Adoption of Transgenic Crops by Smallholder Farmers in Entre Rios, Argentina

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ABSTRACT: This is a study of the adoption of transgenic crops by 120 smallholder farmers interviewed in July 2005 in the communities of San Jose de Feliciano and La Paz in the Entre Rios Province of Argentina. Logistic regression results indicate that access to a planter is essential for smallholders to adopt Bt corn, while adopters of Roundup Ready™ soybeans have larger farms, access to credit, availability of all essential machinery, more years of schooling, and are primarily located in the La Paz community.

Keywords: transgenic crops, technology adoption, Bt corn, Roundup Ready™ soybeans, biotechnology, Argentina, smallholders

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Many people in developing countries suffer from poverty and hunger, especially farm families who comprise two-thirds of the world's poor. Advances in biotechnology can help improve agricultural productivity in developing countries, reduce poverty, and enhance food security worldwide (Pinstrup-Andersen, 1999).

Transgenic crops were first commercialized in 1996. In 2006, the United States (54%), Argentina (18%), Brazil (11%), Canada (6%), India (4%), and China (3%) represented 96% of total transgenic crop production (James, ISAAA, 2007). However, 9.3 million farmers of whom about 90% can be classified as resource-poor, smallholder farmers in 22 different countries have planted transgenic crops. Based on area planted, soybeans, corn, and cotton are the primary transgenic crops.

Several studies have evaluated the benefits of the adoption of *Bacillus thuringiensis* (Bt) cotton by smallholders (Qaim and Zilberman; Purcell and Perlak; Ismael, Y., Bennett, R., and Morse, S.; and Pray, C., Huang, J., Hu, R., and Rozelle, S.). These studies in India, South Africa, and China have concluded that the adoption of Bt cotton increases yields through better insect control, reduces insecticide applications and costs, exposes farmer to less potentially toxic insecticides, and increases farm household income. However, there are minimal studies in the transgenic technology adoption literature on the socioeconomic impacts of the adoption of Bt corn and Roundup Ready™ soybeans by smallholder farmers, especially in Latin America. That is the focus of this paper (Paredes, 2006).

The Study Site

The data for this study were collected in the Province of Entre Rios located about 290 miles northeast of the city of Buenos Aires. This region is on the fringe of the more productive Pampas region of Argentina where large-scale farming and ranching exist. The population in Entre Rios is about 18% rural. The primary crops are soybeans, wheat, and corn. The soils are very erosive and no-till farming methods are strongly encouraged.

The communities analyzed in this case study are San Jose de Feliciano and La Paz. In order to encourage the adoption of no-till farming methods to prevent soil erosion and increased yields through the adoption of transgenic varieties, regional political leaders, an Argentine No-Till Farmer Organization (APRESID) and the Monsanto Company established a program in 2000 to provide inputs (seed, agricultural chemicals, and fertilizer) to smallholder farmers in the community of San Jose de Feliciano. Initially, approximately 80 smallholders participated, but by 2005 only 15 smallholders remained active in the project. The decline in project participation appears to be the result of several factors including limited access to machinery and credit, lack of extension education information, and the departure of a few key technical support personnel.

In 2001, according to the National Agricultural Census, there were 663 farm households in San Jose de Feliciano (53% less than 100 hectares) and 1,323 in La Paz (47% less than 100 hectares). Most of the land in these two communities is devoted to unimproved pasture or brush with a few small fields planted to crops, especially in the San Jose de Feliciano community where only about 6% of the land is devoted to crop production. In the La Paz community, farmers have recently begun to clear fields and establish row-crop production. Unemployment is relatively high (>10%) and most adults have not completed a high school education (only 30% have completed 12 or more years of schooling).

The Survey Data

A questionnaire was designed to collect primary data concerning smallholders' knowledge and adoption of transgenic crops, along with information on production practices and farm and household characteristics. Personal interviews were conducted with 120 smallholders during July 2005. Data collection was very challenging given the distances between farms to be traveled on unimproved roads, lack of telephones, lack of farm recordkeeping by most smallholders, and limited educational attainment in many households. Staff with a local farmer cooperative, regional Monsanto representatives, and local no-till farming technical support staff immensely helped the authors of this study locate and gain the confidence of the smallholders. Since both authors are fluent in Spanish, there was no need for translation during the interviews. Those smallholders interviewed were very willing to cooperate and answer the survey questions to the best of their knowledge and ability. In fact, only two farmers refused to be interviewed.

