An Economic Analysis of Control of the Western Corn Rootworm Variant across Indiana

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Abstract

A variant of the western corn rootworm (CRW) has adapted to the widely used cultural practice of crop rotation. This study analyzed the economic value of control options controlling the western CRW variant across Indiana. The options analyzed are soil insecticides, seed-applied insecticides, the recently commercialized genetically modified corn to resist CRW (CRW corn), or not controlling the western CRW variant. The results suggest that the economic value of CRW corn may exceed that of the alternative options for corn producers with high western CRW variant pressure, irrespective of producers' risk aversion levels and have the highest economic value for risk-averse producers in the moderate western CRW variant pressure region of Indiana.

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Corn rootworm (CRW) beetles and their larvae which feed on the corn roots are the most destructive pest to the corn crop in the United States and accounts for the majority of insecticide applications in corn. The western CRW (*Diabrotica virgifera virgifera* Le Conte) is the most common variety in Indiana, and initially rotating corn with soybeans was sufficient to kill most CRW larvae. However, a behavioral variant of the western CRW has adapted by laying its eggs in soybean fields, and crop rotation is no longer an effective control option for CRW in first-year corn, particularly in northwestern Indiana. As a result Indiana producers now routinely apply soil insecticides to control CRW. The CRW insect is often called the 'billion-dollar bug', as it eats away a billion dollars of U.S. farm profits through yield loss or control costs (Burchett, 2001). In 2003, Monsanto introduced a genetically-modified (GM) corn that is resistant to CRW (CRW corn); it produces the Bt toxin in the corn roots which kills the CRW larvae. With the introduction of CRW corn, producers now have four options for controlling CRW.

The objective of this article is to present a framework for valuing CRW control options under Indiana conditions. One advantage of studying CRW management decisions in Indiana is that there are three distinct regions with different levels of western CRW variant pressure, from a very high risk region where producers routinely control CRW to a very low risk region where producers often choose not to control CRW. The producer will choose the control option which maximizes his expected utility. A stochastic simulation model, using @Risk, is used to determine the most profitable control option, taking into account the producer's location which affects the expected

CRW pressure and potential corn yield, the producer’s level of risk aversion, and the costs of each control option.

The availability of the recently commercialized CRW corn will potentially transform the way CRW is managed. Since one reason for the dominant corn-soybean rotation in the Corn Belt is to manage CRW, the ability to better control CRW may shift more acreage towards a continuous corn rotation from a corn-soybean rotation. In addition, if CRW corn proves to be the most successful method of controlling CRW, then the corn acreage in genetically modified (GM) varieties could increase dramatically from the current level of 37 percent of corn acres in the U.S. with subsequent implications for U.S. exports to the European Union and consumer markets.

Background on the Corn Rootworm and Control Options

Corn rootworms (*Diabrotica* spp.) may be the most economically damaging corn pest in the United States and is certainly the most damaging pest in Indiana. Most of the damage from CRW is caused by larval feeding (Wright, Meinke and Jarvi, 1999). CRW larvae hatch may begin mid-May in Indiana and the timing depends on soil temperature and moisture. Initially, CRW larvae feed on fine root hairs and burrow into the root tips. As they grow larger, the larvae feed on and tunnel into primary roots. This feeding damage makes the roots susceptible to further deterioration by root rot pathogens. Ultimately, the root damage interferes with plant growth leading to yield losses and can cause lodging which makes harvest more difficult.

Adults emerge late June to the end of July in Indiana. Adult CRW feed on pollen, corn silks, leaf tissue and exposed kernels, although this feeding causes minimal yield losses. For the western CRW, mature beetle feeding, mating and egg laying occur in corn fields, while the western CRW variant may also lay eggs in soybean or alfalfa fields. Eggs are dormant through the winter until embryogenesis resumes with warming soil temperatures in spring (Bledsoe, 2005). Thus, the severity of the corn rootworm pressure in a given crop year is determined by the number of eggs laid during the previous crop year. If a farmer chooses to scout for CRW, he would trap adult beetles which would indicate the expected CRW larvae feeding pressure the following crop year. In the case of the western CRW variant, these adult beetle traps would be placed in soybeans fields that would be rotated into corn the following year.

