AgBioForum, 13(1): 1-12. ©2010 AgBioForum.

The Anticipated Value of SmartStax™ for US Corn Growers

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This study provides an estimate of the anticipated value of SmartStax™ corn hybrids in the years after full commercialization. SmartStax™ hybrids have an eight-trait stack of above-ground and below-ground insect-resistance traits and tolerance to two broad spectrum herbicides. Survey data, expert opinion, and public data sources were used to estimate the value of SmartStax™ hybrids to growers. We consider the effects of varying spatial and temporal pest pressure, differing target insects, the current hybrid mix, the anticipated actions of competing seed companies, and geographical location on SmartStax™ adoption and value. We estimate the total value of SmartStax™ hybrids to growers, including the non-pecuniary value, to be $760.98 million per year in the Corn Belt. We then discuss the role that SmartStax™ is expected to play in enhancing crop insurance programs.

Key words: biotechnology, crop insurance, non-pecuniary, partial budget, SmartStax.

Introduction

Since the late 1990s, agricultural biotechnology companies (Monsanto Company [Monsanto]; Dow AgroSciences, Inc. [Dow]; E.I. DuPont de Nemours Company, including its subsidiary Pioneer Hi-Bred International, Inc. [Pioneer]; Syngenta Corporation [Syngenta]; Bayer Crop Science; and others) have been fiercely battling each other for market share. Recently, however, these companies have begun to cross-license their biotechnology traits to each other in some situations. For example, Monsanto licensed its Roundup Ready® traits to Syngenta for inclusion in some of their corn hybrids. The latest and most comprehensive of these recent collaborations involves the new corn hybrids that combine Monsanto, Dow, and Bayer Crop Science traits and germplasm—SmartStax™.

SmartStax™ is an eight-trait stack of technologies that offers three yield-protection components. First, multiple modes of action for above-ground insect protection are offered in SmartStax via inclusion of YieldGard® VT-Pro™ and Herculex® I. Second, SmartStax offers multiple modes of action for below-ground insect protection through inclusion of the YieldGard® VT Rootworm® and Herculex® Rootworm traits. Finally, SmartStax offers dual herbicide tolerance for weed control through inclusion of the Roundup Ready Corn 2® (glyphosate tolerance) trait from Monsanto and the Liberty-Link® (glufosinate tolerance) trait from Dow.[1] The inclusion of all these traits in a single corn plant will result in increased pesticide durability and more complete control of the pests targeted by these traits, implying a higher yield and a much smaller required refuge area. Indeed, in July 2009, the US Environmental Protection Agency (EPA) approved a smaller required refuge area for SmartStax, lowering it from 20% to 5% of planted corn acreage on a farm in the Corn Belt and from 50% to 20% in the Cotton Belt (PR newswire-First Call, 2009). These hybrids became available commercially in 2010, with an initial launch of about 3-4 million acres.[2] Full commercialization (i.e., when supply constraints no longer exist and adoption has reached its expected maximum) is expected to begin with the 2014 crop year.

The purpose of this article is to assess the anticipated value of the SmartStax corn hybrids at full commercialization. We estimate the anticipated value to growers, taking account of the benefits that affect utility directly and those that affect utility indirectly through profit. Then, using projections based on farm-level assessments, we assess the value of SmartStax to the innovators. Finally, we discuss the potential implications of SmartStax adoption for the crop insurance industry. This

1. *For simplicity, all trademark information is assumed in the rest of the article.*

2. *Although 3-4 million acres are a relatively small portion of total US corn acreage (2.4-3.2% of total US corn acres planted in 2009, as reported by the US Department of Agriculture, National Agricultural Statistical Services [USDA-NASS, 2009]), this is the largest launch in history of a crop biotechnology.*

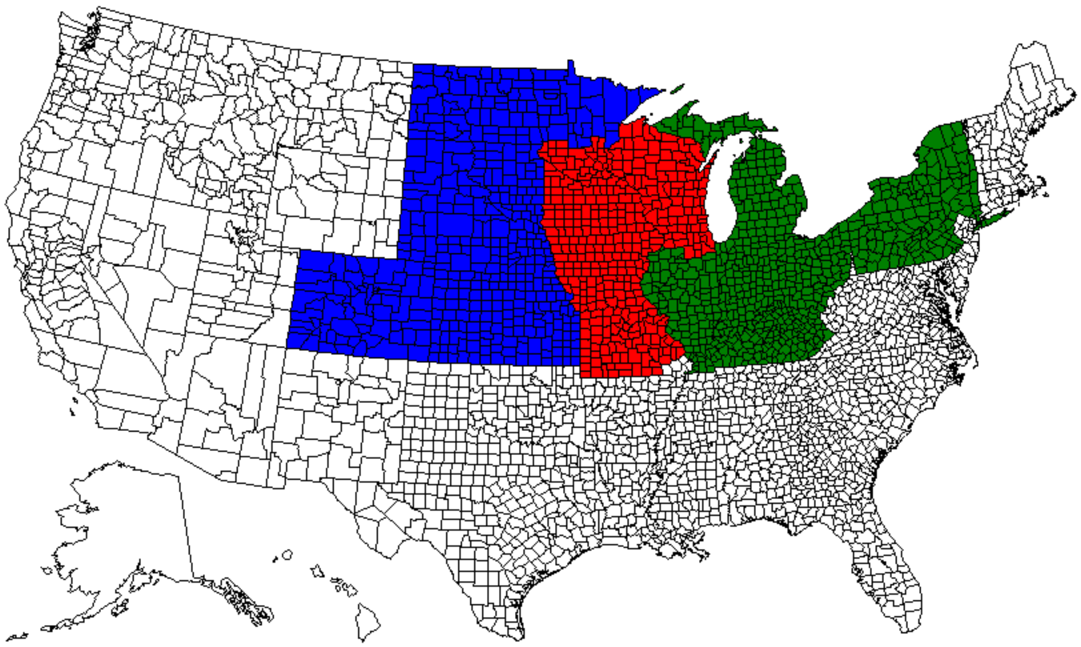

Figure 1. The geographies of the three zones: Western Corn Belt (WCB), the Central Corn Belt (CCB), and the Eastern Corn Belt (ECB).

study is unique in the evaluation of a new crop biotechnology in that we consider the effects of varying spatial and temporal pest pressure, differing target insects, the current hybrid mix, the anticipated actions of competing seed companies, and geographical location on SmartStax adoption and value. Also, the calculation of the non-pecuniary benefits to growers takes account of any potential correlation between the various non-pecuniary characteristics' values.