Typically only 3 or 4 interviews could be completed each day given the traveling challenges of distance between farms, muddy roads, afternoon siestas, farmers not at home at the time of the initial visit, time require to share a cup of coffee or mate, and the effort necessary to develop a rapport and establish the purpose of the interview. Since no local agency could provide a list of names and addresses, farmers were selected randomly from a map of the region considering road access, farm size, and soil characteristics. Based on the 2001 Census of Agriculture, the survey sample of 120 farmers represents 6% of all farmers in the region.

The questionnaire was divided into five major sections: 1) attitudes towards and knowledge of transgenic crops, 2) corn production practices, 3) soybean production practices, 4) general farm management and marketing activities, and 5) household information.

Approximately 50 of the original 80 participants in the Monsanto/Argentine No-Till Farmer Organization sponsored technology transfer program were interviewed. Of these, only 15 were still participating in the technology transfer program in July 2005. About 70 of the 120 farmers interviewed had never participated in the special Monsanto/Argentine No-Till Farmer Organization Bt corn technology transfer project. However, some on their own initiative had adopted transgenic crops and others had not. Almost one-half the farmers (44%) in the sample operated less than 50 hectares, and most generally had less than five hectares of row-crops. About one-third operated more than 100 hectares (33%). Hence, the sample reflects different farm sizes and transgenic crop adoption experience in two adjacent geographic communities in the northwest quadrant of the Entre Rios Province of Argentina.

The average sample farm size was 268 hectares, but ranged from 1.5 to 3,500 hectares in one extreme case. Larger farms often involved more extensive cattle grazing activities. Only 23% of the farmers in the sample had attended school beyond the eighth grade. Approximately two-thirds of the respondents were between 40 and 65 years of age. Also two-thirds indicated that they had no access to credit and relied on personal funds for the purchase of farm inputs.

About one-half (53%) of the farmers did not grow any transgenic crops. Among those with less than 50 hectares, 75% did not produce any transgenic crops. Eighty-four percent of the farmers who indicated that they did not grow a transgenic crop did not have any immediate plans to plant any type of transgenic crop. Reasons stated for not planting transgenic crops included: 1) no knowledge about transgenic crops (50%), 2) seed not available locally (18%), and 3) seeds are too expensive (18%). Forty-five percent of the non-adopters indicated that they would be more likely to grow transgenic crops if they had more knowledge about them; 21% would grow them if the transgenic seed were not more expensive than normal seed; and, 13% if the seed were available locally. When asked about the likelihood to consume food derived from transgenic crops, 69% of all the farmers in the sample responded that they would be very likely, 28% answered that they did not know, 2% are not very likely, 1% are somewhat likely, and 1% are not likely. However, only 56% of the smallholders (<50 hectares) are likely to consume transgenic foods compared to 90% of the larger farmers (>100 hectares).

Logistic Regression Approach

Logistic regression models were specified to determine which explanatory variables were associated with the adoption of Bt corn and Roundup Ready™ soybeans. Logistic regressions may be used to compare the relative importance of the independent variables, to evaluate interaction effects, and to determine the impact of covariate control variables (Garson, 2005). For the purposes of this analysis, the binomial logistic regression model was utilized.

Binary logistic regression is a type of regression employed when the dependent variable is dichotomous. In such a model, the independent, or explanatory, variables may take any form. For this analysis, initially the variable GrowGM was considered the dependent variable for adoption of either Bt corn and/or Roundup Ready™ soybeans.

This variable indicated whether the farmer planted any transgenic crop during the 2004-05 season (=1) or did not grow transgenic crops during the same planting season (=0).

Logistic regression applies maximum likelihood estimation after transforming the dependent variable into a logit variable (the natural log of the odds of the dependent occurring or not). In this way, logistic regression estimates the probability of a certain event occurring. Logistic regression calculates changes in the log odds of the dependent variable, not changes in the dependent variable itself as OLS regression does.

