AgBioForum, 6(1&2): 79-86. ©2003 AgBioForum.

Factors Affecting the Likelihood of Corn Rootworm Bt Seed Adoption

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The likelihood of adopting corn rootworm (CRW) Bt seed technology was analyzed using an ordered logit model. Data used to estimate the model came from United States Department of Agriculture's 2001 Agricultural Resource Management Survey. Statistically significant variables include operator age, farm type, farm size, rootworm loss and current treatment for rootworm, off farm labor, and Bt technology for corn borer. The likelihood of adoption did not appear to be related to crop rotation, tillage system, new variant CRW region, or education.

Key words: corn rootworm, Bt corn, seed technology, Agricultural Resource Management Survey (ARMS), ordered logit model.

Introduction

Bioengineered (BE) seed with an insect-resistant trait has been one of the most rapidly adopted agricultural technologies used by United States corn producers. Between 1996 (when BE corn seed for European corn borer control became available) and 2002, adoption grew to 24% of US planted corn acreage (United States Department of Agriculture National Agricultural Statistics Service [USDA NASS], 2002). In some states, use of BE corn seed exceeded 40% in 2002. A new BE corn seed variety became commercially available in 2003. This seed carries a gene from the soil bacterium *Bacillus thuringiensis* (Bt) selected for resistance against corn rootworm (CRW), which is believed to be an even more destructive corn insect pest than European corn borer. Entomologists estimate that this pest causes at least $1 billion in corn yield losses and insecticide expenditures annually in the United States (Comis, 1997). The widespread adoption of CRW Bt seed could have substantial impacts on farm income, costs of production, productivity, insecticide use, and the environment. Many of the insecticides currently used for CRW control are organophosphate based and pose serious human health and environmental risks. Adoption of Bt seed technology would reduce these risks. However, despite these benefits, BE seeds (including CRW Bt) remain controversial. Issues include consumer choice and environmental impact. Therefore, the extent of likely CRW Bt adoption and the farm-level factors affecting CRW Bt adoption are important research and public policy topics.

Objectives

The objectives of this paper are: (a) to present the results of a 2001 farm-level probability-based survey, in which corn producers in the major US corn-growing states were asked about their likelihood of adopting CRW Bt seed when it became available, and (b) to present the results of a ordered logit analysis that identifies the operator and farm socioeconomic characteristics and insect management practices that influence the likelihood of CRW Bt seed adoption.

Background

Corn is one of the most important crops grown in the United States. In 2001, corn was planted on 75.8 million acres with a harvested value of over $19.2 billion (USDA NASS, 2003). This represents over 21% of the total value of crop production in the United States for 2001.

Corn rootworm is probably the most economically important pest of corn in the United States. Historically, farmers managed CRW by rotating crops or with insecticides. The most common rotation scheme is corn-soybeans. Crop rotation has the effect of breaking the CRW life cycle—CRWs that hatch in a field not planted to corn will starve to death. Almost 67% of all corn acres are in a traditional corn-soybean rotation, whereas 14% are in continuous corn and the remaining acres are in other rotation systems (USDA Economic Research Service [USDA ERS], 2003). However, different species of CRW have apparently evolved to reduce the effectiveness of crop rotation as a pest control practice. For example, the northern CRW began laying eggs that take two years to hatch. Beginning in the middle of the 1990s, farmers in east-central Illinois and northern Indiana began noticing a reduction in the effectiveness of crop rotation in controlling western CRW. Adult western CRW beetles were leaving the cornfields to lay eggs in soybean fields. When the eggs hatched the following year, they were in a cornfield. These new variants of

CRW have spread though most of northern Indiana and east Illinois and into southern Michigan and western Ohio. Given historic movement patterns, the new variants may soon spread as far west as eastern Iowa (Onstad et al., 1999).

