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Re-evaluation Note REV2016-03

Value Assessment of Corn and Soybean Seed Treatment Use of Clothianidin, Imidacloprid and Thiamethoxam

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Executive Summary

The purpose of this document is to present the current value assessment of neonicotinoid corn and soybean seed treatment use in Canada and to seek additional information for consideration in the re-evaluation. This additional information would help clarify the situations in which neonicotinoid corn and soybean seed treatments are needed by Canadian growers.

A value assessment is normally conducted as a part of the overall assessment of any pesticide under re-evaluation. All pest control products, which are regulated under the *Pest Control Products Act*, are required to have value; in other words, they have an actual or potential contribution to pest management. The assessment is typically used to confirm how a product is currently being used and to determine its contribution to pest management. This value assessment has been conducted as a part of the Re-evaluation of the Neonicotinoid Insecticides, which is being carried out in close collaboration with the United States Environmental Protection Agency (USEPA), and examines how these pesticides assist agricultural practices as well as the economic benefits of neonicotinoid seed treatments on corn and soybean production in the current Canadian agricultural environment. There was very little reported use of imidacloprid on corn and soybean in Canada prior to 2013. As a result this value discussion focuses on clothianidin and thiamethoxam.

With respect to agricultural practice, it was found that clothianidin and thiamethoxam seed treatments contribute to insect pest management in agriculture in Canada. For example, neonicotinoid seed treatments control important pests and have replaced some older pesticides that were phased out due to health and environmental risk concerns. Neonicotinoid seed treatments also complement current crop production practices such as the use of reduced tillage or no-till and earlier planting for corn and soybean.

The economic benefit of neonicotinoid seed treatments to the Canadian corn and soybean industries depends in part on whether pest pressures are at a level that warrants the use of treated seeds and whether the economic return exceeds the cost associated with their use. However, identifying pest pressure poses considerable challenges for growers.

Using currently available quantitative and qualitative information collected from a variety of sources, neonicotinoid seed treatments are estimated to be of economic benefit to the Canadian corn industry with benefits varying by province. They are estimated to be of economic benefit to the Canadian crushing soybean industry in Manitoba and Ontario and to the Ontario Identity Preserved (IP) and food grade soybean industry in particular. It is apparent that at the farm level, the need for the use of an insecticide seed treatment on corn and soybean is highly dependent on local pest pressure and the value of these seed treatments could be substantial for affected growers.

Health Canada’s Pest Management Regulatory Agency (PMRA) acknowledges that a variety of models exist to estimate the value of neonicotinoid seed treatment use on corn and soybeans and that various assumptions are used by each model which may lead to a wide range of conclusions.

Health Canada's PMRA used provincial surveys, information from registrants, professional agronomists, AgInfomatics and the Conference Board of Canada along with a number of assumptions in preparing its value assessment of the economic benefits derived from neonicotinoids. Health Canada's PMRA is now seeking additional information to validate these assumptions and finalize the value assessment.

Overview

As part of the Re-evaluation of the Neonicotinoid Insecticides, Health Canada's PMRA has conducted an assessment of the value of clothianidin, imidacloprid and thiamethoxam when used to treat corn and soybean seed.

At the time of the initial registration over ten years ago, value (based primarily on efficacy and effect on host organisms) was demonstrated to be acceptable. In light of the linkages between bee incidents and the planting of neonicotinoid-treated corn and soybean seeds, and in order to understand the current context of neonicotinoid use, this value assessment includes the agronomic benefits which address the contribution of neonicotinoids to insect pest management practices, and the economic benefit of neonicotinoid seed treatments on corn and soybean production in the current Canadian agricultural environment.

As of 2013, virtually all field corn planted in Canada was treated with either thiamethoxam or clothianidin and greater than half the soybean seeds planted in Canada were treated with thiamethoxam. There is very little reported use of imidacloprid on corn or soybean seed in Canada. As a result this value discussion focuses on clothianidin and thiamethoxam.

The value assessment includes an analysis of the contribution of neonicotinoid seed treatments to insect pest management under current crop production practices and estimates the direct economic benefits to the corn and soybean industries in Canada. The value assessment is based on information provided by provincial governments, Canadian grower associations, professional agronomists, registrants and other stakeholders, as well as proprietary use information, published scientific journal articles and considers published reports by the Conference Board of Canada, AgInfomatics and the United States Environmental Protection Agency (USEPA). These information sources are variable in nature and the reports have used different types of information including sometimes unique assumptions. The PMRA's economic estimates are at the industry level (i.e., the aggregate farm gate value) rather than individual farm level and are based upon currently available information. As a result, they are considered approximations. The estimates provided by the provinces are based primarily upon surveys, monitoring and field studies and upon extensive practical experience in extension work with growers. As a result, some of the information provided was qualitative in nature.

The economic benefit analysis is based upon the estimated revenue lost as a result of decreased yield to the corn and soybean crop area estimated to be affected by pest pressure above economic thresholds[1] and the cost for pest management. For Ontario, the cost for pest management includes the difference in the cost of using alternative pest control products compared to the

1 The density of an increasing pest population at which control should be initiated to prevent damage that exceeds the cost of control measures.

neonicotinoid seed treatments (when they are available). For Manitoba, Québec and the Atlantic provinces, the cost of pest management is based upon grower expenses on seed treatments. Health Canada assumed that the entire crop area realizing a yield benefit from using a neonicotinoid seed treatment is harvested and therefore captures the complete net economic benefit. The estimates do not attempt to quantify revenue benefits attributable to the advantages derived from using the seed treatment application method as information required for these assessments was not available. In addition, the assessment did not attempt to quantify the economic impacts to other industries affected by changes in revenue to the corn and soybean industries.

The economic benefit analysis was conducted at the industry level because quantifying the economic impact at the farm level is extremely difficult as the potential economic loss at the farm level is determined by many factors such as crop, variety/hybrid, soil type, crop rotation and past pest pressure. The potential economic benefits from using a neonicotinoid corn or soybean seed treatment at the farm level can be qualified as minimal when there is little pest pressure, to being critical to crop production in cases where pest pressures would require the producer to replant the entire crop, or when several pests are present in a given field, or where the pest affects end product marketability (e.g., cereal leaf beetle in seed and sweet corn; bean leaf beetle in IP/food grade soybean).

This assessment indicates clothianidin and thiamethoxam seed treatments complement current corn and soybean production practices such as the use of reduced tillage and no-till and the earlier planting of corn and soybean, while providing several pest management benefits for the control of soil insect pests. However, the economic return from the use of neonicotinoid seed treatments is correlated to the prevalence of insect pest populations at levels that exceed economic thresholds.

Based on currently available information, the PMRA economic benefit analysis for the corn seed treatment suggests a national economic benefit for the corn industry of approximately $74.2 to $83.3 million or about 3.2% to 3.6% of the national farm gate value for corn in 2013. The majority of these benefits appeared to be realized in Ontario, and vary depending on the type of corn grown (in other words, grain, sweet, seed or forage). In Manitoba, using neonicotinoid corn seed treatments appeared to also prevent economic loss in the forage corn industry (estimated at $0.21 to $1.4 million for 2013). For field corn in Manitoba, the benefits ranged from about $0.1 million, up to a benefit of $3.5 million. In Québec grower expenses on neonicotinoid treated corn seeds were estimated to exceed the yield returns. In all other provinces, at the industry level, grower expenses related to neonicotinoid treated corn seeds were estimated to exceed the yield returns, or information was not available to estimate the economic value.

The economic benefit analysis determined that the national economic value of neonicotinoid seed treatment to the soybean industry 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). This economic benefit appears to be primarily to the Manitoba and Ontario soybean industries.

In Québec, grower expenses on neonicotinoid treated soybean seeds were estimated to exceed the yield returns. For other provinces, grower expenses at the industry level on neonicotinoid seed treatments on soybean were estimated to exceed the yield returns, or data was not available to estimate the economic value.

Seed corn and sweet corn are of greater value per tonne than field corn. This is also the case for IP/food grade soybean which is of greater value per tonne than soybean for crushing. These high value crops require high quality seeds that are free from plant pathogens such as Stewart's wilt (corn) and bean pod mottle virus (soybean). These pathogens are not acceptable to importing countries and if present would effectively close the export markets for infected corn and soybean seed. The estimates do not attempt to quantify the revenue impacts from market access issues as this information was not available. However, it is recognized that the export market contributes to these industries and access to export markets due to seed quality impact these industries significantly.

This assessment did however include the economic impact from quality loss for Ontario soybeans as a result of downgrading IP/food grade seeds to crushing quality. Information on the economic impacts resulting from quality loss for IP/food grade soybean production was not available for Québec and therefore was not included in this assessment. There is little IP/food grade soybean production in the other provinces. As a result neonicotinoid seed treatments are expected to have a greater economic value for these specialised corn and soybean crops.

The PMRA's economic benefit analyses are based upon the available information and are greater (1.5% to 2.1%) than the preliminary estimate reported by the USEPA for soybean (0.14%) and, when standardized for similar pest pressure, the PMRA's estimate for the value of neonicotinoid seed treatments to the corn and soybean industries in Ontario (2.9%) is slightly lower than the estimates provided by the Conference Board of Canada (3.0% to 4.5%).

AgInfomatics assessed the economic value of various insect management practices (including neonicotinoid seed treatments) to corn and soybean growers through a grower survey (i.e., an econometric valuation approach). The results indicate the estimated national benefits from the use of neonicotinoid insecticide seed treatments were $36 million for corn and $47 million for soybean in 2013. This represents 1.5% of the Canadian corn industry value in 2013 and 1.9% of the Canadian soybean industry value in 2013.

The estimates from AgInfomatics are based upon a very different approach than that used by the Conference Board of Canada, the US EPA and Health Canada which are based primarily upon estimates of pest pressure and yield loss. Despite the differing approaches, the national industry level economic value estimates from the different sources are within a small range.

In order to fully assess the economic value of clothianidin and thiamethoxam seed treatments to the Canadian corn and soybean industries, quantitative, more real-world information on typical pest population levels relative to economic thresholds is needed.

The PMRA is seeking additional information to finalize the value assessment for both the corn and soybean seed treatments uses. Stakeholders and interested parties are invited to provide written comments on this document as well as additional information up to 60 days from the date of publication. Please forward all comments to Publications (see contact information indicated on the cover page of this document).

Value Assessment

What are Neonicotinoid Seed Treatments?

The chloronicotinyl nitroguanidine insecticides (referred to herein as neonicotinoids) clothianidin, imidacloprid and thiamethoxam are systemic insecticides used to control a broad spectrum of insect pests on a wide variety of crops. This assessment focuses on the value of clothianidin, imidacloprid and thiamethoxam seed treatments to corn (grain, seed, sweet and silage) and soybean (crush, food grade and identity preserved (IP)).

End-use products containing clothianidin, imidacloprid and thiamethoxam are applied as a coating to corn and soybean seeds prior to planting. They are applied using closed seed treatment equipment by professional applicators at commercial seed companies, seed distributors or seed conditioners. Clothianidin, imidacloprid and thiamethoxam are classified by the Insect Resistance Action Committee (IRAC) as group 4A Mode of Action (MoA) insecticides. They bind to nicotinic acetylcholine receptors in insects causing nerve disruption. These active ingredients control insect pests through contact or by ingestion. Due to their systemic action, clothianidin, imidacloprid and thiamethoxam are absorbed by and distributed throughout the plant thereby imparting protection to the whole plant.

Currently, two end-use products formulated with clothianidin, seven end-use products containing imidacloprid and five end-use products containing thiamethoxam were registered under the *Pest Control Products Act* for use on corn or soybean as a seed treatment (Appendix I). Following the re-evaluation announcement for clothianidin, imidacloprid and thiamethoxam, Sumitomo Chemical Inc., Bayer CropScience Inc., Makhteshim Agan of North America (MANA) and Syngenta Canada Inc., the registrants of the technical grade active ingredient and primary data providers in Canada, indicated that they intend to continue to support all seed treatment uses on corn and soybean included on the labels of Commercial Class end-use products (Appendix II).

What is the Value of Corn and Soybean in Canada?

Corn is Canada’s third largest grain crop after wheat and barley (Statistics Canada, 2012a). It is the most valuable grain crop in Eastern Canada (Howatt, 2006; Statistics Canada, 2014a). Canada ranks twelfth in global corn production and is a net consumer of corn (Spectrum Commodities, 2013a).

Soybean is grown for animal feed, edible oil, food and industrial purposes (biodiesel, resins, glycerol, etc.) (Soy20/20, 2008). Canada is the seventh largest producer of soybean in the world. With a large production relative to consumption, Canada is one of the smallest importers of soybean. Canada's high production to consumption ratio also lends itself to large exports. As a result, Canada ranks fifth in world exports (Spectrum Commodities, 2013b).

Table 1 National Statistics for Corn and Soybean (2011) (Statistics Canada, 2012a; 2012b; 2013)

Corn type	National crop area (hectares)	Crop value ($)	Comments
Field corn	1,300,000	2.1 billion	No comments.
Seed corn	No data	No data	Information on the national crop area and value of seed corn was not available. Ontario indicated that 14,164 ha were planted in 2013 at a value of $48.5 million (OMAFRA, 2014).
Silage corn	273,000	No data	Information on the national value of silage corn was not available. Ontario indicated that 105,218 ha were planted in 2013 at a value of $249 million (OMAFRA, 2014).
Sweet corn	19,042	60.2 million	No comments.
Soybean	1,600,000	1.6 billion	No comments.

Ontario, Québec and Manitoba are the main corn and soybean production regions in Canada.

In 2011, Ontario was the largest producer of corn and soybean accounting for approximately 58% of the Canadian field and sweet corn production area (Figure 1) and approximately 62% of the Canadian soybean production area (Figure 2) (Statistics Canada, 2012a).

Québec was the second largest corn producer with 29% of the field corn crop area and 39% of the sweet corn production area. In comparison, Manitoba was the second largest soybean producer with about 18% of the soybean crop production area and Québec was the third largest with about 17% of the crop production area.

