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Does On-Farm Quality Assurance Pay? A Cost-Benefit Analysis of the *Grainsafe* Program

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Since the introduction of genetically modified (GM) crops, the commodity grain system has been under pressure to segregate GM and non-GM crops. Starting at the level of the grain handler, members of the grain supply chain have successfully used quality assurance and identity preservation programs to segregate non GM crops. Producers delivering high-value, identity-preserved crops have become interested in implementing these quality management systems at the farm level. We conduct a cost-benefit analysis that shows that quality assurance program may be profitable for producers, depending on their farm size and equipment management strategy.

Key Words: @Risk, cost-benefit analysis, identity preservation, on-farm quality assurance

JEL Classifications: Q12, Q16

Trade of agricultural products has been based on the commodity system. With the introduction of genetically modified (GM) crops in 1996, the grain handling system has been under pressure to keep GM crops segregated from non-GM crops (Maier; Phillips). Currently, Europe and Japan have restrictions on the importation of GM crops, and several major U.S. food companies have discontinued the use of GM ingredients in their products (EUREP). The U.S. grain handling system learned that its efforts to segregate GM and non-GM crops were not successful when the food supply chain was found to be contaminated with GM corn not approved for human consumption (e.g., StarLink). While StarLink was supposed to be handled by an identity preservation (IP) program to segregate it from the food market, there was a failure by the industry to follow the required steps (Environmental Protection Agency [EPA]). In response to the StarLink contamination and general concerns about food quality, many companies have introduced programs to assure the quality of the crop and preserve its identity in order to guarantee the segregation of non-GM crops destined for Europe, Japan, or food companies (Hobbs, Kerr, and Phillips,). Quality assurance (QA) and identity preservation (IP) programs, if they had been implemented diligently, would likely have prevented the StarLink contamination of the food supply chain, which was estimated to cost the supply chain $1 billion (EPA).

While much of the food-grade corn supply chain has implemented QA and IP programs, most of these programs start at the level of the first handler (Anderson; Hurburgh 2004;

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Stevenson; Voigt). For instance, National Starch has implemented the TrueTrace™ program, and Cargill has implemented the Innovasure™ program, to name just a few of the QA and IP programs for food-grade corn. Currently, producers are becoming interested in using these programs to gain an advantage in delivering value-added grains. However, any QA or IP program, like the *Grainsafe* On-Farm Quality Assurance Program that guarantees quality and segregation, will require additional handling efforts and will thus create additional costs. In addition to the direct costs, QA or IP programs may add other indirect costs, such as yield penalties due to planting or harvest delays introduced by the additional time and labor required to clean equipment. The main objectives of this paper were 1) to develop a cost analysis model for the production of white corn with and without the *Grainsafe* program for two different equipment management strategies and three farm sizes, 2) to quantify the additional costs associated with the *Grainsafe* program and compare them with the costs of conventional white corn production, and 3) to quantify the producer benefits associated with the *Grainsafe* program.

The *Grainsafe* Program

Grainsafe, developed by the Purdue University Post-Harvest Education and Research Center, is a quality assurance program integrated with good grain production practices and good grain handling practices. The *Grainsafe* program adds additional steps to conventional grain production practices and requires producers to keep records of their farming practices in a prearranged format to ensure high end-use quality and to preserve the identity of the crop leaving the farm. These requirements will create additional costs: labor costs due to training, record keeping and management, field sampling and strict clean-out practices required by the program, and the costs for laboratory testing. Operations planning and equipment management strategies have additional importance in the adoption of QA and IP programs like *Grainsafe*, as they prevent contamination and reduce the labor costs. The first in field–first out of field, also called first-in first-out (FIFO), strategy requires the introduction of the IP grain into the production system before commodity grains (Nielsen and Maier). In other words, IP grains should be planted, harvested, dried, handled, and shipped before commodity grains, when all equipment and facilities of the system were clean at the start of the season. The FIFO equipment management strategy prevents the carryover of commodity grain and avoids in-season clean-out (ISCO) of equipment and facilities.

There are three potential benefits associated with adopting the *Grainsafe* program. First, *Grainsafe* may increase the overall quality of delivered grain. Therefore, producers will avoid discounts for delivering grain below the quality standards to buyers and may capture previously unavailable premiums. Producers who regularly face discounts because of low quality will benefit the most from adopting *Grainsafe*. Second, *Grainsafe* will reduce the likelihood that the grain fails to meet the quality standards. Therefore, quality premiums for grains produced under *Grainsafe* will effectively increase. Third, *Grainsafe* will allow the producer to maintain a reputation for delivering high-quality grains and may increase the likelihood that the producer would be offered additional acreage or bushels under contract for IP and QA grain in the future.

Buyers of the QA and IP grains through the *Grainsafe* program will also benefit. Grain buyers and processors may realize cost advantages in their own processes because of sourcing uniformly higher-quality grain from *Grainsafe* program producers. Most important, buyers and processors may be able to access markets like Japan and the European Union that demand process verification or traceability by linking *Grainsafe* with their QA and traceability protocols.[1]

[1] Currently, the Indiana Crop Improvement Association (ICIA) uses the *Grainsafe* program as a template for certifying seed production programs, adapting the steps to the target quality.

Quantifying the benefits and costs associated with *Grainsafe* generates critical information for producers considering whether to adopt *Grainsafe* for specialty crop production. The cost analysis of *Grainsafe* adoption included the identification of costs associated with the program adoption and comparison of total production costs with those of conventional grain production. The benefit analysis of *Grainsafe* in this paper focused on producers; benefits to buyers and the grain and food industries were outside the scope of this paper.

Literature Review

Several studies have estimated the costs of QA and IP programs. Most of these studies have focused on the additional costs faced by grain elevators. In one of the first studies, Hurburgh (1994) estimated the additional physical costs of segregating soybeans at country elevators based on protein and oil content and found that the additional costs of testing and segregation were $0.02 to $0.03 per bushel. Based on a previous University of Illinois study, Lin, Williams, and Harwood estimated the costs of segregation of non-GM grains and oilseeds along the marketing chain. They estimated that segregation could add about $0.22 per bushel (excluding any premiums to the producer) to the cost of marketing non GM corn from country elevator to export elevator. They also stated that in order to avoid commingling in shipments, grain handlers might require adoption of specific production and harvesting practices from producers.