In cases where crop rotation is not widespread, farmers often use soil insecticides to control CRW. According to 2001 USDA data, about 18% of all corn acres in 2001 were treated for CRW with insecticides. Producers growing continuous corn had a much higher incidence of soil insecticide use, with about 38% of these acres treated with insecticides for CRW (more than double the share for corn-soybean or other rotations). With the loss of crop rotation effectiveness, corn farmers must either increase their use of soil insecticides or turn to other CRW control methods. One option, which became commercially available in early 2003, is the use of seed containing a gene from *Bacillus thuringiensis* (Bt), a soil bacterium that produces a naturally occurring biotoxin that provides resistance to CRW.

CRW Bt as an Alternative

Bt is an insecticidal protein that provides protection from specific insects. This protection is generally greater than the most optimally applied conventional insecticide. Bt proteins have a long history of safe use as microbial pesticides (United States Environmental Protection Agency [US EPA], 2001). Moreover, a complete reassessment of all existing Bt corn and cotton plant-incorporated protectants" (including Bt proteins such as Cry1Ab, Cry1F, Cry1Ac, and Cry3A) completed by the US Environmental Protection Agency (EPA) confirmed the EPA's original findings that "there are no unreasonable adverse health effects from these products" and that there are no unreasonable adverse effects in corn on nontarget wildlife or beneficial invertebrates (US EPA, 2001). After a comprehensive evaluation and a determination that its use was "in the public interest," the EPA approved the use of a new Bt protein (the Cry3Bb protein) for use in corn in February 2003. This protein specifically targets the midgut lining of larval rootworms. In trials, Bt seed yield outperformed both untreated fields and fields treated with conventional soil insecticides (Burchett, 2001).

Use of Bt seed technology has several potential benefits to the farmer, including convenience and reductions in insecticides and labor. The main effect of using Bt seed technology is increased coverage—each individual plant is protected. This results in reduced insecticide use where insecticides are used to control for CRW (which reduces cost and risk to the farmer or farm worker who applies the insecticide), lower labor costs, and increased yields (relative to non-Bt fields that are infested with CRW), in fields with significant CRW infestation. A major drawback to Bt seed technology is the current lack of acceptance of BE products in the European Union (EU) and consequently other countries that trade heavily in agricultural products with the EU. Lack of acceptance of Bt corn in the international marketplace could force some additional costs onto the farmer by increasing management efforts to segregate BE from non-BE crops. In general, crops not acceptable for trade are fed to local livestock. Other potential costs include increased seed cost to the farmer and increased management time needed to learn about the technology.

With crop rotation losing its effectiveness as a CRW control, the primary alternative to Bt technology is traditional insecticide use. More than nine million pounds of insecticide were applied to the 2001 US corn crop. Soil insecticides are generally broad spectrum (i.e., they target more than one pest) and are effective, but they also have the potential for negative effects on the environment and often pose risks to human and animal health. In contrast, CRW Bt seed is pest specific and effective, and, according to the EPA, does not pose an unacceptable health or environmental risk (US EPA, 2003). In addition, *stacked* varieties (such as Pioneer YieldGard + LibertyLink—a seed genetically modified for both herbicide and insect resistance) make Bt seed effectiveness broader. There are currently no stacked corn varieties approved by the FDA and EPA that target multiple insects, although research continues.

Adoption of Bt technology to combat corn borer may have been limited due to the unpredictability of outbreaks—farmers gambling that there would not be an infestation may have chosen to plant non-Bt corn. Even so, by 2002, adoption grew to 24% of planted corn acreage. This unpredictability problem does not exist in relation to corn rootworm—farmers can predict the need to treat for CRW based on current year populations (Gray & Steffey, 2002). Given this difference, the adoption of Bt technology to deal with CRW may be more rapid than that to control corn borers.