Figure 1 Production area (hectares) for grain, silage and sweet corn in (Statistics Canada, 2012a)

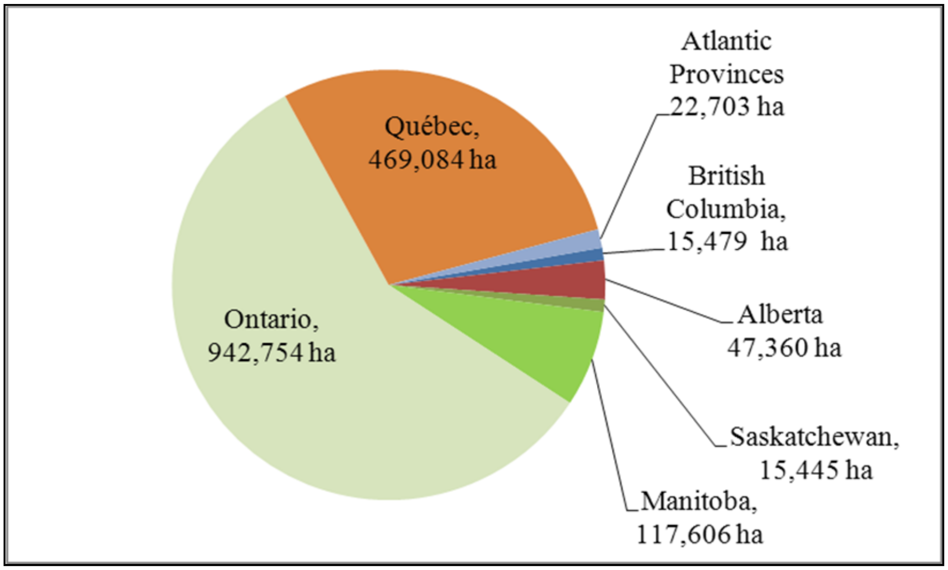
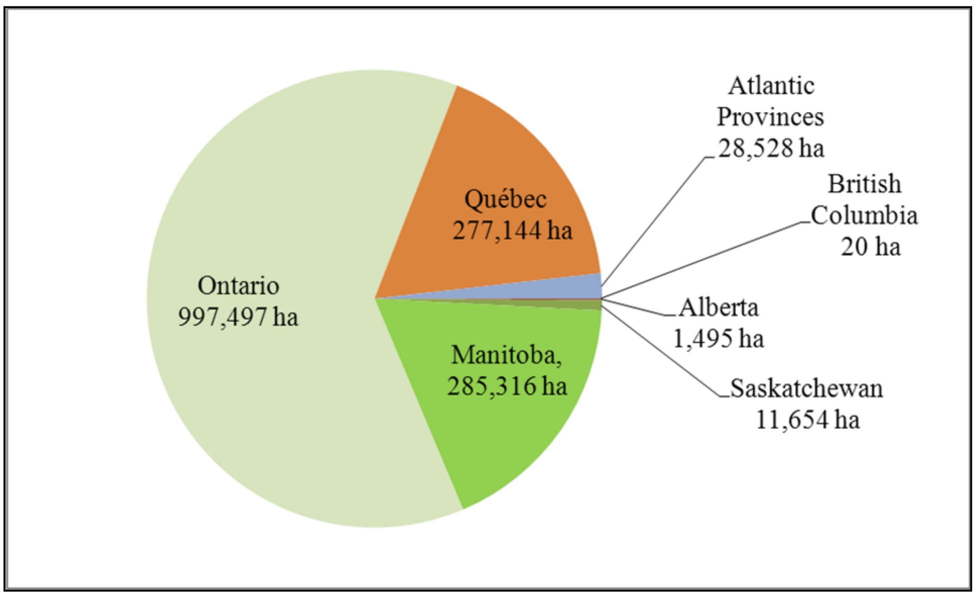


Figure 2 Soybean production area (hectares) in Canada by province (Statistics Canada, 2012a)

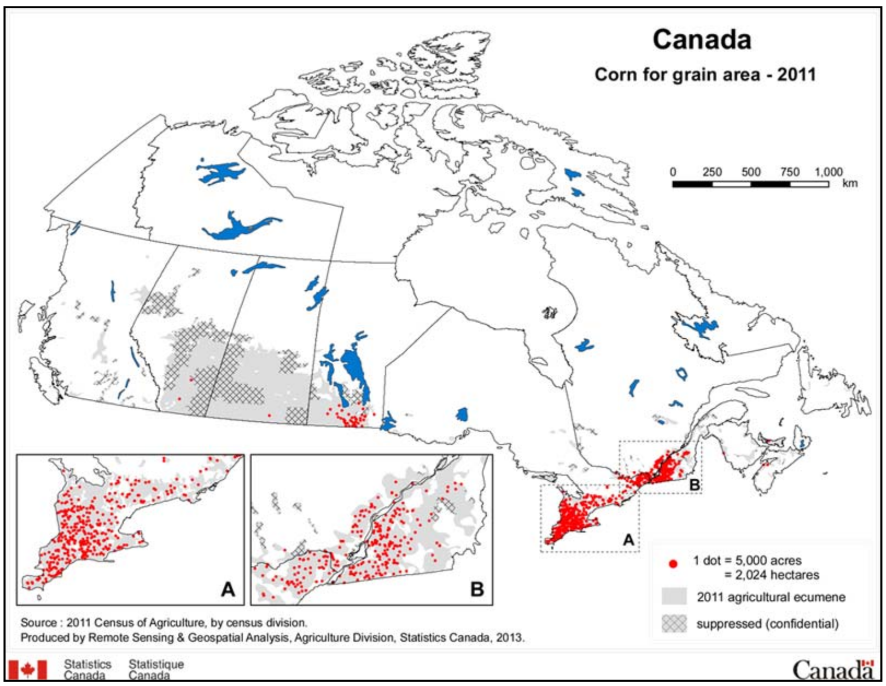


In 2011, in Ontario, field corn was primarily produced in South western, Southern, and Eastern Ontario. In Québec it was produced primarily in the Montérégie region. In Manitoba it was produced in the south central portion of the province (Figure 3).

In 2011, Ontario accounted for 62% of Canadian corn growers and 69% of Canadian soybean growers (Statistics Canada, 2012d). Québec was second with about 26% of the corn growers and 22% of soybean growers while Manitoba was third with about 4% of the Canadian corn growers and 7% of soybean growers (Statistics Canada, 2012d).

However, Manitoba growers had the largest average farm size for grain corn in 2011 at 119.8 ha (Statistics Canada, 2014a). The average farm size in Quebec was 65.3 ha while Ontario farms were the smallest (on average) at 50.8 hectares (Statistics Canada, 2014a).

Figure 3 Principal production regions of corn for grain in Canada (2011) (Statistics Canada, 2014a)



Corn and soybean are rotational crops.

Crop rotation improves soil fertility and structure, diminishes the prevalence of weeds, and breaks disease and pest cycles (Statistics Canada, 2014a). Overall, in 2011, 95.0% of all corn for grain and 97.9% of corn grown for silage was grown in a rotation with another crop (Table 2). Various corn-soybean rotations comprise about half (52%) of the grain corn area in rotation in 2011 (Statistics Canada, 2014a). In comparison, only 5.4% of the silage corn area was rotated with soybean in 2011(Statistics Canada, 2014a).

Table 2 Distribution of cropping pattern by corn variety and seeded area for Canada 2011 (Statistics Canada, 2014a)

Cropping pattern	**Seeded area** (hectares)	**Share of total seeded area** (percent)
Corn for grain		
No rotation (single crop)	66,862	5.0
Corn-soybean-wheat	263,836	19.8
Corn-soybean	239,074	17.9
Corn-hay-soybean-wheat	83,221	6.2
Corn-wheat-soybean-other	58,449	4.4
Corn-hay-soybean	49,127	3.7
Other patterns	573,512	43.0
Corn for silage		
No rotation (single crop)	5,839	2.1
Corn silage-hay	41,309	15.1
Corn grain-hay-soybean-corn silage	14,804	5.4
Corn grain-hay-corn silage	14,406	5.3
Corn silage-hay-barley	12,056	4.4
Corn silage-hay-oats	8,049	2.9
Other patterns	176,714	64.7

Since 2011, corn-soybean and corn-corn-soybean rotations in Ontario have become more intense at the expense of rotations of corn with forage crops and four year corn rotations or rotation of corn with other crops (Table 3) (OMAFRA, 2013).

Table 3 Estimate of corn and soybean rotations in Ontario (OMAFRA, 2013)

Hectares[1]	**Rotation**
1,214,055	Corn/Soybean/Wheat
809,370	Corn/Soybeans, Corn/Corn/Soybeans, etc.
161,874	Soybean/Wheat
101,171	Corn/Soybean/Forages
60,702	Corn/Forages/Cereals
32,699	Other corn rotations (pepper, potato, succulent beans, succulent peas, sugarbeet, tomato)[2]
21,368	Other soybean rotations (pepper, succulent beans, succulent peas, sugarbeet, tomato)
2,217,997[3]	All corn rotations
2,307,838[4]	All soybean rotations

[1] The area reported for each rotational series (for example, corn/soybean/wheat) is a general estimate as the area of each crop will vary from year to year. The estimated crop rotation areas are based upon extensive practical experience in extension work with growers.

[2] Various other crops are grown in rotations with corn and soybean.

[3]Total crop area reports area seeded to corn only and as a result excludes the area reported for soybean/wheat rotations (OMAF, 2013).

[4]Total soybean crop area reports only the area seeded to soybeans and therefore excludes the area reported for corn/forage/cereals rotation and corn/potato rotation.

What Is the Value of Neonicotinoid Corn and Soybean Seed Treatments?

Agronomic benefits

Clothianidin and thiamethoxam seed treatments contribute to insect pest management in agriculture in Canada.

As of 2013, virtually all field corn planted in Canada was treated with either thiamethoxam or clothianidin. Greater than half the soybean seeds planted in Canada were treated with thiamethoxam. There is very little reported use of imidacloprid on corn or soybean seed in Canada (PMRA Proprietary Seed Treatment Survey Data, 2013; OMAFRA, 2014; MAFRD, 2014; MAPAQ, 2014; NSDA, 2014; PMRA No. 2393325, 2393326). As a result the value discussion will focus on clothianidin and thiamethoxam.

The systemic nature of clothianidin and thiamethoxam allows emerging roots and stems from treated seeds to be protected from insect feeding damage during germination. For a period up to 40 days they continue to provide protection to the plant after emergence from the soil (OMAFRA, 2014). As a result, they are recommended for early season control of foliar feeding pests such as flea beetles (OMAFRA, 2014).

The seed treatment application method has several pest management benefits for control of soil insects compared to other application methods (Table 4), (for example, foliar sprays for control of leaf eating adults, granular in-furrow applications, or soil drenches in-furrow or over the row). As a result, seed treatment application is generally recommended by crop advisors for control of soil insects and pests which migrate into crops very early in the season (OMAFRA, 2014).

Table 4 Pest management benefits to using seed treatments

Pest management benefit	Seed treatment	Other application methods (for example, foliar spray)	Comments
Application rate	Typically low (in other words, g a.i./ha)	Typically higher (for example, kg a.i./ha)	Application is made directly to the seed which are the target of insect feeding rather than to the surrounding soil (PMRA No. 2393325, 2393326, 2392934; OMAFRA 2014).

Pest management benefit	Seed treatment	Other application methods (for example, foliar spray)	Comments
Preventative pest management[1]	As seed treatments are present at seeding, there is less chance that early season pest population feeding on stems and foliage will reach the economic threshold[2].	Applications made based upon monitoring. Risk of application being made after pests have surpassed economic thresholds.	Foliar sprays may not be applied early enough to prevent vectoring of diseases via the insect pest to the crop (for example, corn flea beetle and Stewart's wilt, or bean leaf beetle and bean pod mottle virus) (OMAFRA, 2014). For soil pests on corn (corn rootworm, seedcorn maggot and wireworm), the registered alternatives are applied at planting in furrow and as a result are also preventative in nature. There are no registered alternatives for control of soil pests on soybean (European chafer, seedcorn maggot and wireworm).
Number of applications	Neonicotinoid seed treatments provide early season control for up to 40 days (OMAFRA, 2011a; 2014). It does not protect soybean during the critical reproductive stages when soybean aphid affects yield (OMAFRA, 2014).	Several early season foliar applications may be required to control bean leaf beetles on soybean, or black cutworm and flea beetle on corn if pest pressure reaches economic thresholds early in the season.	Several foliar applications may be required for control of pests that otherwise would be controlled by a single seed treatment (PMRA No. 2472429). For example, seed treatments prevent aphid populations from rapidly building early in the summer thereby delaying, (or possibly preventing[3]) the need for later season foliar applications to keep aphid populations below the economic threshold (Magalhaes et al., 2009; OMAFRA, 2014).

Pest management benefit	Seed treatment	Other application methods (for example, foliar spray)	Comments
Complete plant protection	Seed treatments protect the seed from insect pest damage. The systemic nature of neonicotinoids provides additional protection to developing roots and stems.	Foliar applications can only target and control the above ground feeding life stages for some early season pests	Foliar applications may not be appropriate, or as effective as a seed treatment application for the control of certain pests (OMAFRA, 2014).
Reduced operational expenses	No additional application equipment is required. Only one pass with planting equipment is required	Additional granular application equipment or spray equipment is required for application (PMRA No. 2392934; OMAFRA, 2014). The average cost to retrofit planting equipment to apply a granular insecticide is estimated at $15,000 CAD (OMAFRA, 2014) More than one pass may be required (PMRA No. 2393325, 2393326, 2392934, 2472440; OMAFRA, 2014).	Seed treatments are less labor intensive and are more economical for growers (OMAFRA, 2014). Additional passes with equipment adds to production costs.
Protection to rotational crops from soil insect pests	Seed treatment can be used to reduce the pest pressure for subsequent crops in fields impacted by high pest pressure from white grubs (European chafer, June beetle) and wireworm.	Soil drenches or granular products may not be available for use on the rotational crop. Physical control (in other words, tillage) is the only alternative for many crops.	Forage crop growers will rotate to corn, soybean or cereals so that a neonicotinoid product may be used to reduce soil insect pest pressure (OMAFRA, 2014).

1 Timing of monitoring activities impacts a grower's ability to make pest management decisions based upon economic thresholds as it conflicts with when growers must make preventative pest management decisions involving the use of seed treatments (OMAFRA, 2014). Currently, critical IPM activities (in other words, monitoring) for pest management decisions must be performed in the spring of the growing season (OMAFRA, 2014). To obtain the seed varieties/hybrids growers need, seed orders and therefore treatment decisions are made by growers in the fall prior to the growing season. Due to difficulties associated with monitoring (OMAFRA, 2014), in conjunction with widespread use of insecticide seed treatments, very few corn and soybean growers are likely to monitor soil pest populations in the spring and make pest management decisions based upon economic thresholds (Onstad et. al., 2011).

2 The early-season effects of seed treatments may prevent colonization of treated soybean fields by aphids, or sufficiently damp early season population growth of aphids at the landscape scale to the point of having season-long consequences for soybean aphid abundance (Bahlai et al., 2015). Implication of this observation is that area-wide suppression of soybean aphid populations may be a direct result of the adoption of seed treatments, despite limited evidence showing benefits of use of these treatments within individual fields (Bahlai et al., 2015). Note that landscape-level suppression of soybean aphid and *Harmonia* may be possible by using varieties of soybeans that are aphid-resistant (Bahlai et al., 2015). Additionally the management of soybean aphids is not improved when a seed-treatment is applied to varieties incorporating multiple resistance genes. As such, it is possible that the adoption of multi-gene resistant soybean varieties may allow neonicotinoid seed treatments to be reduced or eliminated while maintaining low populations of both soybean aphid and *Harmonia* (Bahlai et al., 2015). Currently one variety of genetically modified soybean which is resistant to insect damage is registered by the CFIA for use in Canada. It prevents damage from lepidopteran pests (CFIA, 2012). None of the soybean pests controlled by neonicotinoid seed treatments are lepidopterans. As a result the currently registered genetically modified soybean varieties are not options as alternatives to the use of neonicotinoid seed treatments.

3 Seed treatments are not recommended for late season control of soybean aphids (OMAFRA, 2014) and would be unlikely to provide protection under high pest pressure (Magalhaes et al., 2009).

Identifying pest pressure and implementing integrated pest management (IPM) on corn and soybean is challenging for growers.

Integrated pest management (IPM) is a broad approach to pest management which involves using cultural practices (for example, crop rotation) to prevent or reduce pest pressure and encourage the presence of beneficial insects, as well as choosing from an array of pest management options. Integral to IPM is identifying the need for the use of pest management. This involves identification of pests, determining the potential pest pressure (for example, from past pest population levels, from monitoring) and using economic thresholds (in other words, the density of an increasing pest population at which control should be initiated to prevent damage that exceeds the cost of control measures).