The Survey

A survey of 501 US corn growers was conducted in Spring 2009 that focused on the growers' current insect-control practices, including insecticide applications and choice of brand/trait combinations, and how those practices might change with the introduction and adoption of SmartStax hybrids.[3] To be eligible, respondents were required to be growing at least 250 acres of corn in 2009 and to be planting at least some of their corn acreage to insect-traited hybrids. Growers were surveyed in the three main agronomic zones in the US Corn Belt; the Western Corn Belt (WCB), the Central Corn Belt (CCB), and the Eastern Corn Belt (ECB). Figure 1 illustrates the geographies of the three zones. The sample was stratified so that total corn acreage represented by the survey respondents is 71,326, or 0.9%, of total WCB corn acres in 2008 (7.9 million acres); 146,946, or 0.8%, of total CCB corn acres in 2008 (18.4 million acres); and 78,362, or 0.8%, of total ECB corn acres in 2008 (9.8 million acres) (USDA NASS, 2009).

The Anticipated Value of SmartStax for Growers

Change in Profit

A partial budgeting framework is employed to determine the value of SmartStax for growers, incorporating information derived from the survey and from other sources. Partial budgeting analysis provides a measure of the net change in profit resulting from a particular

3. *The survey instrument was developed by the authors and the computer-assisted telephone survey was conducted by Market Probe, Inc.*

change in a farming operation. In a partial budgeting framework, only those items of value that *change* with the anticipated change in a farming operation are considered. This reduces the data requirements of the analysis while maintaining the underlying assumption of profit maximization if the change is scale-neutral (Piggott & Marra, 2007; Swinkels, Hogeveen, Zadoks, 2005; Tigner, 2006). The change in profit per acre for each grower in their respective agronomic zone is given by the sum of any additional gross revenue and cost reductions less the sum of any reduced gross revenue and cost increases as a result of the introduction of SmartStax. Finally, utilizing the change in profit for each agronomic zone, the total change in profit per acre from switching to SmartStax across all zones can be derived by calculating an estimated per-acre average of these changes in profits in each agronomic zone and then multiplying each per-acre average by the total number of acres in that zone and summing across zones. More formally this approach can be written as

$$\Delta\Pi_{ss}^{z} = \sum_{z=1}^{Z} A_z \overline{\Delta\pi_z^g}\,, \tag{1}$$

where

$\Delta\Pi_{ss}^{z}$ is the total change in profit from switching to SmartStax across all zones,

A_z is the total number of corn acres in zone z,

$\overline{\Delta\pi_z^g}$ is the estimated average change in profit per acre in agronomic zone z, calculated as $\Delta\pi_z^g = \frac{1}{G}\sum_{g=1}^{G}\Delta\pi_{gz}$, and

$\Delta\pi_{gz}$ is the estimated change in profit from switching to SmartStax for grower g located in zone z.

Increased Revenue. The expected increased revenue per acre in zone z is calculated as

$$\uparrow\Delta R_z^T = P^{corn} \bullet \sum_{b=1}^{B} A_{bz}\Theta_z^{b\to SS}\Delta Y_{bz} \tag{2}$$

where

$\uparrow\Delta R_z^T$ is the expected increase revenue per acre in zone z,

P^{corn} is the price of corn in dollars per bushel,

$A_{bz} = w_{bz} \bullet A_z$ is the estimated acreage of brand/trait combination b in zone z calculated as the product of the estimated share of brand/trait combination b in zone z using the sample acreage of brand/trait combination b for grower g (i.e., $w_{bz} = (A_{bz}^g / A_z^{bg}) = \left[\sum_{g=1}^{G} A_{gbz} \Big/ \sum_{b=1}^{B}\sum_{g=1}^{G} A_{gbz}\right]$, where

A_{gbz} is the number of acres grower g planted to brand/trait combination b in zone z,

$\Theta_z^{b\to SS}$ is the estimated proportion Θ of acres switching from brand/trait combination b to SmartStax (SS) in zone z, and

ΔY_{bz} is the estimated change in yield from switching from brand/trait combination b to SmartStax (SS) in zone z.

Table 1. All (continuous and first year) corn brand/trait penetration in 2009 by agronomic zone (share of total planted corn acres).

	Agronomic zone		
Trait/brand combination	**Western**	**Central**	**Eastern**
YieldGard VT triple [a]	0.410	0.500	0.499
Roundup Ready [b]	0.150	0.122	0.132
Herculex Xtra [c]	0.076	0.082	0.131
YieldGard corn borer Roundup Ready [d]	0.138	0.081	0.030
Herculex corn borer Roundup Ready [e]	0.070	0.049	0.047
Agrisure 3000 GT [f]	0.025	0.021	0.009
Other traited brands [g]	0.016	0.038	0.031
Non-traited	0.115	0.107	0.121

Source: Survey data.
[a] Above-ground and below-ground insect resistance traits and single herbicide tolerance trait
[b] Single herbicide tolerance trait
[c] Above-ground and below-ground insect resistance traits and single herbicide tolerance trait
[d] Above-ground insect resistance trait and single herbicide tolerance trait
[e] Above-ground insect resistance trait and single herbicide tolerance trait
[f] Above-ground and below-ground insect resistance traits and single herbicide tolerance trait
[g] Various single- and double-traited hybrids

Survey respondents were asked to report the various brand/trait combinations they were planting in 2009 and their acres planted to each on their continuous corn acreage and separately on their first-year corn acreage. Conventional corn acres were assumed to be the remainder corn acres after all reported traited corn acres are subtracted from the grower's reported total corn acres. Table 1 presents the average shares of total corn acres planted by the survey respondents to each brand/trait combination by agronomic zone in 2009. Survey respondents reported that Monsanto's YieldGard VT

Table 2. Estimated yield gain from switching to SmartStax.

