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

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Insect pest management in North American corn, soybean, and canola production has been transformed over the past two decades. For corn, the major impetus for change has been the commercialization of genetically engineered (GE) plant-incorporated-protectants (PIPs) including European corn borer (ECB) active Bt corn in 1996 and corn rootworm (CRW) active Bt corn in 2004. The increase in use of CRW Bt corn that followed commercialization was accompanied by an increase in the use of reduced risk neonicotinoid (e.g., clothianidin and thiamethoxam) insecticide seed treatments for supplemental insect control. For soybean, the impetus for change was the emergence of the invasive soybean aphid in 2000. Prior to this invasion, most of the North Central U.S. saw little insecticide use in soybean. More recently, the use of neonicotinoid (e.g., imidacloprid and thiamethoxam) insecticide seed treatments has become more common. Similarly, neonicotinoid seed treatments have become widely used in canola production, especially to manage early-season flea beetle populations historically managed using organophosphate, organochlorine, synthetic pyrethroid, and carbamate insecticides.

The rapid and widespread adoption of PIPs was eclipsed by the even more rapid and more widespread adoption of GE herbicide tolerant (HT) crops such as Roundup Ready soybean, which was hard to explain based on early profitability estimates. However, further exploration revealed that these crops and their associated pest management practices provided value to farmers beyond any potential increase in profitability. Sources of these “non-pecuniary” values include the reduced risk of pest losses; increased flexibility, convenience, and simplicity of pest management; and reduced human and environmental risks.

The objectives of this research were to assess 1) the value of alternative insect management practices to farmers and 2) how these values relate to non-pecuniary factors. Of particular interest is the value of neonicotinoid insecticide seed treatments. These objectives are accomplished using data collected in 2014 from a telephone survey of U.S. corn and soybean farmers and Canadian corn, soybean and canola farmers regarding their 2013 production practices.

Subsequent sections of this report lay out a framework for conceptualizing the pecuniary and non-pecuniary value to farmers of alternative insect pest management practices; discuss the design and administration of the farmer survey that produced the data used to accomplish our research objectives; and describe the analysis and results emerging from this survey data in terms of the most concerning insect pests and how farmers are managing them, the most important factors guiding farmers' insect pest management decisions, and the perceived value of these management decisions. The report concludes with a summary of our findings.

Conceptual Framework

Piggott and Marra (2008) proposed a derived demand approach for conceptualizing how non-pecuniary factors influence the adoption of GE crops. This derived demand approach is ideally suited for framing how non-pecuniary factors influence farmer pest management decisions and the value of these decisions more generally.

The concepts of Piggott and Marra's derived demand approach can be illustrated using a stylized model where a corn farmer chooses between alternative pest management practices. Let $A > 0$ be the total number of corn acres managed by a farmer. For simplicity, assume the farmer can choose between two pest management practices and let $A_1 \geq 0$ and $A_2 \geq 0$ be the number of corn acres managed under each alternative practice such that $A_1 + A_2 = A$. On average, the amount of corn produced, $Y \geq 0$, depends on the number of acres managed using each practice: $Y = f(A_1, A_2)$. This average is assumed to be non-decreasing at a non-increasing rate regardless of the chosen practice: $\frac{\partial f(A_1,A_2)}{\partial A_i} \geq 0$ and $\frac{\partial^2 f(A_1,A_2)}{\partial {A_i}^2} \leq 0$ for $i = 1, 2$ — assumptions that imply planting more acres of corn increases the amount of corn produced and that farmers choose to plant their most productive corn acres first. Average production costs also depend of the number of acres managed under each practice: $c(A_1, A_2)$. These average costs are assumed to be non-decreasing at a non-decreasing rate regardless of the chosen practice: $\frac{\partial c(A_1,A_2)}{\partial A_i} \geq 0$ and $\frac{\partial^2 c(A_1,A_2)}{\partial {A_i}^2} \geq 0$ for $i = 1, 2$ —assumptions that imply planting more acres of corn increases costs and that these increases in costs tend to get larger the more corn acres planted. Given the average price of corn, $P > 0$, the farmer's average profitability is:

(1) $$\pi(A_1, A_2) = Pf(A_1, A_2) - c(A_1, A_2).$$

If average profitability is all a farmer cares about, it can be maximized by choosing $A_1 = A_1^*$ and $A_2 = A_2^*$ such that $A_1^* + A_2^* = A$ and

(2) $$P\frac{\partial f({A_1}^*,{A_2}^*)}{\partial A_1} - \frac{\partial c({A_1}^*,{A_2}^*)}{\partial A_1} = P\frac{\partial f({A_1}^*,{A_2}^*)}{\partial A_2} - \frac{\partial c({A_1}^*,{A_2}^*)}{\partial A_2}.$$

Figure 1 illustrates. Panel (a) shows the marginal revenue curve, $MR_1 = P\frac{\partial f({A_1}^*,{A_2}^*)}{\partial A_1}$, and marginal cost curve, $MC_1 = \frac{\partial c({A_1}^*,{A_2}^*)}{\partial A_1}$, as the acres managed using practice 1 increases to the right decreasing the number of acres managed using practice 2. Similarly, panel (b) illustrates the marginal revenue curve, $MR_2 = P\frac{\partial f({A_1}^*,{A_2}^*)}{\partial A_2}$, and marginal cost curve, $MC_2 = \frac{\partial c({A_1}^*,{A_2}^*)}{\partial A_2}$, as the acres managed using practice 2 increases to the right decreasing the number of acres managed using practice 1. To find the optimal allocation of A between A_1 and A_2, panel (c) shows the marginal net revenue curves for practice 1 and 2 ($MNR_1 = MR_1 - MC_1$ and $MNR_2 = MR_2 - MC_2$) with the axis for practice 2 reversed so A_2 increases to the left, while A_1 increases to the right making $A_1 + A_2 = A$ more explicit. The intersection of the two marginal net revenue curves — the satisfaction of equation (2) — identifies the allocation of corn acres to alternative pest management practices that maximizes the average profit in equation (1). Graphically, the maximal profit equals the gray shaded area under the marginal net revenue curves in panel (c). This maximal average profit can be split into the profit attributable to corn managed using practice 1 (the gray shaded area in panel (a) between the marginal revenue and marginal cost curves) and the profit attributable to corn managed using practice 2 (the gray shaded area in panel (b) between the marginal revenue and marginal cost curves).

While the gray shaded area in panel (b) reflects profit attributable to using practice 2, it does not reflect the additional value practice 2 provides to the farmer because in the absence of practice 2, the farmer would presumably plant all corn acreage using practice 1. Thus, if practice 2 were not available to the farmer, he would give up the shaded gray area in panel (b), but would gain the hashed area in panel (a) by increasing corn managed using practice 1. This would result in a net loss to the farmer of profits equal to the area in panel (c) denoted by the triangle with vertices at points ***a***, ***b*** and ***c***. Therefore, the added value of practice 2 to the farmer is the area of the triangle denoted by ***abc***. Note that this area will equal the product of corn acres planted, the proportion of these acres managed using practice 2, and the additional value per acre practice 2 provides the farmer.

The framework outlined in equations (1) and (2) and illustrated in figure 1 can be augmented to incorporate non-pecuniary factors. Suppose for example that practice 2 provides more consistent and longer lasting control in addition to higher average profits when compared to practice 1. If a farmer only cares about average profit, these additional factors do not matter and the analysis is unchanged. But, if a farmer cares about more consistent and longer lasting control in addition to higher average profits, then these additional factors will matter and the analysis changes.

To show that a farmer cares about more than just average profit, we can use a utility function. Let $U(\pi, \tau)$ represent this utility function where π is average profit and τ is some other factor a farmer cares about like more consistent and longer lasting control. Typical assumptions for a utility function are that it is non-decreasing at a non-increasing rate in profit and other factors the farmer cares about: $\frac{\partial U(\pi,\tau)}{\partial \pi} \geq 0, \frac{\partial U(\pi,\tau)}{\partial \tau} \geq 0, \frac{\partial^2 U(\pi,\tau)}{\partial \pi^2} \leq 0$ and $\frac{\partial^2 U(\pi,\tau)}{\partial \tau^2} \leq 0$. These assumptions imply that more of something the farmer cares about is better, but how much better declines the more the farmer already has. To show that strategy 2 provides more consistent and longer lasting control and that this is valued by a farmer, we can write τ as an increasing function of the number of acres planted using practice 2: $\tau = h(A_2)$ where $\frac{\partial h(A_2)}{\partial A_2} \geq 0$. Again, these benefits are also assumed to decline the more strategy 2 is used also implying $\frac{\partial^2 h(A_2)}{\partial {A_2}^2} \leq 0$. Getting the most utility possible from corn production can then be accomplished by choosing $A_1 = A_1^{**}$ and $A_2 = A_2^{**}$ to maximize $U\big(\pi(A_1, A_2), h(A_2)\big)$. This will occur where $A_1^{**} + A_2^{**} = A$ and

$$(3) \qquad P\frac{\partial f({A_1}^{**},{A_2}^{**})}{\partial A_1} - \frac{\partial c({A_1}^{**},{A_2}^{**})}{\partial A_1} = P\frac{\partial f({A_1}^{**},{A_2}^{**})}{\partial A_2} - \frac{\partial c({A_1}^{**},{A_2}^{**})}{\partial A_2} + \frac{\frac{\partial U\left(\pi({A_1}^{**},{A_2}^{**}),h({A_2}^{**})\right)}{\partial \tau}}{\frac{\partial U\left(\pi({A_1}^{**},{A_2}^{**}),h({A_2}^{**})\right)}{\partial \pi}} \frac{\partial h({A_2}^{**})}{\partial A_2}.$$

Equation (2) and (3) look almost identical with the exception of the last term on the right-hand-side of equation (3). This term reflects the value of non-pecuniary benefits attributable to replacing acres planted using practice 1 with acres planted using practice 2, which provides more consistent and longer lasting control in addition to higher average profit.

Figure 2 shows how the addition of non-pecuniary benefits changes the analysis in figure 1. The difference is that we must account for these non-pecuniary benefits when evaluating the benefits of practice 2 to the farmer. In panel (b) of figure 2, we have added a marginal non-pecuniary benefit curve: $MNPB = \frac{\frac{\partial h(A_2^{**})}{\partial A_2}}{\frac{\partial U(\pi,\tau)}{\partial \pi}} \frac{\partial U(\pi(A_1^{**}, A_2^{**}), h(A_2^{**}))}{\partial \tau}$. Adding these marginal non-pecuniary benefits to marginal revenues then yields the total marginal benefits of using practice 2: $MB_2 = MR_2 + MNPB$. Subtracting marginal costs and reversing the axis gives us the marginal net benefit curve ($MNB_2 = MB_2 – MC_2$) illustrated in panel (c). The intersection of the marginal net revenue curve for practice 1 and the marginal net benefit curve for practice 2 — the satisfaction of equation (3) — identifies the allocation of corn acres to alternative pest management practices that maximize a farmer's utility.

