients were more costly, plus equipment costs for foliar and soil application and scouting. Average cost increases projected for U.S. farmers for each treatment were more than $22.00/ha for corn, almost $9.00/ha for soybean and more than $6.50 for wheat (Mitchell 2014a).

General projected Canadian impacts

We anticipate similar shifts in pest management practices would occur among Canadian farmers if neonicotinoids were not available, but specific quantitative estimates are not available due to a paucity of Canadian data available at the time of this report. Nevertheless, we anticipate a substantial increase in the use of foliar applications of pyrethroids and organophosphates, plus cost increases and yield losses for Canadian farmers.

How these changes would compare to U.S. estimates is unclear due to various factors. First, diamide seed treatments (chlorantraniliprole and cyantraniliprole) are now available in Canada for several crops, which was not the case for U.S. crops at the time of the U.S. study. Although diamides provide adequate control of certain insect pests,[4] they are not considered a complete replacement of neonicotinoids due to their narrower spectrum and failure to control key insect

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[4] See http://www1.agric.gov.ab.ca/$Department/deptdocs.nsf/all/crop15631/$FILE/scott-hartley.pdf.

pests, for example they are not effective for corn rootworm.[5] Nevertheless, if neonicotinoids were not available, many Canadian crop farmers would likely use diamide seed treatments, which would likely increase farmer costs and imply larger yield losses for some farmers in some cases, but not increase pyrethroid and organophosphate use as much as estimated in the U.S. study.

Second, canola, wheat, and soybeans, which represent the largest crop planted area in Canada, do not have soil applied insecticide options available. However, U.S. farmers can use soil-applied insecticides for corn, the crop with the largest planted area in the U.S. As a result, much of the increase in pyrethroid and organophosphate applications in the U.S. analysis was projected to occur in corn as soil-applied insecticide (Mitchell 2014a), which would not be the case in Canada. However, Canadian farms are on average larger and are growing larger more rapidly than U.S. farms (Statistics Canada 2017), with less labor available, and so under greater pressure to reduce time per unit area, such as for scouting. As a result, we anticipate relatively more farmers replacing seed treatments with prophylactic foliar sprays than in the U.S. analysis, particularly among canola farmers due to the size of farm operations and the need for early season control of flea beetles.

Thus, if Canadian crop farmers were no longer able to use neonicotinoid seed treatments, we anticipate an increase in the use of diamide seed treatments and foliar applications of pyrethroids and organophosphates, plus cost increases and yield losses for Canadian farmers. We do not anticipate that the magnitude of the increase in pyrethroids and organophosphates would be as large as projected for the U.S. study, but note that there is substantial uncertainty concerning canola, as the U.S. analysis did not include canola, since it is a relatively minor crop there. Furthermore, the U.S. study assumed the planted area for each crop remained fixed, even if neonicotinoids were no longer available. However, in the listening sessions (held before diamide seed treatments were available), Canadian canola farmers emphasized that they would likely reduce their canola seeded area substantially if neonicotinoid seed treatments were not available (Shaw and Genskow 2014).

Economic impacts in Canada

An additional study (Mitchell 2015b) used small plot data from Canada and estimated projected cost increases for Canadian canola, corn and soybean farmers if neonicotinoids were no longer available, before diamide seed treatments were an available option. If these estimated yield losses and cost increases were to occur for Canadian canola, corn and soybean farmers, they would imply a shift in the supply curve for each crop, reducing the overall availability of each crop for any given price. As a result, the equilibrium market prices and quantities would change as the markets adjusted. In this case, this shift implies a reduction in an economic measure called social surplus – a monetary measure of the value a market generates for society. This loss in the estimated results if neonicotinoids were no longer available, and so are also the societal benefits generated by neonicotinoids relative to the available insecticidal alternatives.

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[5] See http://www.dupont.ca/content/dam/dupont/tools-tactics/crop/canada-label-msds/documents/cp_PSD-93_Lumivia_32154_20170222_Label_E.pdf and https://www.syngenta.ca/pdf/Labels/Fortenza_30899_en_pamphlet.pdf.

For this analysis (Mitchell 2015b), low and high yield loss scenarios were developed based on the small plot data. The overall ranges were a 9.7% to 18.9% yield loss for canola if neonicotinoids were no longer available, a 4.4% to 9.8% yield loss for corn, and a 1.3% to 4.4% yield loss for soybean. These are the yield losses that would occur if neonicotinoids were no longer available or conversely the yield gains generated by neonicotinoids relative to other insecticidal options. The low loss scenario used the average for all the U.S. and Canadian small plot data, while the high loss scenario used only the Canadian small plot data (Mitchell 2014b). Similarly, the average cost increase if neonicotinoids were no longer available due to higher cost for active ingredients, applications and scouting was $7.73/ha for canola, $16.78/ha for corn and $5.85 for soybean.

