The Impact Genetically Modified Traits Have had on Corn Yields

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INTRODUCTION

The percent of corn acres planted in the United States using genetically modified (GM) seeds has almost quadrupled since 2000 (USDA, NASS, 2014). An increasing world population and limited supply of land has required another alternative source to meet the increasing demand for food, feed, and fiber (Barrows et al., 2013). One alternative source to meet increasing demand is GM seeds (Barrows et al., 2013). Studies examining the potential benefits of GM seeds have taken a broad worldview and estimated most of their own data.

The purpose of this paper is to look at the effects GM traits have on corn yields in the United States Corn Belt. This study focuses on an Acreage Report provided by the USDA and NASS. Unlike previous studies, the regression analysis in this study uses reported numbers, not just estimates, and controls for other production factors such as weather. In the next section, the approaches and findings of previous studies are reviewed.

REVIEW OF LITERATURE

Previous studies have examined how changes in market and environmental conditions have affected adoption, profits, and input decisions, analyzed the effects GM crops have had on output and prices, the environment, and on consumer health, assessed whether or not GM crops yield growth is enough to keep up with increasing demand, and examined how GM crops have affected the economics of growing certain crops and the welfare of farmers and consumers. The discussion below examines previous studies that focus on the effects and utilization of GM crops.

The adoption of new technologies creates a change in market and environmental conditions. Fernandez-Cornejo et al. (2012) conducted a two-stage regression analysis using data from a Nationwide Agricultural Resource Management Survey in 2005. The first stage of the analysis was an adoption decision model that determines factors that influence a farmer’s decision to use Bt seeds. The second stage was an impact model to estimate the impact adoption has on yields, seed demand, insecticide demand, and farm variable profits. The adoption model used 12 variables. These included acres planted, operator experience, the relative price of Bt seeds, expected profits, the debt to asset ratio, the percentage of corn grown under production or marketing contracts, crop insurance, conservation tillage, irrigation, crop rotation, operator knowledge about pest infestation, and whether or not the farm is located in the area designated Heartland. This model found that farmers are most likely to adopt if they have a larger farm, purchase crop insurance, have irrigated acres, and are located in the Heartland. This model also found that more experienced operators are less likely to adopt the technology. The impact model showed that adopting Bt seed increases variable profits, yields, and seed demand. A 10%

increase in probability of adoption was associated with 1.65% increase in variable profit, a 1.7% increase in yield, and a 1% increase in seed demand.

Barrows et al. (2013) examined if GM seeds yield growth is enough to keep up with increasing demand from consumers. This study used regression analysis and data from the International Service for Acquisition of Agri-Biotech Applications in 2010. The study used five variables: seed technology, variable chemical pesticide application, initial pest condition, fertilizer, and water to determine if GM seed has an effect on output. The authors found that biotechnology can increase yields as much as 32% in corn when there is a pest problem, but without a previously existing pest problem, GM traits do not provide a yield boost. The authors also examined if GM crops could make previously unfarmed land farmable. The results for this part of the paper could not be determined.

GM seeds have had many effects on the agricultural industry including output and prices, the environment, and on consumer health. Barrows et al. (2014) used data from Graham Brookes and other sources including previous studies as well as their own expertise to draw new conclusions about risks created and mitigated by biotechnology and the yield boost created by biotechnology. The authors found that risks posed by biotechnology require more attention; however, these uncertain risks are outweighed by benefits from increased food production, reduced insecticide use, and avoided health risks to food consumers and farm workers. The authors also showed how biotechnology could be used to boost yields anywhere between 5%-37% and profitably bring new lands into production.

GM crops not only affect yields but also the economics of crops including corn, canola, cotton, and soybeans for farmers and consumers. Zilberman et al. (2010) examined previous studies and summarized the results to explain how GM crops affected the economics of growing corn, canola, cotton, and soybeans around the world. The authors found that GM crops have a greater effect in less developed countries, up to 34% yield increase. In more developed countries, previous methods of pest control have eliminated the majority of the problem and the yield increase is only about 5%. Thus, when GM crops are used as a substitution to earlier methods of pest control, there are only slight yield increases and savings in the cost of pesticide. The authors also examined if different traits had more or less of an impact on yield. They found that Bt traits have a greater impact than HR traits. In addition, the authors found that adopting GM crops decreases management effort.

As shown above, the use of GM crops has increased greatly in recent years. Previous studies have shown the yield effects, price effects, economic effects, and the effects on the use of pesticide caused by GM crops. The previous research is very general in nature including many different crops from all around the world, but it has not focused on the United States. This study will examine if GM seed corn has an effect on corn yields in the United States on a state-by-state basis. The following section will explain the methods and results of this study.