Graphically, the value of this maximal utility in terms of money equals the gray shaded area in panel (c). This maximal value can be split into the profit attributable to corn managed using practice 1 (the gray shaded area in panel (a) between the marginal revenue and marginal cost curves), the profit attributable to corn managed using practice 2 (the lighter gray shaded area in panel (b) between the marginal revenue and marginal cost curves), and the non-pecuniary benefits of using practice 2 with its more consistent and longer lasting control (the darker gray shaded area in panel (b) between the marginal revenue and marginal benefits curves). The additional value to the farmer of using practice 2 is the area of the triangle in figure 2, panel (c) denoted by ***abc***. This area is equal to the difference between the dark and light gray areas in panel (b) and the hashed area in panel (a), which reflects the fact that if practice 2 were not available, the farmer would resort to using practice 1.

The objectives of this research were to explore the size of the area ***abc***, the additional value a pest management practice provides to a farmer as compared to what else he could do, and how this value varies in relation to the non-pecuniary factors that are most important to a farmer's choice over alternative pest management practices. We accomplish this objective by estimating how various non-pecuniary factors affect the likelihood that a farmer uses alternative pest management practices, the proportion of acres managed with alternative pest management practices, and the additional value per acre managed with alternative practices.

Methodology

Data Sources

The primary data used to accomplish the objectives of this research come from a telephone survey of U.S. corn and soybean farmers and Canadian corn, soybean, and canola farmers conducted by Market Probe, a professional market research firm with offices in the U.S. and Canada. A total of 622 corn farmers from twelve U.S. states and three Canadian provinces, 622 soybean farmers from fourteen U.S. states and three Canadian provinces, and 500 canola farmers from three Canadian provinces were surveyed.[1] The telephone surveys were conducted in February and March of 2014 for U.S. farmers and April and May of 2014 for Canadian farmers. All farmers were paid a small participation fee to compensate for the time they took to complete the survey.

The survey instruments were designed by the authors in consultation with Market Probe and technical experts from three registrants of neonicotinoid insecticides commonly used in seed protection products (Bayer, Syngenta, and Valent). First, the survey screened participants to

[1] The twelve U.S. states sampled for corn accounted for 82% of the corn acres planted in the U.S. in 2013, while the fourteen U.S. states sampled for soybean accounted for 90% of the soybean acres planted in the U.S. in 2013 (USDA-NASS 2014a). The three Canadian provinces sampled for corn, canola and soybean represented over 97% of corn, canola, and soybean acres planted in Canada in 2011 (Statistics Canada 2014b).

ensure they had planted at least a minimal amount of the targeted crop (corn, soybean or canola) in 2013 and were not a chemical or seed company employee.[2] For the 2013 growing season, the survey then asked for information on the farmer's

1. operation (e.g., the number of target crop acres, total crop acres, other crops planted, use of conservation tillage practices, number of corn following corn acres for corn farmers, amount of leased land, and presence of a livestock enterprise),
2. actively managed insect pests, including the most important of these pests,
3. use of alternative pest management practices (e.g., Bt corn, insecticide seed treatments, soil insecticides, and foliar insecticides) including specific products and number of acres,
4. average production costs, yields, and price received for any marketed crop,
5. source of insect pest management advice,
6. most important considerations when making insect pest management decisions,
7. perceived value of alternative insect pest management practices,
8. biggest insect pest management concerns in the targeted crop, and
9. education and farming experience.

The most substantial difference between the corn, soybean, and canola surveys is that the corn survey asked about a farmer's use of Bt corn PIPs and soil insecticides, while the soybean and canola surveys did not since there are currently no PIPs or soil insecticides registered for use in soybean and canola.

Econometric Methods

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[2] For U.S. corn and soybean farmers the minimal amount of target crop acres was 250. For Canadian corn, soybean, and canola farmers, the minimal amount of target crop acres was 100, 60, and 250.

Dependent variables explored econometrically included the probability of adoption of a particular pest management practice, the proportion of the target crop acres managed with the practice given it was adopted, and the additional value per acre the practice provided. For corn, the practices that were considered included Bt corn adoption, insecticide seed treatments, soil insecticide treatments, and foliar insecticide treatments. For soybean and canola, the considered practices included insecticide seed treatments and foliar insecticide treatments.

Of particular interest in our analysis was how these dependent variables varied geographically and in relation to various non-pecuniary factors. To explore this variation, for each of our dependent variables, we estimated four nested multivariate regression equations:

(4a) $y_i = \sum_{f \in \mathbf{F}} \alpha_f x_i^f + \sum_{r \in \mathbf{R}} \beta_r d_i^r + \sum_{p \in \mathbf{P}} \beta_{can} d_i^p + \varepsilon_i,$

(4b) $y_i = \sum_{f \in \mathbf{F}} \alpha_f x_i^f + \beta_{us} d_i^{us} + \sum_{p \in \mathbf{P}} \beta_{can} d_i^p + \varepsilon_i,$

(4c) $y_i = \sum_{f \in \mathbf{F}} \alpha_f x_i^f + \sum_{r \in \mathbf{R}} \beta_r d_i^r + \beta_{can} d_i^{can} + \varepsilon_i,$

(4d) $y_i = \sum_{f \in \mathbf{F}} \alpha_f x_i^f + \beta + \varepsilon_i,$

where y_i is the dependent variable for farmer *i*; x_i^f is a measure of importance of non-pecuniary factor *f* to farmer *i* with **F** being the set of non-pecuniary factors; d_i^{us} is an indicator variable equal to one if farmer *i* operated in the U.S. and zero otherwise; d_i^{can} is an indicator variable equal to one if farmer *i* operated in Canada and zero otherwise; d_i^r is an indicator variable equal to one if farmer *i* operated in the United States Department of Agriculture Economic Research Service's (USDA-ERS) farm resource region *r* with **R** being the set of all observed farm resource regions in the data (Heartland, Northern Crescent, Northern Great Plains and Prairie Gateway for corn; and Heartland, Northern Crescent, Northern Great Plains, Prairie Gateway, and Mississippi Portal for soybean); d_i^p is an indicator variable equal to one if farmer *i* operated in the Canadian province *p* with **P** being the set of all observed provinces in the data (Manitoba, Ontario, and Quebec for corn and soybean; and

Alberta, Manitoba, and Saskatchewan for canola); ε_i is a random error with mean zero and estimable variance σ_{us}^2 and σ_{can}^2 for the U.S. and Canada in equations (4a) – (4c) and σ^2 for equation (4d); and α_f for $f \in \mathbf{F}$, β_r for $r \in \mathbf{R}$, β_p for $p \in \mathbf{P}$, β_{us}, β_{can}, and β are other estimable parameters.[3]

With this specification we can test three hypotheses regarding variation in responses across geographic locations:

H1: $\beta_r = \beta_{us}$ for $r \in \mathbf{R}$;

H2: $\beta_p = \beta_{can}$ for $p \in \mathbf{P}$; and

H3: $\beta_r = \beta_p = \beta$ for $r \in \mathbf{R}$ and $p \in \mathbf{P}$, and $\sigma_{us}^2 = \sigma_{can}^2 = \sigma^2$.

Rejection of H1 indicates there were regional differences in responses for U.S. farmers. Rejection of H2 indicates there were provincial differences in responses for Canadian farmers. Rejection of H3 indicates differences in responses between U.S. and Canadian farmers. This specification also allows us to assess if responses differed based on alternative non-pecuniary factors by testing:

H4: $\alpha_f = 0$

for each $f \in \mathbf{F}$ individually.

Different techniques were required to estimate equations (4a) - (4d) for each of our response variables. The responses for whether or not a farmer adopted a particular pest management practice came from a binary yes-no question on the survey, so a probit model was appropriate.

The proportion of acreage managed with a particular practice given the farmer adopted that practice was calculated from a farmer's response to two questions: 1) How many acres of the target crop did you plant in 2013? and 2) How many of these acres were managed with the particular

[3] See http://www.ers.usda.gov/publications/aib-agricultural-information-bulletin/aib760.aspx for map of USDA-ERS farm resource regions.

practice? The responses to these questions were used to construct the proportion of the targeted crop acres managed with a particular practice for farmers reporting that they used the practice. This proportion was bounded between zero and one with frequent observations at the upper boundary, so a censored regression model was appropriate for the analysis.

The responses for the additional value per acre managed with a particular practice were categorical. An example of the questions used to elicit these responses is:

> Please think carefully about **all** the reasons why you chose to plant corn 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 corn**?
>
> Not more than $**5** per acre..(__)
>
> More than $**5**, but not more than $**10** per acre..................................(__)
>
> More than $**10**, but not more than $**15** per acre................................(__)
>
> More than $**15**, but not more than $**25** per acre................................(__)
>
> More than $**25** per acre ....(__)

Because farmer responses reflected increasing ranges in which their individual value may lay, interval regression was appropriate. Currency denominations for this question were based on the country in which the farmer operated, so to combine responses for the U.S. and Canada, an exchange rate of 0.92 U.S. dollars per Canadian dollar was used to adjust the Canadian ranges into U.S. dollars before the analysis was conducted. With the exception of Bt corn, the ranges of values presented to farmers were identical to the example above. For Bt corn, the ranges presented to farmers were: Not more than $**5** per acre; More than $**5**, but not more than $**10** per acre; More than $**10**, but not more than $**25** per acre; More than $2**5**, but not more than $**40** per acre; and More than $**40** per acre. These higher ranges were selected for Bt corn because we anticipated the value of Bt corn would be higher. It is also important to note that the value questions were only presented to farmers who indicated they used the practice in 2013 because the value to those who did not was presumably zero.

STATA's probit command was used to estimate the probit models, while STATA's intreg command was used to estimate the censored and interval regression models. Likelihood ratio statistics were used to test H1- H3, while regression t-statistics were used to test H4 for all target crops. Rejection of these hypotheses was judged based on a ten percent level of significance.