Another consideration for IPM are factors known to increase the probability (risk) of crop damage from the insect pests that feed on corn and soybean seeds (Table 11). In some cases, growers can take steps to avoid conditions that increase the risk of damage to the crop. However, some conditions that may increase the risk of crop damage may be unavoidable (for example, cool wet weather or soil type). Monitoring protocols and economic thresholds have been developed in both Ontario and Québec for the majority of pests listed on the registered corn and soybean neonicotinoid seed treatment product labels with the exception of seedcorn maggot (Bernard et. al., 2013; OMAFRA 2014).

There are significant challenges to implementing some aspects of IPM (in other words, pest monitoring) in corn and soybean as evidenced from experience in Ontario (Table 5). Activities required for monitoring are costly and labour intensive compared to the ease of using clothianidin and thiamethoxam seed treatments. Due to the large field areas grown and the highly variable spatial distribution of the pests, except for very small operations, it has been reported that scouting for insect pests controlled by corn and soybean neonicotinoid seed treatments can be impractical for growers to implement (PMRA No. 2393325, 2393326).

Timing of monitoring activities impacts a grower's ability to make pest management decisions based upon economic thresholds as it conflicts with when growers must make pest management decisions involving the use of seed treatments (OMAFRA, 2014). Due to the volume of corn and soybean seeds that must be processed for planting the next season's crop, seed handling facilities must begin treating seeds starting in September and will continue into May to meet customer demands (PMRA No. 2393325, 2393326). Currently, critical IPM activities (in other words, monitoring) for pest management decisions must be performed in the spring of the growing season (OMAFRA, 2014). To obtain the seed varieties growers need, seed orders and therefore treatment decisions are made by growers in the fall prior to the growing season. Due to difficulties associated with monitoring (OMAFRA, 2014), in conjunction with current widespread use of insecticide seed treatments and resistant hybrids (in other words, *Bt* corn), very few corn growers are likely to monitor soil pest populations in the spring and make pest management decisions based upon economic thresholds (Onstad et al., 2011).

Table 5 Risk factors for pest damage and pest monitoring options for corn and soybean pests in Ontario (OMAFRA, 2014)

Crop	Pest	Risk factors for pest damage	Monitoring options	Challenges to implementing pest monitoring
Corn (field)	Seedcorn maggot	Cool, wet environmental conditions that delay seedling emergence. Deeply planted seed. Recently applied manure or plowed green manure (cover crop or plant material).	None	There are no practical scouting methods as this pest is highly mobile.
Corn (field)	Corn rootworm	Fields with a corn crop following a previous corn crop, especially if the previous corn crop was planted late. Fields with heavy clay soils.	Based on field history for pest damage and monitoring adult populations in the previous season (August).	Scouting must be performed in the previous year to identify the risk for the current year.
Corn (seed, silage and sweet)	Corn rootworm			
Corn (field and sweet)	Wireworm	Fields with very sandy soil. Corn planted in fields following sod or that have grassy weeds. Larvae may be present for up to 6 years in soil.	Place bait stations in the soil in fall or spring to estimate population.	Monitoring is labor intensive and the number of bait stations required is not practical for very large fields. Further research needed to confirm if fall monitoring is effective at predicting spring populations.

Crop	Pest	Risk factors for pest damage	Monitoring options	Challenges to implementing pest monitoring
Corn (field, seed and sweet)	Black cutworm	Past history of cutworm damage. Presence of winter annual weeds in early spring. Fields with light textured soils. Use of no till cultivation in fields with heavy crop residue Use of cover crops present in early spring.	Based on past field history and scouting for pest damage and larvae.	Pest pressure is variable as this pest migrates north from the United States in the spring. There are no monitoring networks presently established.
Corn (field, seed and sweet)	European chafer, June beetle	European chafer feeds primarily on corn, forage and wheat. June beetle feeds on all crops. Fields with sandy soils. Fields with knolls (well drained areas). Corn planted in fields following sod.	Scout in spring to estimate population.	Scouting is labor intensive and requires expertise in species identification. Further research needed to confirm if fall monitoring is effective at predicting spring populations.
Corn (seed and sweet)	Corn flea beetle	Warm winters that improve overwintering survival of pests.	Spring prediction model of flea beetles overwintering success. Monitoring adults in spring.	Corn flea beetle act as a vector of Stewart's wilt disease. There is no tolerance for this quarantinable disease in corn seed destined for export. Pest management decisions require knowledge of what the pest levels were in the previous fall and what the risk is for pest pressure within the current season. It is difficult to scout pests in spring before corn flea beetle has vectored Stewart's wilt to the seedling crop. Corn flea beetle is highly mobile and is difficult to detect when scouting. Foliar applications are less

Crop	Pest	Risk factors for pest damage	Monitoring options	Challenges to implementing pest monitoring
				likely to reduce risk of disease vectoring compared to seed treatments.
Soybean (crush and identity preserved/ food grade)	Bean leaf beetle	Fields with a history of early season infestation. Warm winters that improve overwintering survival. Soybean fields neighboring alfalfa fields.	Scouting once the crop emerges.	Overwintering prediction models are not currently available. Scouting in the fall is required to estimate the size of the overwintering pest populations. Scouting is labor intensive.
	Seedcorn maggot	Cool, wet environmental conditions that delay seedling emergence. Deeply planted seed. Recently applied manure or plowed green manure (cover crop or plant material).	None	There are no practical scouting methods as this pest is highly mobile.
	Soybean aphid	There is a higher risk every other year for a large outbreak[1]. Fields with a history of heavy infestations during the early vegetative stages, resulting in aphids reaching threshold immediately at the reproductive/flowering stage.	Scouting during the reproductive stages.	Scouting for soybean aphids needs to begin earlier in the season if a seed treatment is not used. Scouting is labor intensive and needs to be performed frequently. Scouting requires the ability to identify natural enemies of aphids as their presence influences the economic threshold.

Source: (OMAFRA, 2014)

[1]Biennial population cycles are linked to predator prey population dynamics of soybean aphid (*Aphis glycines*) and the Asian lady beetle (*Harmonia axyridis*) (Bahlai et al, 2015).

Clothianidin and thiamethoxam seed treatments complement current crop production practices such as use of reduced tillage or no-till for soybean and corn and earlier planting for corn.

Tillage

Generally, the use of a seed treatment complements the use of certain good agricultural practices such as reduced tillage, or no-till. Tillage is a physical means of controlling soil insect pests and results in warmer soil which accelerates germination (PMRA No. 2392934). However, this practice increases soil erosion and requires greater input into crop production such as fertilizer, equipment costs and availability, etc. (PMRA No. 2393325, 2392934, 2472440, 2472887; OMAFRA, 2009c). The use of conventional tillage has decreased in Canada since 1991 (Table 6) in favor of conservation tillage or no-till practices (Statistics Canada, 2012c) due to the desire for soil conservation and better soil health. By adopting conservation tillage or no-till, growers are at greater risk from soil pests as crops take longer to germinate due to cooler soil temperatures, extending the window where seeds are vulnerable (PMRA No. 2392934). Insecticide seed treatments protect the seeds during this period of vulnerability, facilitating the adoption of conservation tillage practices by corn and soybean growers.

Table 6 Change in tillage practices in Canada from 1991 to 2011 by province for all crops (Statistics Canada, 2012c)

Land management practices[1]	1991	1996	2001	2006	2011
	% of total crop area				
Canada					
Conventional tillage	69	53	41	28	19
Conservation tillage	24	31	30	26	25
No-till or zero-tillage	7	16	30	46	56
Québec					
Conventional tillage	85	80	77	62	49
Conservation tillage	12	16	19	29	33
No-till or zero-tillage	3	4	5	10	18
Ontario					
Conventional tillage	78	60	52	44	37
Conservation tillage	18	22	22	25	30
No-till or zero-tillage	4	18	27	31	33
Manitoba					
Conventional tillage	66	63	55	43	38
Conservation tillage	29	28	33	35	38
No-till or zero-tillage	5	9	12	21	24

[1] Conventional tillage – Incorporates most of the crop residue into the soil; Conservation tillage - Most of the crop residue is retained on the surface; No-till – soil is left undisturbed.

Seeding date

Seed treatments allow growers to plant corn and soybean earlier in the season by providing protection to slowly germinating seeds in cooler soils (OMAFRA, 2009a; Cox and Cherney, 2011; Gaspar et al., 2014; PMRA No. 2537743). This results in greater yield potential as a result of a longer growing period allowing growers to plant longer season, high yielding hybrids (PMRA No. 2472887, 2537743). The ability to plant corn and soybean early in the season also increases the duration of time when growers can plant these crops.

This allows farm operations to plant a larger area using less equipment and fewer workers (PMRA No. 2472887). For example if the window for planting was increased from a one week period to two weeks, then one tractor could plant the same area (in two weeks) that would otherwise require two tractors in a one week period.

Expanding soybean crop area into Saskatchewan and Alberta is a challenge due to the length of the growing season in these provinces and the heat units required for current soybean varieties to reach maturity. Early planting of soybeans allows growers to exploit a greater portion of the growing period in Alberta and Saskatchewan (PMRA No. 2393326; 2537743). However, neonicotinoid seed treatment is only one factor influencing the expansion of soybean into these provinces since seed treatments will provide an emergence and yield benefit to early planting only if insect pests are present (PMRA No. 2537743). The total heat units required for soybean plants to reach maturity are dependent upon the plant's genetics. As a result, availability of shorter season varieties also influences the adoption of soybeans in these provinces.

Seeding rate/Crop establishment

Registrants identified a greater economic return for corn and soybean growers from reducing seeding rates (and seeding expenses) as a benefit from the use of neonicotinoid seed treatments (PMRA No. 2392934). However, the relationship between seeding rate and economic return is complex as several biotic (crop, variety, yield, pest pressure, etc.), abiotic (weather, soil type, soil nutrients, etc.) and economic (seed price, seed treatment cost, etc.) factors will affect the economic return.

Soybean

As soybean seeds become more expensive, there is greater pressure for growers to find cost efficiencies in plant stand establishment (De Bruin and Pedersen, 2008). Insecticide seed treatments allow growers to use fewer seeds per hectare while maintaining yield potential. However, producers will only realize an economic benefit from the lower seeding rate as a result of using insecticide seed treatments in fields where the following conditions are met:

- there is pest pressure;
- the economic benefit from the yield saved is great enough to compensate for the expense of the seed treatment; and
- the economic benefit from the yield saved by using treated seeds is greater than the cost of seeding at a higher rate with untreated seed.

For soybean, as the cost of seeds increase, focus must be placed on economic return (in other words, costs versus revenues) rather than yield maximization (De Bruin and Pedersen, 2008). This is because soybean can compensate considerably for differences in stands without impacting yield (OMAFRA, 2009a). As a result, increasing seeding rates may simply result in greater costs without increasing revenues from yield. Neonicotinoid seed treatments may allow growers to establish optimal plant populations using fewer seeds per hectare (Cox and Cherney, 2011; Gaspar et al., 2014), yet this may not necessarily translate into greater economic returns as seed treatment costs may offset the savings from reduced seed costs (Cox and Cherney, 2011).

Alternatively the yield loss may be due to other factors including fungal pathogens rather than insect pests (OMAFRA, 2009a). Where fungal pathogens are causing damage to soybean seedlings, application of a fungicide seed treatment would be necessary to prevent yield loss.

Corn

Unlike soybean, the yield for corn is positively correlated with optimal plant population, uniform emergence and stand development (Liu et al., 2004; Stewart, 2013; PMRA No. 2393325). Corn yield increases as plant density increases with optimal populations between 64,000 to 74,000 plants/ha for older hybrids of field corn and 74,000 to 86,000 plants/ha for newer hybrids (OMAFRA, 2009b). The optimal planting densities for sweet corn are lower at 40,000 to 55,000 plants/ha (OMAFRA, 2008). Optimum seeding rates are higher for short-season hybrids than long-season ones, irrigated systems than dry land ones, and corn harvested as silage versus corn harvested as grain (Swihart, 2013). It can be concluded that, neonicotinoid seed treatments for corn have value for corn crop establishment rather than for reducing seeding rate.

Clothianidin and thiamethoxam seed treatments benefits identified by growers.

AgInfomatics conducted a survey of Canadian and American corn and soybean growers to identify the benefits that growers attribute to the neonicotinoid seed treatments.

The primary attributes identified as important, or very important to their decision to use neonicotinoid seed treatments were protecting family and worker safety (99%), protecting yield (96.5%), public safety (94%), protecting water quality (93.5%), improving plant health (91%), improving crop stand (89.5%) consistent insect control (89.5) (AgInfomatics, 2015). Cost, crop marketability, replanting and equipment wear were substantially lower at an overall average of 75.6%.

The use of clothianidin, imidacloprid and thiamethoxam seed treatments replaced the use of pest control products which were phased out due to environmental and health risk concerns.

Historically, lindane and diazinon were used to protect corn and soybean from soil pests and early season pests. Products containing lindane and seed treatment products containing diazinon were phased out due to health and environmental risk concerns. Other pest control products were primarily organophosphates applied in-furrow and over the seed row as a drench or granular application. The majority of these products were phased out due to risk concerns (for example, phorate, terbufos) or voluntarily discontinued by the registrants (for example, disulfoton, fonofos).

Current alternative pesticides to neonicotinoid corn and soybean seed treatments are limited in availability, or present significant obstacles for growers to use.

Currently there are no registered alternative products for the control of some pests on corn and soybean regardless of application method:

- corn flea beetle on corn;
- white grubs (European chafer, Japanese beetle and June beetle) on sweet and seed corn;
- Japanese beetle and June beetle on field corn and popcorn; and
- European chafer, seedcorn maggot and wireworm on soybean.

For other pests, there are alternative pest control products using application methods other than seed treatment (for example, foliar sprays and granular products), however, there are no alternative seed treatment products currently registered (Table 7).

Foliar applications of neonicotinoids are registered to control some pests (for example, bean leaf beetle and soybean aphid on soybean). The majority of the alternative pest control products applied as foliar sprays are carbamates, organophosphates (IRAC MoA group 1A and 1B respectively) or synthetic pyrethroids (IRAC MoA group 3).

Three active ingredients have been recently registered: spirotetramat (IRAC MoA group 23), chlorantraniliprole and cyantraniliprole (IRAC MoA group 28). Only cyantraniliprole is registered for use as a seed treatment and this application method is limited to use on field corn and popcorn. Spirotetramat and chlorantraniliprole are registered as foliar sprays and currently have limited use patterns on corn and soybean since they are only registered to control soybean aphid on soybean; black cutworm on field corn and popcorn; and black cutworm, European chafer, and wireworm on field corn and popcorn respectively.

Tefluthrin (a granular product) is the only alternative product applied in the furrow at planting (corn only) for rootworm, wireworm and seed corn maggot control. There are some drawbacks to using tefluthrin relative to the neonicotinoid seed treatments: tefluthrin is not systemic and will not protect the seedling from foliar feeding pests once emerged from the ground. Also, most corn planters purchased in the past few years are not equipped to apply granular in-furrow products. Growers would need to purchase granular applicators (PMRA No. 2392934) or adapt current equipment at a substantial cost since reconfiguring equipment is estimated to be $15,000 CAD on average (OMAFRA, 2014). Additionally, growers prefer to rotate the crop, or use *Bt* rootworm corn hybrids to control corn rootworm over using granular insecticides (OMAFRA, 2014).