While both the CRW adults and larvae can be controlled, this analysis focuses on options to control larvae because those are the most commonly used by farmers. The effectiveness of CRW control options depends on the CRW larval population, time of larval hatch, planting date of the corn crop and weather. One of the reasons it is so difficult to predict CRW pressure is that the larvae are very susceptible to weather; for example, when there are heavy rains, CRW larvae may drown (Obermeyer and Bledsoe, 2004).

Farmers can partially manage CRW by varying crop rotations and planting date. In the case of the western CRW, a corn-soybean crop rotation is sufficient to control CRW because larvae die when they hatch in a soybean field. However, the western CRW variant has adapted to the corn-soybean rotation by laying its eggs in soybean fields that hatch in the corn rotation the following year. Planting at a later date lowers the risk from CRW larval damage because the newly hatched larvae cannot locate the smaller root masses. However, later planting is very costly since corn planted at a later date will face a yield penalty relative to earlier planted corn (Hyde et al., 1999).

If farmers choose to control CRW, the two conventional control options are soil-applied insecticides in either granular or liquid form and seed-applied insecticides where the seed has been coated with an insecticide. However, soil-applied insecticides are frequently less than 100 percent effective; insecticide effectiveness is hindered by inadequate or excessive rainfall, premature degradation, or cold temperatures (Harbor, 2002). The effectiveness of seed-applied insecticides or seed treatments is a hotly debated subject. While seed-applied insecticides have performed poorly in some Midwestern university trials, other trials have been more positive (Ruen, 2004). Generally, seed-applied insecticides are not suitable for heavy CRW pressure but are reasonably effective at controlling grubs, maggots or other secondary pests that feed on newly planted seeds in early May (Ruen, 2004).

Farmers now have a third control option of GM CRW corn that protects the corn roots by producing the Bt toxin. Before the CRW technology was commercialized, the industry expected that its efficacy would be near 100 percent, due to increased protection of the entire root system and increased consistency of control, because the presence of the Bt toxin does not depend on weather. However, in 2003, the efficacy of CRW corn was much less than 100 percent (Wenzel, 2004). Bledsoe (personal communication) estimates that CRW corn was only 80 percent effective against CRW infestations, offering a level of protection comparable to that of conventional insecticide control options.

Farmers have four management options for controlling CRW larvae: soil-applied insecticides that are applied during planting, seed-applied insecticides, CRW corn and no control. The decision to control CRW larvae is an *ex ante* decision. All of these control options are implemented during planting and there are no post-planting control options for CRW larvae. Farmers must decide which CRW control option to use, if any, before planting and therefore before they know how severe the CRW larvae pressure will be.

Methods and Data

The representative corn producer's CRW management decision is analyzed using a spreadsheet-based stochastic model, where the yield potential and CRW larval yield damage are stochastic variables. We assume that the corn producer will choose the CRW control option that maximizes his expected utility. Following Hyde et al. and Mitchell et al., we use the negative exponential (NE) utility function to approximate risk preferences.[1] The Arrow-Pratt measure of absolute risk aversion (ARA) was chosen using the methodology developed by Babcock et al. (1993). For this analysis, and to be consistent with Mitchell et al., a moderately risk-averse producer has a risk premium of 20 percent while a highly risk-averse producer has a risk premium of 40 percent. The expected utility of the net returns is then converted into a certainty equivalent (CE) for use in calculating the value of each of the CRW control options.

The producer's CRW control choice is based on the expected western CRW variant pressure, the relative expected returns based on production costs and market prices, and the producer's level of risk aversion. The expected western CRW variant pressure differs greatly across Indiana. Obermeyer and Bledsoe (2004) use 2004 western CRW variant beetle counts taken when female CRW beetles were actively laying eggs in soybean fields, reported larval damage and historical CRW data to define the following regions: the northwest region has very high to high risk of CRW pressure, the northeast and central region moderate risk of CRW pressure, and the southern region has low risk of CRW pressure (Figure 1). In terms of 2004 CRW beetle counts, the high risk region had beetle counts in soybean fields between 100 and 1000, the medium risk region had counts mostly between 20 and 100, and the low risk region had counts mostly between 0 and 20 (Obermeyer and Bledsoe, 2004). The producer's CRW control options are analyzed separately for three CRW risk regions where the very high and high regions are combined into on high risk region.