Also of interest for our analysis was the additional value per acre managed with a particular practice as compared to what else the farmer could have done to manage insect pests (e.g., the area of triangle ***abc*** in Figure 2 (c)). This value can be calculated from the interval regression results. When using these results, it is important to recognize that farmers are unlikely to adopt practices that are not perceived as valuable, which must be taken into account when using regression estimates to calculate this value. To take this into account, we assumed farmers' values followed a normal distribution truncated to be greater than zero. With such a distribution, the mean value to farmers in region *r* based on equation (4a) can be calculated as

$$(5) \qquad V_r = \sum_{f\in F} \hat{\alpha}_f \bar{x}_r^f + \hat{\beta}_r + \hat{\sigma}\frac{\phi\left(-\frac{\sum_{f\in F}\hat{\alpha}_f \bar{x}_r^f + \hat{\beta}_r}{\hat{\sigma}_{us}}\right)}{1-\Phi\left(-\frac{\sum_{f\in F}\hat{\alpha}_f \bar{x}_r^f + \hat{\beta}_r}{\hat{\sigma}_{us}}\right)}$$

where $\bar{x}_r^f$ is the average of x_i^f for farmers in region *r*; and $\hat{\alpha}_f^{us}$ for $f \in \mathbf{F}$, $\hat{\beta}_r$, and $\hat{\sigma}_{us}$ are estimated parameters (Greene 2000). The standard deviation of U.S. farmers' values in region *r* based on equation (4a) can be calculated as

$$(6) \qquad S_r = \hat{\sigma}_{us}\sqrt{1 - \frac{\phi\left(-\frac{\sum_{f\in F}\hat{\alpha}_f\bar{x}_r^f+\hat{\beta}_r}{\hat{\sigma}_{us}}\right)}{1-\Phi\left(-\frac{\sum_{f\in F}\hat{\alpha}_f\bar{x}_r^f+\hat{\beta}_r}{\hat{\sigma}_{us}}\right)}\left(\frac{\phi\left(-\frac{\sum_{f\in F}\hat{\alpha}_f\bar{x}_r^f+\hat{\beta}_r}{\hat{\sigma}_{us}}\right)}{1-\Phi\left(-\frac{\sum_{f\in F}\hat{\alpha}_f\bar{x}_r^f+\hat{\beta}_r}{\hat{\sigma}_{us}}\right)} - \frac{-\sum_{f\in F}\hat{\alpha}_f\bar{x}_r^f+\hat{\beta}_r}{\hat{\sigma}_{us}}\right)}$$

(Greene 2000). Similar calculations for Canadian provinces can be done by substituting $\hat{\sigma}_{can}$ for $\hat{\sigma}_{us}$ and *p* for *r* in equations (5) and (6). Confidence intervals for equation (5) and (6) can be obtained using the regression results with the delta method (Greene 2000). STATA's nlcom command was used for this calculation.

The state and county information collected with U.S. survey responses were used to assign farmers to one of the USDA-ERS's nine farm resource regions.[4] All but one corn farmer was from one of four farm resource regions: Heartland, Northern Crescent, Northern Great Plains, and Prairie Gateway. The farmer that was not from one of these four regions was in the Eastern Uplands region and operated in a county close to the Prairie Gateway region, so he was included with this region. All but five soybean farmers were in five of the farm resource regions: Heartland, Northern Crescent, Northern Great Plains, Prairie Gateway, and Mississippi Portal. Four of these five farmers were in the Eastern Uplands region and operated in counties close to the Prairie Gateway region, so their

[4] An excel file with link from county and state fips codes to the USDA-ERS's farm resource regions is available at http://webarchives.cdlib.org/wayback.public/UERS_ag_1/20111128195215/http:/www.ers.usda.gov/Briefing/ARMS/resourceregions/resourceregions.htm.

responses were included with this region. The final farmer was in the Southern Seaboard region in a county close to the Mississippi Portal region, so he was included with this region.

To measure the importance of alternative non-pecuniary factors on farmers' pest management decisions, farmers were asked to rate the importance of twenty different items on a four point scale with 1 equal to "not important," 2 equal to "somewhat important," 3 equal to "important," and 4 equal to "very important." The twenty items and percentage of corn, soybean, and canola farmers that chose "important" or "very important" are reported in Table 1. These items were primarily selected based on the types of non-pecuniary benefits identified in previous research (Carpenter and Gianessi 1999; Marra, Piggott and Carlson 2004; Fernandez-Cornejo, Hendricks, and Mishra 2005; Bonny 2007; Sydorovych and Marra 2008; Gardner, Nehring, and Nelson 2009; Hurley, Mitchell, and Frisvold 2009). Items that were not identified in previous research, but we thought could also be important included "Improving Crop Stand," "Improving Plant Health," "Replant or Other Product Guarantees," "Crop Marketability" and "Protecting Beneficial Insects."

Preliminary analysis of farmer responses to these items showed many were highly correlated. Therefore, we conducted a factor analysis separately for each crop.[5] Factor analysis is commonly used to reduce the number of highly correlated variables. The premise of factor analysis is that there are some underlying unobserved factors driving individual responses to various items resulting in correlation across responses. Factor analysis provides a tool for identifying what these underlying factors are and measuring them for subsequent analysis.

[5] We conducted the factor analysis for each crop separately after determining that there were significant differences in response across crops for most of the twenty items.

Table 2 reports the eigenvalues and proportion of the variance explained by the factor estimates obtained using STATA's factor command for each crop. A large eigenvalue indicates that an important underlying factor has been identified. To test the likelihood that an important factor has in fact been identified, we followed the parallel analysis paradigm reported in Ledesma and Valero-Mora (2007) and compared the observed eigenvalues to the eigenvalues that would be expected if the observed responses were actually just random.[6] Specifically, to determine how many factors were statistically significant, we simulated farmer responses using the observed proportions of farmer responses assuming independence and performed a factor analysis on this simulated data. This was repeated 5,000 times for each crop to develop a distribution of expected eigenvalues under the null hypothesis of independence. These distributions were then compared to the observed eigenvalues to compute the probability that the first *k*th observed factors had eigenvalues that exceeded the simulated eigenvalues where *k* was varied from one to twenty. This boot strapping method identified five statistically significant factors for the corn responses, four for the soybean responses, and three for the canola responses. The factor analysis was then repeated retaining only significant factors and factor scores for each farmer were generated using STATA's predict command with its default regression method selected. These factor scores were included in our econometric analysis as measures of non-pecuniary factors that could influence farmers' pest management decisions and the value of these decisions.

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[6] There are a variety of methods for selecting the appropriate number of factors to retain for further analysis. Two of the most popular are the Kaiser rule, which retains factors with eigenvalues greater than 1, and Cattell's Scree test, which plots eigenvalues from largest to smallest and looks for the point where the change in the eigenvalues becomes negligible. The Kaiser rule is often criticized for being ad hoc, while Cattell's Scree test is often criticized for being subjective. Alternatively, the parallel analysis paradigm has the advantage of having statistical foundations and being more objective. Furthermore, it has been found to perform well in simulation studies (Courtney 2013).

Results

This section provides an overview of operation and farmer characteristics reported by survey respondents. It summarizes the actively managed and most important insect pests reported by farmers and the practices used to manage these pests. After discussing where farmers get their insect pest management advice and what types of non-pecuniary factors were identified as potential influences on the adoption and value of the alternative pest management practices, we turn to a discussion of our econometric results. The section concludes with estimates of the additional value per acre managed with a particular practice ($ per treated acre) and per all acres planted with the crop ($ per planted acre).

Operation and Farmer Characteristics

Surveyed corn farmers planted 1,352 total crop acres on average, with Canadian farmers planting about 150 acres more than U.S. farmers on average (Table 3). Corn acres planted averaged 45 percent of total crop acres planted for all respondents with U.S. farmers planting more corn than their Canadian counterparts. U.S. corn farmers also leased more acres and used no-till practices more than their Canadian counterparts. Alternatively, compared to U.S. corn farmers, Canadian corn farmers planted more corn-following-corn in 2013, were more likely to have livestock enterprises, and tended to plant a wider variety of crops. Both U.S. and Canadian corn farmers averaged close to the equivalent of a two year college or technical degree, though U.S. corn farmers had about 6.5 additional years of experience farming on average.

Surveyed soybean farmers average almost 100 more total crop acres when compared to corn farmers, with U.S. soybean farmers planting about 400 more crop acres than Canadian soybean farmers (Table 4). U.S. soybean farmers planted almost twice as many acres of soybean and leased more than twice as many acres as Canadian soybean farmers. Having livestock enterprises was somewhat more likely for U.S. soybean farmers, while the percentage of no-till soybean was similar for both U.S. and Canadian soybean farmers. While Canadian corn farmers were likely to also being planting soybeans, there were many Canadian soybean farmers who did not plant corn. As with Canadian corn farmers, Canadian soybean farmers tended to plant a wider variety of crops than their U.S. counterparts. U.S. and Canadian soybean farmers averaged the equivalent of a two year college or technical degree, and there was less of a disparity in years of experience farming when compared to the U.S. and Canadian corn farmers.

Canadian canola farmers operated almost twice as many crop acres as Canadian corn farmers and more than twice as many acres as Canadian soybean farmers. More than a third of these acres were planted with canola (Table 4). These canola farmers reported leasing more land than Canadian corn and soybean farmers, though the percentage reporting livestock enterprises was similar to Canadian soybean farmers and lower than Canadian corn farmers. No-till practices were much more common for the Canadian canola farmers when compared to both U.S. and Canadian corn and soybean farmers. The vast majority of Canadian canola farmers also planted wheat, with about half planting barley and about a third planting pulses. Educational attainment was slightly lower for Canadian canola farmers when compared to Canadian corn and soybean farmers, though they had slightly more farming experience.

Insect Pests of Concern to Farmers

For U.S. and Canadian corn farmers, CRW and ECB topped the list of most actively managed and most important insect pests, though U.S. corn farmers tended to see the CRW as a bigger threat, while Canadian corn farmers tended to see the ECB as being more significant. Aphids topped the list of most actively managed and most important insect pests for soybean farmers in both the U.S. and Canada. Beetles came in second in the U.S. followed closely by mites and stink bugs. Interestingly, while mites and beetles were cited as the second and third most actively managed pest in Canadian soybean production, grasshoppers were rated as the second most important insect pest, with no farmers rating beetles as most important. The most actively managed and most important insect pest cited in Canadian canola production was the flea beetle, with the Bertha armyworm coming in a distant second.

Insect Pest Management Practices

Bt corn was the primary tactic to manage corn insect pests reported by survey respondents (Table 5). Over four out of five corn farmers reported using Bt corn, with higher levels of adoption reported in Canada. On average, U.S. respondents planted 435 acres of Bt corn, representing about two-thirds of their total corn acreage. USDA-NASS (2014a) reports that 76 percent of corn acres in the U.S. were planted with Bt corn in 2013. Just under two-thirds of U.S. farmers reported planting stacked varieties of Bt corn that provide control of both above ground insects like the ECB and below ground insects like the CRW, while one in three reported planting Bt corn varieties that only control above ground insects and just over one in ten reported planting Bt corn varieties that only control below ground insects. Canadian corn farmers planted an average of 375 acres of Bt corn representing about three-quarters of their total corn acreage. They were more likely than U.S. farmers to use stacked varieties with both above and below ground insect control and Bt corn that only controls above ground insects, while they were less likely to plant Bt corn that only controls below ground insects — results consistent with the relative rankings of insect pest threats.

The use of insecticide seed treatments was reported by about two-thirds of U.S. and just over three-quarters of Canadian corn farmers (Table 5). Canadian corn farmers reported more corn acres and a higher percentage of these acres were planted with insecticide treated seed when compared to U.S. corn farmers. Based on GfK Kynetec[7] data, U.S. corn acres treated with a neonicotinoid insecticide seed treatment averaged 89 percent of planted acres between 2010 and 2012.