DATA AND METHODS

Methods

GM traits were first introduced in 1996, and since that time, they have become widely accepted. In 2013, 90% of all corn acres in the United States were planted with GM seeds (USDA, NASS, 2014). This widespread acceptance is due to the idea that planting GM seeds will increase yields. The economic theory that best explains this is production. The factors involved in production are inputs and outputs. Theoretically, the more inputs that are applied should result in more outputs. In this study, the output will be corn yield. Two important factors in corn production are water and heat. Total precipitation and average temperature will account for these two factors. The other variables will include different types of GM traits to determine if different traits have a greater or smaller effect on yield. GM traits are a technological advancement and should increase yields.

The following regression equations were used to estimate the production model:

$$Y=\beta_0 + \beta_1 P + \beta_2 T + \beta_3 T^2 + \beta_4 GM$$

$$Y=\beta_0 + \beta_1 P + \beta_2 T + \beta_3 T^2 + \beta_4 IR + \beta_5 HR + \beta_6 SG$$

where the dependent variable, Y, is the average corn yield of a state in a given year. For the first model, the four independent variables are P (the precipitation per year in a state), T (the average temperature for the year in in each state), T^2 (the average temperature squared for the year in each state), and GM (the total percent of corn acres planted with any type of GM traits). For the second model, the first three independent variables are the same as the first model. The additional variables include IR (the percent of corn acres planted with insect resistant traits per year in a state), HR (the percent of corn acres planted with herbicide resistant traits per year in a state), and SG (the percent of corn acres planted with stacked gene traits per year in a state).

The use of economic theory allows for the prediction of the relationships between each variable. For instance, precipitation is an estimate of the available water for the corn to use, so P is expected to be positively associated with yield. Therefore, as P increases, the output, or yield, will also increase. The other weather variable that affects yield in this study is T. An increase in T during the year is expected to have a positive impact on yield to a certain point. However, if T is too hot, there could be a negative effect on yield. This will be captured with the variable T^2.

The four additional independent variables are the focus of this study. All of them measure a different type of GM trait. For the first model, the independent variable is a summation of all of the GM traits. That is, it is the sum of the percentage of all of the remaining variables in the second model. These are all technological advancements and should increase yields. The second model includes three different independent traits including IR, HR, and SG. IR traits have natural resistance to insects built into them and should have a positive impact on and increase yield. HR traits make a corn plant capable of metabolizing different herbicides, which makes weed control easier and more effective for producers. This should also impact yields positively. SG traits are a combination of traits in one seed, possibly herbicide resistant and insect resistant traits combined. SG traits should also have a positive impact on yield. Table 1 below summarizes the dependent and independent variables from the regression equation along with the expected signs that each independent variable will have on the dependent variable.

Data

The data required to perform the regression was obtained from two sources and created by the author. The P was retrieved from the National Oceanic and Atmospheric Administration (NOAA). The T was obtained from NOAA. The author used the T variable from NOAA to create the T^2. The percent of acres planted with IR traits, HR traits, SG traits, and GM varieties was retrieved from the United States Department of Agriculture (USDA). All of the data in the study is time series data. The percent of acres planted data for the different traits is annual data. The precipitation data is the total amount of precipitation recorded for the year and the average temperature variable is the average temperature for the whole year. The last column of Table 1 presents a summary of the sources for each variable. Results from the regression analysis will follow in the next section.

Table 1

Variable Definitions, Expected Signs, and Sources

Variable	Description	Unit	Expected Sign	Source
	Dependent Variable			
Y	Average Corn Yield	Bushels per acre	NA	USDA
	Independent Variables			
P	Total Precipitation	Inches of Precipitation	+	NOAA
T	Average Temperature	Fahrenheit	+	NOAA
T^2	Average Temperature squared	Squared Fahrenheit	-	Created variable
GM	Percent of acres planted with genetically modified traits	Percentage	+	USDA, NASS
IR	Percent of acres planted with insect resistant traits	Percentage	+	USDA,NASS
HR	Percent of acres planted with herbicide resistant traits	Percentage	+	USDA,NASS
SG	Percent of acres planted with stacked gene traits	Percentage	+	USDA,NASS

RESULTS

Descriptive Statistics

The average yield for the states examined from 2000-2013 was 156.91 bushels per acre. The average precipitation across all of the states was 34.07 inches. The average temperature during this period was 49.11 degrees Fahrenheit. For the area and time period examined, on average 19.53% of the corn acres were planted with insect resistant traits, 14.43% of corn acres were planted with herbicide resistant traits, and 29.03% of corn acres were planted with stacked genes. On average throughout the area and period examined, 62.97% of acres were planted with some form of GM traits. Table 2 below shows the descriptive statistics for the data set.

Table 2
Descriptive Statistics.

Variables	**Mean**	**Median**	**St. Dev**	**Min**	**Max**	**n**
Y	156.91	159.00	16.87	99.00	181.00	70
P	34.07	31.98	9.27	15.54	55.54	70
T	49.11	50.08	4.59	32.72	58.06	70
IR	19.53	18.50	10.26	2.00	41.00	70
HR	14.43	15.00	7.36	3.00	32.00	70
SG	29.03	22.00	25.67	0	78.00	70
GM	62.97	73.50	26.68	11.00	93.00	70

Regression Analysis

Two regression analyses were performed. The first model includes the GM variable to show if GM traits do have an impact on yields. The second model substitutes in the IR, HR, and SG variables to determine if certain traits have a greater impact on yields. Table 3 displays the regression results including estimated coefficients, standard errors, p-value designations, and the overall fit of the models.