Technology Adoption

Technological change, which is intertwined with the adoption of innovations, underlies the growth in agricultural productivity (Sunding & Zilberman, 2001). Much of the previous literature on technology adoption has focused on mechanical (e.g., tractors), chemical (e.g., pesticides), and agronomic (e.g., integrated pest management) innovations. More recent research has been devoted to informational (e.g., precision farming) and biological (e.g., BE) innovations (Feder, Just, & Zilberman, 1985; Daberkow & McBride, 2003; Fernandez-Cornejo, Beach, & Huang, 1994; Fernandez-Cornejo & McBride, 2002). Many of these adoption studies assess the factors that affect if and when a specific farm or operator will begin to use an innovation. The most common factors analyzed have been expected profitability, risk, required skill level or education, scale or size of farm, alternative or competing technologies, enterprise specialization, information sources, credit availability, tenure, and environmental policies (Sunding & Zilberman, 2001). More recent studies have examined the hypothesis that off-farm labor within a farm household may also influence the decision to adopt a new technology (Fernandez-Cornejo & Hendricks, 2003).

Modeling Adoption Choices

The adoption of a new technology is usually modeled as a choice between two alternatives: the traditional technology and the new one. Growers are assumed to make their decisions by choosing the alternative that maximizes their perceived utility (Fernandez-Cornejo et al., 1994). Thus, a grower i is likely to adopt new technology if the utility of adopting, U_{i1}, is larger than the utility of not adopting, U_{i0}, that is, if $U_i^* = U_{i1} - U_{i0} > 0$. However, only the binary random variable I_i (taking the value of one if the technology is adopted and zero otherwise) is observed, as utility is unobservable:

$$I_i = \begin{cases} 1 \text{ if } U_{i1} = \text{Max}\,(U_{i1}, U_{i0}) \\ 0 \text{ otherwise} \end{cases} \quad (1)$$

Moreover, because utilities are not known to the analyst with certainty, they are treated as random variables. In the context of adoption of a bioengineered crop and dropping the subscript i for simplicity: $U_j = V_j + \varepsilon_j$, where V is the systematic component of U related to the profitability of adopting (j = 1) and the profitability of not adopting (j = 0), and the random disturbance (ε) accounts for errors in perception and measurement, unobserved attributes and preferences, and instrumental variables.

The probability of adopting is $P_1 = P(I = 1) = P(U^* > 0) = P(U_1 > U_0) = P(V_1 - V_0 > \varepsilon_0 - \varepsilon_1) = P(\varepsilon_0 - \varepsilon_1 < V_1 - V_0)$. Assuming that the stochastic components ε_0 and ε_1 are independently and identically distributed with a Weibull distribution, their difference follows a logistic distribution (Maddala, 1992).

Assuming a linear utility function and that choice probabilities depend only on observed individual-specific characteristics (Judge, Griffiths, Hill, Lutkepohl, & Lee, 1985), the relative odds of adopting are $P_1/P_0 = \exp(\alpha + \delta'\boldsymbol{Z})$, where the odds ratio ($P_1/P_0$) denotes the ratio of the probability of adopting the bioengineered crop to the probability of not adopting, conditional on the vector $\boldsymbol{Z}$ of explanatory variables; α is the intercept parameter and δ_a is the vector of slope parameters. Taking the log of each side, the logit equation is:[1]

$$\log\,(P_1/P_0) = \alpha + \delta'\boldsymbol{Z}. \quad (2)$$

Unlike actual adoption (which is usually represented by a binary choice model), expected adoption may be represented as an ordinal response model, where the response (I) of a farmer is restricted to one of a small number of ordinal values. For example, in the particular case of adoption of Bt corn for control of CRW, we have specified five ordinal choices: j = 1, 2, 3, 4, and 5 (see survey question in the next section). Considering the cumulative probabilities of the response categories, the cumulative logit model may be represented with a slight modification of Equation 2, setting a parallel-lines regression model in which, instead of one intercept (α), we will have four intercepts (α_1, α_2, α_3, and α_4) together with the common vector of slope parameters.