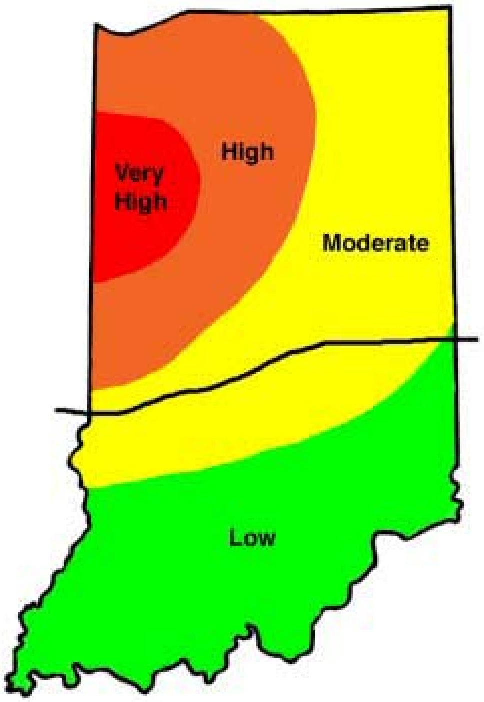

Figure 1: Western CRW variant risk regions across Indiana
Source: Obermeyer and Bledsoe, (2004)

This analysis assumes the producer is planting first-year corn because over 80 percent of the respondents to the CRW Management Survey grow corn in a 50:50 rotation with soybeans. A corn-soybean crop rotation has many agronomic benefits and minimizes the likelihood of CRW infestations compared to second-year corn (Harbor, 2002). However in areas most affected by the western CRW variant, first-year corn often suffers from CRW larvae damage.

Each CRW control option has a different yield distribution depending on how well the option controls CRW larvae for each of the western CRW variant risk regions. The yield function is:

(1) $$Y^*(1-\lambda)$$

where Y is the potential yield in bushels per acre per year; and λ is the percent damage or percent yield loss due to CRW larval feeding.

Potential yield is the maximum bushels per acre the corn producer could harvest were it not for yield penalties due to weather, and pest damage including CRW infestations. Potential yields vary by risk region with the soil type and topography in the high risk region being conducive to higher yields relative to the moderate and low risk regions (Kravchenko and Bullock, 2000). The distribution of potential corn yield for each western CRW variant risk region is simulated using a beta distribution, with the mean yield equal to the five-year average of the IASS county averages for each region. The yield average and standard deviations of each region may be underestimated compared to an individual farm as IASS county averages have been used (table 1). We assume that CRW corn does not suffer from a yield drag, so all the CRW control options are assumed to have identical potential yields (Wenzel, 2004).[2]

Table 1: Beta Distribution for Corn Yields based on 2000-2004 IASS County Data

Yields (Bu/Acre)	High Risk Region	Moderate Risk Region	Low Risk Region
Mean	154	148	138
Standard Deviation	31	30	28
Min	0	0	0
Max.	216	207	193

The major challenge in this research is to model yield losses due to CRW damage. To date, there is no consensus on the single, best yield-loss model for CRW damage

(Bledsoe, personal communication). Mitchell et al. (2004) have developed one of the best pest-damage functions for CRW, using the Hills and Peters root rating scale to compare yield losses in untreated corn and corn treated with soil-applied insecticides. One of their assumptions is that more root damage, as measured by a higher root rating, means a greater yield loss. However, their pest-damage function cannot be extended to CRW corn because this assumption does not hold. In Purdue University yield trials with a side-by-side comparison of CRW corn and corn treated with soil-applied insecticides, the CRW corn always had a lower root rating than the corn treated with insecticides, even when the insecticide-treated corn had substantially larger yields.

The yield losses due to CRW damage were determined using 3 different methods (table 2). First, the proportional yield loss distribution for untreated corn was estimated from previous studies of yield losses due to CRW damage (Howell, 2004; Mitchell et al., 2004; Mitchell, 2000; and Gray and Steffey, 1998), in conjunction with expert opinion from entomologists at Purdue University.