Let Y_i be equal to 1 if the farmer grew any transgenic crops during the 2004-05 season and 0 if he/she did not. The probability that the farmer had grown any transgenic crop, which can be calculated from the logistic distribution function evaluated at Y_i, is:

$$(1)\quad \begin{aligned} &\text{Prob}(Y_i = 1 \mid X_i) = f(X_i\beta) \\ &= f(\beta_0 + \beta_1 X_{i1} + \beta_2 X_{i2} + \beta_3 X_{i3} + \beta_4 X_{i4} + \beta_5 X_{i5} + \beta_6 X_{i6} + \beta_6 X_{i7})) \end{aligned}$$

Where $f(\bullet)$ is the cumulative distribution of a logistic distribution and β is the coefficient to be estimated. In equation (1), X_{i1} represents the location of the farm, X_{i2} is the number of hectares farmed, X_{i3} is education level of the farmer, X_{i4} is the age of the farmer if he or she is from 15 to 39 years, X_{i5} is the age of the farmer if he or she is from 40 to 65 years, X_{i6} is access to credit during 2004-05 crop season, and X_{i6} is machinery access.

The predicted probabilities can then be computed using the logistic function:

$$(2)\quad \hat{P} = F(X_i\hat{\beta}) = \frac{\exp(X_i\hat{\beta})}{1 + \exp(X_i\hat{\beta})}$$

From Equation (2), the probability of transgenic crop adoption can be determined given the farmer's demographic characteristics (age, education, farm size), financial capital (access to credit), and access to machinery.

The dependent variable chosen for this analysis is GrowGM. It is a dummy variable indicating 1 if the farmer adopted a transgenic crop during 2004-05, or a 0 if the farmer did not adopt. Seven independent variables were selected to explain the dependent factor GrowGM. The potential explanatory variables are:

- The location variable indicates if the farm is located in the San Jose de Feliciano or in La Paz community (San Jose de Feliciano=1, La Paz=0).
- Farm Size (HasFarm) indicates the number of hectares farmed during 2004-05 season.
- Education (Ysc) is a variable that refers to the last year of schooling attained by the farmer.
- Farmer's age is divided into various categories. Age1 is a dummy variable that indicates if the farmer's age is within the range from 15 – 39 years (age of the farmer 15 – 39 = 1, otherwise=0). Age2 is another dummy variable that indicates if the farmer is from 40 to 65 years (age of the farmer 40 – 65 years=1, otherwise=0).
- Access to credit (CrAcc) indicates if the farmer obtained any credit during 2004-05 to finance his crop activities (obtained credit= 1, otherwise=0).
- Access to machinery specifies if the farmer owned, borrowed, or rented any machinery during 2004-05 (1=the farmer had access, otherwise = 0 for tractor (TracAcc), tillage equipment (TillAcc), planter (PlanAcc), or combine (CombAcc)).

Model Results for Overall Transgenic Crop Adoption

The results from the GrowGM models are presented in Table 1. In the Model 1 specification, only access to a planter (PlanAcc) was statistically significant at the $\alpha = 0.01$ level. Since only farmers in the La Paz community had access to a combine, in the

Model 2 specification, the combine variable was eliminated. In the Model 3 specification, the location variable was not included because it is highly correlated with the farm size (HasFarm) variable, i.e., farms were much larger in the La Paz community than in the San Jose de Feliciano community. In Model 3, two explanatory variables were statistically significant ($\alpha = 0.05$); access to credit (CrAcc) and access to a planter (PlanAcc). Since virtually all farmers had access to a tractor through ownership or renting, this variable had no explanatory power and was eliminated in Model 4. Finally, in Model 5, the two variables for farmer's age were eliminated since neither age dummy variable was found to be statistically significant. Thus, only two variables for overall transgenic crop adoption were found to be statistically significant ($\alpha = 0.05$)--- access to a planter and access to credit. Farm size was almost significant at the $\alpha = 0.1$ level. Model 5 had the highest correctly predicted value at 88.4%.

Location

Since the majority of the small-scale farmers were located in the San Jose de Feliciano community, and almost all the larger farmers were located in the La Paz community, inclusion of a location variable resulted in a singular matrix problem. The only farmers in the sample who had access to a combine and planted soybeans all resided in the La Paz community.