Kalaitzandonakes, Maltsbarger, and Barnes examined the elevator-level costs of IP. They estimated the costs of identity preserving high-oil corn at the 5% purity level for three case-study elevators with multiple scenarios of bin filling schedules, crop-to-bin assignments, incoming volumes, and other key parameters, using a model they built called Process and Economic Simulation of IP. An additional average IP cost of $0.35 per bushel was reported. The authors also highlighted the importance of hidden or opportunity costs (e.g., grind margin loss, losses from underutilization of capacity) that can occur from adapting current commodity operations to IP. They concluded that added costs were an important obstacle to fast growth in IP markets but that in the long run IP costs would diminish through efforts in organizational learning, technical and institutional innovations, and investments in a more efficient physical infrastructure.

Wilson and Dahl examined the system-level costs of a dual marketing system of GM and identity-preserved non-GM wheat relative to a non-GM system for a vertically integrated grain export chain. They use a stochastic optimization model that maximizes utility of the additional system costs due to testing and rejection by choosing the optimal testing strategy. The model takes into account the costs and risks of adventitious commingling at every stage of the marketing chain, whether growers truthfully report the GM content of the grain, and accuracy of the tests. They find that the total costs of a dual marketing system relative to a non-GM-only system, including direct costs and the risk premium, range from $0.0145 per bushel at a 5% tolerance level to $0.0425 per bushel at a 0.05% tolerance level. The authors conclude that a testing-based system would not be able to meet zero tolerance but would be able to meet a 1% tolerance for GM content.

Two studies have examined on-farm IP costs. First, Gustafson estimated IP costs using the case of certified seed production. Based on two interviews with certified seed producers, he estimated the cost of IP production and marketing to be $4.68 per bushel in addition to the costs normally incurred for commodity production. This cost estimate included direct IP production and economic costs as well as hidden IP costs, such as the amount of time spent for researching opportunities, compiling data, advertising, developing reports, and restricted activities on fields bordering the IP field. Second, Huygen, Veeman, and Lerohl estimated the IP costs at the farm level, primary elevator level, and export elevator level for three supply-chain systems designed to IP non-GM wheat where the GM tolerance levels ranged from 5% to 0.1%. Based on data from 14 seed growers, they

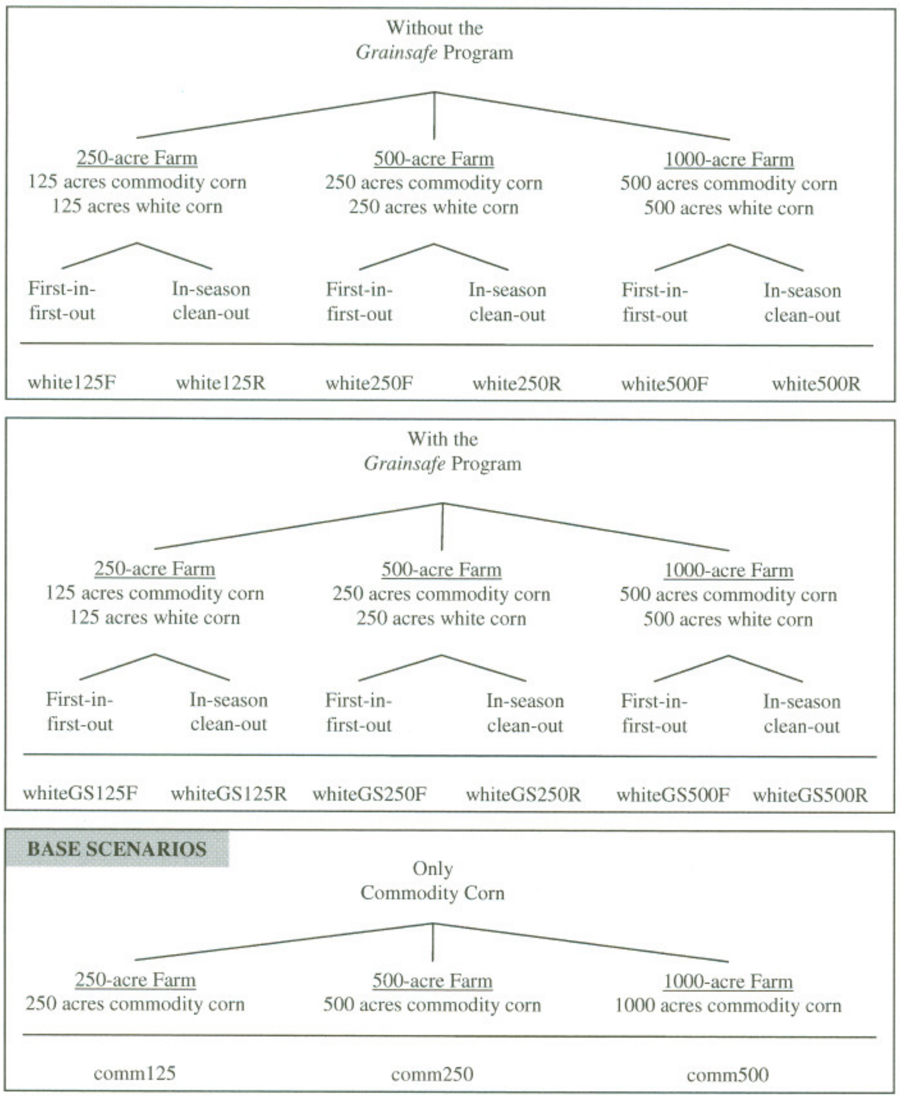

Figure 1. Summary of the Scenarios Evaluated with the Cost Analysis Model

estimated that farm-level IP production costs range from $1.04 per ton ($0.029 per bushel) at the 5% tolerance level to $6.45 per ton ($0.18 per bushel) at the 0.1% tolerance level. This cost estimate included only direct production costs, such as isolating the crop, controlling volunteer plants, and cleaning of the seeder, combine, truck, semi, bin, dryer, and auger.