The proportional yield loss distributions for corn treated with soil-applied insecticides or seed-applied insecticides were estimated based on survey data. Mail surveys were sent to 4,000 Indiana producers who grow at least 200 acres of corn. The random sample was restricted to farms of 200 acres of corn or more in order to focus on the farms that produce the majority of the corn in Indiana. Farms of 250 acres of corn or more account for 26 percent of Indiana corn farms, and produced 77 percent of the 2002 Indiana corn crop (USDA, 2004). The survey was mailed in early March 2004. A follow-up phone survey of non-respondents was conducted. Once mail survey respondents who did not grow row crops in 2003 were eliminated, there were 794 usable surveys, for a mail response rate of 20 percent. There were 128 phone survey respondents, and of these surveys 127 were usable. The total response rate for the mail and phone survey combined was 24 percent. In Indiana, there are approximately 7,000 producers who grow at least 200 acres of corn (IASS, 2004). This survey sampled over half of these producers, and the 921 respondents represent 13 percent of this population.

The yield losses due to CRW damage when either soil insecticides or seed-applied insecticides were used were determined from the survey responses.[3] In the survey, producers were asked what the expected yield loss would be as a result of CRW damage where they had applied insecticide for CRW control and how often they expected this yield loss to occur. These responses were used to calculate a perceived yield loss function, λY, where λY is the bushel per acre per year yield loss, estimated separately for each of the three CRW risk regions. Using the expected yields for each region, the perceived yield loss was then transformed into proportional yield losses or percent damage from CRW infestations, λ.

For CRW corn, the proportional yield loss distributions were estimated relative to the producers' beliefs about the effectiveness of soil insecticides. In 2003, the yield trial data showed that CRW corn performed similarly to soil insecticides but we also assumed that yield losses would be less variable, and this is called the low efficacy case. In 2004, CRW corn performed better in yield trials than soil insecticides with about 2 percent higher yields on average. Thus, for the high efficacy case, we assumed that proportional yield loss distribution would have a mean yield loss about 2 percent lower than the mean of the proportional yield loss distribution for soil insecticides.

Table 2: Mean Proportional Yield Loss of Control Options in Rotated Corn

Proportional Yield Loss	High Risk Region	Moderate Risk Region	Low Risk Region

Soil Insecticides	0.04	0.03	0.02
Seed Treatments	0.05	0.04	0.03
CRW Corn-Low Efficacy	0.04	0.04	0.02
CRW Corn-High Efficacy	0.02	0.02	0.01
Untreated Corn	0.12	0.08	0.03

Finally, the net return function is the revenue associated with the control option, price times realized yield, minus the costs associated with the option. The producer's net return function is:

(2) $$W_{ij}= P(Y_j(1-\lambda_{ij}))-C_i-Z$$

i= 1, 2, 3, or 4 corresponding to the CRW control option

j= 1, 2, or 3 corresponding to the risk region of western CRW variant activity

P= Price of corn

Y= Potential yield

λ = Proportional yield loss attributable to CRW damage

C = Costs that differ between the control options

Z = Costs that are the same across the control options such as herbicides, for purposes of simplifying the analysis.

Each CRW control option has different per-acre costs (table 3). Hauling, drying and handling costs are based on actual corn yield received by producers, while fertilizer costs are based on expected corn yield. The price of corn was assumed to be $2.20 which is a 2000-2004, five-year price average from IASS (2005).

Table 3: Assumed Per-acre Cost Parameters

Corn with Soil Insecticides		Corn Rootworm Resistant Corn	
Seed	$37.82	Seed[1]	$50.76
Insecticides	$18.96	Insecticides[2]	$3.79
Labor	-	Labor[3]	$0.30
Fertilizer[4]	$65.50	Fertilizer- Low Efficacy	$65.30
		Fertilizer- High Efficacy	$69.04