	Agronomic zone (bu/ac)		
Brand/trait combination	**Western**	**Central**	**Eastern**
YieldGard VT triple [a]	7	6	7
Roundup Ready [b]	16	16	16
Herculex Xtra [c]	8	8	8
YieldGard corn borer Roundup Ready [d]	11	11	11
Herculex corn borer Roundup Ready [e]	11	11	11
Agrisure 3000 GT [f]	8	8	8
Other traited brands [g]	11	11	11

Source: Monsanto field trials and experts
[a] Above-ground and below-ground insect resistance traits and single herbicide tolerance trait
[b] Single herbicide tolerance trait
[c] Above-ground and below-ground insect resistance traits and single herbicide tolerance trait
[d] Above-ground insect resistance trait and single herbicide tolerance trait
[e] Above-ground insect resistance trait and single herbicide tolerance trait
[f] Above-ground and below-ground insect resistance traits and single herbicide tolerance trait
[g] Various single- and double-traited hybrids

Table 3. Proportion of acres currently in brand/trait combination projected to switch to SmartStax.

	Agronomic zone		
Brand/trait combination	**Western**	**Central**	**Eastern**
YieldGard VT triple [a]	1.00	1.00	1.00
Roundup Ready [b]	0.75	0.75	0.75
Herculex Xtra [c]	0.20	0.20	0.20
YieldGard corn borer Roundup Ready [d]	1.00	1.00	1.00
Herculex corn borer Roundup Ready [e]	0.10	0.10	0.10
Agrisure 3000 GT [f]	0.00	0.00	0.00
Other traited brands [g]	0.40	0.40	0.40
Non-traited	0.00	0.00	0.00

Source: Survey data and Monsanto experts.
[a] Above-ground and below-ground insect resistance traits and single herbicide tolerance trait
[b] Single herbicide tolerance trait
[c] Above-ground and below-ground insect resistance traits and single herbicide tolerance trait
[d] Above-ground insect resistance trait and single herbicide tolerance trait
[e] Above-ground insect resistance trait and single herbicide tolerance trait
[f] Above-ground and below-ground insect resistance traits and single herbicide tolerance trait
[g] Various single- and double-traited hybrids

Triple hybrids made up the largest share of 2009 total planted, insect-traited acres in the survey, with approximately one-half the insect-traited acres being planted to these hybrids in the CCB and ECB agronomic zones. These hybrids also represent the largest share of insect-traited acres in the WCB agronomic zone, but the share there is about 10 percentage points smaller than the shares in the other two zones. The brand/trait combination with the second largest share on insect-traited acres varies by agronomic zone, with YieldGard Corn Borer Roundup Ready hybrids taking second place in the WCB agronomic zone (13.8%), and Herculex Xtra coming in second in the CCB (8.2%) and the ECB (13.1%) zones. Single-trait, Roundup Ready corn hybrids made up 15% of planted corn acres in the WCB, 12.2% in the CCB, and 13.2% in the ECB. Non-traited planted corn acres ranged from 10.7% in the CCB to 12.1% in the WCB.

Monsanto and university field trial data from 2005 through 2008 involving 523 experiments (each with multiple observations) along with expert opinion from Monsanto agronomists and the SmartStax pricing lead were used to determine the expected change in yield associated with switching to SmartStax from each brand/trait combination. The estimated average change in yield from switching one acre of a particular brand/trait combination to SmartStax is shown in Table 2. The estimated yield gain when switching from the triple stacks (YieldGard VT Triple and Herculex Xtra) ranges from six bushels per acre for YieldGard VT Triple in the CCB to eight bushels per acre for Herculex Xtra and Agrisure 3000 GT in all agronomic zones. The yield gain for the double stacks (YieldGard Corn Borer/ Roundup Ready and Herculex Corn Borer/ Roundup Ready) and other traited brands is expected to be 11 bushels per acre, and the yield gain from switching the Roundup Ready hybrids to SmartStax is projected to be 16 bushels per acre across all agronomic zones. Growers planting the non-traited hybrids are not expected to switch to SmartStax, so their assumed yield gain is zero. The price of corn is taken to be the planting-time base price offered by the USDA Risk Management Agency for the 2009 crop insurance revenue products, which is $4.04 per bushel. The corn price is varied in the sensitivity analysis at the end of this section.

Table 3 shows the projected share of each brand/trait combination that is expected to switch to SmartStax in the first year of full commercialization (i.e., with no supply constraints). It is expected that all acres of both the triple stack and double stack YieldGard corn hybrids

Table 4. Insect control costs by target insect, rotation, and agronomic zone ($/acre).

	Agronomic zone								
	Western			Central			Eastern		
Rotation/target insect	N	Mean	Std error	N	Mean	Std error	N	Mean	Std error
				Continuous corn acres					
Corn rootworm	13	13.73	1.54	56	16.7259	1.4022	25	15.34	1.48
Black and/or western bean cutworm	18	15.86	1.63	20	15.3000	1.9562	13	11.69	1.78
Fall armyworm/corn earworm	9	14.67	1.72	10	19.0000	1.7512	8	11.38	1.91
				First year corn					
Corn rootworm	7	10.29	2.56	42	13.4917	1.4456	36	14.75	1.23
Black and/or western bean cutworm	20	13.05	1.48	21	12.0000	1.6847	15	13.67	1.89
Fall armyworm/corn earworm	7	12.86	1.64	11	18.6364	1.3769	8	15.00	1.16

Source: Survey data.