These average yield losses and cost increases are integrated with supply and demand equations for each crop estimated with historical Canadian data. Based on this model, the estimated monetary benefits generated by neonicotinoids in Canada from their use to grow canola, corn and soybean ranged from $162 million to $300 million per year (Mitchell 2015b). These are aggregate social benefits generated by these crop markets, primarily as lower prices for livestock feed and exports and higher income for farmers.

Note that this estimated value range does not include a wide variety of other benefits generated by neonicotinoid use by Canadian farmers, such as human and environmental safety benefits, risk management benefits for farmers, or insect resistance management benefits. The impact of updating this estimate for the availability of diamide seed treatments is unclear. Also, the seeded area for these three crops has increased from the 2010-2012 period, while crop prices have declined, making the implied net change in the economic surplus generated by the market unclear. Overall, it seems likely that the total market benefit generated by use of neonicotinoids on these crops would still be in this range, and increase if market benefits from their use in small grains and potatoes were included.

Table 1. Canola insecticide target pests and most important pest and available insecticide delivery options

	% of Farmers Reporting				
Insect Pest	Actively Managed	Most Important Pest	Time of Pest Impact	Location of Pest Impact	Insecticide Delivery Options
Flea beetle	50.0%	40.0%	Early season	Above ground	Seed treatment, Foliar spray
Bertha armyworm	24.0%	15.2%	Mid-season	Above ground	Foliar spray
Armyworm	13.4%	8.1%	Mid-season	Above ground	Foliar spray
Diamondback moth	13.0%	5.2%	Mid-season	Above ground	Foliar spray
Lygus bug	12.2%	8.6%	Mid-season	Above ground	Foliar spray
Cutworm	5.0%	2.9%	Early season	Below and Above ground	Foliar spray
Grasshopper	4.0%	1.9%	Mid-season	Above ground	Foliar spray
Cabbage seedpod weevil	3.8%	1.9%	Mid-season	Above ground	Foliar spray
Swede midge	0.8%	0.0%	Mid-season	Above ground	Foliar spray
Worm	0.6%	0.5%	Mid-season	Above ground	Foliar spray
Wireworm	0.6%	0.0%	Early season	Below ground	None
Aphid	0.6%	0.0%	Mid-season	Above ground	Foliar spray
Root maggot	0.2%	0.0%	Early season	Below ground	None
Total for below ground & early season pests	50.6%	40.0%			

Source: Adapted from Hurley and Mitchell (2014)

Table 2. Corn insecticide target pests and most important pest and available insecticide delivery options

	% of Farmers Reporting				
Insect Pest	Actively Managed	Most Important Pest	Time of Pest Impact	Location of Pest Impact	Insecticide Delivery Options
Corn borer	59.8%	54.4%	Early and Mid-season	Above ground	Bt trait, Foliar spray
Rootworm	30.6%	22.3%	Early season	Below ground	Bt trait, Seed treatment, Soil applied
Black cutworm	8.3%	2.9%	Early season	Below and Above ground	Seed treatment, Soil applied, Foliar spray
Wireworm	5.8%	1.0%	Early season	Below ground	Seed treatment, Soil applied
Armyworm	1.7%	0.0%	Mid-season	Above ground	Foliar spray
Grub	1.7%	0.0%	Early season	Below ground	Seed treatment, Soil applied
Seed maggot	1.7%	0.0%	Early season	Below ground	Seed treatment, Soil applied
Aphid	0.8%	0.0%	Mid-season	Above ground	Foliar spray
Flea beetle	0.8%	0.0%	Early season	Above ground	Seed treatment, Foliar spray
Total for below ground & early season pests	48.9%	26.2%			

Source: Adapted from Hurley and Mitchell (2014)

Table 3. Soybean insecticide target pests and most important pest and available insecticide delivery options

	% of Farmers Reporting				
Insect Pest	Actively Managed	Most Important Pest	Time of Pest Impact	Location	Insecticide Delivery Options
Aphid	43.4%	49.5%	Early and Mid-season	Above ground	Seed treatment, Foliar spray
Mite	6.6%	1.1%	Mid-season	Above ground	Foliar spray
Bean leaf beetle	4.9%	0.0%	Mid-season	Above ground	Seed treatment, Foliar spray
Grasshopper	4.1%	5.3%	Mid-season	Above ground	Foliar spray
Wireworm	2.5%	0.0%	Early season	Below ground	Seed treatment
Grub	0.8%	0.0%	Early season	Below ground	Seed treatment
Japanese beetle	0.8%	0.0%	Mid-season	Above ground	Foliar spray
Seed maggot	0.8%	1.1%	Early season	Below ground	Seed treatment
Cutworm	0.8%	1.1%	Early season	Below and Above ground	Seed treatment, Foliar spray
Leafhopper	0.8%	0.0%	Mid-season	Above ground	Foliar spray
Total for below ground & early season pests	53.2%	51.7%			