Table 7 Registered active ingredients for the control of corn and soybean pests identified on the neonicotinoid seed treatment product labels (as of June 17, 2015)

Crop	Pest	Resistance Management Group[1]: Active Ingredient[2]	Comments
Corn	Flea beetles	**None**	**No registered alternative active ingredients.**
	Corn rootworms	1A: carbaryl 1B: chlorpyrifos	Carbaryl is applied as a foliar spray for control of adult Northern corn rootworm. Chlorpyrifos is applied as a band or granular in-furrow application. Carbaryl and chlorpyrifos are currently under re-evaluation.
		3A: tefluthrin	Tefluthrin is applied as a band or granular in-furrow application.
Corn	Black cutworm	1A: carbaryl 1B: chlorpyrifos 3A: cypermethrin, lambda-cyhalothrin, permethrin, tefluthrin 28: chlorantraniliprole (field, seed, sweet and popcorn), cyantraniliprole (field and popcorn)	Carbaryl, chlorpyrifos, cypermethrin, lambda-cyhalothrin and permethrin are currently under re-evaluation. Carbaryl, cypermethrin, lambda-cyhalothirn and chlorantraniliprole are applied as foliar sprays. Chlorpyrifos is applied as a spray to the soil surface and foliage. Chlorantraniliprole is registered for use as a foliar spray. Cyantraniliprole is registered for use as a seed treatment on field corn and popcorn. Tefluthrin is applied as a band or granular in-furrow application.
	Seedcorn maggot	3A: tefluthrin	Tefluthrin is applied as a granular in-furrow application.

	European chafer, Japanese beetle, June beetle	**NONE – seed and sweet corn** 28: cyantraniliprole (field and popcorn)	**There are no registered alternatives to the neonicotinoid seed treatments for seed and sweet corn. There are also no alternative active ingredients for the control of June beetle and Japanese beetle on field corn and popcorn.** Cyantraniliprole is registered for use as a seed treatment on field corn and popcorn.
	Wireworms	3A: tefluthrin 28: cyantraniliprole (field and popcorn)	Tefluthrin is applied as a granular in-furrow application. Cyantraniliprole is registered for use as a seed treatment on field corn and popcorn.
Soybean	Seedcorn maggot	**NONE**	**No registered alternative active ingredients.**
	European chafer	**NONE**	**No registered alternative active ingredients.**
	Wireworms	**NONE**	**No registered alternative active ingredients.**
	Bean leaf beetle	3A/4A: deltamethrin and imidacloprid 3A: lambda-cyhalothrin 4A: thiamethoxam 3A/28: lambda-cyhalothrin and chlorantraniliprole	Deltamethrin and imidacloprid are currently under re-evaluation. Deltamethrin and imidacloprid are co-formulated into one product for application as a foliar spray. Lambda-cyhalothrin is currently under re-evaluation. Lambda-cyhalothrin and thiamethoxam are applied as foliar sprays. Chlorantraniliprole is co-formulated with lambda-cyhalothrin for application as a foliar spray.

	Soybean aphid	1B: dimethoate 3A: lambda-cyhalothrin, deltamethrin 4A: imidacloprid 23: spirotetramat 3A/28: lambda-cyhalothrin and chlorantraniliprole Other: insecticidal soap	Dimethoate, deltamethrin, lambda-cyhalothrin and imidacloprid are currently under re-evaluation. Dimethoate, deltamethrin, lambda-cyhalothrin, imidacloprid and spirotetramat are all applied as foliar sprays. Chlorantraniliprole is co-formulated with lambda-cyhalothrin for application as a foliar spray.

[1] Insecticide and Acaricide Resistance Management Group Numbers based on DIR 99-06 *Voluntary Pesticide Resistance Management Labelling based on Target Site/Mode of Action*, with updates from the Insecticide Resistance Action Committee (IRAC) Mode of Action Classification scheme v7.2 April 2012: http://www.irac-online.org: 1A = acetylcholinesterase inhibitors (carbamates); 1B = acetylcholinesterase inhibitors (organophosphates); 3A = sodium channel modulators; 4A = acetylcholine receptor agonists/antagonists; 23 = inhibitors of acetyl CoA carboxylase; 28 = ryanodine receptor modulators.

[2] The list includes registered options and does not constitute an endorsement from Health Canada. The registration status of active ingredients under re-evaluation may change pending the final regulatory decision. For additional information, consult the PMRA publications website: http://www.hc-sc.gc.ca/cps-spc/pubs/pest/_decisions/index-eng.php#rvd-drv (English) and http://www.hc-sc.gc.ca/cps-spc/pubs/pest/_decisions/index-fra.php (French) for Re-evaluation Decision (RVD and RRD) documents and Re-evaluation Note (REV) documents or http://www.hc-sc.gc.ca/cps-spc/pest/part/consultations/index-eng.php (English) and http://www.hc-sc.gc.ca/cps-spc/pest/part/consultations/index-fra.php (French) for current and past consultation documents including Proposed Re-evaluation Decisions (PRVD and PACR) and certain Re-evaluation Note (REV) documents.

Cultural pest management options are alternatives to the use of neonicotinoid seed treatments but they have some disadvantages – tillage, crop rotation and resistant hybrids (corn) or varieties (soybean).

Conventional tillage is used as a physical pest management practice for the control of soil insect pests by removing food sources (weeds), physically damaging the insect and exposing them to predation by birds and other vertebrates (PMRA No. 2392920, 2392933, 2392934; OMAFRA, 2009c). However, this practice increases soil erosion and requires greater input into crop production such as fertilizer, equipment costs and availability, etc. (PMRA No. 2393325, 2392934, 2472440, 2472887; OMAFRA, 2009c). In general, the use of conventional tillage has decreased due to the desire for better soil conservation. Therefore fewer growers are able to take advantage of the benefits derived from the physical control of soil pests and must rely on other pest management practices (e.g., crop rotation, planting resistant varieties, seed treatments, etc.).

Crop rotation can be used as an effective cultural control for corn rootworm and is recommended for control of corn rootworm over the use of seed treatments in Ontario (OMAFRA, 2011b; OMAFRA, 2014). For instances where crop rotation is not feasible (e.g., growers producing livestock feed on limited crop production area) the use of resistant corn hybrids is an alternative to insecticide seed treatments (OMAFRA 2011b).

Approximately 60% of the Canadian corn and soybean crops are planted with genetically modified varieties for herbicide tolerance (corn and soy) or insect resistance (corn) (Council for Biotechnology, 2011). Currently one variety of genetically modified soybean which is resistant to insect damage is registered by the CFIA for use in Canada. It prevents damage from lepidopteran pests (CFIA, 2012). None of the soybean pests controlled by neonicotinoid seed treatments are lepidopterans. As a result the currently registered genetically modified soybean varieties are not options as alternatives to the use of neonicotinoid seed treatments.

For fields where corn rootworm and other pests may be a concern, the use of resistant (i.e., *Bt*) corn hybrids allows growers to use a lower application rate of neonicotinoid seed treatments. An application rate of 1.25 mg (thiamethoxam or clothianidin)/kernel is required for control of corn rootworm on conventional corn. Growers can obtain equivalent protection while using a lower rate of clothianidin (0.25 to 0.5 mg clothianidin/kernel), or thiamethoxam (0.125 to 0.25 mg/kernel) when seed treatments are used in conjunction with *Bt* hybrids.

There are some limitations to the use of resistant corn hybrids in lieu of neonicotinoid seed treatments. Only a small percentage (1% or less) of fresh market sweet corn growers plant *Bt* sweet corn for corn rootworm control. None of the varieties registered in Canada contain a Cry protein to control black cutworm. As a result, crop rotation and foliar applications are the only alternative to the neonicotinoid seed treatments to control these pests (OMAFRA, 2014).

The use of *Bt* corn varieties which produce the Cry proteins from *Bacillus thuringiensis* requires the planting of a susceptible corn hybrid (i.e., a refuge) in close proximity to prevent the development of resistance to the Cry proteins contained in the *Bt* varieties. Growers may experience yield loss for the crop area devoted to the refuge. Resistance management regulations requires that 20% of the corn crop area be planted to non- *Bt* corn (Baute and Tenuta, 2013; Stewart and Sears, 2013), unless a “refuge in a bag” is used (where seed from a *Bt* hybrid is mixed with a non-*Bt* hybrid with similar characteristics) in which case 5% of the crop is planted to the susceptible hybrid (Eastern Ontario AgriNews, 2011).

There is also some potential for increased incidence of rootworm resistance to Cry 3Bb1 *Bt* rootworm which is already prevalent in the US (OMAF, 2014). As such, there is a need to ensure that stacked *Bt* hybrids (i.e., hybrids which produce more than one type of Cry protein) are used (OMAFRA, 2014).

Economic benefits

Scope and considerations

The economic benefit assessment is based on information provided by provincial governments, Canadian grower associations, registrants and other stakeholders and considers recently published reports by the Conference Board of Canada, the US Environmental Protection Agency (EPA) and AgInfomatics.

This assessment is not intended to be an exhaustive economic analysis of the benefits of neonicotinoid seed treatments on the corn and soybean industries. It is limited to economic benefits directly linked to insect pest management. This assessment is also not intended to analyse the impact of neonicotinoid seed treatments to industries that are upstream (e.g., their economic benefit to seed companies) or downstream of the corn and soybean industry (e.g., ethanol, or feed/food industries) or their impact to the provincial economies.

The estimates for the economic value do not account for potential changes to soil insect pest populations as a result of a potential decrease in use of neonicotinoid seed treatments. The current estimates of pest incidence and pressure may be attributable to the current widespread use of insecticide seed treatments.

Furthermore, while the analysis was done at the industry level, quantifying the economic impact at the farm level is extremely difficult as the potential economic loss at the farm level is determined by many factors such as crop, variety/hybrid, soil type, crop rotation and past pest pressure in Canada.

Sources of information

In response to the PMRA's request for information on the benefits of neonicotinoid seed treatments the re-evaluation of clothianidin, imidacloprid and thiamethoxam, the province of Ontario provided a detailed analysis of the economic benefits of neonicotinoid seed treatments for corn and soybean. Responses were also received from British Columbia, Saskatchewan, Manitoba, Québec and Nova Scotia. The responses from these Provinces account for greater than 90% of the Canadian corn production area and 97% of the Canadian soybean crop production areas.

Registrants provided information on pest prevalence and their impacts to yield (PMRA No. 2392920, 2392933, 2392883, 2392904, 2538672). These responses were used along with provincial estimates to identify the crop area likely to experience pest pressure resulting in yield loss and identify the yield impacts for each pest.

Information used in the economic benefit assessment

Provincial level estimates of the economic impacts to the corn and soybean industry from use of neonicotinoid seed treatments are based upon currently available information and are approximations as the actual economic benefits will vary based upon several parameters such as year assessed, commodity price, yield, crop area, cost of seed treatments and other factors. To assess the economic benefit, the following information was requested from the provinces and registrants of clothianidin, imidacloprid and thiamethoxam including information on:

- crop production (for example yield, farm gate value);
- pest prevalence and pest pressure;
- pest impacts to yield;
- usage and cost of neonicotinoid seed treatment; and
- usage and cost of alternative pest control products.

All the information provided by MAPAQ for corn was based upon monitoring or field studies and are considered quantitative in nature. Information on pest prevalence was based upon information from 276 sites over several years (2009 to 2013). The yield impact was estimated based upon field trials conducted at 28 sites. These field study sites were considered representative of all corn growing regions in Québec (MAPAQ, 2014). No information was provided for soybean. However, based upon the extent of the monitoring and field studies in corn, it is unlikely that soil insect pest prevalence in soybean would be greater than that reported for corn. The economic benefits reported by OMAFRA are mostly based upon surveys, monitoring and field studies. In some cases a “best annual estimate” was provided based upon extensive practical experience in extension work with growers. Information was also available from independent agronomists. The estimates from OMAFRA for both the crop area expected to experience a yield loss and the yield loss for each pest were similar (i.e. within 10%) to the estimates provided by the independent agronomists (PMRA No. 2392920, 2392933, 2392883, 2392904, 2538672). Where estimates from agronomists varied greatly, the mean of those estimates were similar to the estimates from OMAFRA, or the estimates from OMAFRA were more conservative. For Manitoba, information from both independent agronomists and MAFRD were used to assess the economic benefits from neonicotinoid seed treatments. Information was available from provincial crop experts for Nova Scotia. As a result, some information provided was qualitative in nature. Additional quantitative information (i.e., data from research trials) on typical pest population levels relative to economic thresholds would allow for refinement of the value assessment for clothianidin and thiamethoxam seed treatments. No information on pest pressure and yield impact was available for the other provinces as they are minor producers of corn and soybean.

In 2014, AgInfomatics was commissioned by Syngenta, Bayer CropScience and Valent to assess the value of neonicotinoid seed treatments to the Canadian corn and soybean industries. Part of that study included a survey of Canadian corn and soybean growers (Table 8).

Table 8 AgInfomatics 2014 corn and soybean grower survey size details (AgInfomatics, 2015)

Province surveyed	Corn (Number of growers)	Soybean (Number of growers)
Manitoba	30	32
Ontario	60	60
Québec	31	30

This survey identified pests of concern and their prevalence (defined as the % of growers actively managing the pest) and their perceived impact (identified as the most important pest). The results from AgInfomatics (2015) are presented in Table 9. Corn borer and corn root worm were identified as major pests while black cutworm, wireworm, seedcorn maggot, grubs, and corn flea beetle were identified as minor pests on corn (AgInfomatics, 2015). Soybean aphid was identified as a major pest while wireworm, seedcorn maggot and bean leaf beetle were minor pests on soybean (AgInfomatics, 2015). In general, the portion of growers actively managing soil insect pests match the crop area estimated to be at risk from these pests by the provincial crop experts from Ontario and Manitoba and Québec.

AgInfomatics (2015) also conducted a meta-analysis of yield data (a statistical technique used to combine the findings from independent studies) for Ontario corn and soybean that was based upon several years of data at eight sites primarily near Ridgetown, Ontario (AgInfomatics, 2015). This meta-analysis identified an average yield benefit of 11% with a large amount of variability (±17.6%) for corn when neonicotinoid seed treatments were used. Similarly, the average yield gain for soybean when neonicotinoid seed treatments were used was 8.5% with a standard deviation of ±22.7%. The authors suggest that the large variability in the meta-analysis suggests a sporadic nature for the pest distribution between regions and within a given region (AgInfomatics, 2015). This is confirmed by regional data from Wisconsin, Michigan and New York which reported different yield benefits from the use of neonicotinoid seed treatments (AgInfomatics, 2015) and is further supported by the provincial weighted average estimate of a 6% yield benefit for field corn from OMAFRA (2014) and 3% yield benefit for soybean. These provincial estimates include Ontario regions not included in the meta-analysis conducted by AgInfomatics (e.g., eastern Ontario). Due to eastern Ontario's proximity to western Québec, pest pressures in eastern Ontario would be expected to be similar to those reported for western Québec which were reported as low (MAPAQ, 2014). As a result OMAFRA's estimates are expected to be lower than those from AgInfomatics' meta-analysis of yield benefits which are specifically relevant to southern and south western Ontario.

The variability in yield identified by AgInfomatics is highlighted by a survey where pest distribution for wireworm and grubs within a field was highly variable (PMRA No 2537742). Since spatial variability of soil pests is great within a given field, it is likely that soil pest variability will also be great between fields and as a result small plot studies may or may not be placed in a location with pest pressure, or at the least may be placed at locations with differing pest pressure.

Table 9 Pests actively managed and reported as most important to manage by Canadian corn and soybean farmers (% of respondents).