will switch to SmartStax because these traited hybrids are scheduled to be phased out by the time full commercialization of SmartStax hybrids is achieved (Monsanto Corn Pricing Lead, personal communication, August 2009). The Dow hybrids, Herculex Xtra and Herculex CBRR, are projected to undergo a switch to SmartStax by 20% and 10%, respectively—much less than the YieldGard hybrids. This lower projected adoption of SmartStax by Herculex users results from the fact that Dow is assumed to be planning to keep their triple and double stack products on the market throughout the full commercialization of SmartStax. Seventy-five percent of Roundup Ready acres are expected to switch to SmartStax. This high percentage is due to the smaller refuge requirement (5%) for SmartStax compared to other insect-traited hybrids (20%). Forty percent of other insect-traited acres are expected to be switched to SmartStax by 2014, while non-traited acres are not expected to be converted to SmartStax because we assume the growers planting them are either organic growers, are planting non-traited hybrids to obtain a premium for doing so, or they just do not care to adopt any traited hybrids. As a result of calculations using data from Tables 1-3 and Equation 2, the expected *increased gross revenue* after full commercialization of SmartStax is estimated to be $26.10 per acre in the WCB, $23.07 in the CCB, and $23.47 in the ECB.

Reduced Costs. Reduced costs in this study are the insect-control cost savings, if any, brought about by changing acreage from current brand/trait combinations to SmartStax hybrids. These per acre cost savings in zone z are determined as

$$\downarrow\Delta C_z^{insectcontrol} = \sum_{g=1}^{G}\sum_{r=1}^{R} w_{rgz} \sum_{i=1}^{I}(C_{irgz}^{insectcontrol} \bullet w_{irgz}^{spray} \bullet \Theta_{irgz}^{spray}) \quad (3)$$

where

$\downarrow\Delta C_z^{insectcontrol}$ is the insect-control cost per acre savings in zone z,

w_{rgz} is the proportion of acres in rotation r planted by grower g in zone z (i.e., A_{rgz}/A_{gz}), where the numerator is number of acres in rotation r planted by grower g in zone z and the denominator is grower g's total planted acres in zone z,

$C_{irgz}^{insectcontrol}$ is the per-acre insect-control cost for insect i ($i = 1$ if corn rootworm, $i = 2$ if black and/or Western bean cutworm, or $i = 3$ for fall armyworm and/or corn earworm) in rotation r ($r = 1$ if continuous corn or $r = 2$ for first year corn) for grower g in zone z,

w_{irgz}^{spray} is the proportion of acres that are typically sprayed for insect i in rotation r by grower g in zone z (i.e., A_{irgz}^{spray}/A_{rgz}), where the numerator is the number of acres sprayed for insect i in rotation r by grower g in zone z and the denominator is the number of acres planted in rotation r by grower g in zone z, and

Θ_{irgz}^{spray} is the probability that insect i in rotation r will be treated in any one year by grower g in zone z.

The survey respondents were asked to estimate their per-acre insecticide-control costs—including the cost of

Table 5. Typical proportion of acres treated by target insect, rotation, and agronomic zone.

	Agronomic zone								
	Western			Central			Eastern		
Rotation/target insect	**N**	**Mean**	**Std error**	**N**	**Mean**	**Std error**	**N**	**Mean**	**Std error**
				Continuous corn					
Corn rootworm	66	0.130	0.037	157	0.180	0.026	73	0.178	0.035
Black and/or western bean cutworm	92	0.067	0.026	222	0.105	0.018	118	0.146	0.025
Fall armyworm/corn earworm	20	0.210	0.063	25	0.346	0.079	13	0.200	0.079
				First year corn					
Corn rootworm	21	0.271	0.077	26	0.278	0.062	17	0.307	0.091
Black and/or western bean cutworm	10	0.520	0.127	13	0.455	0.118	8	0.159	0.091
Fall armyworm/corn earworm	8	0.325	0.151	14	0.424	0.102	6	0.433	0.161

Source: Survey data.

the insecticide(s) and the application cost—for controlling corn rootworm, black and/or western bean cutworm, and fall armyworm and/or corn earworm on both their continuous corn acres and their first-year corn acres. The average insect-control costs are presented in Table 4 as reported by survey respondents by agronomic zone and rotation.[4] In all cases, the cost of controlling corn rootworm is reported to be higher in continuous corn rotation than the control costs in first-year corn rotations. This cost difference ranges from $0.59 per acre in the ECB to $3.44 per acre in the CCB. In the WCB, CCB, and ECB for continuous corn, fall armyworm/corn earworm control is most expensive; however, corn rootworm control is most expensive in first-year corn in the ECB. Control costs range from $10.29 per acre for corn rootworm in first-year corn in the WCB to $19.00 per acre for fall armyworm/corn earworm in the CCB.

Table 5 contains the reported typical proportions of acres treated for each insect type by agronomic zone and rotation. By far, areas threatened by the fall armyworm/corn earworm pest complex have the highest proportion of acres treated except for cutworm control in the ECB. The proportion of acres treated for corn rootworm ranges from 0.067 in the WCB in first-year corn to 0.178 in the ECB in continuous corn. The proportion of acres treated for black and/or western bean cutworm ranges from 0.200 in the ECB on continuous corn acres to 0.307 on first-year corn acres in the ECB. For the fall armyworm/corn earworm complex, the proportion of acres treated ranges from a low of 0.159 in the ECB on continuous corn to a high of 0.520 in the WCB on continuous corn.

Respondents were asked to estimate the number of years out of five that they typically treat for each insect type on continuous and first-year acres. The relative frequencies are reported in Table 6. Corn rootworm is treated more frequently than the other insects in continuous corn in comparison to first-year corn in all agronomic zones. Treatment for the cutworm complex and the fall armyworm/corn earworm complex are reported to be much less frequent, with cutworm being treated more frequently than the fall armyworm/corn earworm complex.

Insect control costs, weighted by the typical proportion of acres treated and the frequency of treatment (the expression in parentheses in Equation 3), are shown in Table 7. These are the *reduced costs* from switching to SmartStax and are estimated to be $11.03 per acre in the WCB, $8.86 per acre in the CCB, and $5.68 per acre in the ECB. Adding the increased gross revenue to the reduced costs gives the *net addition to gross revenue*, which is $37.13 per acre in the WCB, $31.93 per acre in the CCB, and $29.15 per acre in the ECB.