Cost Analysis

The cost analysis compares two production alternatives to evaluate the costs associated with the *Grainsafe* program: production of food-grade white corn and commodity corn (#2 yellow corn) on the same farm with and without *Grainsafe*. Each alternative had two different operations planning and equipment management strategies (FIFO and ISCO) for three different farm sizes (250, 500, and 1,000 acres). Figure 1 shows the resulting 12 different scenarios.

The base scenarios assumed that the whole farm was planted to commodity corn. Because only one variety of corn was produced in the base scenarios, operations planning and equipment management strategies were not

Table 1. Corn Yields and Prices Used in the Cost Analysis Model

	Commodity Corn		White Corn	
Yield (bu/acre)				
Mean	137.1		131.1	
Standard deviation	13.09		13.51	
Minimum	121.0		115.9	
Maximum	156.0		149.8	
	January	May	January	May
Price ($/bu)				
Mean	2.26	2.32	2.55	2.61
Standard deviation	0.277	0.382	0.353	0.354
Minimum	1.97	1.95	2.16	2.23
Maximum	2.66	3.08	3.21	3.21

relevant. The white corn scenarios assume that half the acres were planted with commodity corn and the remaining half with white corn. For all scenarios, the field size was 125 acres. The cost analysis was only conducted for the white corn acres. For instance, for the 500-acre farm the cost analysis covered only the 250 acres of white corn, which was planted on two 125-acre fields.

The FIFO equipment management strategy assumed that the planting, harvest and handling equipment, and associated facilities were thoroughly cleaned out before the growing season started and that there was absolutely no downtime due to clean-out during the season. In the without-*Grainsafe* FIFO scenarios (white-F), where the equipment and facilities clean-outs occurred before the growing season, clean-out times were assumed to be included in the two-hours-per-acre base labor time. In the with-*Grainsafe* FIFO scenarios (whiteGS-F), additional labor

Table 3. Equipment and Facilities Clean Out Labor Hours in the Cost Analysis Model

	Clean-Out Time (hour per equipment/facility)	
	Conventional	*Grainsafe*
Planter	1.00	1.33
Combine	2.00	12.00
Handling equipment and storage structures	1.00	3.00

was added to the base (shown in Table 3). The ISCO equipment management strategy assumed that the planting, harvesting and handling equipment, and associated facilities were cleaned out one time during the growing and harvest seasons in addition to the pre-season clean-out. In all ISCO scenarios (white-R and whiteGS-R), the additional clean-out times were added to the base.

Two delivery times, in January and in May, were chosen to evaluate the costs for different storage periods and different corn prices at the time of delivery. Corn was assumed to be stored on farm and delivered to the buyer at 15% moisture content in January and at 14% moisture content in May. The cost analysis model included both variable and fixed costs of crop production. The assumption was that producers already owned the required farm equipment, machinery, storage, and other facilities to produce, handle, and store white and commodity corn in the same growing season; that is, they did not need to invest into new equipment, machinery, and so on.

The total production costs were simulated using @Risk to conduct a Monte Carlo analysis with 1,000 iterations for the 12 scenarios. The stochastic variables in the model were corn prices and yields, which were

Table 2. Correlation Coefficients between Corn Yield and Price Used in the Simulation of the Cost Analysis Model

	Commodity Corn Price			White Corn Price		
	October	January	May	October	January	May
Commodity corn yield	−0.689	−0.568	−0.136	—	—	—
White corn yield	—	—	—	−0.672	−0.524	−0.165

assumed to be normally distributed. The commodity corn yield and price distributions were based on 1997–2003 Indiana corn yield and price data shown in Table 1 (Indiana Agricultural Statistics Service [IASS]). For both white and yellow corn, Table 2 reports the Pearson correlation coefficients for corn yields and prices and shows that yields and prices are inversely related as expected. The correlation between yields and prices is stronger in October than in January and May. Because corn prices and yields are correlated, this correlation is taken into account in sampling corn prices and yields using the Corrmat function in @Risk. It is important to account for this correlation in sampling. Otherwise, some iterations would reflect highly unlikely conditions, such as high corn yield and high corn prices.

We assume a normal distribution for crop yields for several reasons. First, the correct crop yield distributions are still under debate in the literature. One strand of the literature has found sufficient evidence of skewness and/or kurtosis in their yield data and chosen to use the beta distribution instead of the normal distribution (e.g., Babcock and Hennessey; Coble et al.; Nelson and Preckel). However, as pointed out by Racine and Ker, none of these studies have tested the appropriateness of the beta distribution. Adding to the debate, Just and Weninger observe that no consensus for skewness and nonnormality has emerged and that some studies find positive skewness and others negative skewness. Furthermore, they examine the evidence for nonnormality of crop yields and show that this evidence is not sufficient to disprove normality because of the use of aggregate data, inflexible trend modeling, and the interpretation of the normality test results. Instead, Just and Weninger suggest that the normal distribution is not an unreasonable empirical distribution for studying production under uncertainty. In contrast, Ker and Coble provide support for nonparametric methods instead of parametric methods; they tested corn yields for 87 counties in Illinois and rejected the normal distribution at the 95% confidence level for 56 of the counties and rejected the beta distribution at the 95% confidence level for 41 of the counties. Goodwin and Ker and Racine and Ker have also used nonparametric methods to estimate yield densities. While these papers show that nonparametric methods have advantages over parametric methods, one drawback of the nonparametric estimators is that they require more data than the seven state-level observations we have for Indiana corn yields. Second, we conducted tests for normality on the residuals of the time-detrended yield data and could not reject normality. Third, assuming a normal distribution for crop yields enables us to take into account the correlation between the yield distribution and the price distribution, which we believe is essential for the simulation to reflect reality.

White corn yields were calculated using the yield drags for the respective years (Sparks). On average, the white corn yield was 4.43% lower than the commodity corn yield. Since we did not have any white corn yield variance data, we assumed that white corn yield variance is the same as that of yellow corn. While one may expect white corn and yellow corn yield variances to be different, discussions with buyers of white and yellow corn did not provide any information on which yields were more variable. The white corn prices were calculated using premiums for the respective years (Sparks). On average, white corn producers received a $0.29 per bushel premium over commodity corn.