Farm Size

According to the extensive technology adoption literature, larger farmers tend to adopt a technological innovation more readily than small-scale farmers. Large farmers have more resources to mitigate any risk associated with trying a new technology, plus the transactions costs per unit of land tend to be lower for larger farmers. So, it was expected that larger farmers (Hasfarm) in the sample would be more likely to adopt transgenic crops. The logistic regression results suggest, however, that for the entire sample for overall transgenic crop adoption this is not the case. This is likely due to the dichotomy that the adoption Roundup Ready™ soybeans only occurred in the La Paz community where the farms are larger than in the San Jose de Feliciano community and only the La Paz farmers had access to a combine for soybean harvest. This issue is addressed in more detail later.

Education

Years of schooling (Ysc) was used in this logistic regression model to determine the effect education might have on farmers' decisions to adopt transgenic crops, all other factors being held constant. The highest education level was recorded for each interviewed farmer. It was expected that education beyond high school would have a positive impact on adoption of transgenic crops. While the sign for education in the various logistic regression models was always positive, the variable never was statistically significant. This may be a result, in part, of the influence of the Monsanto/Argentine No-Till Farmer Organization program which provided technical assistant and subsidized input incentives to adopt Bt corn for only the smaller, less-educated farmers in the San Jose de Feliciano community. It is not likely that these smallholders would have adopted the Bt corn without this special intervention effort. This question is addressed in more detail later.

Farmer Age

Younger farmers are more likely to be risk takers compared to older farmers. While their asset base may be more limited, they have more years to recover from any potential loss.

Since the adoption of new technologies may increase production and/or income risk, older, more traditional farmers may be less likely to adopt a new technology. In this study, both age range dummy variables (younger age (15 to 39) and middle age (40 to 65)) had negative coefficients suggesting that farmers over age 65 are less likely to adopt transgenic crops, but neither age variable was statistically significant. Hence, age does not appear to be a determining factor in the in their decisions to adopt transgenic crops, at least for this sample of smallholders. Also the Monsanto/Argentine No-Till Farmer Organization intervention project encouraged all small farmers, regardless of age, in the San Jose de Feliciano community to consider the adoption of Bt corn. An alternative model specification later addresses this issue.

Access to Credit

Trying a new technology often requires additional financial resources. Thus, the availability of credit to support crop production activities may be vital to successful technology adoption. The logistic regression results indicate that when farmers have access to some type of credit, the likelihood of adoption increases. The access to credit variable (CrAcc) was statistically significant ($\alpha = 0.05$) in versions 3, 4, and 5 of the model specification. Hence, this result appears to be rather robust.

Access to Machinery

The availability of machinery for crop activities was hypothesized to be a critical factor in determining the adoption of transgenic crops by smallholder, limited-resource farmers in this marginal region of Argentina. Farmers were divided in four categories to better assess their access to different types of machinery (e.g., tractor (TracAcc), tillage implements (TillAcc), planter (PlanAcc), and combine (CombAcc)) for the crop year

2004-05. The logistic regression results indicate that access to a planter is the most critical determinant of who might be more likely to adopt transgenic crops. All the larger farmers in the La Paz community had a planter. Several of the smaller farmers in the San Jose de Feliciano community had formed an alliance to co-own and operate a planter that was originally provided by the Monsanto/Argentine No-Till Farmer Organization project. Access to a tractor and tillage equipment did not seem to be a barrier to transgenic technology adoption. However, as indicated above, access to a combine did appear to influence the adoption of Roundup Ready™ soybeans since only farmers in the La Paz community planted any soybeans. Most smallholders in the San Jose de Feliciano community harvested their small plots of corn by hand. They indicated that since their fields were relatively small they could not justify the ownership or renting of a combine.

Model Specification Modifications

Because the initial transgenic crop adoption logistic regression model results suggested several differences between Bt corn adopters and Roundup Ready™ soybean adopters, two separate models were specified- one for Roundup Ready™ soybean adoption (GrowRR) only and one for Bt corn adoption (GrowBt) only. In one version the dependent variables has a value of 1 if the farmer grows Roundup Ready™ soybeans (Table 2). In the other version the dependent variable has a value of 1 if the farmer grows Bt corn (Table 3). The same explanatory variables described above were included in both modified versions of the transgenic crop adoption model. The percent correctly predicted was 94.9% for Roundup Ready™ Soybeans and 73% for Bt corn.

Farm Size

Farm size (Hasfarm) has a positive association with the likelihood to adopt Roundup Ready™ soybeans and Bt corn (Tables 2 and 3). Both coefficients are statistically significant (α=0.05) for Roundup Ready™ soybeans and (α=0.10) for Bt corn. Thus, despite the Monsanto/Argentine No-Till Farmer Organization project efforts to encourage the very small farmers to adopt Bt corn, those farmers with a larger farm size were more likely to adopt one or both of the transgenic crops, especially soybeans.