Increased Cost. The expected increased cost from switching to SmartStax is the additional trait cost the

4. *Numbers of observations are relatively low for all insect-control costs in the WCB and for the fall armyworm/corn earworm control costs across all rotations and agronomic zones. However, all means are statistically significant at the 5% level.*

Table 6. Probability of controlling target insect in any one year by rotation and zone.

	Agronomic zone								
	Western			Central			Eastern		
Rotation/target insect	N	Mean	Std error	N	Mean	Std error	N	Mean	Std error
				Continuous corn					
Corn rootworm	65	0.292	0.048	159	0.442	0.033	73	0.458	0.050
Black and/or western bean cutworm	67	0.119	0.029	158	0.087	0.019	73	0.066	0.020
Fall armyworm/corn earworm	67	0.072	0.027	160	0.039	0.013	73	0.036	0.018
				First year corn					
Corn rootworm	92	0.150	0.031	223	0.239	0.025	119	0.390	0.039
Black and/or western bean cutworm	93	0.084	0.020	223	0.048	0.010	118	0.059	0.016
Fall armyworm/corn earworm	93	0.024	0.014	224	0.021	0.008	119	0.005	0.004

Source: Survey data.

Table 7. Insecticide application costs saved (weighted by proportion of acres treated and probability of treating; $/acre).

	Agronomic zone								
	Western			Central			Eastern		
Target insect	N	Mean	Std error	N	Mean	Std error	N	Mean	Std error
Corn rootworm	14	6.47	1.20	74	4.06	0.46	40	3.61	0.45
Black and/or western bean cutworm	30	1.74	0.69	34	1.71	0.68	20	1.50	0.55
Fall armyworm/corn earworm	12	2.82	1.42	15	3.09	1.29	10	0.57	0.42
Total insecticide control costs saved		11.03			8.86			5.68	

Note: Costs are weighted by continuous corn acre costs and first year corn acre costs.
Source: Survey data.

grower will pay if he/she switches brand/trait combination b to SmartStax in zone z.[5] That is,

$$\uparrow\Delta C_z^{trait} = \sum_{z=1}^{Z} \Theta_z^{(b\to SS)} \sum_{g=1}^{G}\sum_{b=1}^{B} \Delta C_{gbz}^{s} \bullet w_{gbz}, \qquad (4)$$

where

$\uparrow\Delta C_z^{trait}$ is the increased cost per acre of switching to SmartStax in zone z,

$\Theta_z^{(b\to SS)}$ is the estimated proportion Θ of acres switching from brand/trait combination b to SmartStax (SS) in zone z,

ΔC_{gbz}^{s} is the difference between SmartStax and the current brand/trait price per acre for brand/trait combination b in zone z, and

w_{gbz} is the proportion of acres grower g has planted to brand/trait combination b, (i.e., $w_{gbz} = (A_{gbz} / A_{gz}^{b}) = \left[A_{gbz} / \sum_{b=1}^{B} A_{gbz}\right]$), where the numerator is grower g's acres planted to brand/trait combination b in zone z and the denominator is grower g's total planted brand/trait combination corn acres in zone z.

The typical projected differences in seed prices for each brand/trait combination relative to the expected price of SmartStax seed in each agronomic zone were based on Monsanto market research, combined with the expert opinion of Monsanto's Corn Pricing Lead (per-

5. *Note that seed-cost changes can differ from trait-cost changes, depending on the cost of the germplasm the grower chooses to plant.*

Table 8. Incremental cost of brand/trait combination relative to projected SmartStax seed cost ($/acre).

	Agronomic zone		
Brand/trait combination	Western	Central	Eastern
YieldGard VT triple	23.75	21.67	25.00
Roundup Ready	44.58	56.25	53.33
Herculex Xtra	26.25	29.16	33.33
YieldGard corn borer/ Roundup Ready	36.25	34.17	37.50
Herculex corn borer/ Roundup Ready	40.42	36.67	40.83
Agrisure 3000 GT	n/a	n/a	n/a
Other traited brands	38.34	35.42	39.17
Non-traited	n/a	n/a	n/a

Source: Monsanto Corn Pricing Lead (personal communication, August 2009)

Note. n/a means not applicable because no acres of brand/trait combination are expected to be replaced by SmartStax.

sonal communication, August 2009) and are shown in Table 8. Using the information from Tables 1, 3, and 8 and Equation 4, the *increased costs* are calculated to be $20.69 per acre for the WCB zone, $19.96 per acre for the CCB zone, and $20.45 per acre for the ECB zone. These increased costs—because they are the additional cost of the SmartStax traits relative to the traits growers are planting now—also measure the increased gross revenue to the innovators but do not reflect their R&D costs or the cost of producing the seed.

Reduced Revenue. No reductions in revenue are expected from switching to SmartStax. One component of reduced revenue could be the foregone price premium available in the marketplace for either conventional or organic field corn. However, we assume here that growers of conventional corn will not switch to SmartStax and, therefore, any price premium for conventional or organic field corn is not relevant. Since there is no reduced revenue, increased cost is equal to the net addition to cost component of the partial budget. Based on the data and assumptions described above, the net change in profit from the introduction of SmartStax in the first year of full commercialization is estimated to average $16.44 per acre for the WCB, $11.98 per acre for the CCB, and $8.70 per acre in the ECB.