Source: Adapted from Hurley and Mitchell (2014)

Table 4. Relative importance of various factors in pest management decisions (% of farmer responding “Important” or “Very important”) and their grouping into three categories

Factor	Canola	Factor	Corn	Factor	Soybean
🟩 Family and Worker Safety	97%	🟩 Family and Worker Safety	98%	🟩 Family and Worker Safety	100%
🟧 Protecting Yield	96%	🟩 Protecting Water Quality	96%	🟧 Protecting Yield	97%
🟧 Consistent Insect Control	94%	🟩 Public Safety	95%	🟩 Public Safety	93%
🟧 Crop Marketability	93%	🟧 Protecting Yield	95%	🟩 Protecting Water Quality	91%
🟧 Improving Plant Health	90%	🟧 Improving Plant Health	94%	🟧 Cost	87%
🟩 Public Safety	90%	🟧 Improving Crop Stand	93%	🟧 Improving Plant Health	87%
🟩 Protecting Water Quality	88%	🟧 Consistent Insect Control	92%	🟧 Consistent Insect Control	86%
🟧 Long-Lasting Insect Control	86%	🟩 Protecting Beneficial Insects	91%	🟧 Crop Marketability	86%
🟧 Cost	85%	🟧 Crop Marketability	85%	🟧 Improving Crop Stand	86%
🟧 Improving Crop Stand	85%	🟩 Protecting Wildlife	83%	🟩 Protecting Beneficial Insects	85%
🟩 Protecting Beneficial Insects	85%	🟦 Saving Time and Labor	83%	🟩 Protecting Wildlife	84%
🟩 Protecting Wildlife	78%	🟧 Long-Lasting Insect Control	82%	🟧 Long-Lasting Insect Control	81%
🟦 Saving Time and Labor	75%	🟧 Cost	80%	🟦 Ability to Plant Early	79%
🟦 Simplicity	74%	🟦 Ability to Plant Early	78%	🟦 Flexibility	76%
🟦 Flexibility	74%	🟦 Flexibility	76%	🟦 Saving Time and Labor	76%
🟦 Convenience	71%	🟦 Simplicity	75%	🟦 Convenience	72%
🟦 Ability to Plant Early	69%	🟦 Replant/Product Guarantee	71%	🟦 Reducing Equipment Wear	66%
🟦 Reducing Equipment Wear	63%	🟦 Convenience	68%	🟦 Replant/Product Guarantee	65%
🟦 Replant/Product Guarantee	63%	🟦 Reducing Equipment Wear	64%	🟦 Simplicity	65%
🟦 Reducing Scouting	54%	🟦 Reducing Scouting	50%	🟦 Reducing Scouting	52%

Color Legend	🟩 Human and Environmental Safety	🟧 Profitability and Product Performance	🟦 Convenience and Saving Time

Source: Adapted from Hurley and Mitchell (2014)

Table 5. Estimated canola, corn and soybean seeded areas treated with insecticides by application method

Application Method	Estimated Area Treated (1,000,000 ha)	Share of Total
Seed Treatment	9.507	76.7%
Foliar Spray	1.721	13.9%
Bt Trait	1.130	9.1%
Soil Applied	0.040	0.4%
Total	12.398	

Source: Adapted from Hurley and Mitchell (2014)

Table 6. Estimated canola, corn and soybean seeded areas treated with insecticides by insecticide class

	------- Estimated Area Treated (1,000,000 ha) -------				
Insecticide Class	Canola	Corn	Soybean	Total	Class Share
Neonicotinoids	7.148	1.121	1.237	9.507	76.7%
Pyrethroids	0.990	0.059	0.125	1.174	9.5%
Bt Traits		1.130		1.130	9.1%
Organophosphates	0.382	0.003		0.386	3.1%
All Other Classes	0.136	0.053	0.013	0.202	1.6%
Total	8.656	2.366	1.376	12.398	
Crop Share	69.8%	19.1%	11.1%		

Source: Adapted from Hurley and Mitchell (2014)