Corn			Soybean		
Pest	**Portion of growers actively managing the pest (%)**	**Portion of growers identifying the pest as the most important pest to manage (%)**	**Pest**	**Portion of growers actively managing the pest (%)**	**Portion of growers identifying the pest as the most important pest to manage (%)**
Corn borer	60	54	Aphid	43	50
Corn rootworm	31	22	Mite	7	1
Black cutworm	7	3	Beetle	5	0
Wireworm	6	1	Grasshopper	4	5
Armyworm	2	0	Wireworm	3	0
Grub	2	0	Nematode	3	1
Maggot	2	0	Slug	2	0

Corn			Soybean		
Pest	**Portion of growers actively managing the pest (%)**	**Portion of growers identifying the pest as the most important pest to manage (%)**	**Pest**	**Portion of growers actively managing the pest (%)**	**Portion of growers identifying the pest as the most important pest to manage (%)**
Cutworm	2	0	Grub	1	0
Aphid	1	0	Japanese beetle	1	0
Flea beetle	1	0	Maggot	1	1
Nematode	1	0	Cutworm	1	1
			Leafhopper	1	0

Source: AgInfomatics (2014; 2015)

Based on currently available information, neonicotinoid seed treatments are estimated to be of economic benefit to the Canadian corn industry with benefits varying by province and type of corn produced. They are also estimated to be of economic benefit to the soybean industry in Ontario, particularly the IP/food soybean industry and to the crushing soybean industry in Manitoba.

Prior to the initial registration of products or uses containing clothianidin, imidacloprid or thiamethoxam, efficacy assessments were conducted demonstrating that the products control a wide variety of soil pests. However, an economic benefit to the corn and soybean industries from the use of neonicotinoid seed treatments is only realized when the prevalence of soil insect pest population levels affect yield gains in excess of the expenditures on these seed treatments.

Since there is little reported use of imidacloprid on corn or soybean seed in Canada, the economic value for this active ingredient could not be estimated. The extent of the economic benefits to these industries from clothianidin and thiamethoxam varies significantly by crop and by region across Canada. At a national level the economic benefits are estimate to range between $74.2 to $83.3 million for corn, or about 3.2% to 3.6% of the total Canadian farm gate value and $37.3 to $51 million for soybean or about 1.5% to 2.1% of the total Canadian farm gate value (Table 10).

Saskatchewan, Alberta and British Columbia are minor producers of corn and soybean. Data on pest pressure, distribution and impact to corn and soybean yield were not available for these provinces. Soybean is a very new crop in British Columbia (BCMA, 2014) and only a very small area is planted (for example, 20 ha in 2011) (Statistics Canada, 2012a).

In Manitoba, using neonicotinoid seed treatments appeared to prevent economic loss in the corn and soybean industries. The soybean industry in Manitoba realizes the greatest benefit from the use of neonicotinoid seed treatments at an estimated benefit of $7.5 million to $17.3 million. This represents 2.1 to 4.8% of the provincial value.

Ontario appears to realize the greatest economic benefit in terms of actual dollars as a result of yield retention from using neonicotinoid corn and soybean seed treatments. Neonicotinoid seed treatments are also of particular value to the seed and sweet corn industries in Ontario along with the IP/food grade soybean industry due to economic impacts from export market access and from quality loss.

In Québec, using neonicotinoid seed treatments did not appear to prevent economic loss in the corn and soybean industries (Table 10) as the estimated seed treatment costs exceed the estimated value of the yield retained from using neonicotinoid seed treatment (MAPAQ, 2014). Studies conducted in 2012 and 2013 indicated that soil insect pests (wireworm, corn rootworm and seedcorn maggots) are widespread; however, pest pressures at economic thresholds are reported to be rare in Québec (MAPAQ, 2013; MAPAQ 2014; Labrie, *et. al*, 2014). For grain corn MAPAQ estimates an economic loss of $4 million if neonicotinoid seed treatments were not used (MAPAQ, 2014). However total grower expenses for neonicotinoid seed treatments are estimated at $5 million (MAPAQ, 2014) which exceeds the economic benefits at the industry level. For silage corn MAPAQ estimates an economic loss of about $0.5 million if neonicotinoid seed treatments were not used (MAPAQ, 2014). However the cost of neonicotinoid seed treatments is estimated at $0.7 million (MAPAQ, 2014) which exceeds the economic benefits at the industry level. As a result grower expenses on seed treatments are estimated to exceed yield benefits by $1.2 million (MAPAQ, 2014).

No information was provided for soybean in Québec. However, based upon the extent of the monitoring and field studies in corn, it is unlikely that soil insect pest prevalence in soybean would be greater than that for corn. Unlike Ontario, where soybean aphid and bean leaf beetle are the main pests of economic concern, surveys in Québec indicate an overall decline in soybean aphid populations since 2004 and bean leaf beetle populations are extremely low in Québec (MAPAQ, 2014). Information provided by MAPAQ for seedcorn maggot, wireworm and black cutworm in corn indicates that there is lower pest pressure in Québec than in Ontario (OMAFRA, 2014; MAPAQ, 2014). As a result, it is not anticipated that pest pressure at economic levels will be as widespread for soybean in Québec as it is in Ontario and it is unlikely that the economic benefit at the industry level from the use of neonicotinoid seed treatments in Québec would exceed that estimated for Ontario where the pest pressure is greater.

For the Atlantic Provinces there appears to be no evident economic benefit at the industry level for either corn or soybean due to low pest pressure as the estimated expenses on seed treatments exceed the estimated value of the retained yield

If a grower experiences pest pressure, the use of a seed treatment is likely to be cost effective.

In Ontario the estimated yield loss on soybeans for crushing ranges from $119.72/ha for seedcorn maggot to $175.36/ha for soybean aphids while the estimated cost for the neonicotinoid seed treatment is $24.71/ha. In Manitoba at the grower level it is estimated that there is a benefit to soybean growers from using a seed treatment if pest pressure is present as the estimated loss to yield ($70 to 176/ha) is estimated to exceed the cost of the seed treatment ($24.71/ha assuming treated seed has the same cost as for Ontario).

In Nova Scotia and the Atlantic provinces at the grower level (for soybeans) it is estimated that there may be a benefit, since the cost of the seed treatment ($24.71/ha) was estimated to be less than the estimated yield loss caused by bean leaf beetle ($55.60/ha).

This is also identified at the industry level when the seed treatment costs are considered only for the crop area actually affected by pest pressure. For example in Québec, if the seed treatment costs are considered only for the area affected by pest pressure then there is a net economic benefit of up $3.3 million, or 0.5% of the corn industry and $1.14 million (or 0.3%) of the soybean industry, indicating that neonicotinoid seed treatments have an economic benefit only when pests are present above economic thresholds (which is not common in Québec (MAPAQ, 2014)).

Table 10 Industry level estimate of economic benefit from use of neonicotinoid corn and soybean seed treatments in 2013 based upon provincial information[1]

Province	Industry	Farm gate value (CAD)	Estimated net economic benefit[2] (CAD)	Portion of industry value (%)
Canada	**Corn**	**2.336 billion** (Statistics Canada, 2015b)	**74.2 to 83.3 million** (OMAFRA, 2014; MAFRD, 2014; MAPAQ, 2014; NSDA, 2014)	**3.2 to 3.6**
	Soybean	**2.482 billion** (Statistics Canada, 2015b)	**37.3 to 51 million[3, 4]** (OMAFRA, 2014; OMAFRA, 2015; MAFRD, 2014; NSDA, 2014)	**1.5 to 2.1[3, 4, 11]**
British Columbia, Alberta, Saskatchewan	Corn, Soybean	These provinces are minor producers of corn and soybean. Data on pest pressure, distribution and impact to corn and soybean yield was not available (BCMA, 2014; SMA, 2014).		
Manitoba	Field corn	161.6 million in 2013 (Statistics Canada, 2015b)	0.1 million up to a benefit of 3.5 million[5] (MAFRD, 2014; PMRA# 2392904)	0 to 2.2[5]
	Silage corn	70.4 Million in 2013[6] (Statistics Canada, 2015a; 2015b)	0.21 to 1.4 million[6] (MAFRD, 2014; PMRA# 2392904)	0.3 to 2.0[6]
	Soybean	357 million in 2013 (Statistics Canada, 2015b)	7.5 to 17.3 million[4, 7] (MAFRD, 2014; PMRA# 2392904; OMAFRA, 2014).	2.1 to 4.8[4, 7]
Ontario[8, 9]	Field corn	1.691 billion (OMAFRA, 2014)	57.9 million[10]	3.4
	Silage corn	249 million (OMAFRA, 2014)	2.3 million[10]	1
	Seed corn	48.5 million (OMAFRA, 2014)	9.7 million[10]	20
	Sweet corn	36.6 million (OMAFRA, 2014)	5.5 million	15

Province	Industry	Farm gate value (CAD)	Estimated net economic benefit[2] (CAD)	Portion of industry value (%)
	Corn total	**2.025 billion** (OMAFRA, 2014)	**75.4 million**[10]	**3.7**[10]
	Soybean (crush)	1.194 billion (OMAFRA, 2014)	10.4 million [4, 10]	0.9
	Soybean (IP/food grade)	508 million (OMAFRA, 2014)	22.3 million[4, 10, 11]	4.4
	Soybean total	**1.702 billion** (OMAFRA, 2014)	**32.7 million**[4, 10, 11]	**1.9**[4, 10, 11]
	Ontario total	**3.727 billion** (OMAFRA, 2014)	**108.1 milllion**[4, 10]	**2.9**[4, 10, 11]
Québec	Field, silage corn	715.3 million in 2013 (Statistics Canada 2015b)	Grower expenses on seed treatments are expected to exceed yield gains by about 1.2 million up to a benefit of 3.3 million[11] (MAPAQ, 2014)	0 to 0.5[12]
	Soybean	454.1 million in 2013 (Statistics Canada, 2015b)	Grower expenses on seed treatments are expected to exceed yield gains by about 2.8 million up to a benefit of 1.14 million[12]	0 to 0.3[13]
Atlantic provinces	Field corn	Information on yield impacts from soil pests was not available. No pest pressure was reported. Grower expenses on neonicotinoid seed treatments are estimated to be about 275 thousand CAD[14] (NSDA, 2014).		
	Soybean	Grower expenses on neonicotinoid seed treatments are estimated to exceed yield returns by about 100 thousand CAD[15] (NSDA, 2014).		

[1] The estimates do not attempt to quantify revenue benefits attributable to the advantages derived from using the seed treatment application method, or quantify the revenue impacts from market access issues particularly for IP/food grade soybeans as information required for these assessments was not available. The assessment did not attempt to quantify the economic impacts to other industries affected by changes in revenue to the corn and soybean industries. In addition this assessment only considers current pest pressures and does not take into consideration potential changes to pest pressures as a result of a change in insecticide seed treatment use: The estimates for the economic value do not account for potential changes to soil insect pest populations as a result of a potential decrease in use of neonicotinoid seed treatments. Conversely, the current estimates of pest incidence and pressure may be attributable to the current widespread use of insecticide seed treatments. These estimates are approximations only as the actual economic benefits will vary based upon several parameters such as year assessed, commodity price, yield, crop area, cost of seed treatments, etc.

[2] For Manitoba, Québec and the Atlantic provinces the net economic benefit includes the estimated benefits derived from yield retention from the crop area planted and grower expenses on seed treatment to the area affected by pest pressure (i.e., Health Canada assumed that all the crop that realized a yield benefit was harvested).

For Ontario the grower expenses on neonicotinoid seed treatment has not been factored in as it is assumed there is no change in cost between treated seed and untreated seed due to a premium cost associated with the additional handling and distribution costs associated with untreated seed (OMAFRA, 2014). The net economic benefit for Ontario identifies the additional cost to growers for applying registered alternative pest control products to the neonicotinoid seed treatments when they are available. Where registered alternative products are not available, the yield loss from the pest is included.

[3] Estimated economic benefits are for crush soybean only except for Ontario where information on IP/food grade soybean crop is included as information on crop area, yield, area at risk and yield loss for each pest was available. Ontario and Québec are the primary production regions for IP/food grade soybeans (OMAFRA 2015).

[4] The estimated yield loss and additional cost to growers for alternative pest control products to the neonicotinoid seed treatments are estimated for early season control of soybean aphids only as seed treatments are only effective up to 40 days and are not recommended for control of soybean aphid later in the growing season when foliar sprays are the only control option for growers (OMAFRA, 2014).

[5] The value for grain corn is based upon the 2013 crop season (Statistics Canada, 2015b). Estimates of the potential acres at risk from pest damage were provided by MAFRD (2014) and PMRA# 2392904). Corn flea beetle and corn rootworm were not identified as pests of concern in Manitoba (MAFRD, 2014; PMRA# 2392904). European chafer and June beetle were not identified as pests of concern in Manitoba (MAFRD, 2014). Black cutworm was identified as a minor issue in Manitoba (MAFRD, 2014). Health Canada assumed the crop area at risk was the worst case: 20% for wireworm, 10% for seedcorn maggot; and 0% for grubs. Health Canada assumed the area at risk would be less than 10% for black cutworms, as was estimated for seedcorn maggot by MAFRD. Health Canada assumes that there was no overlap in affected area by the pests (i.e., a total of 40% of the corn crop area at risk), for the 2013 corn crop area: 153,800 ha (Statistics Canada, 2015a). Estimated yield loss for wireworm was 2-3 bu/ac or about 126 to 188 kg/ha (PMRA# 2392904). The estimated yield loss for black cutworm was 5 bu/ac or about 314 kg/ha (PMRA# 2392904). The estimated yield loss for seedcorn maggot was 2-3 bu/ac (PMRA# 2392904) up to 13 bu/ac (MAFRD, 2014) or up to about 800 kg/ha.

If the cost of untreated seed is assumed to remain equivalent to the cost of treated seed, then the net yield retention is equivalent to the gross yield retention at approximately $2 to 4.3 million.

Assuming the estimated cost for neonicotinoid seed treatment was identical to Ontario at $5/acre (OMAFRA, 2014) or about $12.36/ha for wireworm, seedcorn maggot, grubs and black cutworm, field corn growers are estimated to have spent about $0.7 million to protect the affected hectares using insecticide seed treatments. Therefore based upon these assumptions, the net yield benefit to the grain corn industry is estimated to have been about $3.5 million in 2013 (i.e., $2 to 4.3 million from yield retained – $ 0.7 million in neonicotinoid seed treatment expenditures = $ 1.3 to 3.5 million).

Note however that if the neonicotinoid seed treatments expenses for all the grain corn is included in the provincial estimate ($1.9 million) then grower expenses on grain corn seed treatments are about the same as the yield gain (i.e., a gross yield benefit of $2 to 4.3 million – $1.9 million in grower seed treatment expenses = $100 thousand up to a benefit of $2.4 million (e.g., $4.3 million in gross yield benefit - $1.9 million in grower expenses = $2.4 million).

[6] In 2013, there was 34,400 ha of silage corn harvested (Statistics Canada 2015a), yielding on average 44,310 kg/ha (Statistics Canada, 2015a) for a provincial total of 1.5 million tonnes of silage valued at $70.4 million (based upon a value of $46.19/tonne (OMAFRA, 2014). Health Canada assumes that the yield loss for silage corn is equivalent to grain corn (e.g., 10% yield loss of grain = 10% stand loss in silage corn to 36,400 ha seeded) and that the area at risk of pest pressure that would result in yield loss is also equivalent to grain corn. Based upon these assumptions the gross yield benefit is valued between $0.64 and $1.4 million.