Net Addition to Profit

The product of total planted corn acres in each agronomic zone in 2008 (USDA NASS, 2009) and the net change in profit estimates above gives estimates of the total net additions to profit (total on-farm benefit) of $128.94 million per year in the WCB, $205.61 million per year in the CCB, and $65.43 million per year in the ECB, for a grand total anticipated pecuniary benefit per year across all agronomic zones of $399.98 million. This estimate may be conservative for several reasons. First, we assume that none of the acres currently planted to Agrisure 3000 GT (triple-stack hybrids sold by Syngenta) or conventional hybrids will switch to SmartStax. Second, we assume that Dow will continue to market their double- and triple-stack hybrids and that a significant percentage of growers will continue to use them. And third, we assume that all producers who currently do not plant any insect-traited acres will not adopt SmartStax. The estimate could turn out to be an overstatement if a series of unusually good growing conditions exists throughout much of the Corn Belt in a particular period, so that the yield protection offered by the SmartStax trait combination is not fully utilized, if the incremental cost of the SmartStax trait combination is higher than the projections in Table 8, or if the price of corn falls below $4.04/bushel.

Sensitivity Analysis

Results of varying corn prices and the trait price differences are presented in Table 9. The corn price varies from $3.00 per bushel to $5.00 per bushel, and the SmartStax trait price differences were increased by 10% and lowered by 10% for each trait/brand combination compared with the projected price differences in the base case. The first thing to notice about Table 9 is that the anticipated change in profit per acre remains positive throughout so that even if corn prices are $3.00 per bushel and the SmartStax hybrids are priced 10% higher than projected, the technology remains profitable in all agronomic zones, albeit marginally so in the ECB ($0.62/acre). As global incomes begin to rise again as the global recession eases and the demand for protein (meats) and fuel (gasoline blended with ethanol)—and therefore corn—rebounds, the change in profit per acre for SmartStax hybrids is projected to increase to $22.64 in the WCB, $17.46 in the CCB, and $14.28 in the ECB, given currently projected trait pricing and assuming the change in demand for corn increases the average corn price to $5.00 per bushel.

The interval elasticities of the percent change in the net addition to profit from a 1% change in corn price are 1.43 in the WCB, 1.64 in the CCB, and 2.03 in the ECB. The interval elasticities with respect to a 1% change in trait price differences are lower, at 1.12 in the WCB, 1.43 in the CCB, and 1.90 in the ECB. Each elasticity

Table 9. Sensitivity analysis: Per-acre net addition to profit by corn price and trait price.

	Agronomic zone								
	Western			Central			Eastern		
	Corn price ($/acre)								
Trait price differences	3	4.04	5.00	3	4.04	5.00	3	4.04	5.00
	$/acre								
10% lower	11.79	18.51	24.71	8.03	13.97	19.46	4.71	10.75	16.33
Estimated	9.72	16.44	22.64	6.04	11.98	17.46	2.66	8.70	14.28
10% higher	7.65	14.37	20.57	4.04	9.98	15.46	0.62	6.66	12.24

increases moving eastward across the Corn Belt, implying that the net addition to profit is most sensitive to corn price changes and trait pricing changes as one moves eastward in the Corn Belt.

Change in Non-Pecuniary Benefits

Non-pecuniary characteristics are those characteristics embedded in a good for which no individual markets exist. Therefore, we must elicit the values of these characteristics some other way. In this study, we chose to ask producers to place values on these characteristics in a stated-preference format. Stated-preference techniques have been used to estimate these types of values for some time and have become a widely accepted elicitation format. We use a random-rotated, open-ended question format. This format has been shown to result in values that are not significantly different from values elicited from the dichotomous choice format (Loomis, Brown, Lucero, & Peterson, 1997). The open-ended question format also has been shown to be acceptable or preferred to other question formats if respondents are familiar with the characteristics or goods they are valuing or if the distribution of the reported values is important to the study objectives (Champ, Boyle, & Brown, 2003). Both criteria are met in this study.

Biotech corn insect traits have been commercially available since 1996 and have been adopted extensively across the Corn Belt.[6] Further to this point, all respondents in the survey were required to have planted at least some insect-traited corn hybrids on their farm in 2009 and so should be familiar with their performance and their non-pecuniary characteristics. Open-ended questions result in a continuum of responses and so response distributions can be characterized easily. For example, in our study the distribution of the responses to each val-

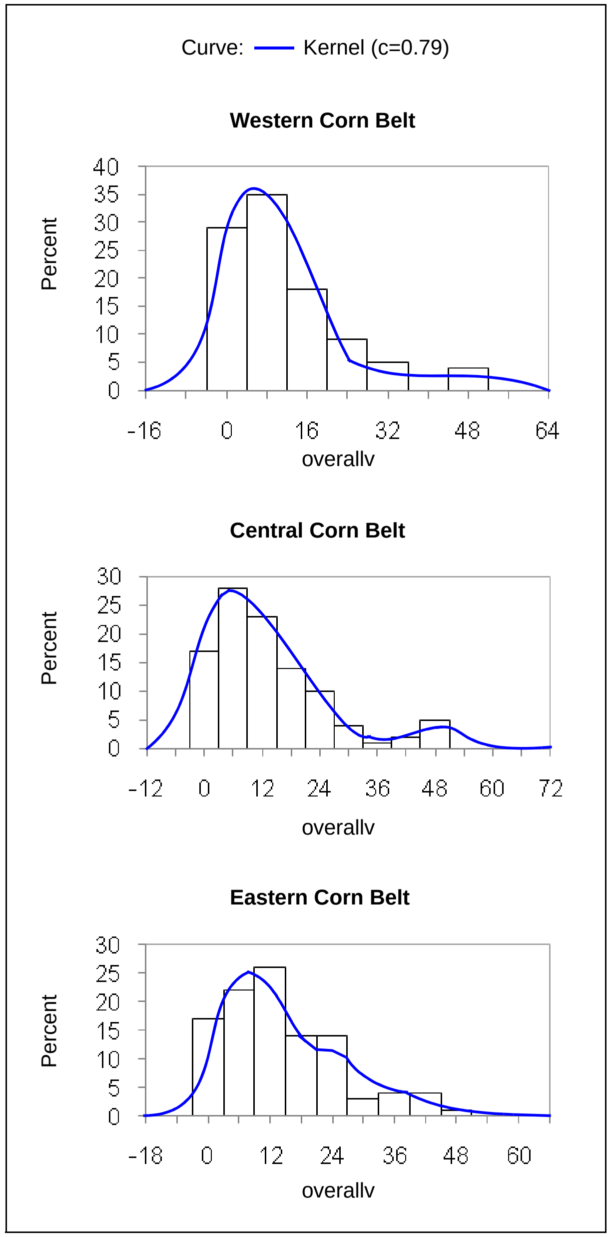

Figure 2. Empirical probability functions of overall non-pecuniary value by zone.