One in five U.S corn farmers reported using a soil insecticide, while 8.2 percent reported using a foliar insecticide (Table 5). On average, U.S. corn farmers reported 97 acres were treated with a soil insecticide and 42 acres were treated with a foliar insecticide representing 14.2 and 6.0 percent of all corn acres. Based on GfK Kynetec data, U.S. corn acres treated with soil and foliar insecticides averaged 11.0 and 4.3 percent between 2010 and 2012. Canadian corn farmers were less likely to use soil insecticides (3.4 percent) and more likely to use foliar insecticides (11.7 percent), which is again consistent with the relative rankings of insect pest threats.

Just over half of U.S. soybean farmers used an insecticide seed treatment and almost one quarter used foliar insecticides (see Table 6). This equates to farmers planting 322 acres of insecticide treated seed on average, representing 44.6 percent of total soybean acreage. Alternatively, 123 acres on average were treated with a foliar insecticide, representing 16.2 percent of total soybean acres. Based on GfK Kynetec data, U.S. soybean acres planted with insecticide treated seed and treated with foliar insecticides averaged 38.0 and 26.5 percent between 2010 and 2012. Almost three-quarters of Canadian soybean farmers used an insecticide seed treatment, with only about one in seven using foliar insecticides. On average, these Canadian farmers had 216 acres or almost two-thirds of their soybean acres planted with insecticide treated seed and 20 acres or 7.4 percent of their soybean acres treated with a foliar insecticide.

[7] GfK Kynetec data are widely recognized as among the best survey-based data on agricultural chemical use and have been collected annually for almost 50 years.

Almost nine out of every ten Canadian canola farmers reported planting insecticide treated seed (Table 6). This represented 836 acres of the canola planted or 87.2 percent of all canola acreage on average. Just over one in four used foliar insecticide applications representing 182 canola acres or 18.4 percent of all canola acres on average.

Non-Pecuniary Factors Guiding Insect Pest Management Choices

Tables 7 - 9 report the factor loadings and item uniqueness based on how farmers rated the importance of the twenty items in Table 1. In each table, the loading for an item with the highest absolute value across factors is bolded to help show which of the twenty items had the greatest influence on which factor. Recall that five factors were identified as significant for corn farmers, while four and three factors were identified as significant for soybean and canola farmers (Table 2).

For corn farmers, "Reducing Equipment Wear & Tear," "Convenience, Saving Time & Labor," "Simplicity," "Reducing Scouting, Flexibility," "Cost, Being Able to Plant Early," and "Replant or Other Product Guarantees" all have relatively high absolute loadings for the non-pecuniary factor referred to as **Cost, Planting, Time & Ease** (Table 7). These high factor loadings are all positive indicating that corn farmer responses to these items are relatively highly and positively correlated likely due to some more general underlying preference for pest management practices that share the attributes described by these items. The non-pecuniary factor labeled **Health, Environment, & Marketability** has relatively high absolute loadings for "Public Safety," "Protecting Water Quality," "Protecting Beneficial Insects," "Protecting Wildlife," "Family & Worker Health," and "Crop Marketability." The non-pecuniary factor labeled **Plant Performance** has relatively high absolute loadings for "Improving Plant Health," "Improving Crop Stand," and "Protecting Yield." The non-pecuniary factor labeled **Yield Risk** has relatively high absolute loadings for “Having Consistent Insect Control” and “Having Long Lasting Insect Control.” Compared to the first four factors, the final non-pecuniary factor labeled as **Marketability versus Ease** does not have the highest absolute loadings for any of the twenty items. However, the items with relatively high absolute loadings for this factor are “Crop Marketability,” “Simplicity,” and “Convenience.” The positive loading for “Crop Marketability” and negative loadings for “Simplicity” and “Convenience” are indicative of negative correlation between corn farmer responses to “Crop Marketability” and “Simplicity,” and “Crop Marketability” and “Convenience.” Thus, this factor suggests a weak, though still significant, underlying preference where some farmers are willing to give up simplicity and convenience for greater crop marketability.

Two of the four non-pecuniary factors identified from the soybean farmer responses are similar to non-pecuniary factors identified from the corn farmer responses (Table 8). For the soybean farmers’ factor labeled **Cost, Planting, Time & Ease**, eight of the items with relatively high absolute loadings are the same as the factor labeled the same for corn farmers. The difference is that for soybean farmers “Replant or Other Product Guarantees” separated out with a high loading in an alternative non-pecuniary factor labeled **Replant Guarantees**. The six items with relatively high absolute loadings for the soybean farmers’ **Health, Environment, & Marketability** factor are the same six items with relatively high absolute loadings for the factor with the same label for corn farmers. The third non-pecuniary factor identified for soybean farmers, labeled **Plant Performance & Yield Risk** had relatively high absolute loadings on the same items as the **Plant Performance** and **Yield Risk** factors identified for corn farmers, which suggests that corn farmers view plant performance and yield risk concerns as more separable when making insect pest management decisions, while soybean farmers view these items as more of a package. Alternatively, soybean farmers view planting guarantees as more separable from cost, planting, time and ease, while corn farmers tend to view these items as more of a package.

The first non-pecuniary factor for canola farmers labeled **Cost, Planting, Time & Ease** has relatively high absolute loadings for the same items as the factor identified for corn farmers with the same label (Table 9). Alternatively, the third non-pecuniary factor for canola farmers labeled **Plant Performance & Yield Risk** has relatively high absolute loadings for the same items as the factor identified for soybean farmers with the same label. The items with the relatively high loadings for the **Health, Environment, & Marketability** factor identified for canola farmers are the same items with relatively high loadings for the factors identified for corn and soybean farmers with the same label.

Taken together, these factor loadings reveal that there are commonalities between what non-pecuniary factors corn, soybean, and canola farmers' report are important for making insect pest management decisions — a general concern for family, worker, public, and environmental health. However, the results also identify important idiosyncrasies — concerns for plant performance, yield risk, and replant guarantees — in what corn, soybean, and canola farmers report are important for making insect pest management decisions, which makes sense given the differences in available control options and types of insect pests these options target.

Non-Pecuniary and Regional Difference in Pest Management Practices and Value

Table 10 reports the significance of our likelihood-ratio tests for regional, provincial, and country differences (hypotheses H1 – H3), while Table 11 reports the direction and significance of non-pecuniary effects (hypotheses H4). Overall, these results reveal few consistent effects, which likely reflect the complexities of controlling insect pests in different crops across a broad geographic landscape with a variety management options available.

Value Estimates

Tables 12 - 14 report the estimated mean and standard deviation along with the 95 percent confidence intervals for the $ per treated acre value to corn farmers from using Bt corn, insecticide seed treatments, soil insecticides, and foliar insecticides. They also report the estimated mean and standard deviation along with the 95 percent confidence intervals for the $ per treated acre value to soybean and canola farmers from using insecticide seed treatments and foliar insecticides. These estimates are reported for the various U.S. regions and Canadian provinces in addition to the U.S. and Canada. The estimates are based on equations (5) and (6) using interval regression results from equation (4a). The estimated value represents the additional value per acre managed with the practice as compared to what else the farmer could have done to manage insects (i.e., the area of triangle ***abc*** in Figure 2 (c)).

The estimated mean values of Bt corn for U.S. and Canadian corn farmer respondents are similar — $19.78 per acre with a confidence interval of $18.61 to $20.95 per acre and $20.05 per acre with a confidence interval of $17.54 to $22.55 per acre (Table 12). This result masks regional and provincial differences with estimated means ranging from $16.75 per acre in the Prairie Gateway region to $25.16 per acre in Quebec. The estimated standard deviation is also similar for U.S. and Canadian respondents — $10.85 per acre with a confidence interval of $10.15 to $11.55 per acre versus $11.46 per acre with a confidence interval of $9.94 to $12.99 per acre. Regional and provincial variation in these standard deviations, which range from $10.06 in the Prairie Gateway region to $11.98 in Quebec, is not as large as the regional variation in the mean values.

The difference between U.S. and Canadian corn farmer respondents in the estimated mean value of planting insecticide treated seed is also modest — $13.38 per acre with a confidence interval of $12.55 to $14.21 per acre and $12.02 per acre with a confidence interval of $10.41 to $13.64 per acre (Table 13). Regional and provincial variation ranged from $10.00 per acre in Quebec to $13.64 per acre in the Northern Great Plains. As with Bt corn, there is less variation in the estimated standard deviations: $6.91 per acre in the U.S. with a confidence interval of $6.40 to $7.43 per acre, $6.79 per acre in Canada with a confidence interval of $5.79 to $7.80 per acre, and regional variation ranging from $6.96 per acre in the Northern Great Plains to $6.21 per acre in Quebec.

The estimated mean value of using soil insecticides on corn for U.S. respondents is $12.92 per acre with a confidence interval of $11.43 to $14.42 per acre (Table 12). Regionally, this value varied from a high of $18.97 per acre in the Northern Great Plains to a low of $12.10 per acre in the Northern Crescent. The estimated standard deviation for the U.S. is $6.89 with a confidence interval of $5.98 to $7.81 and regional variation from $6.70 per acre in the Northern Crescent to $7.57 per acre in the Northern Great Plains.

The estimated mean value of using a foliar insecticide on corn is $14.17 per acre in the U.S. with a confidence interval of $11.87 to $16.48 per acre (Table 14). In Canada, the estimated mean was $14.75 per acre with a confidence interval of $9.39 to $20.11 per acre. The U.S. standard deviation is $6.88 per acre with the confidence interval $5.43 to $8.34 per acre, while the Canadian standard deviation is somewhat larger at $8.27 per acre with the confidence interval $4.87 to $11.68 per acre.

Compared to corn, there are more substantial differences between the U.S. and Canada soybean farmer respondents for the estimated mean value of planting insecticide treated seed —

$11.93 per acre with a confidence interval of $11.11 to $12.75 per acre and $14.53 per acre with a confidence interval of $12.54 to $16.53 per acre (Table 13). Regional and provincial variation ranged from $9.04 per acre in the Northern Crescent to $16.25 per acre in Manitoba. These more substantial differences are mirrored in the standard deviation estimates: $5.99 per acre in the U.S. with a confidence interval of $5.48 to $6.49 per acre, $7.82 per acre in Canada with a confidence interval of $6.55 to $9.10 per acre, and regional and provincial variation ranging from $5.29 in the Northern Crescent to $8.13 in Manitoba.