Education

Years of schooling (Ysc) of the farmer appears to have a positive effect on the adoption of both transgenic crops, but it is only statistically significant for Roundup Ready™ soybeans (α=0.05). The Monsanto/Argentine No-Till Farmer Organization contacted smallholders of difference ages in the San Jose de Feliciano community to encourage them to adopt Bt corn, while the farmers in the La Paz community were not involved in this focused technology transfer effort. Hence, only where normal market forces occur and where there is no special technology intervention effort such as the Bt corn project is the farmer's educational attainment associated with transgenic crop adoption in this case study.

Access to Credit

Access to an external source of funds has a positive effect on the adoption of Roundup Ready™ soybeans and the coefficient is statistically significant (α=0.001). If the farmer has access to some form of credit, the odds that the farmer will be likely to adopt Roundup Ready™ soybeans is considerably greater. However, the coefficient for Bt corn was negative and not statistically significant. A possible explanation for the Bt corn case is that many of the Bt corn adopters were participants at some point in the Monsanto/Argentine No-Till Farmer Organization program. This project provided an indirect source of credit through access to a planter without the need to purchase or rent, and while the farmers were expected to purchase the Bt seed and fertilizer, in some cases it was discovered during the interviews that no payments were ever made by the smallholder project participants, i.e., a significant no-cost source of input credit!

Access to Machinery

Having access to a tractor (TracAcc), tillage equipment (TillAcc), and a planter (PlanAcc) appears to have a positive influence on the adoption of Roundup Ready™ soybeans and Bt corn. However, only the coefficient for access to a planter was statistically significant ($\alpha=0.05$) for both crops. While essentially all farmers owned or rented a tractor and tillage equipment, a critical issue was access to a planter for the very small farmers in the San Jose de Feliciano community who participated in the Bt corn project.. Also for the production of Roundup Ready™ soybeans a combine was essential, but only the larger farmers located in the La Paz community owned or rented a combine for soybean harvest. Smaller farmers, whether they planted Bt or conventional corn varieties, reported that they harvested their small plots (often less than 5 hectares) by hand over a period of several weeks. Some of the corn was used to feed their own livestock and small amounts were available for market sale.

Partial Budget Analysis of Bt Corn Adoption

Benefit/cost analysis was conducted to corroborate the logistic regression results for the adoption of Bt corn by smallholder Argentine farmers. This benefit/cost partial budget analysis should help confirm why some farmers are adopting and others are not adopting

Bt corn in this case study region. While transgenic crop knowledge, product information, and general biotechnology awareness are important, it must also be economically feasible to adopt Bt corn based on expected yields, potential revenues, and costs of production. Also this benefit/cost analysis may provide some insights as to what intervention might induce smallholders to adopt Bt corn.

A benefit/cost ratio was calculated for small-scale farmers (< 50 hectares), mid-size farmers (50 – 150 hectares), and large farmers (> 150 hectares). The fewer than 50 hectare farmers were entirely in the San Jose de Feliciano community and the largest farmers were exclusively found in the La Paz community. Both communities had some mid-sized farmers. Yield, fertilizer rates, amount of seed used, and harvesting data were obtained from the survey. The survey data also includes information on two different types of small-scale farmers (<50 hectares): a low technology group who do not use any herbicide and fertilizer inputs and a moderate technology/input group of farmers who use both chemical herbicides and commercial fertilizer. Separate analyses were conducted to assess any differences between these two groups based on their input usage.

In the first scenario, based on the data reported in the survey, for the small-scale farmers (<50 hectares) not using any chemical herbicides and commercial fertilizer, the Bt corn adopters reported a 26% increase in yields and revenues compared to the non-Bt adopters. The adoption of the Bt corn varieties increased their per hectare seed costs by 36% relative to the conventional varieties. However, in order to achieve the higher yield potential of the Bt technology package, the Bt corn adopters incurred US$39 per hectare in additional fertilizers costs and US$22.92 more per hectare for herbicide applications. The benefit/cost (B/C) ratio for this scenario is 0.58 suggesting that under these conditions it is not economically viable for these traditional, small-scale farmers to adopt Bt corn since the costs of the additional inputs (seed, fertilizer, and herbicides) to achieve the yield potential of the Bt corn would be greater than the additional revenues (Table 4).