Drying and handling	$17.03	Drying and handling-Low Drying and handling-High	$17.00 $17.32
Hauling[5]	$8.82	Hauling- Low Efficacy Hauling- High Efficacy	$8.81 $8.97
Total	$148.13	Total- Low Efficacy Total- High Efficacy	$145.96 $150.18
Corn with Seed-Applied Insecticides		Untreated Corn	
Seed[6]	$56.19	Seed	$37.82
Insecticides	-	Insecticides	-
Labor	-	Labor	-
Fertilizer	$64.90	Fertilizer	$62.40
Drying and handling	$16.87	Drying and handling	$16.24
Hauling	$8.74	Hauling	$8.41
Total	$146.69	Total	$124.83

1. CRW resistant seed cost is high as technology fee and seed-applied insecticides to control secondary pests are included in price of CRW corn seed.
2. Insecticide for CRW corn is the 20 percent soil insecticide applied on the refuge corn.
3. Extra labor cost associated with planting refuge obtained from Hyde et al., (2000).
4. Fertilizer cost is based on expected yield in bushel/acre by control option, and risk region.
5. Hauling and drying fuel and handling costs are based on actual yield in bushel/acre by control option.
6. Conventional corn with seed-applied insecticides is high as it controls for CRW as well as secondary insects.

Results

In @Risk, a Monte Carlo analysis was conducted using 1,000 iterations to evaluate expected net returns and certainty equivalents for each CRW control option in each of the three CRW risk regions in Indiana (see Tables 4-6).

Table 4: High Risk Region Control Options: Expected Net Returns and Certainty Equivalents

Control Option	Expected Net Returns (Risk Neutral)	Certainty Equivalents 20% Risk Premium	Certainty Equivalents 40% Risk Premium
Soil Insecticides	$114.77	$101.93	$85.28
Seed Treatments	$113.49	$100.69	$84.10
CRW Corn-Low Efficacy CRW Corn-High Efficacy	$117.16 $122.50	$108.21 $113.42	$96.83 $101.44
Untreated Corn	$115.04	$101.85	$82.95

Table 5: Moderate Risk Region Control Options: Expected Net Returns and Certainty Equivalents

Control Option	Expected Net	Certainty	Certainty

	Returns (Risk Neutral)	Equivalents 20% Risk Premium	Equivalents 40% Risk Premium
Soil Insecticides	$110.20	$97.96	$81.72
Seed Treatments	$109.39	$94.81	$81.25
CRW Corn-Low Efficacy	$110.26	$102.81	$92.54
CRW Corn-High Efficacy	$113.82	$105.44	$94.52
Untreated Corn	$118.52	$104.07	$85.33

Table 6: Low Risk Region Control Options: Expected Net Returns and Certainty Equivalents

Control Option	Expected Net Returns (Risk Neutral)	Certainty Equivalents 20% Risk Premium	Certainty Equivalents 40% Risk Premium
Soil Insecticides	$100.91	$90.11	$75.74
Seed Treatments	$98.59	$87.86	$73.88
CRW Corn-Low Efficacy	$102.80	$95.98	$86.27
CRW Corn-High Efficacy	$104.16	$96.86	$87.69
Untreated Corn	$118.21	$107.42	$92.96

In the high risk region, the risk-neutral and moderately risk-averse producer would choose CRW corn, as it has the highest expected net returns, and CE value respectively, followed by untreated corn, soil insecticides, and seed treatments (table 4). For the highly risk-averse producer with a 40 percent risk premium, CRW corn is the most preferred option; however these producers would choose seed treatments and soil insecticides over untreated corn. Because of the very variable net returns for untreated conventional corn in the high risk region, the highly risk-averse producer is willing to pay the higher costs of seed-treated conventional corn and soil insecticides to insure against the risk of yield damage from CRW and secondary pests.

In the moderate risk region, the greatest payoff for the risk-neutral producer comes from growing untreated corn because the expected yield loss due to CRW damage is relatively low (table 5). However, since CRW damage can be severe in the moderate risk region, risk-averse producers are willing to pay for control technologies that reduce the variance of their net returns. A moderately risk-averse producer would choose high efficacy CRW corn, followed by untreated corn, and then low efficacy CRW corn. Similarly, a highly risk-averse producer would choose CRW corn, followed by untreated corn. The value of CRW corn increases as producers become more risk averse. High efficacy CRW corn is more valuable than low efficacy CRW corn because it offers a larger reduction in the variability of net returns. Regardless of the producer's risk preferences, soil insecticides and seed treatments were the last choice because while these control options reduce the expected CRW damage, they do not provide a large enough reduction in variability and thus have a low insurance value.