All costs reported in the analyses are as of 2004 unless otherwise specified. The production costs of corn following soybeans (with expected yield of 145 bushels per acre) are based on Schnitkey. Drying, storage, interest on operating inputs, labor costs, transportation, and laboratory test fees were calculated using other data, to be described below.

Corn was assumed to be harvested at 22% moisture content and then artificially dried to 15% on farm in two dedicated drying systems. The continuous-flow drying system was assumed to be part of a standard grain handling system including a receiving pit, bucket elevator, wet holding bin, and storage bins. The in-bin drying system was assumed to be filled and unloaded with a dedicated portable belt conveyor, and it also served as the storage bin. Thus, no additional clean-out of system components was required to avoid contamination of white and yellow corn. The per-bushel continuous-flow drying cost was calculated using the reference data and method given in Uhrig and Maier, and the per-bushel in-bin drying cost was calculated using the continuous-heat data for Indianapolis given in Bartosik. For the 2004 harvest, drying costs were $0.1481 per bushel for the continuous-flow drying method and $0.1434 per bushel for the in-bin drying method, a $0.0046-per-bushel cost difference between these two methods.

Storage costs include conveyance, aeration, and interest costs after drying. Conveyance and aeration costs were taken from Dhuyvetter, Hamman, and Harner and were assumed to be one-time costs that did not change with the storage period. Interest costs occurred during the storage period because holding the grain did not allow producers to invest the grain sales income. The interest rate was taken as 6.43%, which was the average of the 2003 fixed annual interest rate for other farm operating loans for the Seventh (Chicago) Federal Reserve District (Federal Reserve Board). Interest costs constituted nearly two-thirds of the total storage costs. While Kalaitzandonakes, Maltsbarger, and Barnes found that elevators face an opportunity cost associated with IP grains because of underutilization of capacity, we do not consider storage efficiencies in this analysis since the farmers can choose the quantity of white corn they deliver under contract to match the size of their grain bins. Should farmers produce more white corn than required to meet the contract, they can deliver this excess production to the active local white corn market for export rather than storing it on farm.

In white corn production, there were additional transportation costs because producers may be delivering their product to a more distant delivery point than the nearest open market buyer. Based on the 2003 USDA National Agricultural Statistics Service report, producers had to travel 12 more miles in order to deliver specialty corn to a contract delivery point in the Corn Belt region. The trucking rate of $2.68 per mile was taken from the weekly Grain Transportation Report of the USDA Agricultural Marketing Service (AMS). Each truck was assumed to deliver 1000 bushels of corn.

The base labor required for corn production was two hours per acre (Schnitkey). The wage rate of $9.10 per hour was the average of the 2003 and 2004 average field-work rates (IASS). The ISCO equipment management strategy and *Grainsafe* require additional labor, and these steps included training, record keeping, sample collection, and extra cleaning of equipment and facilities.

Grainsafe requires keeping records of several farming practices using the forms in the *Grainsafe* Manual. Producers have to participate in a four-hour training session before adopting *Grainsafe* where they are given detailed instructions about the work procedures and the record-keeping forms. Producers testing the beta version of *Grainsafe* reported the record-keeping time as 15 to 30 minutes, but it was not clear whether this time was per field or per record-keeping form. Therefore, the record-keeping time was assumed as 1.5 hours per field for the entire production season. This time also included all management activities, such as communicating with neighbors, that are required to comply with *Grainsafe*.

Grainsafe requires strict equipment and facilities clean-out procedures that are usually more labor intensive than conventional equipment cleaning practices. Table 3 shows the labor hours for equipment and structure cleaning. These values were obtained from Hanna, Quick, and Jarboe; Hanna and McGuire; and unpublished data from Ess and Fleck.

Grainsafe requires laboratory test for pre-harvest genetic and physical purity. Collection of corn ears from different parts of the field, shelling them, and then sending the samples to a laboratory for testing were assumed to take three hours per field. The cost of the laboratory test was assumed to be $125 per test, the Indiana Crop Improvement Association fee for PCR Testing (Indiana Crop Improvement Association). It was assumed that eight samples were collected from each field, which resulted in a $0.0665-per-bushel test cost for all farm sizes. Laboratory test costs might be paid by the buyer depending on the contract terms. In this analysis, it was assumed to be paid by the producer. *Grainsafe* program audit costs were ignored on the basis of the assumption that the buyer would pay these costs. The buyer might audit the *Grainsafe* program with its own staff or hire a third-party service.

Results and Discussion

The laboratory test costs were found to be the largest cost associated with *Grainsafe*, and these costs are scale neutral. In addition to laboratory test costs, farmers who adopt *Grainsafe* will face additional labor and production costs associated with training, record keeping, sample collection, and extra cleaning of equipment and facilities. Farm size and equipment management strategies influenced these labor and production costs, while delivery time had only a minor impact on cost.

Farm Size

As farm size increased, per-bushel total production costs decreased because larger farms captured economies of scale in storage and can spread fixed costs over a larger number of bushels. For instance, for January corn delivery, the average total production cost on the 1,000-acre farm was $0.0083 per bushel, or 0.23% lower than the 250-acre farm. Equipment clean-out times were assumed to be the same in all farm sizes (equipment capacity might change), so equipment clean-out costs diminish as farmed acres increase. Of course, this analysis may be underestimating the cost advantages of larger farms because it ignored potential input cost differences; larger farms often receive volume discounts that are not available to smaller farms.

Adoption of *Grainsafe* and implementation of ISCO required more labor hours for the equipment clean-out practices, which increased fixed production costs and thereby increased the cost advantage of larger farms (Table 4). In the least labor-intensive scenario, FIFO without *Grainsafe*, the total production cost difference between the 250-acre and 500-acre farms was $0.0010 per bushel. In the most labor-intensive scenario, adoption of *Grainsafe* with ISCO, the total production cost difference increased by 11 times to $0.0110 per bushel. Adoption of *Grainsafe* with FIFO increased the total production costs by six times to $0.0060 per bushel.