A second scenario, using the available survey data, compares small-scale farmers (<50 hectares) who adopt the Bt seed corn with similar small-scale farmers who plant non-Bt corn, but where both groups were already using chemical herbicides and commercial fertilizer. On average, this group of Bt corn adopters obtained 37% more yield and revenue than those similar small-scale farmers who plant non-Bt corn. As before, the seed cost increased by 36% for the Bt corn adopters. The B/C ratio for those farmers who adopted Bt corn is 3.02. Hence, for this scenario, smallholder farmers who already use chemical herbicides and commercial fertilizer can more than cover the additional seed cost for Bt corn with the additional yield and revenues. For this group of modern input users, additional corn yields more than compensate for the additional cost of the Bt corn seed and Bt corn adoption is economically feasible (Table 5)

The third scenario compares the mid-size (50 – 150 hectares) Bt corn adopters with non-Bt corn adopters operating farms of a similar size. On average, a 24% increase in yield and revenue was reported. Again, the seed cost increment (36%) is the main additional direct cost for the Bt corn adopters, since the cost of fertilizer, herbicides, and harvesting is essentially the same for both moderate sized farm groups. The Bt corn adopters spent US$38.10 more per hectare on average than non-adopters. The B/C cost ratio for this scenario is 1.15 (Table 6). Hence, for the mid-sized farmers in this survey, the adoption of the Bt corn technology package is slightly better than a breakeven proposition.

The last scenario contrasts the performance of large farmers (>150 hectares) who adopt Bt corn versus large farmers who are non-adopters of Bt corn. Based on the survey data, in this case there is a 13% increase in yield and revenues by the Bt corn adopters. The main cost difference is the cost of the Bt corn seed which as before is 36% more for adopters. There is a difference of US$20.55 in the total direct costs for the Bt corn versus non-Bt corn adopters. The B/C cost ratio for this scenario is 2.46 (Table 7). Thus, there is an excellent market incentive for large farmers to adopt Bt corn.

Implications of the Case Study

The socioeconomic impact of the adoption of transgenic crops by smallholder farmers is a controversial topic in many developing countries. Among the smallholders in this Argentine case study, limited education, lack of technology awareness, and minimal access to land and capital inputs tend to discourage the adoption of transgenic crops. However, with technical education and guidance by private companies and farmer organizations, reasonably priced transgenic seed, a willingness to use commercial fertilizer and herbicides, and access to capital can make it economically feasible for smallholders to adopt transgenic crops such as Bt corn.

Multiple years of consistent technical support will be critical as small farmers gain experience with modern inputs such as Bt corn under different weather conditions, and, weed, disease and insect pressures. The high dropped out rate, nearly 80%, in the San Jose de Feliciano community where this survey was conducted appears to be largely the result of the withdrawal over several years of technical assistance and access to seed, fertilizer, herbicides, and a community-shared planter.

Micro-credit access also may be essential for successful adoption of transgenic crops. This was a very robust empirical finding in this study. On-farm demonstration plots and field days may help growers to gain knowledge and confidence in the management and potential benefits of transgenic crops. To be successful, the adoption of transgenic crops requires a systems approach in terms of appropriate input use, record keeping, and awareness of the need to plant a refugia to minimize the potential development of insect resistance in the region.

While the income benefits may be modest, at least in this study, under appropriate technology transfer arrangements smallholders may be able to increase yields and income from insect-resistant, transgenic corn hybrids in Latin America.

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Table 1. Logit Regression Results for Adoption of Transgenic Crops (Bt Corn and/or Roundup Ready™ Soybeans)