The estimated mean value to U.S. soybean respondents from using a foliar insecticide is $13.48 per acre with a confidence interval of $11.98 to $14.98 per acre (Table 14). In Canada, the estimate is lower at $10.06 per acre with a confidence interval of $7.00 to $13.13 per acre. Ontario respondents had the lowest estimated mean value ($9.03 per acre), while Mississippi Portal respondents had the highest ($15.93 per acre). The estimated standard deviation in the U.S. is $7.21 per acre with a confidence interval of $6.28 to $8.14 per acre. The estimated standard deviation in Canada is $5.50 per acre with a confidence interval of $3.59 to $7.41 per acre. Mississippi Portal respondents had the highest estimated standard deviation ($7.52 per acre), while Ontario respondents had the lowest ($5.23 per acre).

The estimated mean value of using insecticide treated canola seed for Canadian respondents is $12.85 per acre with a confidence interval of $12.13 to $13.58 per acre (Table 13). Provincial variation ranged from $12.39 per acre in Alberta to $13.74 per acre in Manitoba. The standard deviation is $6.84 per acre with a confidence interval of $6.39 to $7.29 per acre, and provincial variation ranging from $6.74 per acre in Alberta to $6.99 per acre in Manitoba.

Canadian canola respondents' estimated mean value from using a foliar insecticide is $13.88 per acre with a confidence interval of $12.27 to $15.50 per acre (Table 14). Respondents from Manitoba have the highest estimated mean value ($15.66 per acre), while those from Alberta have the lowest ($11.93 per acre). The estimated standard deviation is $7.83 per acre with a confidence interval of $6.82 to $8.85 per acre. This standard deviation ranged from $7.25 per acre in Alberta to $8.09 per acre in Manitoba.

The value estimates reported in Tables 12 – 14 are only for acres where a particular management practice was used. Therefore, they do not take into account the proportion of acres that did not use a particular management practice. To take this into account, we use the information on the proportion of acres managed with each practice in Tables 5 – 6 to measure the value of a practice as $ per planted acre for each crop acre rather than the value per treated acre managed with the practice. For example, a practice with a value of $20 per treated acre that is used on 60% of a farmer's planted acres has a value of $20 x 60% = $12 per planted acre. These values per planted acre are reported in Table 30 for the U.S. and Canada.

As expected, these estimated values decrease when expressed on a per planted acre basis, with the largest decreases for those practices used on the fewest acres (foliar insecticides in corn and soybean) and the smallest decreases for those practices used on the most planted acres (insecticide seed treatments on canola in Canada). For corn farmer respondents, the value of Bt corn in the U.S. and Canada are $13.09 and $15.18 per acre of corn (Table 15). The value of using insecticide seed treatments in the U.S. and Canada are $7.56 and $9.03 per acre of corn. The value of soil insecticides in the U.S. is $1.83 per acre of corn. The value of foliar insecticides in the U.S. and Canada are $0.85 and $0.74 per acre of corn. For soybean farmer respondents, the value of an insecticide seed treatment in the U.S. and Canada are $5.32 and $9.62 per acre of soybean, while the value of foliar insecticides in the U.S. and Canada are $2.18 and $0.74 per acre of soybean. For canola farmer respondents, the value of an insecticide seed treatment in Canada is $11.20 per acre of canola, while the value of foliar insecticides in Canada is $2.55 per acre of canola.

Multiplying these values expressed as $ per planted acre by the total planted acres of each crop gives a national level estimate of the total farmer value of that practice. Planted acres in the U.S. for 2013, the production year about which farmers were surveyed, were 95.4 million for corn, 76.8 million for soybean, and 1.3 million for canola (USDA-NASS 2014b). Planted acres in Canada for 2013 were 3.7 million for corn, 4.6 million for soybean and 19.9 million for canola (Statistics Canada 2014a). This planted acres information shows the small amount of corn and soybean acres planted in Canada relative to the U.S. and how much more important canola is in Canada relative to the U.S.

Table 16 reports the total farmer value in the U.S. and Canada for each practice based on these total crop planted acres and the $ per planted acre values in Table 15. As a reminder, these values are the additional value for that insect management practice relative to available alternatives, and all values are U.S. dollars, with Canadian values converted to U.S. dollars using an exchange rate of 0.92 U.S. dollars per Canadian dollar.

Bt corn generated almost $1.25 billion in value for U.S. farmers and $56 million in Canada, where far fewer corn acres were planted. The total farmer value for insecticide seed treatments was an estimated $1.13 billion in the U.S. for corn and soybean farmers, with almost two-thirds of this value ($721 million) for corn farmers. In Canada, total farmer values were smaller due to fewer total planted acres. Nevertheless, the total farmer value was $33 million for Canadian corn farmers, $44 million for Canadian soybean farmers and $223 million for Canadian canola farmers, so that all combined, the estimated total farmer value for insecticide seed treatments was more than $301 million in Canada. In the U.S., the total farmer value for soil insecticides was $175 million for corn, while for foliar insecticides the total farmer value for corn was $81 million and $168 million for soybean. In Canada, the total farmer value of foliar insecticides was $3 million each for corn and soybeans, and $56 million for canola.

These results indicate that for North American corn farmers Bt corn is the most valuable insect management practice, followed by insecticide seed treatments, soil insecticides (U.S. farmers only), and finally foliar insecticides. For North American soybean and canola farmers, insecticide seed treatments are substantially more valuable than foliar insecticides. Comparing across crops, insecticide seed treatments in the U.S. are more valuable to corn farmers than to soybean farmers. In Canada, insecticide seed treatments are much more valuable to canola farmers, than to soybean and corn farmers. Foliar insecticides are more valuable to soybean farmers than to corn farmers in the U.S., while they are much more valuable to canola farmers than to soybean and corn farmers in Canada.

Summary

The objectives of this research were to assess 1) the value of alternative insect pest management practices to farmers and 2) how these values relate to non-pecuniary factors. To accomplish these objectives, we conducted telephone surveys in 2014 of corn and soybean farmers in the U.S. and corn, soybean and canola farmers in Canada. Corn farmers were queried about their use in 2013 of Bt corn, insecticide seed treatments, soil insecticides, and foliar insecticides. Soybean and canola farmers were queried about their use in 2013 of insecticide seed treatments and foliar insecticides. All farmers were queried about their educational background, farming experience, insect pests of concern, source of insect pest management information, non-pecuniary factors influencing their pest management decisions, and the value they receive from alternative pest management practices. Factor analysis was used to better understand the non-pecuniary factors influencing farmer pest management decisions. Econometric methods were used to better understand regional difference in pest management practices and the value of these practices as well as how differences in these pest management practices and the value of these practices related to various non-pecuniary factors. The results of the econometric analysis were also used to estimate the value of the alternative pest management practices.

The major pests of concern noted by corn farmers were the corn rootworm (CRW) and European corn borer (ECB). Interestingly, while U.S. farmers tended to see the CRW as the most important threat, Canadian farmers saw the ECB as the most important threat. U.S. and Canadian farmers agreed that the aphid was the biggest threat in soybean. For Canadian canola farmers, the biggest threat was the flea beetle.

Bt corn was the primary management tactic U.S. and Canadian corn farmers reported using to control insect pests. This was followed by insecticide seed treatments. Both soil and foliar insecticide applications were relatively uncommon in corn, though Canadian corn farmers were more likely to use foliar insecticides, while U.S. corn farmers were more likely to use soil insecticides. About 50 percent more soybean farmers in Canada reported using insecticide seed treatments when compared to U.S. soybean farmers. Alternatively, U.S. soybean farmers were more likely to use foliar insecticides than Canadian soybean farmers. About nine out of ten Canadian canola farmers used insecticide seed treatments with only one in four using foliar insecticides.

There were similarities in the factors of importance to corn, soybean and canola farmers when making insect pest management decisions. For example, all farmers viewed human and environmental health risk like family, worker, public safety, water quality, wildlife, and beneficial insect protection similarly in terms of their importance for making pest management decisions. However, there were also interesting idiosyncrasies. For example, corn farmers viewed the importance of plant performance (e.g., plant health, crop stand, and yield protection) and yield risk (e.g., consistent and long lasting control) differently, while soybean and canola farmers tended to view these factors similarly.

A variety of significant country differences between the U.S. and Canada, regional differences in the U.S., and provincial differences in Canada were evident. Various non-pecuniary factors were found to be significantly related to the pest management practices farmers reported using, the proportion of the crop farmers reported managing with the practices, and the value of the practices reported by farmers. How these geographic and non-pecuniary factors were associated with the use and value of alternative practices varied by crop and practice.

The estimated value of Bt corn is about $20 per treated acre in both the U.S. and Canada. The estimated farmer value for insecticide seed treatments is $13.38 per treated acre for U.S. corn farmers and about $12 per treated acre for Canadian corn farmers. The estimated value of insecticide seed treatments for soybean differs substantially in the U.S. and Canada: more than $14.50 per treated acre in Canada, but not quite $12 per treated acre in the U.S. The estimated value of insecticide seed treatments is $12.85 per treated acre for Canadian canola farmers, while the estimated value of soil insecticides is almost $13 per treated acre for U.S. corn farmers. The estimated value of foliar insecticides is more than $14 per treated acre for both U.S. and Canadian corn farmers, while the value for Canadian canola farmers is just under $14 per treated acre. Just as for insecticide seed treatments, the estimated value of foliar insecticides for soybean differs substantially for the U.S and Canada: almost $13.50 per treated acre in the U.S., but about $10 per treated acre in Canada.

The estimated total value of Bt corn in 2013 was $1.25 billion in the U.S. and $56 million in Canada. The estimated total value of insecticide seed treatments in 2013 was $1.13 billion in the U.S. and $301 million in Canada. The estimated total value of soil insecticide treatments in 2013 was $175 million in the U.S. The estimated total value of foliar insecticide treatments in 2013 was $249 million in the U.S. and $57 million in Canada.

Acknowledgements:

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Figure 1: Illustration of the benefits of optimal pest management without non-pecuniary benefits.