Overall, producers adopting *Grainsafe* will face higher production costs, and these production costs increases will be relatively higher for small farms. The maximum cost increase found in this analysis was $0.0110 per bushel. However, implementation of FIFO with *Grainsafe* reduces these additional production costs by almost 50%.

Equipment Management Strategy

The total production costs were higher for ISCO than for FIFO because of the additional equipment clean-outs (Table 4). However, the cost difference was negligible. For example, on the 500-acre farm, implementing ISCO without *Grainsafe* had an additional $0.0012-per-bushel (0.04%) cost over FIFO. Adoption of *Grainsafe* further increased the cost of ISCO because the additional in-season equipment clean-outs were more labor intensive with *Grainsafe*. For example, on the 500-acre farm, adoption of *Grainsafe* with ISCO increased the total production cost by $0.0050 per bushel (0.14%) compared to FIFO, and most of this increase ($0.0038 per bushel, or 76%) was due to *Grainsafe* (Table 4). Producers adopting *Grainsafe* with ISCO will incur more production costs than those implementing FIFO. However, these increases in the total production costs were small, less than a penny per bushel for the three farm sizes evaluated.

Additional Labor Hours and Costs of the Grainsafe Program

As mentioned before, *Grainsafe* requires strict equipment clean-out practices and additional training, field sampling, and record-keeping times that increase the labor time and costs.

Table 4. Total Production Costs for Different Scenarios in the Cost Analysis Model

	January						May					
Scenarios	Mean	Standard Deviation	Min.	Max.	5% Percentile	95% Percentile	Mean	Standard Deviation	Min.	Max.	5% Percentile	95% Percentile
Comm125	3.2725	0.3057	2.5172	4.7457	2.8234	3.8162	3.3511	0.3147	2.5172	4.7457	2.8904	3.8162
White125F	3.4424	0.3468	2.6189	5.0635	2.9396	4.0631	3.5299	0.3556	2.6189	5.0635	3.0096	4.0631
White125R	3.4440	0.3470	2.6201	5.0658	2.9409	4.0649	3.5314	0.3558	2.6201	5.0658	3.0110	4.0649
WhiteGS125F	3.5234	0.3554	2.6795	5.1852	3.0080	4.1596	3.6119	0.3644	2.6795	5.1852	3.0787	4.1596
WhiteGS125R	3.5334	0.3565	2.6869	5.2002	3.0165	4.1714	3.6220	0.3654	2.6869	5.2002	3.0872	4.1714
Comm250	3.2715	0.3057	2.5162	4.7447	2.8224	3.8152	3.3501	0.3147	2.5162	4.7447	2.8894	3.8152
White250F	3.4414	0.3468	2.6179	5.0625	2.9386	4.0621	3.5289	0.3556	2.6179	5.0625	3.0087	4.0621
White250R	3.4427	0.3469	2.6188	5.0643	2.9396	4.0636	3.5301	0.3558	2.6188	5.0643	3.0097	4.0636
WhiteGS250F	3.5175	0.3549	2.6747	5.1767	3.0028	4.1526	3.6058	0.3638	2.6747	5.1767	3.0735	4.1526
WhiteGS250R	3.5224	0.3554	2.6785	5.1842	3.0070	4.1586	3.6109	0.3644	2.6785	5.1842	3.0777	4.1586
Comm500	3.2700	0.3057	2.5147	4.7432	2.8209	3.8137	3.3487	0.3147	2.5147	4.7432	2.8879	3.8137
White500F	3.4399	0.3468	2.6164	5.0610	2.9371	4.0606	3.5274	0.3556	2.6164	5.0610	3.0072	4.0606
White500R	3.4405	0.3469	2.6169	5.0619	2.9376	4.0613	3.5280	0.3557	2.6169	5.0619	3.0077	4.0613
WhiteGS500F	3.5135	0.3546	2.6714	5.1714	2.9992	4.1481	3.6018	0.3636	2.6714	5.1714	3.0699	4.1481
WhiteGS500R	3.5160	0.3549	2.6732	5.1752	3.0013	4.1511	3.6044	0.3638	2.6732	5.1752	3.0720	4.1511

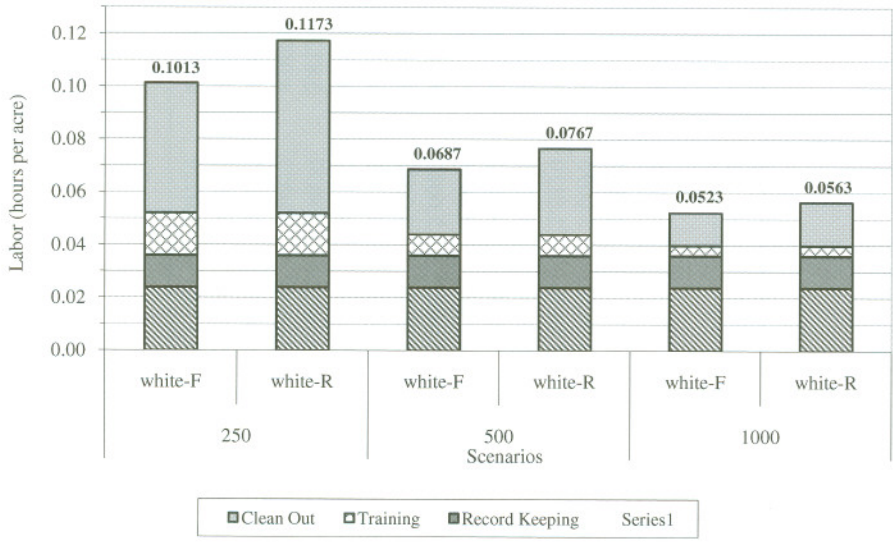

Figure 2. Additional Labor Hours Required by the *Grainsafe* Program (refer to Figure 1 for horizontal axis labels)

The additional labor hours required on top of the two-hours-per-acre base labor are shown in Figure 2, and the associated labor costs are shown in Figure 3.[2] Sampling and record keeping required an additional 0.024 and 0.012 hours per acre and cost $0.0018 and $0.0009 per bushel, respectively. Sampling and record keeping are per-field costs that do not depend on the farm size because the field size was assumed to be 125 acres regardless of farm size.