In the low risk region, growing untreated corn was the most preferred CRW control option, irrespective of the producer's preference for risk (table 6). After untreated corn, producers would choose CRW corn, followed by soil insecticides and seed treatments.

Sensitivity to CRW Risk Region

The probability of a CRW larvae infestation and the severity of the infestation varies greatly by CRW risk region (figure 1). While the expected returns for the CRW control options are very sensitive to the probability of an infestation and the expected severity of the infestation, the expected returns are not directly comparable across the risk regions because of the substantial difference in potential corn yields between regions. Clearly, CRW control options will be more valuable in the high risk region relative to the moderate and low risk regions based only on the expected yield loss due to CRW damage. In addition, the CRW control options are also more valuable in the high risk region because the mean yield is higher: 154 bushels per acre compared to 148 bushels per acre for the moderate region and 138 bushels per acre for the low risk region.

Overall, the risk neutral producer would only choose to control CRW in the high risk region given the high potential yields, the high probability of an infestation and the expected severity of an infestation. In the moderate and low risk regions, untreated corn has the highest expected net returns. In the high risk region, the producer would choose CRW corn over untreated corn. Untreated corn only has a 27 cent per acre advantage over soil insecticides, so this risk neutral producer is almost indifferent between soil insecticides and untreated corn.

Sensitivity to Risk-Aversion Level

For all the results, it is clear that the certainty equivalent of net returns is very sensitive to the producer's risk preferences. As expected, the difference in certainty equivalent net returns for CRW corn and untreated corn increases for producers who are more risk averse. For example, in the high risk region, high efficacy CRW corn offers $7.46 per acre more than untreated corn for the risk neutral producer and $18.49 per acre more for the highly risk averse producer. The risk averse producer gains insurance value from the added protection against CRW and thus places a higher value on CRW corn than the risk neutral producer.

For the producer located in the moderate risk region, the best CRW control option depends on the producer's risk preferences. The risk neutral producer will choose to plant untreated corn. The highly risk averse producer will choose CRW corn, valuing it at between $7.21 per acre to $9.19 per acre more than untreated corn depending on its efficacy. The moderately risk averse producer will only choose high efficacy CRW corn, valuing it at $1.37 per acre more than untreated corn. The producer in the moderate risk region will need to decide if he is sufficiently risk averse to justify planting CRW corn.

Compared with Hyde et al. (1999), who estimated the value of Bt corn resistant to European corn borer (ECB corn), the insurance value from CRW corn is much larger than the insurance value from ECB corn. For example, Hyde et al. (1999) found that the highly risk averse producer was willing to pay $1.08 per acre more than the risk neutral producer when the probability of infestation was 40 percent. In contrast, in the high risk region, the highly risk averse producer was willing to pay $11.03 per acre more than the risk neutral producer. There are three explanations for why the insurance value for CRW corn is so much larger than for ECB corn. First, the probability of a CRW infestation in the high risk region is much higher than 40 percent so the protection will be needed more often for CRW than ECB. Second, the potential yield losses from a CRW infestation are much larger than from an ECB infestation. Third, the variance in yield loss due to CRW damage is much larger than the variance in yield loss due to ECB damage, which increases the insurance value of improved CRW control. Mitchell et al. (2004) demonstrate that the large variance in yield loss due to CRW damage is partially due to measurement error in conventional models of CRW yield loss. Instead, they propose a composed-error model which reduces the standard deviation of proportional yield loss by more than 40 percent. With the composed error model, the cost of controlling CRW with soil insecticides is $2.11 per acre more for the highly risk averse producer compared with the risk neutral producer when the expected yield is 140. With the conventional model, this cost is $10.59 per acre more for the highly risk averse producer compared with the risk neutral producer. The Mitchell et al. (2004) findings suggest that the insurance values implied by this simulation model are too large due to measurement error in the estimates of yield loss due to CRW damage. However, as previously mentioned, the composed error model cannot be used to estimate yield losses for CRW corn.