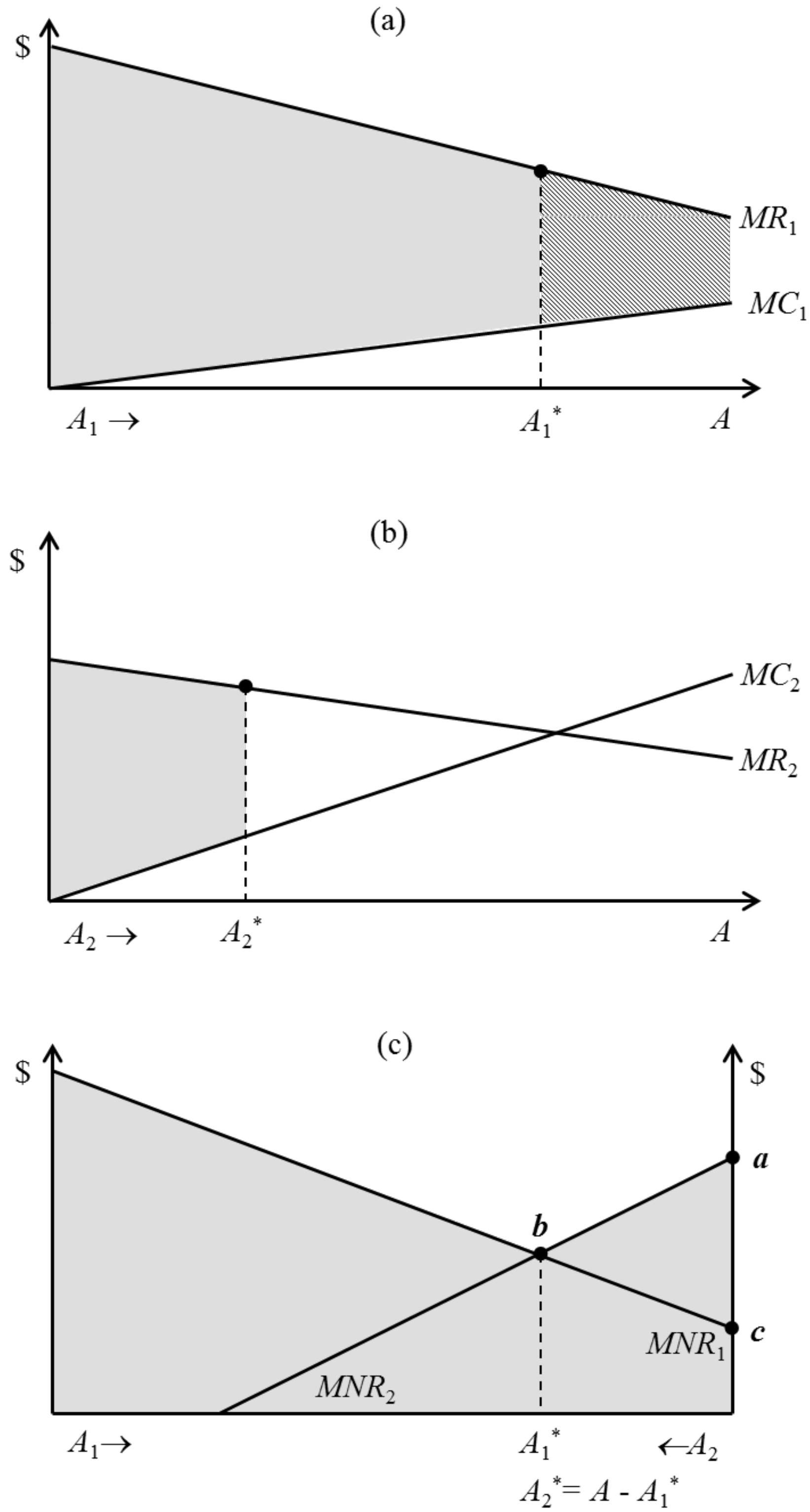

Figure 2: Illustration of the benefits of optimal pest management with non-pecuniary benefits.

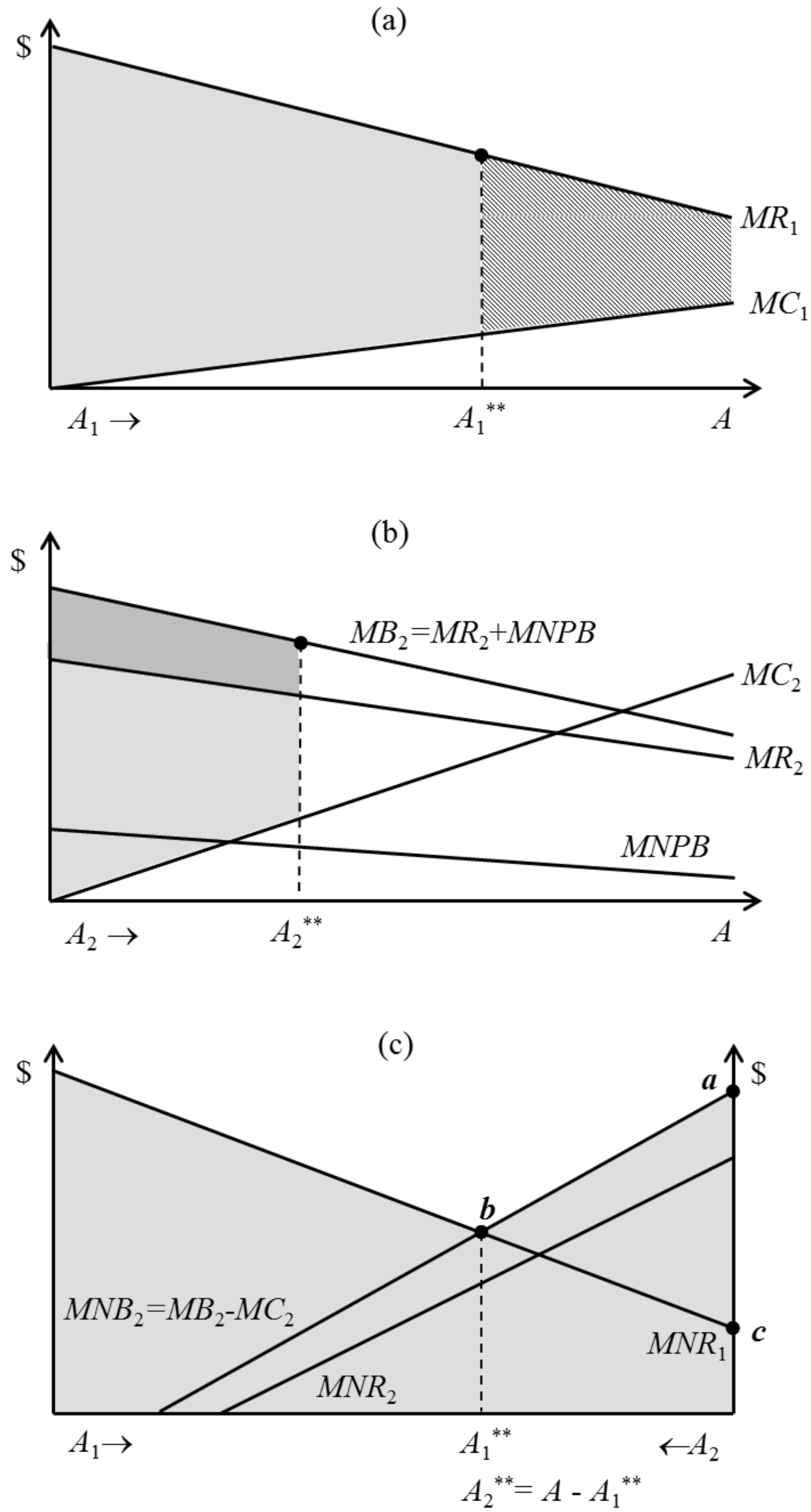

Table 1: Rankings for Factors Affecting Corn, Soybean, and Canola Farmers' Insect Pest Management Decisions

Factors	**Corn**	**Soybean**	**Canola**
		Percent of Farmers Reporting "Important" or "Very Important"	
Reducing Equipment Wear & Tear	63.3	67.3	63.4
Saving Time & Labor	76.0	76.6	75.4
Replant or Other Product Guarantees	64.3	62.0	63.2
Reducing Scouting	55.4	52.6	53.7
Convenience	71.1	69.5	70.7
Flexibility	70.5	70.7	73.8
Simplicity	74.0	70.2	73.9
Cost	83.5	86.1	85.2
Being Able to Plant Early	67.6	66.3	69.5
Family & Worker Safety	93.2	95.3	97.4
Public Safety	86.2	85.7	89.8
Protecting Water Quality	88.7	89.4	87.6
Protecting Wildlife	74.7	74.5	78.4
Protecting Beneficial Insects	79.4	77.1	85.1
Crop Marketability	81.8	83.4	93.0
Improving Plant Health	89.1	88.3	90.0
Improving Crop Stand	90.8	85.3	85.2
Protecting Yield	93.8	93.8	95.6
Having Consistent Insect Control	89.5	90.7	94.4
Having Long Lasting Insect Control	82.9	85.0	85.5

Table 2: Eigenvalues and Proportion of Variance Accounted for by Factors

	Corn Farmers		**Soybean Farmers**		**Canola Farmers**	
	Eigenvalue	**Proportion of Variance**	**Eigenvalue**	**Proportion of Variance**	**Eigenvalue**	**Proportion of Variance**
Factor 1	5.59***	0.81	5.36***	0.85	4.68***	0.77
Factor 2	0.98***	0.14	0.94***	0.15	1.29***	0.21
Factor 3	0.79***	0.11	0.64***	0.10	0.71***	0.12
Factor 4	0.35***	0.05	0.31***	0.05	0.24	0.04
Factor 5	0.29***	0.04	0.16	0.03	0.21	0.03
Factor 6	0.12	0.02	0.14	0.02	0.17	0.03
Factor 7	0.11	0.02	0.11	0.02	0.14	0.02
Factor 8	0.07	0.01	0.05	0.01	0.08	0.01
Factor 9	0.02	0.00	0.02	0.00	0.00	0.00
Factor 10	-0.01	0.00	-0.01	0.00	-0.02	0.00
Factor 11	-0.06	-0.01	-0.03	-0.01	-0.04	-0.01
Factor 12	-0.07	-0.01	-0.05	-0.01	-0.05	-0.01
Factor 13	-0.08	-0.01	-0.09	-0.01	-0.09	-0.02
Factor 14	-0.11	-0.02	-0.09	-0.01	-0.11	-0.02
Factor 15	-0.13	-0.02	-0.14	-0.02	-0.12	-0.02
Factor 16	-0.16	-0.02	-0.15	-0.02	-0.14	-0.02
Factor 17	-0.18	-0.03	-0.19	-0.03	-0.17	-0.03
Factor 18	-0.20	-0.03	-0.20	-0.03	-0.21	-0.03
Factor 19	-0.22	-0.03	-0.21	-0.03	-0.24	-0.04
Factor 20	-0.25	-0.04	-0.25	-0.04	-0.28	-0.05
Observations	577		556		457	

*** Significant at 1 percent based on the Parallel Analysis Paradigm (Ledesma and Valero-Mora 2007).

Table 3: Mean (Standard Deviation) of Operation and Farmer Characteristics in 2013 for Corn Farmer Respondents

	U.S.	**Canada**	**All**
Total Crop Acres	1,324	1,467	1,352
	(1,443)	(1,684)	(1,493)
Corn Acres	637	495	609
	(659)	(392)	(619)
Leased Acres	510	407	490
	(824)	(606)	(787)
Livestock Operations			
% of Farmers	45.3	49.6	46.1
No-Till Acres			
% of Farmers	44.6	24.8	40.7
% of Corn Acres	35.5	18.1	32.1
	(44.1)	(35.1)	(43.1)
Corn Following Corn Acres			
% of Farmers	52.1	60.3	53.7
% of Corn Acres	27.6	33.3	28.7
	(35.5)	(37.3)	(35.9)
Other Crops			
% Planting Hay/Alfalfa	18.9	11.6	17.5
% Planting Cotton	0.2		
% Planting Canola		24.0	
% Planting Soybean	77.8	82.6	78.8
% Planting Wheat	29.5	54.5	34.4
% Planting Other	9.4	30.6	13.5
Education (Years)[a]	13.7	13.6	13.7
	(1.9)	(2.2)	(2.0)
Years Farming	34.4	27.9	33.1
	(12.7)	(11.7)	(12.8)

[a] Did not complete high school = 10 years, high school = 12 years, some college = 14 years, vocational/technical training = 14 years, college graduate = 16 years, and advanced degree = 18 years.