Training hours per acre decreased with the increasing farm size because training time was constant. Producers attended one training session before the growing season. Per-acre training hours were 0.016, 0.008, and 0.004, and per-bushel training costs were $0.0024, $0.0012, and $0.0006 for the 250-, 500-, and 1,000-acre farms, respectively.[3]

[2] The labor cost calculations were done only for January delivery because there was no additional labor between January and May, and the labor cost difference for the two hours per acre of base labor between January and May was negligible at only $0.0014 per bushel.

[3] During the interviews, farmers reported that sampling and record keeping take only about 30 minutes per field. We believed that these estimates were low, so we assumed that sampling takes three hours per field and that record keeping takes 1.5 hours per field in order to be conservative.

The equipment and facilities clean-outs were the largest component of the additional labor required by the *Grainsafe* program. These labor costs decreased as farm size increased, indicating that there are significant economies of scale in IP production (Figure 3). These labor costs were higher for ISCO, which has one more clean-out practice during the season. For example, *Grainsafe* required an additional 0.0687 hours per acre (3.44%) on top of the two-hours-per-acre base labor time on the 500-acre farm with FIFO, which translated into an additional $0.0078-per-bushel (5.13%) labor cost on top of the $0.1513-per-bushel base labor cost. For the 500-acre farm, *Grainsafe* with ISCO required an additional 0.0767 hours per acre (3.84%) more than the base labor time, which translated into an additional $0.0115-per-bushel (7.62%) labor cost above the base labor cost and $0.0037 per bushel more than that of *Grainsafe* with FIFO.

Overall, the labor cost increase with the adoption of *Grainsafe* was very small, less than 1%, even in the most labor-intensive scenario (i.e., ISCO in the 250-acre farm).

Laboratory Test Cost of the Grainsafe Program

Laboratory test costs were the largest cost associated with *Grainsafe* and comprised 75%

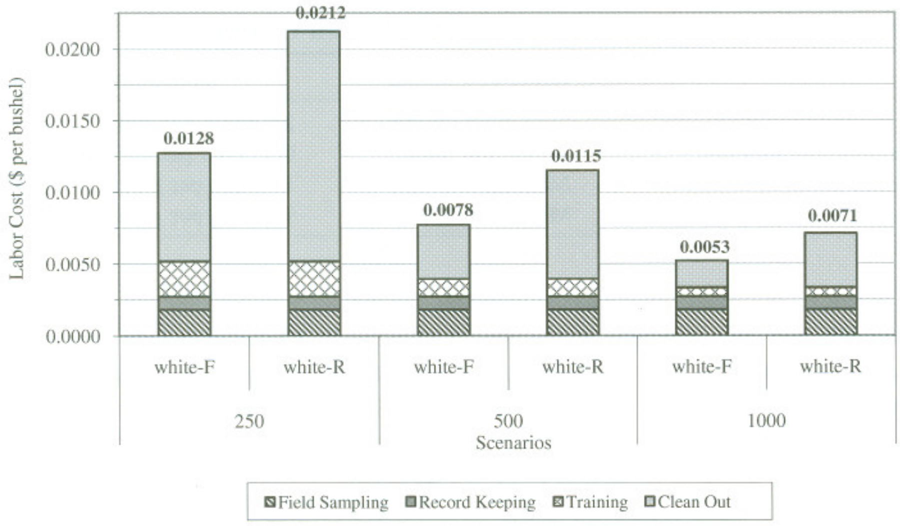

Figure 3. Additional Labor Costs Associated with the *Grainsafe* Program (refer to Figure 1 for horizontal axis labels)

to 93% of the total additional costs depending on the farm size (Figure 4). The laboratory test costs for preharvest purity tests required by *Grainsafe* were $125 per test, and since one test is required per field, the per-bushel laboratory test cost was $0.0665 for all farm sizes regardless of the equipment management strategy. Laboratory test costs might be paid by the buyer depending on the contract between the parties. Including the laboratory test costs, the percent increase in the total production costs with the adoption of *Grainsafe* was the highest, 2.48%, for the 250-acre farm with ISCO and the lowest, 2.04%, for the 1000-acre farm with FIFO. Assuming that the laboratory test costs were paid by the buyer does not change the ranking in terms of percentage increase in the total production costs. However, the percent increase in the total production costs is substantially smaller,

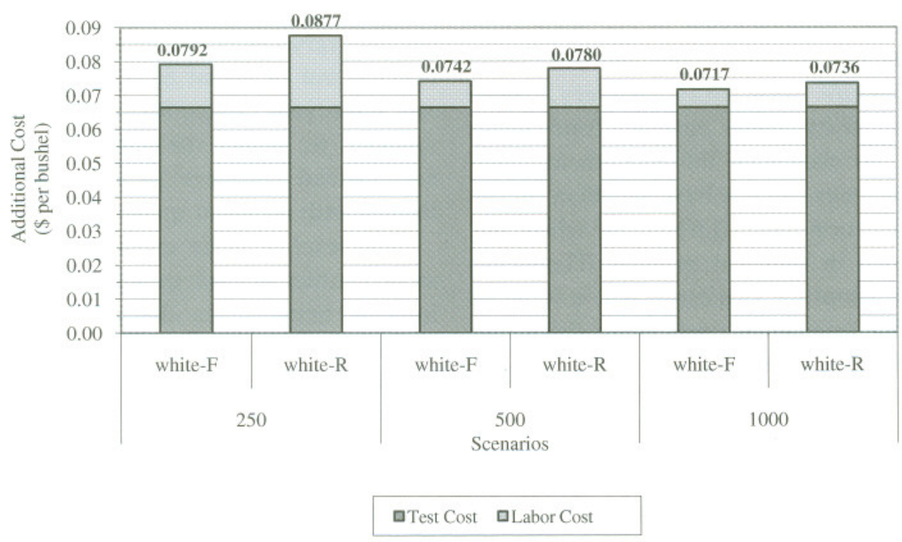

Figure 4. Total Additional Costs Associated with the *Grainsafe* Program (refer to Figure 1 for horizontal axis labels)

Table 5. Quality Standards of a Typical White Food Corn Contract

	Reception Limits	Discounts (¢/bu)
Moisture	Maximum 20.0%	2.0 cents per point above 14.0%
Broken corn/foreign material	Maximum 3.0%	0.5 cents per point above 2.0%
Stress crack	Maximum 25.0%	1.0 cent per point above 20.0%
Total damages	Maximum 6.0%	1.0 cent per point above 3.0%

at most 0.60%, for the 250-acre farm with ISCO and at least 0.15% for the 1,000-acre farm with FIFO.