Survey Data and Estimation

The data used to estimate the ordered logit are from the USDA's Agricultural Resource Management Survey (ARMS; USDA ERS, 2003). The ARMS is the USDA's primary vehicle for collecting data on a broad range of issues about agricultural resource use, costs of production, and farm financial conditions. The ARMS is a flexible data collection tool with several phases, versions, and uses. The ARMS is designed to meet four goals: (a) gather information about the relationships among agri-

1. *For continuous variables, the change in the probability of adoption relative to the change of the kth individual attribute is*

$$\frac{\partial P_1}{\partial Z_K} = f(Z) = \frac{e^{-\delta Z}}{(1 + e^{-\delta Z})^2} \bullet \delta_K.$$

In the discrete case, the change in probability attributable to the kth variable or attribute is equal to the difference in probability $P_1(Z_k = 1) - P_1(Z_k = 0)$ (Putler & Zilberman, 1988).

cultural production, resources, and the environment; (b) estimate costs associated with the production of various crop and livestock commodities; (c) estimate net farm income; and (d) estimate the characteristics and financial situations of farm/ranch operators and their households, including information on management strategies and off-farm income. The ARMS is a series of related farm surveys that provide primary data for these functions. The Phase I survey is a mail/telephone screening instrument designed to improve survey efficiency. Phase II is a series of commodities surveys conducted to obtain mostly physical data on production inputs, practices, and costs for specific crops. Phase III is designed to represent all US farms and mostly focuses on farm operation characteristics, farm expenditures, and receipts. Farms in the Phase II surveys are automatically selected for a follow-up questionnaire in Phase III (the commodity cost of production surveys); the information from both surveys can be linked and used to represent the population of all producers of a specific commodity or all US farms.

The data used in this study are from farms that planted corn during 2001. The states included in the survey accounted for 93.4% of the US corn acreage planted in 2001. The ARMS is a multiframe probability-based survey in which sample farms are randomly selected from groups of farms stratified by attributes such as economic size, type of production, and land use. Within a stratum, the weight (expansion factor) is the inverse of the probability of its selection. After selecting those farms in the sample that planted corn in 2001 and eliminating those observations with missing data, there were 1,587 observations available for analysis.

This analysis is unique in that we examine the expected, as opposed to actual, adoption of an innovation. Because CRW Bt was not available for commercial use in 2001, producer's expectations about their likelihood of adoption were based primarily on their exposure to precommercialization information and familiarity with similar technology. In the case of CRW Bt, popular magazines and public notices of regulatory applications for commercialization were the most likely sources of early information about CRW Bt. Bt corn seed to control European corn borer is a similar technology to CRW Bt and had been commercially available for seven years prior to the 2001 survey. Corn producers' expected adoption of CRW Bt seed was obtained in the 2001 ARMS by asking the following question: If a CRW Bt seed becomes available, how likely would you be to plant it on this field (very likely, somewhat likely, uncertain, somewhat unlikely, or very unlikely)? Producers would not have a critical piece of economic data—the price of CRW Bt seed—available when responding to this question, but they likely made the assumption that the additional cost of the CRW Bt seed would be similar to the cost of a soil insecticide application or the additional cost of European corn borer Bt seed over regular seed.

The choice of factors hypothesized to influence producer's likelihood of CRW Bt adoption was based primarily on earlier research on innovation adoption (Table 1). Human capital variables (age and education) were included as were two farm characteristics (farm size in acres and specialization in corn production). A competing pest control option (crop rotation) was also included as a dummy variable (i.e., equal to one if the farm does not rotate, implying that it plants corn continuously). Previous studies have identified perceived risk and lack of information about an innovation as a barrier to adoption. Hence, we included a variable to control for the operator's use of a similar technology (e.g., Bt corn to control for European corn borer). Because CRW levels may be influenced by tillage system, according to some entomologists, we included a control variable for tillage system (Bessin, 2001). As an indication of the benefit from adopting CRW Bt seed, we included several variables: the expected degree of pest infestation measured as the anticipated CRW losses (reported in bushels) without treatment for CRW; whether an insecticide is currently used to control for CRW; and two location variables. The first location dummy variable, *NEW-VARIANT*, was equal to one if the farm was located in counties where the new variant of CRW is able to survive crop rotation.[2] The second location variable, *EAST*, controls for the fact that farmers in areas where a higher proportion of the corn is sold for the export market are