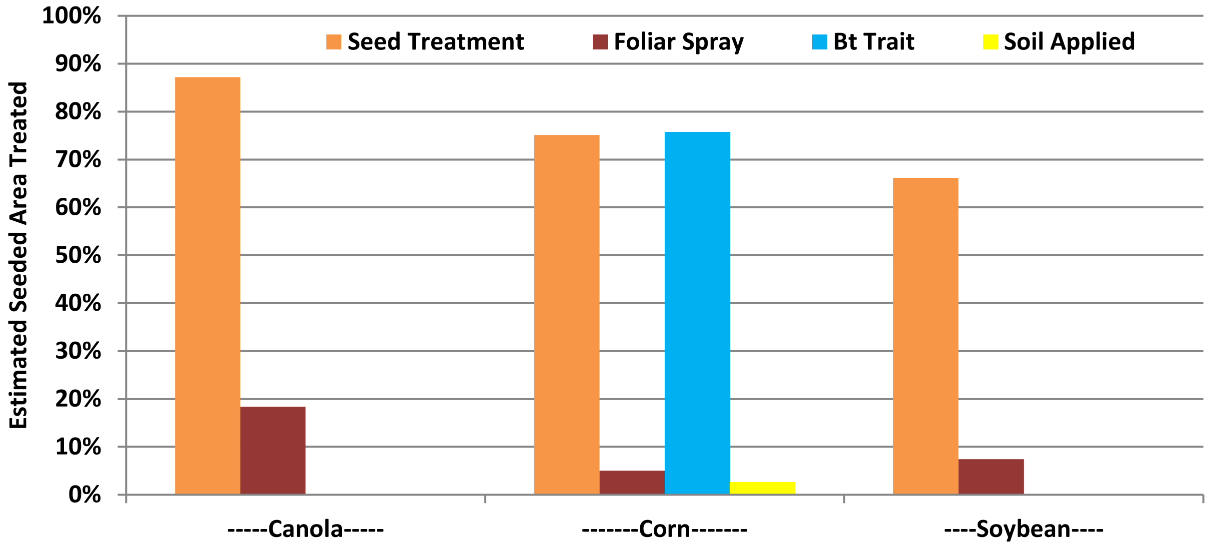

Figure 1. Estimated percentage of seeded area treated with insecticides by method of application
Source: Adapted from Hurley and Mitchell (2014)

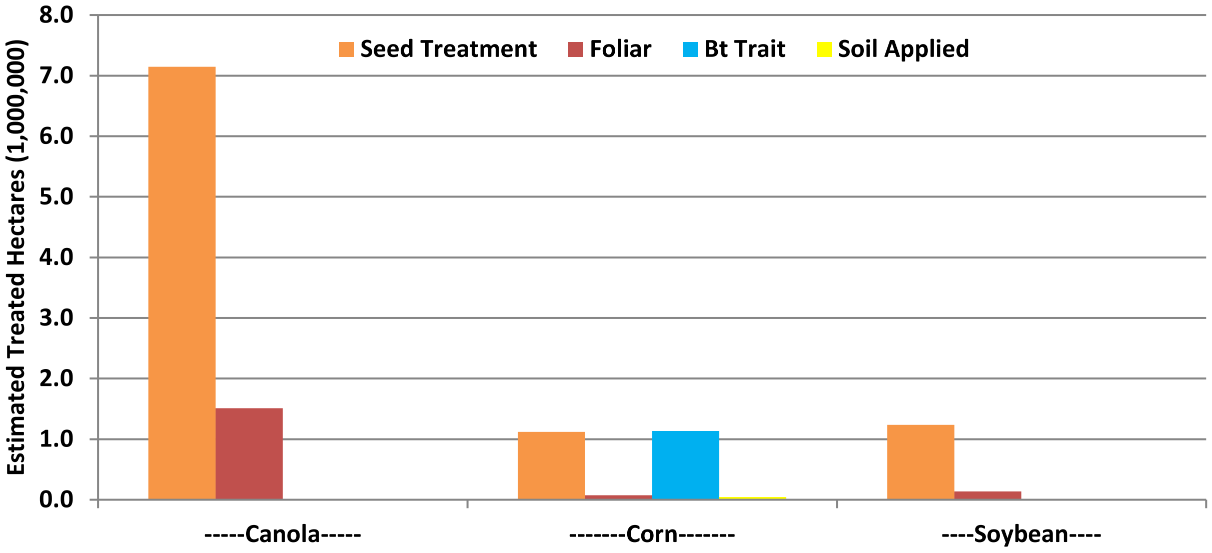

Figure 2. Estimated area treated with insecticides by method of application
Source: Adapted from Hurley and Mitchell (2014)