January versus May Delivery

The per-bushel total production cost of delivering corn in May was, on average, $0.0880 per bushel (2.53%) higher than delivering in January (Table 4). Almost half of this additional cost (48%) was due to the additional interest cost of storing corn four extra months. Another component of the additional costs of delivering corn in May is due to the assumed 1% difference in moisture that caused shrinkage (i.e., decreased the number of bushels delivered in May).

Adoption of *Grainsafe* increased the total production cost difference between January and May deliveries only by $0.0009 (1.07%) per bushel. This negligible difference was due mainly to the interest costs of the additional labor costs and laboratory test fees associated with *Grainsafe*. For May delivery, these additional costs were carried four more months. The choice of the equipment management strategy did not have an effect on the total production cost differences when delivering corn in different months. Therefore, producers adopting *Grainsafe* will not incur considerable additional costs when delivering corn at different times after harvest.

Benefit Analysis

The benefit analysis of the *Grainsafe* program focused on the benefits to producers of *Grainsafe* with respect to avoiding discounts due to delivering grain below the quality standards. Quantifying all benefits of *Grainsafe* to producers was not possible.

The quality standards of grain delivered to the buyer, which were taken from a white corn processor's food corn contract, are shown in Table 5. These values were used as the basis for the expected grain quality. The moisture content standards were not considered as a potential cause of discount or rejection because *Grainsafe* assumes successful on-farm drying and storage of corn before delivery. In addition, it was assumed that any delivery that contained any trace amount of GM yellow corn would be rejected.

There were no available data on the rejections of and discounts applied to grain deliveries or on the percentage of grain deliveries that did not meet the quality specifications. Thus, it was not possible to build a model for discounts and rejections on the basis of data. However, conversations with buyers of food-grade white corn indicated that loads were rejected very rarely, on the order of five loads rejected out of about 8,000 loads delivered in any given year. Thus, for the purposes of this analysis, we ignore the possibility of rejection and instead compare hypothetical grain deliveries with different quality levels.

The level of grain quality was represented as percentiles of each quality parameter in the interval between its discount and rejection limits. For instance, grain with an 80% quality had a broken corn/foreign material (BCFM) level of 2.20%, stress cracks of 21.00%, and total damages of 3.60%. The BCFM rejection limit is 3.00%, and the BCFM discount limit is 2.00%. The 80% BCFM quality occurs in the interval between the rejection and discount limits $(3.00\% - 2.00\%) \times 80\% = 0.80\%$. The BCFM level that is 0.80% less than the

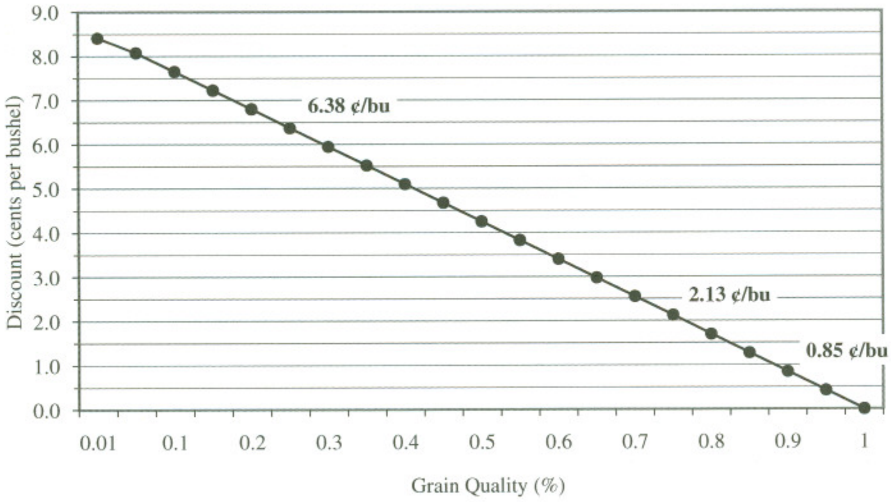

Figure 5. Discounts for Different Corn Quality Levels on Deliveries

rejection limit is 3.00% − 0.80% = 2.20%. The same method was used to calculate stress crack and total damage levels.

The price discounts were found by multiplying the different quality parameter values and their discount limits with the discounts listed in Table 5. For example, grain with an 80% quality level will have the following price discount: (2.20% − 2.00%) × (0.5 ¢/bu) + (21.00% − 20.00%) × (1.0 ¢/bu) + (3.60% − 3.00%) × (1.0 ¢/bu) = 1.70 cents per bushel.

The average January price of white corn was $2.5514 per bushel. Grain with an 80% quality level would have been sold for $2.5344 per bushel after a discount of 1.70 cents per bushel. If the producer delivered 60,000 bushels (500-acre field with a 120-bushel-per-acre yield after drying and storage losses), he would lose $1,020 because of the discount calculated above.

Discounts and rejections avoided with the adoption of *Grainsafe* were a benefit to the producer. If a producer usually delivered grain at an 80% quality level and was able to improve grain quality to levels above the discount limits through adoption of *Grainsafe*, then the producer would have a benefit of 1.70 cents per bushel. Producers already delivering high-quality grain would have the other two benefits that were discussed in the introduction to this paper but that were not possible to quantify.