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2. *Counties in Illinois include Champaign, Christian, Coles, De Kalb, De Witt, Douglas, Edgar, Ford, Grundy, Iroquois, Kane, Kankakee, Kendall, La Salle, Lee, Livingston, Logan, McLean, Marshall, Mason, Moultrie, Ogle, Peoria, Piatt, Putnam, Sangamon, Shelby, Tazewell, Vermilion, Warren, Will, and Woodford; counties in Indiana include Adams, Allen, Benton, Blackford, Boone, Carroll, Cass, Clinton, De Kalb, Delaware, Elkhart, Fountain, Fulton, Grant, Hamilton, Hancock, Hendricks, Henry, Howard, Huntington, Jasper, Jay, Johnson, Kosciusko, Lagrange, Lake, La Porte, Madison, Marion, Marshall, Miami, Monroe, Montgomery, Newton, Noble, Parke, Porter, Pulaski, Putnam, Randolph, Rush, St. Joseph, Shelby, Starke, Steuben, Tippecanoe, Tipton, Vermillion, Wabash, Warren, Wayne, Wells, White, and Whitley; counties in Michigan include Berrien, Calhoun, Cass, Huron, Kalamazoo, St. Joseph, and Van Buren.*

less likely to adopt technologies that may cause concerns in those markets.[3] The export market is more important to major corn producers in the eastern Corn Belt (Illinois, Indiana, and Ohio) than to producers in the rest of the country. All three eastern Corn Belt states are in the top 10 corn-producing state, and exports account for slightly more than 31% of corn production in these three states compared to 21.3% in the other seven (Fruin, Halbach, & Hill, 1985). Finally, we included a variable for household (spouse and operator) off-farm employment to account for the level of management time available to learn about new production technologies.

Because of the complexity of the survey design, a weighted technique was used to estimate the parameters of the ordered logit model using a maximum likelihood method and full-sample weights developed by the National Agricultural Statistics Service (NASS) of the USDA. A delete-a-group jackknife method was used to calculate the variances and standard errors because of the complex survey design. The method follows the logic of the standard jackknife method except that a group of observations is deleted in each replication (Dubman, 2000). It consists of partitioning the sample data into *r* groups of observations ($r = 15$ in this survey) and resampling, thus forming 15 replicates and deleting one group of observations in each replicate (Rust, 1985; Kott, 1998; Kott & Stukel, 1997). A set of sampling weights was calculated by NASS for each replicate.

Results

The results from this process relate to farms and not to corn acres. No attempt was made in the survey to determine whether a farmer would plant both Bt and non-Bt seed (exclusive of the required refuge area). Thus, we were unable to estimate the acreage that would be planted to CRW Bt. Tables 1-5 present the results from the statistical analysis of the survey data. Table 1 provides the mean values of the variables used in the ordered logit analysis. For a binary indicator variable, the mean represents the percentage of growers of each group with that attribute. For example, the *NOTILL* variable indicates that 17.5% of the farmers used no-till. In comparison, the continuous variables represent the actual means. For example, *OP_AGE* represents the mean operator age (52 years). Table 2 presents the means of the categorical dependent variable, *EXPTADOP*. Overall, about 15% of the corn producers in the sample were very likely to adopt CRW Bt, nearly 20% were likely to adopt, 25% were uncertain, nearly 12% were somewhat unlikely to adopt, and about 28% were very unlikely to adopt.

Table 1. Variable definitions and means.

Variable	Definition	Mean
OP_AGE	Age of the operator (years)	52.001
AGE_SQ	Square of the age of the operator	2856.2
HIGHPLUS	Education dummy (1 if operator has at least high school)	0.8891
CORNFARM	Corn specialization dummy (1 if corn represents more than 50% of production)	0.3705
SIZE	Size of the farm (thousands of acres in corn)	0.2039
SIZESQ	Size of the farm squared	0.1378
ROOTWORM	Insecticide dummy (1 if insecticide is used for CRW)	0.1241
CRWLOSS	Expected CRW losses (bushels)	5.5015
NEWVARIANT	New variant CRW dummy (1 if farm is located in counties where new variant of CRW is able to survive crop rotation)	0.0912
OFF_HOURS	Off-farm work, operator and spouse (hours per year)	1454.6
CONTIN	Continuous corn dummy (1 if operation is on continuous corn)	0.1367
BTDUM	ECB dummy (1 if operation is using Bt corn for European corn borer)	0.1767
NOTILL	No-till dummy (1 if operation is using no-till)	0.1745
EAST	Eastern Corn Belt dummy (1 if farm is located in eastern Corn Belt, where a larger share of the corn is exported and used for food)	0.2591

Table 2. Expected adoption of Bt corn to control CRW (*EXPTADOP*).