Comparison to Survey Results

The results of the simulation model are consistent with the behavior of Indiana producers in 2003, as measured by the CRW Management survey (table 7). Respondents in the high risk region were the most likely to control CRW (88%), with respondents moderate risk region less likely to control CRW (66%) and respondents in the low risk region being the least likely to control CRW (55%). In all three regions, producers reported using soil-applied and seed-applied insecticides to control for other pests besides CRW such as wireworm (49%), white grubs (49%), cutworm (47%), and seed corn maggots (42%). Conversations with producers in the moderate risk region suggest that these secondary pests drive their use of soil-applied and seed-applied insecticides, which may account for their high rate of use in the moderate and low CRW risk regions. CRW corn was available for the first time in 2003, and producers in the high risk region were the most likely to adopt it (12%), consistent with the simulation results that CRW corn is the optimal control method for that region. Fewer producers adopted CRW corn in the moderate risk region (9%) and very few in the low risk region (3%).

Table 7: Frequency of Methods to Manage CRW in 2003[a]

Insecticide Use	High Risk Region	Moderate Risk Region	Low Risk Region
Used insecticides	88%	66%	56%
Used soil insecticides	86%	60%	55%
Used seed treatments	8%	12%	19%
Planted CRW corn	12%	9%	3%
No control (Untreated)	12%	32%	45%

[a] Frequencies do not add to 100 percent because producers can use multiple control options on continuous or rotation corn.

Research Limitations and Concluding Remarks

This article used a simulation model to value the four CRW control options available to Indiana producers given the three distinct CRW risk regions. Under these assumptions, CRW corn was the best control option in the high risk region for all producers regardless of their risk preferences and in the moderate risk region for risk averse producers. In the low risk region, untreated corn was the best option. In Indiana, the high and moderate risk regions account for approximately 75 percent of the corn production, suggesting that the majority of producers in Indiana will consider planting CRW corn.

The value of this research is limited by the accuracy of our assumptions about yield loss due to CRW damage. The proportional yield loss distributions for soil-applied and seed-applied insecticides were estimated based on results from the CRW Management Survey. Analysis of the survey showed a non-response bias for the expected yield loss due to CRW between the mail survey respondents and non-respondents who were called in a follow-up phone survey. Consequently, the perceived CRW yield losses may be overstated which would lead to these control options being overvalued.

Clearly, future research is needed to develop an accurate model of yield loss due to CRW damage that does not depend on root ratings so that it can also be applied to CRW corn. An accurate yield loss model would allow producers to make better decisions about CRW control options and researchers to better understand the potential impact of CRW corn. The rapid spread of ethanol plants in Indiana will greatly increase the demand for corn in the next two years. In order to meet this demand, producers will need to shift acreage into a continuous corn rotation from the current corn-soybean rotation. This shift in rotations may be greatly facilitated by CRW corn which allows producers to reduce yield losses due to CRW.

At the same time, some food-grade corn processors in Indiana are also increasing their processing capacity and they only purchase non-GM corn. These processors offer premiums for non-GM corn on the order of $0.10 to $0.25 per bushel. Assuming an average yield of 150 bushels per acre, these premiums translate to additional revenue of $15 to $37.50 per acre. Even in the high risk region, the additional revenue from CRW corn was less than $15 per acre relative to conventional corn with soil insecticide, except for high efficacy CRW corn and the highly risk averse producer who would be willing to give up $16.16 per acre to grow CRW corn. For producers in the high risk region who have the opportunity to deliver non-GM corn for a premium, the CRW management decision depends on the potential premium for food-grade corn versus the potential revenue from planting CRW corn instead of conventional corn with soil insecticides.

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[1] The NE utility function is commonly used to represent utility, because it is easy to compute (Raiffa, 1970) and consistent with economic theory because the appropriate arguments of utility are wealth, losses and gains, or (transient) income (Hyde, 2000; Hardaker and Lien, 2003).

[2] A yield drag is a decrease in yield due to the introduction of the Bt gene when the conventional and transgenic corn varieties are identical (Coaldrake, 1999).

[3] The survey specifically asked about the following soil-applied insecticides: Aztec, Fortress, Force, Lorsban, Regent. The seed-applied insecticides or seed treatments included Poncho 1250 and Cruiser. The CRW corn was YieldGard.