Table 3
Regression Results.

	Estimated Coefficients	
Variables	**GM Model**	**IR, HR, SG Model**
Intercept	-37.9307	-12.3580
	(123.6694)	(124.7617)
P	0.5240 *	0.6842 **
	(0.2079)	(0.2348)
T	7.9596	6.4225
	(5.2001)	(5.3380)
T^2	-0.0932	-0.0781
	(0.0549)	(0.0565)
GM	0.2053 **	
	(0.0723)	
IR		0.6840 *

		(0.2624)
HR		-0.1180
		(0.3372)
SG		0.3025*
		(0.1155)
R-Squared	0.2315	0.2727
F-Statistic	4.8950 **	3.9369 **
Observations	70	70

Standard errors are in parenthesis.
*p-value<0.05 (two-tailed); **p-value<0.01 (two-tailed)

The regression results show that a relationship does exist between the independent variables and yield. For the first model, the R-Squared indicated that 23% of the increase in yields can be explained by the variables in the model. This model also has an F-Statistic of 4.90 with a p-value of 0.00, which indicates that as a whole the model is significant. The second model, which is used to determine which traits are the most effective, shows that 27% of the change in yield can be attributed to these variables. This model has an F-Statistic of 3.94 with a p-value 0.00, indicating that this model as a whole is also significant.

The weather-related variables performed as expected. The results show that as more precipitation is received, yield will increase. For both models, precipitation was statistically significant. The results also show that an increase in temperature to a certain point will increase yields, but if it gets too hot, this will start to decrease yields.

The remaining variables were the variables of interest for this regression analysis. For the first model, the GM variable gave an expected result and is statistically significant. The estimated coefficient shows that for each additional percent of acres planted with a genetically modified trait, yield will increase by 0.21 bushels per acre. While this does not sound like much, it is. For example, on a 1000-acre farm, if a farmer decides to plant one quarter, 160 acres, with GM seeds, this would increase the percent of acres planted with GM seed by 16%. This would result in a 3.36 bushel per acre increase, or an additional 3,360 bushels of corn.

The second model splits the GM variable into more specific traits to identify which traits have a greater impact on yield. The results were not all as expected. The IR variable gave an expected result showing that for each additional percent of acres planted with this trait, a 0.68 bushel per acre increase in production will occur, which is statistically significant. Therefore, a 16% increase in planted acres will result in an additional 10.88 bushels per acre or an additional 10,880 bushels for a 1000-acre farm. The second variable in the equation was HR. This result was not as expected and was not statistically significant. The final variable measured SG and preformed as expected in the equation. The results for the SG variable show that for each additional percent of acres planted with SG traits, an additional 0.30 bushels per acre will be produced. This result was statistically significant. Following the earlier example, a 16% increase in acres planted using this trait will result in an additional 4.80 bushels per acre across the farm for a total of 4,800 bushels of additional production.

The results of this study are similar to what the study conducted by Zilberman et al. (2010) found. That study showed that IR traits significantly increased yields. However, that study showed that HR traits had no effect to a slight positive effect on yield. One possible reason for this difference is that this study looks at production in the United States where there was previously weed control. The study by Zilberman et al. mostly examined developing countries where limited methods of weed control were being used before. The results of this study are also consistent with what Fernandez-Cornejo and Wechsler (2012) found which is that Bt traits, a strain of IR traits, will increase production. The next section will provide the concluding remarks for this study.

SUMMARY AND CONCLUSIONS

The purpose of this research is to determine if GM seeds have an effect on corn yield and if so, do different traits have a greater or lesser effect than other traits. This was accomplished using regression analysis and data from the USDA to account for the use of GM seeds and average corn yields. Other variables included temperature and precipitation data from NOAA. The hypothesis for this study is that planting GM seeds will improve corn yields. This research focused specifically on corn grown in the Heartland of the United States. Previous studies have examined multiple crops including cotton, corn, and soybeans on a worldwide scale.

The results for the first regression model show that for each additional percent of acres planted with GM seeds, a 0.21 bushel per acre increase in production will occur. The results for the second regression model show that these gains in production from GM crops are realized from IR and SG traits. For each additional percent of acres planted with IR traits, yields are expected to improve by 0.68 bushels per acre. For each additional percent of acres planted with SG traits, yields are expected to increase by 0.30 bushels per acre. The results of this study are similar to that conducted by Zilberman et al. (2010) which showed that for GM traits, IR traits produce the greatest increase in yields.

Results of this study are informative for the states examined. To strengthen the results of this study, more states could be included into the model. In addition, additional factors that influence production could be included in the model to account for more variations in production.

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