6. *In 2008, insect-traited hybrids were planted on 63% of all US corn acres in 2009, on 65% of corn acres in Illinois, and on 69% of corn acres in Iowa (USDA NASS, 2009).*

Table 10. Non-pecuniary values and descriptive statistics ($/acre/year).

	Agronomic zone											
	Western				Central				Eastern			
Characteristic/insect or non-insect acres	N	Mean	Median	Std error	N	Mean	Median	Std error	N	Mean	Median	Std error
					Insect-traited acres							
Operator/worker safety	96	3.27	0.00	0.80	235	3.09	0.00	0.40	116	4.24	0.00	0.86
Environment safety	93	2.51	0.00	0.57	232	3.65	0.00	0.50	119	4.51	0.00	0.86
Convenience	92	5.76	2.00	0.95	230	6.98	5.00	0.63	109	6.21	3.00	0.77
Risk reduction	94	6.50	2.50	1.07	220	7.51	5.00	0.69	117	8.17	5.00	0.92
Two herbicide options	96	3.89	0.00	0.92	232	3.81	0.00	0.54	122	4.61	0.00	0.72
Sum of the charactistic values	102	20.21	10.00	2.90	244	23.42	15.00	1.95	126	25.58	15.00	2.93
Overall non-pecuniary value	81	11.46	10.00	1.29	207	13.36	10.00	0.85	105	14.04	10.00	1.22
Ratio of sum to overall	64	1.69	1.55	0.11	183	1.74	1.50	0.07	92	1.86	1.67	0.12
					Non-insect-traited acres							
Operator/worker safety	94	2.47	0.00	0.60	230	4.61	0.00	0.54	114	4.41	0.00	0.74
Environment safety	98	3.11	0.00	0.79	231	4.20	0.00	0.62	115	3.70	0.00	0.63
Convenience	92	6.22	1.75	1.11	228	6.84	3.50	0.69	109	6.65	3.50	0.90
Risk reduction	90	6.56	2.00	1.08	224	7.56	5.00	0.65	110	8.15	5.00	1.00
Two herbicide options	99	3.02	0.00	0.73	231	3.61	0.00	0.50	117	4.20	0.00	0.71
Sum of the charactistic values	103	19.40	10.00	2.87	246	24.87	15.00	2.05	125	24.32	15.00	2.59
Overall non-pecuniary value	84	12.76	10.00	1.30	207	14.05	10.00	0.89	103	13.39	10.00	1.12
Ratio of sum to overall	71	1.49	1.17	0.12	188	1.79	1.63	0.08	90	1.80	1.63	0.11

Source: Survey data.

uation question and to the overall non-pecuniary valuation question is positively skewed (see Figure 2 for the estimated probability density function [pdf] for the overall valuation question, for example), which implies that the median is the best measure of central tendency to use in describing the distribution. We randomly rotate the order of the non-pecuniary characteristics questions and also the order of the set of questions that apply to the insect-treated and non-insect-treated acres in order to eliminate any order effects on the stated values (Payne, Schkade, Desvousges, & Aultman, 2000).

The non-pecuniary characteristics of SmartStax hybrids include operator and worker safety, environmental improvement, convenience, yield risk reduction, and the option of being able to use two herbicides to control weeds by spraying over the top of the growing plants. They are similar qualitatively to those of other biotech innovations that have been valued in the past (e.g., Alston, Hyde, Marra, & Mitchell, 2003; Marra & Piggott, 2006; Piggott & Marra, 2007) except for the option of using two different herbicides to control weeds over the top. Table 10 shows descriptive statistics of the response distributions of the valuation questions asked in the survey by agronomic zone and by whether the responses refer to insect-traited corn acres or non-insect-treated corn acres. Because the distribution of each characteristic considered separately and the distribution of the package of characteristics considered as a whole are negatively skewed, we consider the median of each as the more informative indicator of the distribution's central tendency.

Convenience and yield risk reduction are the most highly valued characteristics in the set of non-pecuniary characteristics. As expected, the median values of these characteristics are highest in the CCB on insect-traited acres with each median value equal to $5.00 per acre per year. The median convenience value ranges from $1.75 per acre per year on non-insect-traited acres in the WCB to $5.00 per acre in the CCB on insect-traited acres. The value of yield risk reduction ranges from $2.00 per acre per year in the WCB on non-insect-traited acres to $5.00 per acre in the CCB and ECB regardless of whether the comparison of SmartStax to currently planted hybrids is on insect-traited acres or non-insect-traited acres.

Looking at the values of the separate characteristics gives a comparison of the *relative* values, but does not consider any possible *interactions* among the characteristics in the respondents' preference functions (Johnston, Swallow, Allen, & Smith, 2002). Therefore, we use the respondents' reported overall value in our calculation of the non-pecuniary benefits because it should reflect any potential interactions among the separate characteristics. The median value of the package of characteristics is consistently $10.00 per acre per year across all zones and whether valued on insect-traited or non-insect-traited acres. Therefore, the total value by zone of the non-pecuniary characteristics is equal to $79 million in the WCB, $184 million in the CCB, and $98 million in the ECB for an estimated total value of $361 million per year. The sum of the anticipated net pecuniary and non-pecuniary benefits of SmartStax when compared with currently planted hybrids is estimated to be $760.98 million per year in the Corn Belt.

Conclusion

This study provides a comprehensive and detailed estimate of the anticipated net increase in value to adopters of SmartStax hybrids in 2014, the first full year of commercialization. The estimates are based on grower survey data, field trial data, and expert opinion. The net addition to profit for the SmartStax hybrids totals $399.98 million per year. When combined with the anticipated additional non-pecuniary value of SmartStax of $361 million per year, the total anticipated value of SmartStax is estimated to be $760.98 million per year in the US Corn Belt.