Table 4: Mean (Standard Deviation) of Operation and Farmer Characteristics in 2013 for Soybean and Canola Farmer Respondents

	Soybean			Canola
	U.S.	**Canada**	**All**	**Canada**
Total Crop Acres	1,509	1,107	1,430	2,797
	(1,576)	(1,002)	(1,489)	(3,107)
Soybean Acres	676	347	611	
	(808)	(265)	(745)	
Canola Acres				974
				(1,069)
Leased Acres	667	312	597	792
	(1,109)	(445)	(1,022)	(1,131)
Livestock Operations (% with)	37.4	34.4	36.8	35.6
No-Till Acres				
% of Farmers	54.7	52.9	54.4	70.6
% of Soybean Acres	45.5	45.0	45.4	69.9
	(45.7)	(46.2)	(45.8)	(45.3)
Other Crops				
% Planting Hay/Alfalfa	11.4	11.5	11.4	2.8
% Planting Cotton	2.6			
% Planting Canola		46.7		
% Planting Corn	87.8	41.0	78.6	4.8
% Planting Soybean				8.6
% Planting Wheat	30.6	66.4	37.6	87.0
% Planting Barley				47.6
% Planting Pulses				29.0
% Planting Other	10.8	29.5	14.5	44.6
Education (Years)[a]	14.0	13.9	14.0	13.4
	(2.1)	(2.2)	(2.1)	(2.2)
Years Farming	33.2	30.7	32.7	31.7
	(14.2)	(11.8)	(13.8)	(12.2)

[a] Did not complete high school = 10 years, high school = 12 years, some college = 14 years, vocational/technical training = 14 years, college graduate = 16 years, and advanced degree = 18 years.

Table 5: Mean (Standard Deviation) of Insect Pest Management Practices Employed by Surveyed Corn Farmers

	U.S.	**Canada**	**All**
Bt Corn			
% of Farmers	82.2	90.1	83.7
Acres	435	375	423
	(502)	(372)	(479)
% of Corn Acres	66.2	75.7	68.1
	(39.4)	(33.2)	(38.4)
ECB & CRW Bt Corn (% of Farmers)[a]	64.6	76.3	66.9
ECB Only Bt Corn (% of Farmers)[a]	33.6	37.3	34.3
CRW Only Bt Corn (% of Farmers)[a]	13.4	11.9	13.1
Insecticidal Seed Treatment			
% of Farmers	64.1	79.1	66.9
Acres	358	413	368
	(525)	(432)	(509)
% of Corn Acres	56.5	75.1	60.0
	(46.8)	(41.0)	(46.3)
Soil Insecticidal Treatment			
% of Farmers	19.7	3.4	16.5
Acres	97	11	81
	(290)	(68)	(264)
% of Corn Acres	14.2	2.7	12.0
	(32.9)	(15.9)	(30.7)
Foliar Insecticidal Treatment			
% of Farmers	8.2	11.7	8.9
Acres	42	23	38
	(189)	(91)	(174)
% of Corn Acres	6.0	5.0	5.8
	(22.2)	(18.8)	(21.5)

[a] ECB = European corn borer and CRW = corn rootworm.

Table 6: Mean (Standard Deviation) of Insect Pest Management Practices Employed by Surveyed Soybean and Canola Farmers

	Soybean			Canola
	U.S.	**Canada**	**All**	**Canada**
Insecticidal Seed Treatment				
% of Farmers	51.4	73.9	55.8	88.0
Acres	322	216	301	836
	(738)	(230)	(671)	(972)
% of Acres	44.6	66.2	48.8	87.2
	(46.8)	(43.5)	(46.9)	(33.2)
Foliar Insecticidal Treatment				
% of Farmers	23.0	14.4	21.3	27.0
Acres	123	20	103	182
	(336)	(65)	(306)	(473)
% of Acres	16.2	7.4	14.5	18.4
	(34.1)	(23.9)	(32.6)	(34.5)

Table 7: Factor Loadings and Uniqueness for Corn Farmers with Five Factors Retained and Varimax Rotation

	Cost, Planting, Time & Ease[a]	**Health, Environment & Marketability**[b]	**Plant Performance**[c]	**Yield Risk**[d]	**Marketability versus Ease**[e]	**Uniqueness**
Reducing Equipment Wear & Tear	**0.63**	0.28	0.07	0.09	0.04	0.50
Saving Time & Labor	**0.56**	0.21	0.11	0.15	-0.09	0.60
Replant or Other Product Guarantees	**0.53**	0.09	0.20	0.17	0.15	0.61
Reducing Scouting	**0.52**	0.21	0.05	0.12	0.13	0.66
Convenience	**0.51**	0.14	0.28	0.18	-0.25	0.54
Flexibility	**0.48**	0.26	0.28	0.08	-0.02	0.62
Simplicity	**0.42**	0.22	0.24	0.14	-0.26	0.63
Cost	**0.38**	0.07	0.13	0.09	0.15	0.81
Being Able to Plant Early	**0.37**	0.19	0.16	0.32	0.12	0.68
Family & Worker Safety	0.11	**0.69**	0.06	0.16	-0.02	0.49
Public Safety	0.20	**0.68**	0.13	0.10	-0.02	0.47
Protecting Water Quality	0.16	**0.62**	0.15	0.15	0.04	0.55
Protecting Wildlife	0.23	**0.56**	0.18	-0.04	0.03	0.60
Protecting Beneficial Insects	0.14	**0.43**	0.27	0.06	-0.14	0.70
Crop Marketability	0.26	**0.38**	0.20	0.08	0.28	0.67
Improving Plant Health	0.20	0.22	**0.58**	0.13	-0.04	0.56
Improving Crop Stand	0.15	0.15	**0.56**	0.26	0.00	0.58
Protecting Yield	0.12	0.16	**0.50**	0.28	0.09	0.63
Having Consistent Insect Control	0.13	0.22	0.28	**0.54**	-0.01	0.57
Having Long Lasting Insect Control	0.28	0.16	0.27	**0.53**	-0.03	0.54

Note: The highest loading for an item across factors is bolded. [a] Corresponds to factor 1 for corn in Table 5. [b] Corresponds to factor 2 for corn in Table 5. [c] Corresponds to factor 3 for corn in Table 5. [d] Corresponds to factor 4 for corn in Table 5. [e] Corresponds to factor 5 for corn in Table 5.

Table 8: Factor Loadings and Uniqueness for Soybean Farmers with Four Factors Retained and Varimax Rotation

	Cost, Planting, Time & Ease[a]	**Health, Environment & Marketability**[b]	**Plant Performance & Yield Risk**[c]	**Replant Guarantees**[d]	**Uniqueness**
Reducing Equipment Wear & Tear	**0.59**	0.25	0.26	0.11	0.51
Saving Time & Labor	**0.56**	0.19	0.26	0.03	0.59
Replant or Other Product Guarantees	0.29	0.23	0.14	**0.41**	0.67
Reducing Scouting	**0.39**	0.21	0.04	0.28	0.73
Convenience	**0.60**	0.14	0.11	0.06	0.60
Flexibility	**0.49**	0.19	0.09	0.25	0.66
Simplicity	**0.59**	0.17	0.07	0.09	0.61
Cost	**0.30**	0.12	0.21	0.12	0.84
Being Able to Plant Early	**0.33**	0.11	0.25	0.32	0.72
Family & Worker Safety	0.17	**0.56**	0.21	0.04	0.61
Public Safety	0.18	**0.67**	0.17	0.04	0.49
Protecting Water Quality	0.17	**0.59**	0.17	0.09	0.59
Protecting Wildlife	0.21	**0.53**	0.09	0.15	0.64
Protecting Beneficial Insects	0.14	**0.48**	0.07	0.32	0.65
Crop Marketability	0.21	**0.44**	0.24	0.02	0.70
Improving Plant Health	0.19	0.32	**0.46**	0.15	0.63
Improving Crop Stand	0.24	0.20	**0.44**	0.29	0.63
Protecting Yield	0.00	0.34	**0.47**	0.06	0.66
Having Consistent Insect Control	0.18	0.14	**0.56**	0.02	0.63
Having Long Lasting Insect Control	0.33	0.20	**0.52**	0.02	0.59

Note: The highest loading for an item across factors is bolded. . [a] Corresponds to factor 1 for soybean in Table 5. [b] Corresponds to factor 2 for soybean in Table 5. [c] Corresponds to factor 3 for soybean in Table 5. [d] Corresponds to factor 4 for soybean in Table 5.

Table 9: Factor Loadings and Uniqueness for Canola Farmers with Four Factors Retained and Varimax Rotation

	Cost, Planting, Time & Ease[a]	**Health, Environment & Marketability**[b]	**Plant Performance & Yield Risk**[c]	**Uniqueness**
Reducing Equipment Wear & Tear	**0.64**	0.15	0.18	0.53
Saving Time & Labor	**0.58**	0.16	0.13	0.62
Replant or Other Product Guarantees	**0.40**	0.24	0.14	0.76
Reducing Scouting	**0.52**	0.11	0.20	0.68
Convenience	**0.62**	0.13	0.08	0.60
Flexibility	**0.51**	0.20	0.26	0.63
Simplicity	**0.56**	0.13	0.14	0.65
Cost	**0.43**	0.12	0.02	0.80
Being Able to Plant Early	**0.43**	0.10	0.17	0.78
Family & Worker Safety	0.01	**0.50**	0.32	0.65
Public Safety	0.09	**0.63**	0.19	0.56
Protecting Water Quality	0.22	**0.60**	-0.01	0.59
Protecting Wildlife	0.19	**0.59**	0.01	0.61
Protecting Beneficial Insects	0.14	**0.60**	0.01	0.62
Crop Marketability	0.10	**0.37**	0.22	0.80
Improving Plant Health	0.31	0.16	**0.40**	0.72
Improving Crop Stand	0.32	0.12	**0.44**	0.69
Protecting Yield	0.14	0.20	**0.48**	0.71
Having Consistent Insect Control	0.18	0.12	**0.49**	0.71
Having Long Lasting Insect Control	0.36	-0.01	**0.50**	0.61

Note: The highest loading for an item across factors is bolded. . [a] Corresponds to factor 1 for canola in Table 5. [b] Corresponds to factor 2 for canola in Table 5. [c] Corresponds to factor 3 for canola in Table 5.