If the cost of untreated seed is assumed to remain equivalent to the cost of treated seed, then the net yield retention is equivalent to the gross yield retention at approximately $0.64 to $1.4 million.

Assuming the estimated cost for neonicotinoid seed treatment was identical to Ontario at $5/acre (OMAFRA, 2014) or about $12.36/ha for wireworm, seedcorn maggot, grubs and black cutworm, field corn growers are estimated to have spent about $0.17 million to protect the affected hectares using insecticide seed treatments. Therefore based upon these assumptions, the net benefit to the grain corn industry is estimated to have been about $0.41 million to 1.1 million in 2013 (i.e., $0.64 to 1.4 million from yield retained – $0.17 million in neonicotinoid seed treatment expenditures = $0.47 to 1.2 million).

Note however that if grower expenses on neonicotinoid seed treatments for all the silage corn that was planted in 2013 ($0.43 million) is included in the provincial estimate then the net benefit for yield retention drops to about $0.21 to 0.97 million (i.e., a gross yield benefit of $0.64 to 1.4 million – $0.43 million in grower seed treatment expenses = 0.21 to 0.97 million).

[7] Estimates of the potential soybean acres at risk from pest damage and percent crop treated with neonicotinoid seed treatments were provided by MAFRD. Impacts to yield and grower expenses on neonicotinoid seed treatments were estimated by Health Canada and are based upon crop information from Statistics Canada for the 2013 crop season and commodity prices and estimated cost of neonicotinoid seed treatments provided by OMAFRA (OMAFRA, 2014).

Information on pest prevalence and pressure for wireworm was reported as highly variable (MAFRD, 2014). The worst case reported by MAFRD was 20% of the crop area may be affected by wireworm. Information on yield loss for wireworm on soybean was reported as 2-3 bu/acre (PMRA No 2392904), or about 134 to 202kg/ha based upon a bushel weight of 27.2 kg/bu (Murphy, 1993) and 1 acre = 0.404685 ha. The estimated gross yield retention for wireworm is estimated at $ 5.9 to 9 million based upon a seeded crop area of 424,900 ha x 20% area at risk = 84,980 ha at risk in 2013 (Statistics Canada 2015a) and commodity price of $14.25/bu, or about $523.90/tonne for crush soybean (OMAFRA, 2014). Economic loss/ha = $70.20 to 105.82/ha (e.g., 134 kg x 1tonne/1000 kg x $523.9/tonne = $70.20). The economic loss to Manitoba from wireworm ranges from $70.20/ha x 424,900 ha x 20% area at risk = $6 million, up to $9 million with a $105.82/ha loss.

Health Canada assumed the impact from seedcorn maggot in Manitoba was no greater than for Ontario at 2 to 3.4 bushels/acre (OMAFRA, 2014; PMRA No 2392904), or about 134 to 228 kg/ha and the pest prevalence and pressure was the worst case reported by MAFRD (10% of the crop area) and PMRA No 2392904 at 10% crop area at risk. Based upon a harvested crop area of 424,900 ha of soybean in Manitoba in 2013 (Statistics Canada, 2015a) the estimated gross yield retention to soybean in Manitoba from seedcorn maggot was between $3 to 5.1 million based upon an estimated value of $14.25/bushel (OMAFRA, 2014), or about $523.90/tonne.

For soybean aphid Heath Canada assumes the worst case scenario would match that of Ontario with 10% of the crop area at risk from early season soybean aphid populations at an estimated loss of 5 bu/acre (PMRA No 2392904) or about 336 kg/ha from a seeded area of 424,900 ha (Statistics Canada 2015a) with a value of $523.90/tonne (OMAFRA, 2014) for an estimated gross yield retention of $7.5 million in gross yield retention.

If the cost of untreated seed is assumed to remain equivalent to the cost of treated seed, then the net yield retention is equivalent to the gross yield retention at approximately $16.4 to 21.5 million.

Assuming the estimated cost for neonicotinoid seed treatment was identical to Ontario at $10/acre (OMAFRA, 2014), or about $24.71/ha for wireworm, seedcorn maggot, and soybean aphid, Manitoba soybean growers are estimated to have spent about $4.2 million to protect the affected hectares using insecticide seed treatments. As a result the estimated net yield retention value in Manitoba ranges from $12.1 to 17.3 million assuming soybean production in Manitoba is for crushing only (Note additional value for IP/food grade soybeans from quality retention etc. is not included in this estimate). (i.e., gross yield retention benefit is $16.4 to 21.5 million – $4.2 million (grower expenditures on seed treatments) = $12.2 to 17.3 million).

Note however that if grower expenses on neonicotinoid seed treatments for the planted soybean crop (85% crop treated) (MAFRD, 2014) is included in the provincial estimate then the net benefit for yield retention drops to about $7.5 to 12.6 million (i.e., gross yield benefit of $16.4 to 21.5 million – $8.9 million in grower seed treatment expenses = $7.5 to 12.6 million).

[8] The benefit estimates are based upon surveys or research, or in some cases a "best annual estimate". The area at risk and projected yield loss reflect the understanding of the current pest populations. The calculations are specific to the crop, insect and specific levels of impact. The economic analysis only considers alternatives that are currently registered and has the pest on the label for that crop (OMAFRA, 2014).

[9] Crop statistics were taken from the 2013 OMAFRA Field Crop Production and Prices Estimates available at: http://www.omafra.gov.on.ca/english/stats/crops/ (OMAFRA, 2014):

Grain corn -
Yield 160.5 bu/ac, or about 10,074kg/ha based upon a weight of 25.4 kg/bu (Murphy, 1993); commodity price: $4.77/bu ($187.79/tonne); crop area: 894,354 ha.

Sweet corn -
Yield: 4.71 tons/ac, or about 10,581 kg/ha; commodity price $370.74/tonne ($337/ton); crop area 9,308 ha.

Silage corn -
Yield: 20 tons/acre, or about 44,928 kg/ha; commodity price 46.19/ton, or about 50.81/tonne; crop area 105,218 ha

Seed corn -
Yield 180 bu/ac, or about 11,298 kg/ha based upon a weight of 25.4 kg/bu (Murphy, 1993); commodity price $7.70/bu, or about $303.15/tonne; crop area 14,164 ha

Soybean crush and IP/food grade -
Yield: 45.3 bu/ac, or about 3045 kg/ha based upon a bushel weight of 27.2 kg/bu (Murphy, 1993); commodity price: crush soybean $14.25/bu, or about $523.90/tonne, food grade/IP soybean – commodity price $17.25/bu or about $634.19/tonne; crop area 1,011,713 ha.

[10] Ontario farm cash receipts lost due to pests even with alternative products including additional costs incurred by at risk farmers. This estimate assumes untreated seed costs the same as treated seed. As a result growers at risk are assumed to have increased pest control expenditures. Estimated values account for the impacts to yield from all pests of economic concern and also account for scenarios where pest pressure may overlap (e.g., fields affected by European chafer are frequently affected by June beetle larvae.) Estimated values are based upon economic impact in a single year and do not take into account the effects of pest pressure on yield due to crop rotation (e.g., rotation from corn to soybean) (OMAFRA, 2014).

[11] IP soybeans are used for human consumption and have strict standards including cleanliness, uniformity of size, colour, test weight, protein, varietal purity, etc. Soybean insect pests transmit viruses that reduce the quality of seed making them unmarketable for IP markets. It's estimated that up to 20% of IP seed may not meet IP quality standards without the use of neonicotinoid seed treatments. This is equivalent to $17.7 million in losses due to downgrading (OMAFRA, 2015).

[12]The average yield gain to corn from neonicotinoid seed treatment use is estimated to be 0.56% based upon field trials at 28 sites (MAPAQ, 2014). The potential area of corn at risk from seedcorn maggot is estimated to be 0.5% based upon surveys of 28 sites between 2012 and 2013 (MAPAQ, 2014). 5% of the corn crop area is at risk from yield loss by wireworm based upon 85 sites in 13 regions surveyed between 2011 and 2013 (MAPAQ, 2013). 8% of the corn crop is at risk from corn rootworm based upon monitoring 83 sites between 2009 and 2013 (MAPAQ, 2014). 8% of the corn crop is estimated to be at risk from corn flea beetle and black cutworm as these are rare pests (MAPAQ, 2014). No information was available for grubs (MAPAQ, 2014). The estimated benefit from yield retention is $4 million for field corn and $0.5 million for silage corn for a total of $4.5 million (MAPAQ, 2014).

Estimated grower expense on seed treatment for field and silage corn (i.e., the whole crop area planted) is estimated to be $5.7 million (MAPAQ, 2014). This exceeds the estimated yield benefit of 4.5 million by $1.2 million.

However, if grower expenses on seed treatments are considered for the crop area estimated to realize a yield benefit only (i.e. 21.5 % of the crop area assuming there is no pest overlap), grower expenses are estimated to be $1.1 million (grain corn) and $0.15 million (silage corn). As a result the net benefit for the corn crop area affected by pest pressure is estimated to be $3.3 million (i.e., $4.5 million in yield benefits - $1.25 million in grower expenses = $3.3 million).

[13] Soybean yield loss from wireworm is estimated by Health Canada to be no worse in Québec than in Ontario. In Ontario yield loss is estimated to be between 3 to 10 bu/ac (PMRA# 2392920; 2392883). As yield loss for all pests on corn was 0.56% (MAPAQ, 2014), yield loss on soybeans in Québec from soil pests is also expected to be low. Therefore, the estimate from PMRA# 2392920) of 3 bu/acre is assumed by Health Canada to reflect the best estimate of potential yield loss due to wireworm damage. This is about 202 kg/ha based upon a bushel of soybean weighing 27.2 kg (Murphy, 1993) and 1 acre = 0.404685 ha. 5% of the soybean crop area is at risk from yield loss by wireworm based upon 85 sites in 13 regions surveyed between 2011 and 2013 (MAPAQ, 2013). The estimated economic impact to the Québec soybean industry for wireworm is estimated at $1.5 million based upon a seeded crop area of 288,500 ha in 2013 (Statistics Canada 2015a) with 5% of the area at risk (14,425 ha) from wireworm damage and a commodity price of $14.25/bu, or about $523.90/tonne for crush soybean (OMAFRA, 2014) (i.e., 202 kg/ha x 1tonne/1000 kg x $523.9/tonne = $105.82/ha x 14,375 ha = $1.5 million). Yield loss for seedcorn maggot was reported as low (MAPAQ, 2014). Pest population levels were reported as very low for bean leaf beetle and populations of soybean aphid as declining since 2004 due to natural predators (this trend started before neonicotinoid seed treatments were being used) (MAPAQ, 2014). Information on potential area at risk from other soil pests was not available for this crop.

If the cost of planting using untreated seed is assumed to be equivalent to the cost of planting treated seed, then the net yield retention is equivalent to the gross yield retention at approximately $1.5 million.

Health Canada estimates the net potential benefits could range from grower expenses exceeding yield benefits from $2.8 million up to a benefit of $1.14 million as follows:

> Grower seed treatment expenses on the crop area expected to have wireworm pressure (i.e., 5% of 288,500 ha) is estimated at $0.36 million assuming the cost of seed treatment in Québec was the same as for Ontario at $10/acre (OMAFRA, 2014), or about $24.71/ha. As a result the net benefit is estimated to be $1.14 million (i.e., $1.5 million in yield benefits - $0.36 million in grower expenses = $1.14 million).
>
> Assuming the cost of seed treatment in Québec was the same as for Ontario at $10/acre (OMAFRA, 2014), or about $24.71/ha and 60% of the planted crop was treated with a seed treatment like in Ontario (OMAFRA, 2014) the estimated costs of neonicotinoid seed treatment is $24.71/ha x 288,500 ha seeded (Statistics Canada 2015a) x 0.6 = $4.3 million. As a result grower expenses on seed treatments outweigh the yield gains by $2.8 million.

[14] No pest pressure was reported for the pests controlled by neonicotinoid seed treatments on field corn (NSDA, 2014). At an estimated cost of $5/acre (OMAFRA, 2014), or about $12.36/ha and 100% of the seeded area treated (NSDA, 2014), growers are estimated to have spent approximately $275 thousand dollars at the industry level.

[15] Bean leaf beetle was identified as a pest of economic concern for soybean (crush) (NSDA, 2014). The estimated impact to soybean from bean leaf beetle was $225 thousand dollars assuming a 5% yield impact to four thousand hectares (about 18% of the crop area) and a value of $450/tonne (NSDA, 2014). Based upon the estimated cost of $10/acre (OMAFRA, 2014), or about 24.71/ha for thiamethoxam seed treatment and half the crop area being planted using treated seed (NSDA, 2014), growers collectively are estimated to have spent about $352 thousand dollars on seed treatments. As a result at the industry level, there was no economic benefit from the use of seed treatments in the Atlantic Provinces.

The estimated economic benefit of neonicotinoid seed treatments to the Canadian soybean industry are somewhat greater (as a proportion of industry level yield retained) than the initial estimated value of neonicotinoid seed treatments to the American soybean industry.

The estimated economic benefits for thiamethoxam seed treatment on Canadian soybean are proportionately greater than the economic benefits initially estimated by the USEPA for the American soybean crop (Table 11).

Note that the US EPA sought comments on the soybean benefit assessment from stakeholders and therefore the estimated benefit may change as a result of the consultation. No equivalent national level assessment for the corn industry is yet available from the US EPA.

Table 11 Summary of economic studies available for neonicotinoid seed treatments on the Canadian soybean industry

Scope of economic benefits study	Source	Estimated benefit
National industry level - soybean	USEPA[1]	$52 million USD (0.14%) (USEPA, 2014)
	Health Canada (PMRA)	$37.3 to 51 million CAD (1.5 to 2.1%)

[1] Estimated benefit that may be derived if switching from the most costly foliar treatment (flubendiamide) to neonicotinoid treated seed - approximately $6/acre to 8.6 million acres (USEPA, 2014).

Using different approaches to estimate the economic benefits of neonicotinoid seed treatments consistently provide national industry level benefit estimates within a small range.

In response to a request from the registrants of clothianidin, imidacloprid and thiamethoxam, AgInfomatics (2014; 2015) quantified the economic value ($/ha) of various insect management practices (including neonicotinoid seed treatments) to corn and soybean growers through a grower survey (an econometric valuation approach).

The methodology used to estimate the economic value of the pest management strategies included the following variables: the probability of a grower adopting the pest management strategy, the proportion of the crop managed with the pest management strategy and the perceived additional value of the pest management strategy over using other pest management practices that are available to the grower.

To measure these variables, for the 2013 crop season AgInfomatics queried growers in Manitoba, Ontario and Québec on:

- their operations, production costs, yield and commodity price received;
- actively managed pests;
- use of pest management practices;
- source of pest management recommendations, most important considerations and concerns when making pest management decisions;
- perceived value of pest management practices[2]; and
- experience.

The reported estimates included:

- the perceived value to growers of various pest management strategies (including neonicotinoid seed treatments) per acre treated; and
- the perceived total economic benefit from using a given pest management strategy compared to using other insect control strategies.

Note that since the value estimates are based upon the grower's perception of value, the information obtained by AgInfomatics is qualitative in nature rather than quantitative.

Responses to value questions of this sort were used to estimate the full value of the practice, not just the direct monetary benefits due to higher yields and/or lower cost but also the non-monetary benefits of these pest management practices, such as safety, convenience and risk reduction[3] (AgInfomatics, 2015). The results indicate the estimated benefits from the use of neonicotinoid insecticide seed treatments were $36 million for corn and $47 million for soybean in 2013 (AgInfomatics, 2015). This represents 1.5% of the Canadian corn industry value in 2013 and 1.9% of the Canadian soybean industry value in 2013.