Results and Discussion

Discounts for delivering grain below the expected quality standards are shown in Figure 5. The leftmost end of the horizontal axis represents the theoretical point where the grain quality is at the minimum level. To the left of this point, all individual quality parameters are above the rejection limits, which results in the rejection of the grain delivery. The maximum discount applied at this point was 8.42 cents per bushel. The rightmost point of the horizontal axis represents grain with 100% quality. To the right of this point, no discounts are applied to the delivered grain, and the producer is paid the full contract price. For example, a producer who delivered corn corresponding to the 25% quality level would face a discount of 6.38 cents per bushel. Adoption of *Grainsafe* could help to improve the quality of corn delivered. If the producer delivered corn at the 75% quality level after adopting *Grainsafe*, he would face only a 2.13-cent-per-bushel discount and would receive a 4.25-cent-per-bushel benefit from *Grainsafe*. If the quality improved to 90%, he would face only a 0.85-cent-per-bushel discount and would receive a 5.53-cent-per-bushel benefit.

However, *Grainsafe* has additional costs that were quantified in the previous sections of this paper. Assuming that the producer im-

Table 6. Probability of Benefit Exceeding the Cost of *Grainsafe* When the Buyer Pays the Test Cost

	When the benefit is:		
Scenarios	0.85 cents	2.13 cents	3.41 cents
WhiteGS125F	25%	80%	95+%
WhiteGS125R	<5%	45%	85%
WhiteGS250F	45%	90%	95+%
WhiteGS250R	25%	80%	95+%
WhiteGS500F	60%	95%	95+%
WhiteGS500R	50%	90%	95+%

plemented ISCO on his 250-acre farm, which had the highest additional costs of the *Grainsafe* program, he would incur 8.77 cents per bushel of additional costs (i.e., labor and laboratory test costs) if he paid the laboratory test costs but only 2.12 cents per bushel if the buyer paid the laboratory test costs. Assuming that the buyer paid the laboratory test costs, the producer's net benefit would be 2.13 cents per bushel if he improved the quality from 25% to 75% and 3.41 cents per bushel if he improved the quality from 25% to 90%. Using the distribution of costs and assuming that the buyer pays the laboratory test costs, the probability that the benefits exceed the costs is shown in Table 6 for three benefit levels: 0.85 cents, 2.13 cents, and 3.41 cents. The profitability of *Grainsafe* and thus the likelihood of adoption increases with the probability that the benefits exceed the costs. The 1,000-acre farm with FIFO has the highest probability of profiting from *Grainsafe*, at 60% of the time for the lowest benefit of 0.85 cents, and reaching 95% of the time for even the moderate benefit of 2.13 cents. In contrast, the 250-acre farm with ISCO is the least likely to adopt *Grainsafe*, with the probability of benefits exceeding costs at less than 5% chance when the benefit is 0.85 cents, only 45% chance when the benefit is 2.13 cents, and only 85% chance at the highest benefit level of 3.41 cents.

Conclusions

A comprehensive cost analysis model was developed for the production of white food corn and commodity corn on the same farm with and without the *Grainsafe* program. Each alternative had two different operations planning and equipment management strategies for three different farm sizes (250, 500, and 1,000 acres). The additional costs associated with the adoption of the *Grainsafe* program were quantified and compared for 12 scenarios. On average, the additional labor costs associated with the *Grainsafe* program ranged from $0.0053 to $0.0212 per bushel depending on the equipment management strategy, farm size, and stated assumptions. This corresponded to a 0.15% to 0.60% increase in the total production costs. The laboratory test costs associated with *Grainsafe* was $0.0665 per bushel for all farm sizes regardless of the equipment management strategy. If the producers paid the laboratory test costs, the total additional costs associated with *Grainsafe* ranged from $0.0717 to $0.0877 per bushel, and this corresponded to a 2.04% to 2.48% increase in total production costs.

Overall, these QA and IP cost estimates are lower than those reported in the literature review. The per-bushel cost of *Grainsafe* excluding the laboratory test costs is similar to the production cost associated with IP estimated by Huygen, Veeman, and Lerohl at the 5% tolerance level and 10% of the IP cost at the 0.1% level. The per-bushel cost of *Grainsafe* is less than 1% of the cost estimated by Gustafson for on-farm IP costs in the case of certified seed production. There are three explanations for these cost differences. First, Gustafson included the costs of marketing the seed, while we assumed that the farmer already had a buyer of food-grade white corn. Second, certified seed production requires restricted activities on fields bordering the IP field, while food-grade white corn production requires only some planning of field locations and planting time. Third, the producers who beta tested *Grainsafe* may have underestimated the amount of additional labor required by *Grainsafe*. These producers were already established food-grade white corn growers, and they commented that many of the steps required by *Grainsafe* were already part of their procedures and so do not require much additional labor. We tried to compensate for this by assuming that the additional labor required by *Grainsafe* was 4.5 hours per field instead of the 30 minutes per field reported by producers.

The IP costs for elevators have been estimated in the range of \$0.20 to \$0.40 per bushel, which is 4 to 20 times the estimated per-bushel cost of *Grainsafe*. It is reasonable to expect that on-farm IP and QA for operations of 1,000 acres or less would be less costly than for an elevator because the amount of grain handled is so much smaller. Farmers would also have a much smaller opportunity cost associated with underutilizing their storage capacity for two reasons. First, farmers can choose the quantity of contracted food-grade corn to match the size of their grain bins. Second, farmers fill their bins only once a year rather than multiple times a year in the case of elevators.

The producer benefits associated with the adoption of the *Grainsafe* program were quantified on the basis of a typical discount schedule for food-grade corn deliveries. Depending on the improvement in the grain quality due to the adoption of the *Grainsafe* program, the producer could gain up to \$0.0842 per bushel. Other benefits, such as the increased market access due to a good reputation for delivering high-quality grains, were not measured in this study. The quantifiable benefits of *Grainsafe* were found to be higher than the additional costs associated with the program except for one case, that is, adoption of the program with the ISCO equipment management strategy on a 250-acre farm. As farms increase in size, the per-bushel costs of *Grainsafe* decrease, and thus producers operating larger farms are more likely to profit from adopting the program. It is recommended that producers adopt the *Grainsafe* program with the FIFO equipment strategy in order to reduce the additional labor costs associated with the program. Producers need to carefully analyze their farm-specific production costs to be certain that the additional costs associated with the program will indeed be lower than the benefits from adopting the *Grainsafe* program.

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