	Model 1		Model 2		Model 3		Model 4		Model 5	
% Correctly Predicted	82.2		83.1		83.1		83.1		88.4	
Log Likelihood Function	81.942		83.707		87.464		87.467		82.2	
Variables	β	Sig.	β	Sig.	β	Sig.	β	Sig.	β	Sig.
HasFarm	0	0.82	0	0.796	0.003	0.15	0.003	0.149	0.003	0.133
Location	-17.827	0.999	2.625	0.094						
CombAcc	20.872	0.999								
TracAcc	0.131	0.901	0.03	0.977	0.055	0.958				
PlanAcc	2.069	0.008	2.198	0.005	2.447	0.002	2.471	0	2.472	0
TillAcc	0.358	0.63	0.504	0.493	0.565	0.428	0.579	0.384	0.693	0.288
Ysc	0.052	0.554	0.088	0.286	0.111	0.181	0.112	0.177	0.084	0.262
Age1	-0.453	0.63	-0.484	0.604	-0.747	0.416	-0.743	0.417		
Age2	-0.397	0.606	-0.442	0.567	-0.659	0.379	-0.654	0.379		
CrAc	0.379	0.701	0.635	0.472	1.461	0.039	1.461	0.04	1.329	0.047
Constant	-2.71	0.01	-2.964	0.004	-3.249	0.002	-3.235	0.001	-3.668	0

Table 2. Logistic Regression Results for Adoption of Roundup Ready™ Soybeans

% Correctly Predicted	94.9	
Log Likelihood Function	31.170	
Variable	β	Sig.
Hasfarm	0.013	0.006
Ysc	0.354	0.026
CrAcc	4.408	0.000

Table 3. Logistic Regression Results for Adoption of Bt Corn

	Model 1		Model 2	
% Correctly Predicted	73.7		72.9	
Log Likelihood Function		120.58		120.596
Variables	β	Sig.	β	Sig.
Hasfarm	0.001	0.062	0.001	0.062
Ysc	0.011	0.841	0.013	0.821
CrAcc	-0.706	0.222	-0.712	0.216
TracAcc	0.32	0.753	0.276	0.772
PlanAcc	1.826	0.012	1.841	0.011
TillAcc	-0.076	0.9		
Constant	-2.53	0.003	-2.566	0.001

Table 4. Small-scale Farmer Adoption of Bt Corn Technology Package Relative to Low Input Users

	Bt Corn	Non-Bt Corn	Difference
	$/Ha	$/Ha	$/Ha
Revenues	231.03	182.97	48.06
Costs			
Planting	27.76	27.76	
Seed	94.5	69.3	
Fertilizer			
Urea	18.8	0	
DAP	20.28	0	
Herbicides			
Glyphosate	5.4	0	
Atrazine	8.4	0	
Acetochlor	9.12	0	
Cultivation	0.00	5	
Harvesting	16.3	15	
Total Direct Costs	200.56	117.06	83.5
Ratio			0.58

Table 5. Small-scale Farmer Adoption of Bt Corn Relative to Those Already Using Herbicides and Commercial Fertilizer

	Bt Corn	Non-Bt Corn	Difference
	$/Ha	$/Ha	$/Ha
Revenues	231.03	167.94	63.09
Costs			
Planting	27.76	27.76	
Seed	94.5	69.3	
Fertilizer			
Urea	18.8	24.4	
DAP	20.28	20.28	
Herbicides			
Glyphosate	5.4	5.4	
Atrazine	8.4	8.4	
Acetochlor	9.12	9.12	
Harvesting	16.3	15	
Total Direct Costs	200.56	179.66	20.9
Ratio			3.02

Table 6. Mid-size Farmer Comparison for Bt Corn Adoption

	Bt Corn	Non-Bt Corn	Difference
	$/Ha	$/Ha	$/Ha
Revenues	224.1	180.36	43.74
Costs			
Planting	27.76	27.76	
Seed	94.5	69.3	
Fertilizer			
Urea	25.6	23.2	
DAP	24.18	18.33	
Herbicides			
Glyphosate	5.4	5.4	
Atrazine	8.4	8.4	
Acetochlor	9.12	9.12	
Harvesting	18.65	14	
Total Direct Costs	213.61	175.51	38.1
Ratio			1.15

Table 7. Large Farmer Comparison for Bt Corn Adoption

	Bt Corn	Non-Bt Corn	Difference
	$/Ha	$/Ha	$/Ha
Revenues	443.34	392.67	50.67
Costs			
Planting	27.76	27.76	
Seed	94.5	69.3	
Fertilizer			
Urea	28.4	32.4	
DAP	25.74	23.01	
Herbicides			
Glyphosate	5.4	5.4	
Atrazine	8.4	8.4	
Acetochlor	9.12	9.12	
Havesting	21.7	25.08	
Total Direct Costs	221.02	200.47	20.55
Ratio			2.46