Reconciliation of the results from AgInfomatics to the estimates from Health Canada is challenging as these estimates are based upon very different approaches. The estimates of the economic value of neonicotinoid seed treatments from Health Canada are based upon impact to

[2] The valuation survey of neonicotinoid seed treatment value to growers based upon the following question: "*Please think carefully about all the reasons why you chose to plant (crop) with an insecticide seed treatment in 2013 and what else you could have done to manage insects instead of using an insecticide seed treatment.* ***Compared to these alternatives, what additional value would you say using an insecticide seed treatment provided to you per acre of treated soybean?"***

[3] The methodology used to obtain the benefit estimates is discussed by AgInfomatics in The Value of Neonicotinoids in North American Agriculture: Value of Insect Pest Management to U.S. and Canadian Corn, Soybean and Canola Farmers R1-20OCT-2014.

yield and the portion of the crop estimated to be affected by insect pests. The econometric estimates from AgInfomatics are based upon grower perceptions of the cost differential between pest management approaches (i.e., seed treatment vs soil insecticides or foliar insecticides, etc.) and do not consider pest presence or pressure. It is also not clear what factors growers considered (e.g., yield) in their value estimates. As the estimates from the US EPA, the Conference Board of Canada and Health Canada used a similar approach in terms of basing the estimates on assumptions surrounding pest pressure and their impact to yield, these studies could be compared. The estimates from AgInfomatics indicate that different approaches to estimating the value of pest management may not be equivalent and comparisons may not always be possible or appropriate. Despite this, the national industry level economic value estimates are within a small range.

The economic benefit of neonicotinoid seed treatments to the Ontario corn and soybean industries estimated by OMAFRA are slightly less than the estimated benefit from the Conference Board of Canada when pest pressure in the Conference Board of Canada model is assumed to approximate those provided by OMAFRA.

The Grain Farmers of Ontario and CropLife Canada commissioned the Conference Board of Canada to conduct a study on the economic value of neonicotinoid seed treatments to the Ontario corn and soybean industries (Grant et al., 2014).

The Conference Board of Canada generated micro economic level models (based upon farm size) to estimate the reduced profit from using alternate pest control products to the neonicotinoid seed treatments (Grant et al., 2014). This provided the estimated revenue lost to the corn and soybean industries from four base scenarios (Table12) ranging from the best case scenario to a worst case scenario. All scenarios were based upon the assumption that 99% of corn and 65% of soybean is impacted economically by pest pressure.

Table 12 Summary of base scenarios modelled by the Conference Board of Canada

Scenario	Scenario assumptions[1]			Estimated revenue lost to the corn and soybean industries ($ CAD)
	Yield impact and relative efficacy	Cost of alternative pesticides	Pest Pressure	
Best case	No yield loss.	Farmers are already using alternate soybean pesticides so they only have to pay for new corn pesticide (tefluthrin).	99% of corn and 65% of soybean is impacted economically by pest pressure.	$ 90 million
No yield loss/higher pesticide costs	No yield loss.	Farmers pay for alternative pesticides for both soybean and corn (lambda-cyhalothrin and tefluthrin).	99% of corn and 65% of soybean is impacted economically by pest pressure.	$ 125 million

Medium yield loss/higher pesticide costs	Average 5% yield loss as alternatives are not as effective.	Farmers pay for alternative pesticides for both soybean and corn (lambda-cyhalothrin and tefluthrin).	99% of corn and 65% of soybean is impacted economically by pest pressure.	$ 225 million
Worst case	Average 10% yield loss as alternatives are not as effective.	Farmers pay for alternative pesticides for both soybean and corn (lambda-cyhalothrin and tefluthrin).	99% of corn and 65% of soybean is impacted economically by pest pressure.	$ 325 million

Source: (Grant et al., 2014)

[1] All four scenarios implicitly assume that changes in price and consumption of seed are proportionately equivalent therefore there are no net costs or savings from using untreated seed compare to treated seed.

[2] Excluding the impacts of farms cutting back acreage or dropping out of the market.

The results from the micro economic level assessments were then input into a macro economic model to estimate the impact to Ontario's economy (Grant et al., 2014). The cost to the Ontario economy was estimated by the Conference Board of Canada to be approximately $630 million (Grant et al., 2014). Health Canada is unable to confirm the estimate of the economic impact to Ontario's economy as the information provided by OMAFRA and the registrants only support an assessment of the revenue loss to the corn and soybean industries. Assessment of the economic impacts to provincial economies and impacts to their GDP are beyond the typical scope of the value assessments conducted by Health Canada.

The estimated economic benefit of neonicotinoid seed treatments to the Ontario corn and soybean industries from OMAFRA ($86.1 to $108.1 million or 2.3% to 2.9%) is slightly less than the estimated value from the Conference Board of Canada (3 to 4.5%) once pest pressure and impacts to yield are considered and adjusted to match those from OMAFRA (Table 13).

Table 13 Summary of economic studies available for neonicotinoid seed treatments on the corn and soybean industries in Ontario[1]

Source	Assessment Variables	Estimated benefit
OMAFRA[2]	Average[3] yield impact: 6% Average[4] crop area at risk of economic loss: Corn and soybean: 42% Alternative pest control products: lambda-cyhalothrin, dimethoate, imidacloprid/deltamethrin	$86.1 million[5] to 108.1 million[6] (2.3% to 2.9%) (OMAFRA, 2014)
Conference Board of Canada	Average yield impact: 5% to 10% Crop area assumed at risk of economic loss: Corn: 99% Soybean: 65% Alternative pest control products: lambda-cyhalothrin	$90 million to 325 million[7] (Grant et al., 2014)

	Average yield impact: 5% Crop area assumed at risk of economic loss: Corn and soybean: 42% Alternative pest control products: lambda-cyhalothrin	$112.6 to 167 million[8] (3 to 4.5%) (PMRA# 2538670)

[1] The economic assessments from both OMAFRA and the Conference Board of Canada include the following variables: impact to yield, pest pressure, costs of alternative insecticide products and assume that the cost of seeding is static.
[2] Estimated values account for the impacts to yield from all pests of economic concern and also account for scenarios where pest pressure may overlap (for example, fields affected by European chafer are frequently affected by June beetle larvae). Estimated values are based upon economic impact in a single year and do not take into account the effects of pest pressure on yield due to crop rotation (for example, rotation from corn to soy).
[3] Weighted average based upon decline in crop receipts and crop value (OMAFRA, 2014).
[4] Weighted average based upon crop area at risk (for each crop) and crop area (OMAFRA, 2014).
[5] Estimated total cash receipts lost on crop area at risk including loss of IP premiums due to poor seed quality caused by insects valued at $17.7 million (OMAFRA, 2014, 2015).

[6] Estimated total cash receipts lost on crop area at risk including additional costs for alternative pest control products including loss of IP premiums due to poor seed quality caused by insects valued at $17.7 million (OMAFRA, 2014, 2015). Growers at risk are assumed to have increased pest control expenditures (excluding those estimated for soybean aphid).
[7] The Conference Board of Canada estimated a revenue loss due to additional costs for pesticides and a 0 to 10% yield loss to 99% of the corn crop and 65% of the soybean crop (the percentage of the corn and soybean planted with treated seed) (Grant et al., 2014).
[8] Estimated economic benefit when the Conference Board of Canada's estimate for the 5% yield loss model was standardized to the area at risk estimated by OMAFRA (about 42%). The estimated benefit of $112.6 million assumes only the farms affected by pest pressure would adjust their pesticide purchases. The estimated benefit from neonicotinoid seed treatments increases to $167 million if the assumption that all corn and soybean growers (including those not impacted by pest pressure) use alternative active ingredients to the neonicotinoid seed treatments. This assumption accounts for the prophylactic use of tefluthrin on corn as an alternative to the neonicotinoid seed treatments for control of black cutworm, corn rootworm, seedcorn maggot and wireworm as it must also be applied at planting time.

The Conference Board of Canada estimated a revenue loss of $225 million due to additional costs for pesticides based upon a 5% yield loss to 99% of the corn crop and 65% of the soybean crop (the percentage of the corn and soybean planted with treated seed). OMAFRA conducted detailed economic assessments for corn (grain, silage seed and sweet) and soybean (crush and IP/food grade) that estimated the impacts to revenue from each pest based upon the portion of the crop estimated to be at risk of pest pressure above economic thresholds which are typically much lower than 99% - on average around 42% (OMAFRA, 2014). The average decline in cash receipts was estimated to be about 6% on average (OMAFRA, 2014). If the pest pressure in the Conference Board of Canada model is assumed to approximate those provided by OMAFRA (that is, about 42%) for a yield loss of 5%, then the estimated reduction in revenue lowers from $225 million to between $112.6 to 167 million or about 3 to 4.5% of the Ontario farm gate value for corn and soybean. This is greater than the estimate from OMAFRA ($108.1 million). However, the Conference Board of Canada's model is based upon different assumptions and as a result is expected to estimate a somewhat different impact.

As indicated above, the approaches used by OMAFRA and the Conference Board of Canada are based on different assumptions, particularly with respect to the level of pest pressure in Ontario corn and soybeans. The differences in the overall estimated economic benefit between these studies highlight the importance of, and the need for additional information and comprehensive soil pest population surveys to characterize pest distribution and population levels across the Canadian provinces.

Ontario seed corn, sweet corn and Identity Preserved (IP)/food grade soybean industries are more dependent on clothianidin and thiamethoxam insecticide seed treatment than field corn and crush soybean industries.

Seed corn and sweet corn are of greater value per tonne than field corn (OMAFRA, 2014). This is also the case for IP/food grade soybean which is of greater value per tonne than soybean for crushing (OMAFRA, 2014). As a result, economic thresholds are reached with lower pest pressures. In addition, these crops require high quality seeds that are free from plant pathogens such as Stewart's wilt (corn) and bean pod mottle virus (soybean) (OMAFRA, 2014). These pathogens are not acceptable to importing countries and if present would effectively close the export markets for infected corn and soybean seed (OMAFRA, 2014). The economic assessment did not attempt to quantify the economic impacts to the IP/food grade soybean industry, or to the sweet and seed corn industries as a result of impacts to export market access since information required to assess these impacts was not available. However, it is recognized that the export market contributes to these industries and access to export markets due to seed quality impact these industries significantly.

The Ontario field corn industry realizes the greatest economic benefit from using clothianidin and thiamethoxam seed treatments (OMAFRA, 2014) however, the seed and sweet corn industries are relatively more dependent upon using neonicotinoid seed treatments. The estimated benefit to Ontario field corn is equivalent to 3.4% ($57.9 million) of the provincial farm gate value, whereas the estimated benefit to the Ontario seed and sweet corn industry is about 20% ($9.7 million) and 15% ($5.5 million) of the provincial farm gate value respectively.

The estimated benefit to the Ontario soybean industry is $10.4 million for crush soybean (0.9% of the provincial farm gate value) and $22.3 million for IP/food grade soybean (4.4% of the provincial farm gate value) (OMAFRA, 2014). The estimated benefit to the soybean industry includes the estimated additional cost to growers for alternative pest control products for the control of soybean aphid populations attaining economic thresholds early in the season only. Seed treatments are not recommended for control of soybean aphid later in the season as they are only effective up to 40 days following emergence (OMAFRA, 2014). If soybean aphids attain economic thresholds later the season, foliar sprays would be required regardless of the early season use of an insecticide seed treatment.

Individual corn and soybean growers are dependent on the use of clothianidin and thiamethoxam seed treatments when pest pressure is above economic thresholds. Small operations and those producing high value crops (for example, sweet corn, seed corn and IP soybean) are at greater risk of revenue loss.

The yield benefit reported from using clothianidin, imidacloprid and thiamethoxam seed treatments on corn range from 2 to 23 bushels/acre (about 43 to 1444 kg/ha[4]) (PMRA No. 2473988, 2472224, 2472887; Arnason, 2013; Ontario Farmer.com, 2014; OMAFRA, 2014; MAPAQ, 2014). The yield benefit reported from using clothianidin, imidacloprid and thiamethoxam seed treatments on soybean range from about 2 to 8.6 bushels/acre (about 141 to 578 kg/ha[5]) (PMRA No. 2473988; GFO, 2012; OMAFRA, 2014).

As need for the use of an insecticide seed treatment on corn and soybean is highly dependent on pest pressure at the farm level, the economic benefits from clothianidin and thiamethoxam seed treatments could be substantial for some affected growers.

While the analyses in the previous sections of this report were conducted at the industry level, quantifying the economic impact to corn and soybean operations is extremely difficult as the potential economic loss at the farm level is determined by many factors such as crop, variety/hybrid, soil type, crop rotation and past pest pressure. However, the potential economic benefits from using a neonicotinoid corn or soybean seed treatment can be qualified as minimal when there is little pest pressure, to being critical to crop production in cases where pest pressures would require the producer to replant the entire crop, or when several pests are present in a given field, or where the pest affects end product marketability (for example, cereal leaf beetle in seed and sweet corn; bean leaf beetle in IP/food grade soybean).

Seed corn, sweet corn and IP/food grade soybean operations are more likely to experience economic impacts from pests than grain corn, silage corn and soybean destined for crushing due to the greater per unit value of the crop. Additionally, potentially inadequate control of insect vectors for corn and soybean diseases could impact Canadian corn and soybean exports due to the risk of Stewart's wilt on corn and bean pod mottle virus (BPMV) on soybean which could lead to quarantine and render the products unmarketable for export (OMAFRA, 2014). However, field corn operations affected by soil pests with no alternative pest management options (for example, European chafer) will also be impacted economically if these pests are present.

Individual soybean operations are likely to be impacted economically by soil pests of economic concern if thiamethoxam seed treatment is not used when pests with no alternative pest management options are present (for example, seedcorn maggot). However, seedcorn maggot affects a small portion of the soybean crop compared to bean leaf beetle and soybean aphid. Despite the limitations of foliar applications relative to the seed treatments, growers do have access to alternative pest control products for control of bean leaf beetle and soybean aphids.

4 1 bushel of corn weighs approximately 56 lbs which is equivalent to 25.4 kg (Murphy, 1993).
5 1 bushel of soybean weighs approximately 60 lbs which is equivalent to 27.2kg (Murphy, 1993).

The Conference Board of Canada also examined the impact of reduced revenue based upon farm size. The benefit of economy of scale was evident in the form of reduced input costs on a per hectare basis for larger operations (Grant et al., 2014). The report highlighted the reduced ability for small operations to respond to reductions in revenue (Grant et al., 2014). As a result of revenue reduction, small operations are more likely to permanently leave the corn and soybean industries, whereas large operations are more likely to change marginally producing land to another crop (Grant et al., 2014).

Increases in the cost of corn or soybean production would be borne by the producer due to the Canadian market size for corn and soybean compared to the global markets.

Field corn represents a significant portion of the crop income for Ontario. In 2011, corn accounted for 24% of Ontario’s total crop receipts (PMRA No. 2472886). Soybean also represents a significant portion of the crop income for Ontario. In 2011 soybean accounted for 19% of Ontario’s total crop receipts (PMRA No. 2472886).

The United States is the world leader in corn production and export and as such, establishes world corn grain prices (Spectrum Commodities, 2013a). The United States is also the largest producer and consumer of soybean in the world (Spectrum Commodities, 2013b) and as a result has significant influence on the world price for soybean. Comparatively, Canada ranks twelfth in global corn production and is approximately 1/20th the size of the American corn industry. Canada is the seventh largest producer of soybean in the world and is approximately 1/19th the size of the American soybean industry.