After extensive underwriting and actuarial reviews, the Federal Crop Insurance Corporation (FCIC) Board of Directors approved the Biotech Yield Endorsement (BYE) for the federal crop insurance program on September 12, 2007, for implementation in the 2008 crop year. This public insurance program was revolutionary in that, for the first time, the US federal government formally recognized the yield risk-reducing and yield-increasing benefits of biotechnology and further quantified these benefits in terms of reduced crop insurance premium rates. In its first two years, the program has saved US corn farmers and taxpayers in excess of $100 million through lower premium rates and reduced crop insurance subsidies.

Tangible evidence of the benefits associated with reduced yield risks and increased corn yields is obvious in the BYE crop insurance discounts and the resultant benefits that have accrued to US taxpayers and farmers. SmartStax will further enhance these benefits because the technology will be available on additional acres due to the reduced refuge, thereby providing the benefits of reduced risk across a wider portion of the growers' acreage. This is true even if the insurance premium discounts are not increased to account for this lower risk because insurance premiums and terms of coverage are adjusted over time to reflect higher yields and lower production risk. In the immediate term, crop insurance providers and taxpayers will enjoy benefits in that indemnity payments should fall in response to adoption of SmartStax. In many areas, the crop insurance program has claims that exceed indemnities and any measures such as adoption of biotechnology that reduce risk will lower expected indemnities and improve the actuarial performance of the program.

An additional, complementary value of SmartStax hybrids is the timing of their commercialization and the recent announcement by the Risk Management Agency on November 4, 2008, of a Whole-Farm and Enterprise-Unit Pilot Program.[7] This new pilot program offers producers who insure at the whole-farm or enterprise unit level an increase in premium subsidies. A whole-farm unit insures all of a grower's acres of at least two insurable crops in a county. An enterprise unit is comprised of all of a grower's acres of one insurable crop in a county. This new program, combined with SmartStax's anticipated increased homogeneity in crop health, should lead to more grower confidence to insure their corn on a whole-farm or enterprise unit basis, rather than on a smaller unit basis, because of a lower likelihood of spot losses. Insuring these SmartStax acres under this unit structure will mean further savings to the SmartStax adopter because of this program's premium discounts and the reduction in producer paid premiums.

It is clear that the additional value produced by SmartStax hybrids will be substantial. Sensitivity analysis shows that the additional profit from SmartStax is anticipated to remain significantly positive under a range of corn prices and relative SmartStax seed prices. SmartStax is expected to provide additional value for adopting growers, innovators, the Risk Management

7. *http://www.rma.usda.gov/news/2008/11/1104wholefarm.html*

Agency, and taxpayers. Further study of the ex-post value of SmartStax hybrids should be made to confirm the projections from this study.

References

Alston, J.M., Hyde, J., Marra, M.C., & Mitchell, P.D. (2003). An ex-ante analysis of the benefits from the adoption of corn rootworm resistant, transgenic corn technology. *AgBioForum*, *5*(3), 71-84. Available on the World Wide Web: http://www.agbioforum.org.

Champ, P.A., Boyle, K.J., & Brown, T.C. (Eds.). (2003). *A primer on nonmarket valuation*. Boston, MA: Kluwer Academic Press.

Johnston, R.J., Swallow, S.K., Allen, C.W., & Smith, L.A. (2002). Designing multidimensional environmental programs: Assessing tradeoffs and substitution in watershed management plans. *Water Resources Research*, *38*(7), 1-13.

Loomis, J., Brown, T., Lucero, B., & Peterson, G. (1997). Evaluating the validity of the dichotomous choice question format in contingent valuation. *Environmental and Resource Economics*, *10*, 109-123.

Marra, M.C., & Piggott, N.E. (2006). The value of non-pecuniary characteristics of crop biotechnologies: A new look at the evidence. In R. Just, J. Alston, & D. Zilberman (Eds.), *Regulating agricultural biotechnology: Economics and policy* (Chapter 8, pp. 145-178). New York: Springer Publishers.

Payne, J., Schkade, D., Desvousges, W., & Aultman, C. (2000). Valuation of multiple environmental programs. *Journal of Risk and Uncertainty*, *21*(1), 95-115.

Piggott, N.E., & Marra, M.C. (2007). The net gain to cotton farmers of a natural refuge plan for Bollgard II® cotton. *AgBioforum*, *10*(1), 1-10. Available on the World Wide Web: http://www.agbioforum.org.

PR Newswire-First Call (2009, July 20). *Monsanto, Dow AgroSciences complete U.S. and Canadian regulatory authorizations for SmartStax corn; Plans set to launch seed platform on 3 million- to 4 million-plus acres* (Press Release). New York: Author. Available on the World Wide Web: http://monsanto.mediaroom.com/index.php?s=43&item=729.

Swinkels, J.M., Hogeveen, H., & Zadoks, R.N. (2005). A partial budget model to estimate economic benefits of lactational treatment of subclinical *Staphylococcus aureus* mastitis. *Journal of Dairy Science*, *88*, 4273-4287.

Tigner, R. (2006). *Partial budgeting: A tool to analyze farm business changes* (Ag Decision Maker File C1-50). Ames: Iowa State University Extension. Available on the World Wide Web: http://www.extension.iastate.edu/agdm/wholefarm/html/c1-50.html.

US Department of Agriculture, National Agricultural Statistical Services (USDA NASS). (2009, June 30). *Acreage*. Available on the World Wide Web: http://jan.mannlib.cornell.edu/usda/current/Acre/Acre-06-30-2009.pdf.

Acknowledgements

This study was funded by Monsanto Company and the North Carolina Agricultural Experiment Station. We would like to acknowledge the extremely helpful input of Brian Naber, Holly Butka, Bob Jasper, and Tim Hennessy during the course of this study. We take responsibility for all remaining errors.