Table 10: Significance of Regional and Provincial Differences Probability of Use, Percentage of Treated Acres, and Value Per Treated Acre

	Use[a]	**Acres[b] (%)**	**Value[b]**	**Use[a]**	**Acres[b] (%)**	**Value[b]**
Corn						
	Bt			Soil Insecticide[c]		
No U.S. Regional Differences	*	*	**	***		
No Canadian Provincial Differences		***	**			
No U.S. and Canada Differences	**	***	**			
	Insecticide Seed Treatment			Foliar Insecticide[d]		
No U.S. Regional Differences	*					
No Canadian Provincial Differences	***					
No U.S. and Canada Differences	***	*			***	
Soybean						
	Insecticide Seed Treatment			Foliar Insecticide		
No U.S. Regional Differences			***			
No Canadian Provincial Differences	**	**				
No U.S. and Canada Differences	***	*	***	***	*	
Canola						
	Insecticide Seed Treatment			Foliar Insecticide		
No Canadian Provincial Differences	***			**	*	

[a] Probit Estimates. [b] Interval Regression Estimates. [c] Only U.S. regional differences explored due to negligible soil insecticide use reported in Canada. [d] Only U.S. and Canadian differences tested due to limited foliar insecticide use in corn in both the U.S. and Canada. *** Significant at 1 percent, ** 5 percent, and * 10 percent.

Table 11: Non-Pecuniary Effects (Direction and Significance) for Probability of Use, Percentage of Treated Acres, and Value Per Treated Acre

	Use[a]	Acres[b] (%)	Value[b]	Use[a]	Acres[b] (%)	Value[b]
Corn						
	Bt			Soil Insecticide		
Cost, Planting, Time & Ease	-	+**	-**	-	+***	-
Health, Environment & Marketability	+	+	+	+	-	-
Plant Performance	-	+*	+*	-	+	-*
Yield Risk	+***	+	+	+**	-*	+
Marketability versus Ease	-	-**	+	+	+	+
	Insecticide Seed Treatment			Foliar Insecticide		
Cost, Planting, Time & Ease	-	+	-	-	-	+
Health, Environment & Marketability	+	-	+	+	+	+
Plant Performance	+	+	-	+	-	+
Yield Risk	+**	-	+**	+	+**	-
Marketability versus Ease	+*	+	+	+**	-	+
Soybean						
	Insecticide Seed Treatment			Foliar Insecticide		
Cost, Planting, Time & Ease	-	+**	-**	-**	-	-
Health, Environment & Marketability	+	-	-	+	-	-
Plant Performance & Yield Risk	-	+***	+	+*	+	+
Replant Guarantees	+	+	-	+	+	+
Canola						
	Insecticide Seed Treatment			Foliar Insecticide		
Cost, Planting, Time & Ease	-**	+	-	-	+	-
Health, Environment & Marketability	-	+	-	+	+	-
Plant Performance & Yield Risk	+*	+	-	+	+	+

[a] Probit Estimates. [b] Interval Regression Estimates. *** Significant at 1 percent, ** 5 percent, and * 10 percent.

Table 12: Estimated Mean and Standard Deviation of Value ($) Per Treated Acre for Bt Corn and Soil Insecticides on Corn

	Bt Corn	**Soil Insecticide**
	Mean	
U.S.	**19.78**	**12.92**
	[18.61, 20.95]	**[11.43, 14.42]**
Heartland	20.62	12.92
	[19.21, 22.04]	[11.29, 14.54]
Northern Crescent	20.13	12.10
	[17.08, 23.17]	[8.35, 15.85]
Northern Great Plains	17.80	18.97
	[15.13, 20.46]	[2.96, 34.98]
Prairie Gateway	16.75	13.22
	[14.06, 19.44]	[8.45, 17.98]
Canada	**20.05**	
	[17.54, 22.55]	
Manitoba	19.30	
	[15.07, 23.53]	
Ontario	17.76	
	[14.88, 20.64]	
Quebec	25.16	
	[19.97, 30.34]	
	Standard Deviation	
U.S.	**10.85**	**6.89**
	[10.15, 11.55]	**[5.98, 7.81]**
Heartland	10.96	6.87
	[10.24, 11.68]	[5.95, 7.79]
Northern Crescent	10.86	6.70
	[9.96, 11.76]	[5.54, 7.86]
Northern Great Plains	10.34	7.57
	[9.43, 11.25]	[6.12, 9.01]
Prairie Gateway	10.06	6.92
	[9.11, 11.02]	[5.69, 8.15]
Canada	**11.46**	
	[9.94, 12.99]	
Manitoba	10.94	
	[9.27, 12.61]	
Ontario	10.56	
	[9.05, 12.07]	
Quebec	11.98	
	[10.24, 13.72]	

Note: 95th percent confidence intervals are reported in brackets.

Table 13: Estimated Mean and Standard Deviation of Value ($) Per Treated Acre Managed With Insecticidal Seed Treatments for Corn, Soybean, and Canola

	Corn	Soybean	Canola
		Mean	
U.S.	**13.38**	**11.93**	
	[12.55, 14.21]	**[11.11, 12.75]**	
Heartland	13.41	12.73	
	[12.42, 14.40]	[11.72, 13.73]	
Northern Crescent	13.42	9.04	
	[11.20, 15.64]	[7.19, 10.89]	
Northern Great Plains	13.64	9.79	
	[11.30, 15.99]	[7.70, 11.88]	
Prairie Gateway	12.97	12.41	
	[10.89, 15.05]	[9.74, 15.08]	
Mississippi Portal		11.28	
		[8.44, 14.12]	
Canada	**12.02**	**14.53**	**12.85**
	[10.41, 13.64]	**[12.54, 16.53]**	**[12.13, 13.58]**
Alberta			12.39
			[11.15, 13.63]
Manitoba	10.92	16.25	13.74
	[8.30, 13.55]	[12.34, 20.17]	[12.23, 15.25]
Ontario	12.84	14.39	
	[10.88, 14.80]	[11.93, 16.84]	
Quebec	10.00	13.16	
	[6.61, 13.39]	[9.55, 16.77]	
Saskatchewan			12.74
			[11.82, 13.67]
		Standard Deviation	
U.S.	**6.91**	**5.99**	
	[6.40, 7.43]	**[5.48, 6.49]**	
Heartland	6.92	5.96	
	[6.39, 7.44]	[5.44, 6.48]	
Northern Crescent	6.92	5.29	
	[6.29, 7.54]	[4.66, 5.91]	
Northern Great Plains	6.96	5.46	
	[6.32, 7.59]	[4.83, 6.10]	
Prairie Gateway	6.84	5.92	
	[6.22, 7.46]	[5.31, 6.53]	
Mississippi Portal		5.75	
		[5.09, 6.42]	
Canada	**6.79**	**7.82**	**6.84**
	[5.79, 7.80]	**[6.55, 9.10]**	**[6.39, 7.29]**
Alberta			6.74
			[6.25, 7.23]
Manitoba	6.47	8.13	6.99
	[5.35, 7.59]	[6.69, 9.56]	[6.48, 7.50]
Ontario	6.91	7.80	
	[5.88, 7.95]	[6.49, 9.10]	
Quebec	6.21	7.53	
	[4.89, 7.53]	[6.09, 8.96]	
Saskatchewan			6.81
			[6.35, 7.27]

Note: 95^{th} percent confidence intervals are reported in brackets.

Table 14: Estimated Mean and Standard Deviation of the Value ($) Per Treated Acre Managed With Foliar Insecticides for Corn, Soybean, and Canola

	Corn	Soybean	Canola
		Mean	
U.S.	**14.17**	**13.48**	
	[11.87, 16.48]	**[11.98, 14.98]**	
Heartland		13.04	
		[11.32, 14.75]	
Northern Crescent		10.67	
		[6.27, 15.06]	
Northern Great Plains		14.01	
		[9.58, 18.44]	
Prairie Gateway		14.67	
		[9.10, 20.24]	
Mississippi Portal		15.93	
		[11.88, 19.99]	
Canada	**14.75**	**10.06**	**13.88**
	[9.39, 20.11]	**[7.00, 13.13]**	**[12.27, 15.50]**
Alberta			11.93
			[9.57, 14.30]
Manitoba		10.36	15.66
		[6.02, 14.69]	[12.78, 18.54]
Ontario		9.03	
		[4.76, 13.31]	
Quebec		11.98	
		[4.34, 19.62]	
Saskatchewan			13.92
			[11.80, 16.05]
		Standard Deviation	
U.S.	**6.88**	**7.21**	
	[5.43, 8.34]	**[6.28, 8.14]**	
Heartland		7.05	
		[6.13, 7.98]	
Northern Crescent		6.48	
		[5.01, 7.95]	
Northern Great Plains		7.23	
		[6.06, 8.41]	
Prairie Gateway		7.34	
		[6.08, 8.60]	
Mississippi Portal		7.52	
		[6.41, 8.62]	
Canada	**8.27**	**5.50**	**7.83**
	[4.87, 11.68]	**[3.59, 7.41]**	**[6.82, 8.85]**
Alberta			7.25
			[6.16, 8.34]
Manitoba		5.52	8.09
		[3.48, 7.57]	[6.97, 9.21]
Ontario		5.23	
		[3.25, 7.22]	
Quebec		5.79	
		[3.53, 8.04]	
Saskatchewan			7.75
			[6.70, 8.80]

Note: 95th percent confidence intervals are reported in brackets.

Table 15: Implied Value Per Crop Acre for Bt Corn, Insecticide Seed Treatments, Soil Insecticides, and Foliar Insecticides for U.S. and Canadian Corn, Soybean and Canola Survey Respondents

	U.S.		**Canada**		
	Corn	**Soybean**	**Corn**	**Soybean**	**Canola**
	$/Corn Acre	*$/Soybean Acre*	*$/Corn Acre*	*$/Soybean Acre*	*$/Canola Acre*
Bt Corn	13.09		15.18		
Insecticide Seed Treatments	7.56	5.32	9.03	9.62	11.20
Soil Insecticides	1.83				
Foliar Insecticides	0.85	2.18	0.74	0.74	2.55

Table 16: Estimated Total Farmer Value for Bt Corn, Insecticide Seed Treatments, Soil Insecticides, and Foliar Insecticides for U.S. and Canadian Corn, Soybean and Canola in 2013 (US$ Million)

Insect Management Practice	**U.S.**	**Canada**	**North America**
Bt Corn (Corn only)	$1,248	$56	$1,304
Insecticide Seed Treatment			
Corn	$721	$33	$754
Soybean	$409	$44	$453
Canola	---[a]	$223	$223
Soil Insecticide (Corn only)	$175	---[b]	$175
Foliar Insecticide			
Corn	$81	$3	$84
Soybean	$168	$3	$171
Canola	---[a]	$56	$56

[a] Canola farmers only surveyed in Canada.
[b] Too few survey respondents in Canada reported using soil insecticides to estimate a value.