Any impact to corn and soybean production in the United States would likely result in a change in world prices. This is not the case for the Canadian industry where a reduction in yield would have a much smaller effect on the available world stock (and hence commodity price). As a result, any increases in the cost of Canadian corn or soybean production would not be passed on to consumers and would be borne by the producer.

Summary

Clothianidin and thiamethoxam seed treatments contribute to insect pest management in agriculture in Canada and complement current crop production practices such as use of reduced tillage or no-till for soybean and corn and earlier planting for corn and soybean.

The economic value of seed treatments to the corn and soybean industries is linked to the extent of pest pressures above economic thresholds; however, identifying pest pressure poses considerable challenges for growers.

Based on currently available information, neonicotinoid seed treatments are estimated to be of economic benefit to the overall Canadian corn industry with benefits varying by province and type of corn produced. They are also estimated to be of economic benefit to the soybean industry in Ontario, particularly the IP/food soybean industry, and to the crushing soybean industry in Manitoba.

Individual corn and soybean operations are dependent on the use of clothianidin and thiamethoxam seed treatments when pest pressure is above economic thresholds. Small operations and those producing high value crops (for example, sweet corn, seed corn and IP soybean) are at greater risk of revenue loss.

Quantifying the economic impact at the farm level is extremely difficult as the potential economic loss at the farm level is determined by many factors such as crop, variety/hybrid, soil type, crop rotation and past pest pressure. However, increases in the cost of corn or soybean production would be borne by the producer due to the Canadian market size for corn and soybean compared to the global markets.

Next Steps

The PMRA will accept written comments for up to 60 days from the date of publication of this document. Please forward all comments to Publications (see contact information indicated on the cover page of this document).

Additional Information

Guidance on minimizing exposure to bees during corn and soybean seed planting can be found at www.healthcanada.gc.ca/pollinators.

PMRA documents can be found on the Pesticides and Pest Management portion of Health Canada's website at www.healthcanada.gc.ca/pmra. PMRA documents are also available through the Pest Management Information Service. Phone: 1-800-267-6315 within Canada or 1-613-736-3799 outside Canada (long distance charges apply); fax: 613-736-3798; e-mail: pmra.infoserv@hc-sc.gc.ca.

List of Abbreviations

ac	acre
a.i.	active ingredient
BPMV	bean pod mottle virus
bu	bushel
CAD	Canadian dollars
CFIA	Canadian Food Inspection Agency
g	gram
ha	hectare
IP	Identity Preserved
IPM	Integrated Pest Management
IRAC	Insect Resistance Action Committee
kg	kilogram
MAFRD	Manitoba Agriculture, Food and Rural Development
MAPAQ	Le ministère de l’Agriculture, des Pêcheries et de l’Alimentation du Québec
MoA	Mode of Action
OMAFRA	Ontario Ministry of Agriculture, Food and Rural Affairs
PMRA	Pest Management Regulatory Agency
PRVD	Proposed Re-evaluation Decision document
t	tonne
USEPA	United States Environmental Protection Agency
USD	US dollar

Appendix I

Registered Clothianidin, Imidacloprid, and Thiamethoxam Products with Corn and/or Soybean Seed Treatment Uses as of 17 June 2015

Discontinued products or products with a submission for discontinuation are excluded.

Registration Number	Registrant	Product Name	Formulation Type	Guarantee
Clothianidin				
27453	Bayer CropScience	PONCHO® 600 FS Seed Treatment Insecticide	Suspension	600 g/L
28975	Valent	NIPSIT INSIDE ™ 600 INSECTICIDE		600 g/L
Imidacloprid				
26124	Bayer CropScience	GAUCHO 480FL INSECTICIDE	Suspension	480 g/L
27170		GAUCHO 600FL INSECTICIDE		600 g/L
29610		STRESS SHIELD® for cereals and soybean		480 g/L
30668		Stress Shield 600		600 g/L
31068		Acceleron IX-409		600 g/L
28475	Makhteshim	Alias 240SC		240 g/L
30505		SOMBRERO 600FS		600 g/L
Thiamethoxam				
27045	Syngenta Canada Inc.	CRUISER® 5FS Seed Treatment	Suspension	47.6%
27986		CRUISER® 350FS Seed Treatment		29.9%
28821		CRUISER MAXX® BEANS Seed Treatment		22.6%
29113		A14379B Seed Treatment		22.6%
30388		A18046A Seed Treatment		261 g/L

Appendix II

Commercial Class Seed Treatment Uses on Corn and Soybean for Clothianidin, Imidacloprid and Thiamethoxam as of 17 June 2015

Uses from discontinued products or products with a submission for discontinuation are excluded.

Active ingredient	Site(s)	Pest Control Product Registration Number	Pest(s)	Formulation Type	Application Methods and Equipment	Application Rate (a.i.)		Comments
						Single[1]	Maximum	
Clothianidin	Corn (field), corn (sweet), corn (pop)	27453, 28975	Corn rootworm	Suspension	Commercial seed treatment equipment: closed transfer including closed mixing, loading, calibrating, and closed treatment equipment only	1.25 mg/kernel {100 g/80,000 seeds} {78.8 to 118.3 g/ha} field corn {52.5 to 75.6 g/ha} sweet corn	118.3 g/ha field corn 75.6 g/ha sweet corn	The a.i. rate per hectare is based upon a recommended plant stand of 60 000 to 86 000 plants/ha for field corn and 40 000 to 55 000 plants/ha for sweet corn. The additional seeding rate of 5 to 10 % is also included to account for the germination rate to obtain the recommended plant stand. Seed required at planting ranges from 63 000 to 94 600/ha for field corn and 42 000 to 60 500 for sweet corn.
			Corn flea beetle, black cutworm, seedcorn maggot, wireworm			0.25 to 0.5 mg/kernel {20 to 40 g/80,000 seeds} {15.8 to 47.3 g/ha} field corn {10.5 to 30.3 g/ha} sweet corn	47.3 g/ha field corn 30.3 g/ha sweet corn	
			White grub (larvae of European chafer, May/June beetle, Japanese beetle)			0.25 mg/kernel {20 g/80,000 seeds} {15.8 to 23.7 g/ha} field corn {10.5 to 15.1 g/ha} sweet corn	23.7 g/ha field corn 15.1 g/ha sweet corn	
Imidacloprid	Field corn (seed production only)	26124, 27170, 30505	Corn flea beetle	Suspension	Commercial seed treatment equipment: liquid/slurry	48 g/80 000 seeds 0.6 mg/kernel {37.8 to 56.8 g/ha}	56.8 g/ha	The a.i. rate per hectare is based upon a recommended plant stand of 60 000 to 86 000 plants/ha. The additional seeding rate of 5 to 10 % is also included to account for the germination rate to obtain the recommended plant stand. Seed required at planting ranges from 63 000 to 94
			Wireworm			13 g/80 000 seeds 0.16 mg/kernel {10.1 to 15.1	15.1 g/ha	

Active ingredient	Site(s)	Pest Control Product Registration Number	Pest(s)	Formulation Type	Application Methods and Equipment	Application Rate (a.i.)		Comments
						Single[1]	Maximum	
	Field corn	30505				g/ha}		600/ha.
	Sweet corn (Ontario and Québec only)	26124	Corn flea beetle			250 g/100 kg seed {27.5 to 42.5 g/ha}	42.5 g/ha	The a.i. rate per hectare is based upon a seeding rate of 11 to 17 kg/ha for sweet corn.
			Wireworm			67.2 g/100 kg seed {7.4 to 11.4 g/ha}	11.4 g/ha	
	Soybean	28475, 31068	Soybean aphid, bean leaf beetle, wireworm, seedcorn maggot	Suspension	Non-commercial seed treatment equipment: slurry	62.5 to 125 g/100 kg seed {35.63 to 157.5 g/ha}	157.5 g/ha	Seeding rate: 57 to 126 kg seed/ha (mean = 91.5 kg).
		29610, 31068			Commercial and on farm seed treatment equipment: slurry			
		30668	Soybean aphid, bean leaf beetle, wireworm, seedcorn maggot, European chaffer, Japanese beetle					
Thiamethoxam	Corn (field, seed, sweet, popcorn)	27045, 27986	European chafer, wireworm	Suspension	Commercial seed treatment equipment: Closed system	0.125mg/kernel 50g/100kg seed {7.9 to 11.8 g/ha} field corn {5.3 to 7.6 g/ha} sweet corn	11.8 g/ha field corn 7.6 g/ha sweet corn	The a.i. rate per hectare is based upon a recommended plant stand of 60 000 to 86 000 plants/ha for field corn and 40 000 to 55 000 plants/ha for sweet corn. The additional seeding rate of 5 to 10 % is also included to account for the germination rate to obtain the recommended plant stand. Seed required at planting ranges from 63 000 to 94 600/ha for field corn and 42 000 to 60 500 for sweet corn.
			Seedcorn maggot, corn flea beetle			0.125 – 0.250 mg/kernel 50-100 g/100kg seed {7.9 to 23.7 g/ha] field corn {5.3 to 15.1 g/ha} sweet corn	23.7 g/ha field corn 15.1 g/ha sweet corn	

Active ingredient	Site(s)	Pest Control Product Registration Number	Pest(s)	Formulation Type	Application Methods and Equipment	Application Rate (a.i.)		Comments
						Single[1]	Maximum	
Thiamethoxam	Corn (field, seed, sweet, popcorn - for planting in Canada)	27045	Corn rootworm	Suspension	Commercial seed treatment equipment: Closed system	1.25 mg/kernel {375 g/100kg seed} field corn {500 to 1000 g/100 kg seed} sweet corn {78.8 to 118.3 g/ha} field corn {52.5 to 75.6 g/ha} sweet corn	118.3 g/ha field corn 75.6 g/ha sweet corn	Application rate per 100 kg seed: Average field corn seed weight: 3 seeds per gram (PMRA, 2013). Therefore, there are 300 000 seeds in 100 kg. 300 000 seeds x 0.00125g a.i./seed = 375 g a.i. Sweet corn seed weight ranges from 4 to 8 seeds per gram (PMRA, 2013). Therefore there are between 400 000 and 800 000 seeds in 100kg. 0.00125 g a.i./seed x 400 000 seeds = 500 g a.i. 0.00125 g a.i./seed x 800 000 seeds = 1000 g a.i. Application rate per ha: The a.i. rate per hectare is based upon a recommended plant stand of 60 000 to 86 000 plants/ha for field corn and 40 000 to 55 000 plants/ha for sweet corn. The additional seeding rate of 5 to 10 % is also included to account for the germination rate to obtain the recommended plant stand. Seed required at planting ranges from 63 000 to 94 600/ha for field corn and 42 000 to 60 500 for sweet corn.
	Corn (field, seed, sweet, popcorn - for export)	27045				0.5 mg/kernel {150 g/100kg seed} field corn {200 to 400 g/100 kg seed} sweet corn	{Not applicable – not planted in Canada}	Application rate per 100kg seed: Average field corn seed weight: 3 seeds per gram. Sweet corn seed weight ranges from 4 to 8 seeds per gram. 0.0005 g a.i./seed x 300 000 seeds/100 kg = 150 g a.i./100 kg seed. 0.0005 g a.i./seed x 400 000 seeds/100kg = 200 g a.i. /100 kg seed. 0.0005 g a.i./seed x 800 000 seeds/100kg = 400 g a.i. /100 kg seed.

Active ingredient	Site(s)	Pest Control Product Registration Number	Pest(s)	Formulation Type	Application Methods and Equipment	Application Rate (a.i.)		Comments
						Single[1]	Maximum	
Thiamethoxam	Soybean	27045, 27986, 28821, 29113, 30388	Seedcorn maggot	Suspension	Commercial seed treatment equipment: Closed system	30 to 50 g/100 kg seed {0.045 to 0.075mg/seed} {17.1 to 63g/ha}	64 g/ha	Application rate per seed: 6,660 soybean = 1 kg; (Reg. No. 27045) 666,000 soybean = 100 kg. 50.2 g a.i./666,000 seeds = 0.075 mg/seed 50.8 g a.i./666 000 seeds = 0.076 mg/seed Application rate per hectare: Seeding rate: 57 to 126 kg/ha mean = 91.5 kg The typical application rate is 46.2 g/ha.
			Bean leaf beetle, European chafer, soybean aphid, wireworm			50.2 to 50.8 g/100kg seed {0.075 to 0.076mg/seed} {28.5 to 64g/ha}		

References

A. Studies/Information Provided by Registrants – Unpublished

PMRA Document Number	Title
2393325	2014. Value of Neonicotinoid Seed Treatments in Corn in Canada.
2393326	2014. Value of Neonicotinoid Seed Treatments in Soybean in Canada.
2392920	2014. Attachment II: Value information for clothianidin (COD), imidacloprid (IMI) and thiamethoxam (THE) seed treatment on corn and soybean.
2392933	2014. Attachment II: Value information for clothianidin (COD), imidacloprid (IMI) and thiamethoxam (THE) seed treatment on corn and soybean.
2392934	2014. Thiamethoxam Value Summary: Use of Thiamethoxam as a Seed Treatment on Corn and Soybean.
2392883	Attachment II: Value information for clothianidin (COD), imidacloprid (IMI) and thiamethoxam (THE) seed treatment on corn and soybean.
2392904	Attachment II: Value information for clothianidin (COD), imidacloprid (IMI) and thiamethoxam (THE) seed treatment on corn and soybean.
2537742	2015. Spatial Variability of Insect Pests in an Ontario Field. Bayer CropScience Inc.
2537743	2015. Effect of Seed Treatments and Planting Dates in Soybean. Summary of Year 1 of 2.
2538672	2015. Monsanto Canada input on Draft Value Assessment of Corn and Soybean Seed Treatment Use of Clothianidin, Imidacloprid and Thiamethoxam.

B. Studies/Information Provided by Third Parties - Unpublished

PMRA Document Number	Title
2472886	2012. Economic Impact Analysis: Grain Farmers of Ontario 2011.
2472883	MAFRD. 2014. Appendix I Value Information. Response to PMRA use information request from the Manitoba Agriculture, Food and Rural Development. March 6, 2014.
2472885	MAPAQ. 2014. Response to PMRA use information request fromMinistère de l'Agriculture, des Pêcheries et de l'Alimentation du Québec (MAPAQ). April 10, 2014.
2470064	NSDA. 2014. Appendix I Value Information. Response to PMRA use information request from the Nova Scotia Department of Agriculture . February 20, 2014.
2504660	OMAFRA. 2013. Question on Corn and Soybean Rotation. Email response from OMAF Crop Specialist to PMRA dated July 25, 2013.
2473458	OMAFRA. 2014. Impact of Neonics on Ontario Field Crops November 3, 2014. Response to Notice of Intent and value information Data Call In January 2014.
2538670	The Conference Board of Canada notes on Neonicotinoid Economic Impact Model – May 25, 2015 in response to the targeted consultation on seed treatment value by Health Canada.
2545727	SMA. 2014. Response to PMRA use information request from the Saskatchewan Ministry of Agriculture. February 19, 2014.
2545717	BCMA. 2014. Response to PMRA use information request from the British Columbia Ministry of Agriculture and Lands. February 19, 2014.
2547947	OMAFRA. 2015. OMAFRA Response to the targeted consultation on seed treatment value by Health Canada

C. Additional Information - Unpublished

PMRA Document Number	Title
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