Value of the dependent variable	Frequency	Percent of producers
Very likely	240	15.12
Likely	313	19.72
Uncertain	397	25.02
Somewhat unlikely	188	11.85
Very unlikely	449	28.28
Total	1587	100.00

3. Note that this study does not directly address the relationship between market destination and BE crop adoption (see Saak & Hennessy, 2002; Fernandez-Cornejo, Alexander, & Goodhue, 2003).

Table 3. Testing global null hypothesis: BETA=0.

Test	Chi-square	DF	Pr > ChiSq
Likelihood ratio	56694	14	<.0001
Score	51218	14	<.0001
Wald	53174	14	<.0001

Table 4. Model fit statistics.

Criterion	Intercept only	Intercept and covariates
Akaike	943475	886809
Schwartz	943496	886905
-2 Log L	943467	886773

Table 5. Association of predicted probabilities and observed responses.

Percent concordant[a]	64.7
Percent discordant[a]	34.5
Percent tied	0.8
Pairs	984223

[a] A pair of observations is defined as concordant (discordant) if the larger response to has a higher (lower) predicted probability than the smaller response. Tied if neither concordant nor discordant.

Tables 3, 4, and 5 present the ordered logit regression results for the expected adoption of Bt corn to control the CRW. The overall goodness of fit is very good, and the classification accuracy is about average compared with other adoption studies. For example, using the transformed log likelihood function, which is a distributed chi-squared function, the null hypothesis that all regressors in the model are zero is strongly rejected at the 1% level (p-value about 0.0001). Similarly, the Score and Wald statistics (Table 3) show that the combined regressors are very significant (with a p-value of 0.001). Results are also good for the Akaike (information) and Schwartz criteria (Table 4), which adjust the log likelihood function for the number of observations and the number of regressors in the model. Finally, the percent of concordant responses, used to determine the predictive ability of the model, is 65%, which is within the range of other studies (Table 5). About 70% of the coefficients are statistically significant at the 1% level using the delete-a-group jackknife method (Table 6).

As with previous adoption studies, several operator and farm variables were related to the likelihood of CRW Bt adoption. Both linear and quadratic coefficients were significant for operator's age (i.e., the linear term positive and quadratic term negative), implying that expected adoption increases with age only up to a point. This maximum was reached at slightly over 49 years of age. Similarly, both the linear and quadratic coefficients were significant for farm size, implying that expected adoption increases with size only up to the point at which expected adoption reaches a maximum, and then declines as size increases further. This maximum was reached at a size of about 2,900 acres, which is less than half of the size of the largest farm in the sample. In addition, operators who specialized in corn production were more likely to adopt CRW Bt, which may be an indication of their self-interest in keeping abreast of emerging production technologies peculiar to their primary commodity.

Table 6. Maximum likelihood parameter estimates of drop-ordered logit model, using the jackknife variance estimator (dependent variable: *EXPTADOP*).

Variable	Parameter estimates	Standard error	t statistics
Intercept_1	-4.78351***	1.07580	-4.44646
Intercept_2	-3.51523***	1.08207	-3.24861
Intercept_3	-2.35819**	1.07627	-2.19108
Intercept_4	-1.77170	1.09953	-1.61132
OP_AGE	0.09302**	0.03836	2.42475
AGE_SQ	-0.00094***	0.00033	-2.83255
HIGHPLUS	0.08192	0.21165	0.38705
CORNFARM	0.50443***	0.17732	2.84480
SIZE	0.77356**	0.30536	2.53331
SIZESQ	-0.13358*	0.07127	-1.87425
ROOTWORM	0.62950***	0.13750	4.57808
CRWLOSS	0.01397**	0.00600	2.32738
NEWVARIANT	0.27528	0.28935	0.95136
OFF_HOURS	-0.00015***	0.00006	-2.71405
CONTIN	0.08727	0.19298	0.45224
BTDUM	1.23644***	0.12855	9.61839
NOTILL	0.04725	0.16475	0.28679
EAST	-0.55644***	0.14497	-3.83823