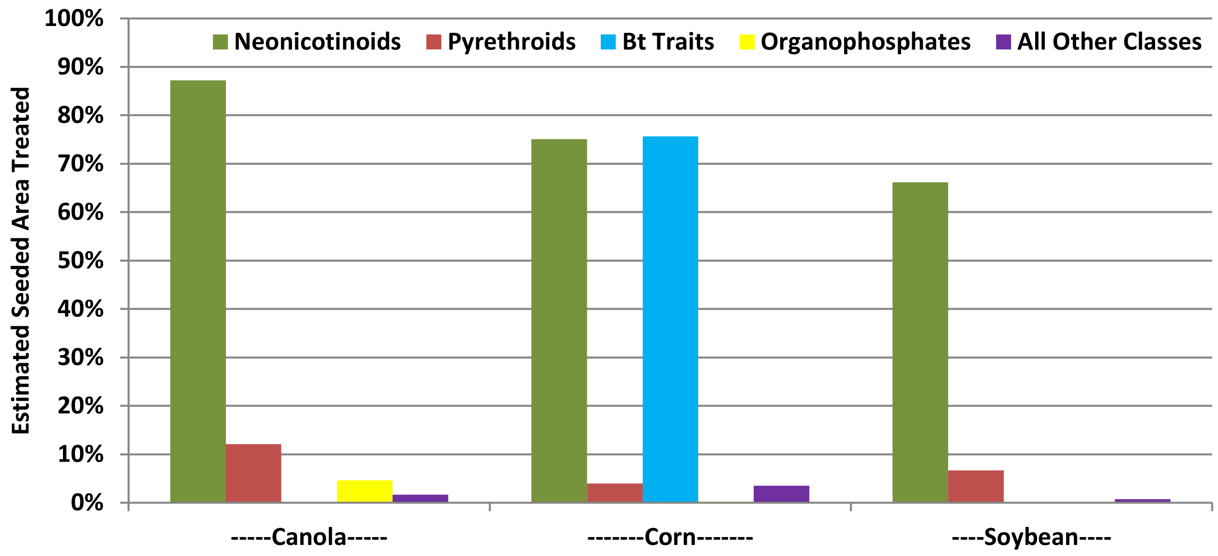

Figure 3. Estimated percentage of seeded area treated by insecticide class
Source: Adapted from Hurley and Mitchell (2014)

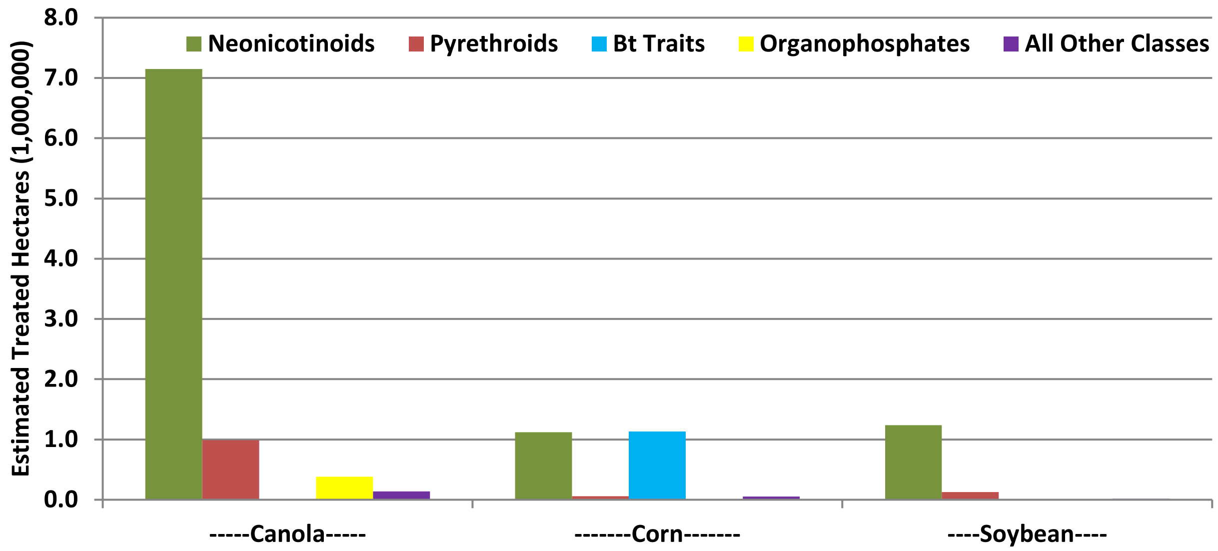

Figure 4. Estimated area treated by insecticide class
Source: Adapted from Hurley and Mitchell (2014)

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