*Note. ***, **, and * indicate statistically significant coefficients at the 1%, 5%, and 10% significance levels, respectively.*

The perception of likely benefits and costs from the adoption of CRW Bt was reflected in the statistically significant signs on the CRW infestation and farm location variables. As expected, those farmers that were currently using insecticides to control the CRW as well as those that expected to incur a large yield loss in their fields were very significantly inclined to adopt CRW Bt. On the other hand, expected adoption was less likely in the eastern Corn Belt, where a larger portion of the crop is destined for the export market. Although producers apparently recognized that there might be substantial pest control benefits of the use of CRW Bt, they may perceive some risks associated with marketing their crop, especially for producers in the eastern Corn Belt. Understandably, farmers who are familiar with a particular technology are inclined to adopt a related innovation. Farmers who had already adopted Bt corn to control the European corn borer were more likely to adopt Bt corn to control the CRW.

Expected adoption was negatively related to off-farm work by the operator and spouse. A possible explanation of this result, which is counter to a previous study (Fernandez-Cornejo & Hendricks, 2003) of actual adoption of herbicide tolerant soybeans, is that farmers and/or their spouses who work off the farm may have been less informed about the new technology and thus were less inclined to adopt CRW Bt at this point. Furthermore, information on CRW Bt prior to the 2001 survey may not have been easily accessible to producers with off-farm commitments.

Finally, the other variables in the analyses did not influence the likelihood of adopting CRW Bt. Expected adoption was not significantly related to the use of no-till practices, the use of continuous corn, or location of the farm on the new variant region. Surprisingly, unlike many other studies, our study showed that expected adoption was not significantly dependent on education. However, this technology may not require new skills or training, because the new technology or trait is embodied in a familiar input (i.e., hybrid seed).

Summary and Conclusions

CRW is probably the most economically important corn insect pest. Farmers' options to manage CRW include crop rotation, insecticide use, and (as of 2003) Bt seed technology. Adaptation of the CRW to crop rotation has reduced farmers' control options. Farm and operator characteristics such as age, education level, farm size and type, current technology use, current CRW infestation, geographic location, off-farm labor, and current CRW management practices provide insights into the technology adoption process. The ARMS provides the data needed for this analysis.

Thirty five percent of farmers reported that they were either likely or very likely to adopt Bt seed technology for CRW. Likelihood of adoption was positively related to both age and farm size—up to a point. Farmers who currently manage for CRW with insecticides or estimate a large loss without treatment were also more likely to adopt this technology. This is almost certainly because these farmers either had, or anticipated, a CRW infestation problem. Farmers who managed European corn borer with Bt seed technology were also more likely to use this technology. Specialized corn farmers (farms that derived more than 50% of value of production from corn) were also more likely to adopt Bt seed technology when it became available.

Farms that were located in the eastern Corn Belt were less likely to adopt this new technology, possibly due to the high percentage of their production bound for the export market. Off-farm labor had a negative effect. A limitation of this study is that it focuses on expected adoption, which introduces greater uncertainty than actual adoption. The uncertainty is greater because at the time of the survey (2001), when farmers were asked about the likelihood of CRW Bt adoption, respondents had incomplete information about this technology—particularly regarding the costs of the CRW seed.

Differences between expected and actual adoption behavior merit further study. However, given that this technology was only approved for commercial use in 2003 (and availability was limited for that year), an analysis of actual adoption will need to await the next ARMS corn survey (scheduled for 2004).

Authors' Note

The views expressed are those of the authors and do not necessarily represent the views or policies of the Economic Research Service or the United States Department of Agriculture.

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