Profitability Comparison for Glyphosate-Resistant and Conventional Sugarbeet Production Systems

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ABSTRACT

A Monte Carlo Simulation was conducted to compare the profitability of glyphosate-resistant (GR) and conventional sugarbeet systems. GR sugarbeet systems were more profitable than low-cost conventional systems as long as GR sugarbeet systems realize a 0.76 tonne ha^{-1} yield increase. If the expected 4.48 tonne ha^{-1} yield increase is realized, GR systems are on average \$236.36 ha^{-1} more profitable than low-cost conventional sugarbeet systems and \$552.86 ha^{-1} more profitable that high-cost conventional sugarbeet systems.

Nomenclature: glyphosate

Key words: Monte Carlo, Simulation

Sugarbeet (*Beta vulgaris* L.) is an important crop in the state of Wyoming and several other U.S. states. Wyoming's sugarbeet production was 811,930 tonnes in 2012 with a production value of $66,767,000 (NASS, 2013). This was 9th in the nation in 2012 for total production. The total value of production in the United States was almost 2.2 billion dollars in 2011; data for 2012 had not been completed at time of publication (NASS, 2013).

Sugarbeet has been genetically modified for resistance to the herbicide glyphosate, and was commercially introduced in Wyoming in 2007. Since the introduction of glyphosate-resistant (GR) sugarbeet the industry has seen 95% acceptance among producers nationally (Bartlett, 2011). The GR technology allows producers to streamline their herbicide programs and increase flexibility in timing of weed control by allowing glyphosate application to a growing sugarbeet crop (Kemp et al., 2009; Kniss et al. 2004; Wilson et al. 2002). Glyphosate application to GR sugarbeet results in significantly less crop injury compared with herbicides applied to conventional sugarbeet cultivars (Kniss et al. 2004). The rapid adoption rate of this technology combined with recent litigation (McGinnis et al. 2010) led to uncertainty for producers. Sugarbeet growers in the U.S. were unsure whether enough conventional seed existed to plant a full crop if GR seed was not available due to the ongoing litigation. On July 19, 2012, GR sugarbeet were once again fully deregulated by the USDA. This brought to a close one phase of the litigation. However, additional lawsuits have been filed against the USDA after full deregulation of GR alfalfa, and thus, it is quite possible that additional lawsuits against GR sugarbeet may again result in uncertainty for sugarbeet growers in the future.

In addition to concerns about GR seed availability due to litigation, it is possible that weeds developing resistance to glyphosate may reduce the economic advantage of GR sugarbeet production. The growing trend regarding labeling laws for biotechnology-derived products being considered by states and the federal government may result in a shift away from GR sugarbeet in the future. It is therefore important to determine differences in profitability between conventional and GR sugarbeet production so that the potential economic impact of reductions or changes in GR sugarbeet production can be quantified. The high adoption rate of GR sugarbeet supports previous research (Kniss et al. 2004; Kniss 2010) that documented an immediate, positive economic impact for producers. However research to date comparing the economics of GR and conventional system has been limited, in that only a small subset of potential economic situations were considered. The objectives of this analysis are to determine the differences in profitability of GR and conventional sugarbeet on a ha^{-1} basis, and to evaluate the effects of input and output price variability on sugarbeet profitability for GR vs. conventional sugarbeet production.

MATERIALS AND METHODS

A Monte Carlo simulation using historical prices was used to compare the profitability of GR and conventional varieties and production systems over a range of economic situations. Historical prices from National Agriculture Statistics Service (NASS) were used to simulate a realistic range of prices for fuel, fertilizer, chemicals, and output prices (NASS, 2013, NASS-USDA, 2011). The 2011 GR sugarbeet budget from the University of Nebraska-Lincoln (UNL) Extension (Klein & Wilson, 2012) provided the basis for our work. Due to the similarity of climates and soils between the panhandle of Nebraska and Southeast Wyoming, those budgets were used as insight for costs of production for GR sugarbeet. The UNL budget contains common production practices and forecasts a yield goal of 58.3 tonne ha^{-1} of sugarbeet. The budget is based on a center-pivot irrigation system that produces 3,028 liters per minute and applies 40.6 centimeters ha^{-1} during the growing season. Field operations, materials and services, operating and use-related ownership cost, overhead, and real estate costs are all included in the calculation of expenses (Klein & Wilson, 2012).

Due to the high adoption rate of GR sugarbeet cultivars, very few (if any) conventional sugarbeet cultivars are grown in the study area. However, the University of Nebraska-Lincoln published a companion article to the GR sugarbeet budget that reported 'conventional' sugarbeet production practices (Burgerner, 2000). From this companion article, a current budget based on conventional sugarbeet production was created to compare with GR sugarbeet practices. When creating the conventional sugarbeet budget, glyphosate applications were removed in lieu of other herbicide applications as well as manual weeding (Burgerner, 2000). Table 1 shows a comparison of the expected costs and revenues associated with high- and low-cost conventional and high- and low-yield GR sugarbeet using 2010 prices. Manual weeding was estimated to be \$37.05 ha^{-1}. Due to reduced supply of laborers over the last decade, however, there may be trouble locating labor at this cost in this region of Wyoming; therefore, this is a rather conservative estimate and actual costs are likely to be greater.

Fuel is an important cost for sugarbeet production. Fuel makes up 28% of the tillage expense, 8% of the spraying liquid fertilizer expense, 21% of the till and plant beet expense and 16.5% of row-crop cultivation expense. Fuel makes up 64% of the pivot irrigation system expense, 15% of top beet expense, 14% of lift beet expense, and 33% of the subsoil expense. Fuel is included at \$0.79/liter in the calculations for Table 1, but given it is such an integral component of the production system, it is included as a stochastic variable later in the Monte Carlo analysis.

Glyphosate costs in the GR sugarbeet budget were \$45.10 ha^{-1} consisting of three applications in the growing season (Table 1). This compares to the low-cost conventional sugarbeet herbicide estimated at \$151.91 ha^{-1} which was the mean cost of conventional sugarbeet herbicide application documented in Wyoming by Kniss (2010). Sugarbeet seed is typically sold in price per unit (100,000 seeds), and approximately 123,500 seeds are planted ha^{-1}. It is expected that conventional cultivars would include all of the same seed treatments that a GR seed would have for any given variety of seed (pesticides, priming, etc.). The sugarbeet seed cost for GR seed is estimated at \$407.55 ha^{-1} compared to \$222.30 ha^{-1} for conventional sugarbeet seed. The difference between GR and conventional seed price is due to the seed royalty (often referred to as the “technology fee”), charged by the seed company and Monsanto for the GR technology in the product.

In addition to the low-cost conventional sugarbeet budget, an alternative, high-cost, conventional budget was prepared for comparison to the original as a way to capture alternative practices seen in the region. The differences between the high- and low-cost budgets include the cost of row crop cultivation and the conventional sugarbeet herbicide program. It is believed that the \$151.91 ha^{-1} used in the original conventional sugarbeet budget was at the low end of the potential conventional costs based on practices in the region. This herbicide cost is the average cost of herbicides reported by Kniss (2010). In that study, however, hand-weeding was required in all conventional sugarbeet fields. We anticipate in southeast Wyoming growers will be more likely to use greater herbicide rates and decrease reliance on hand-weeding. Therefore, a budget with a herbicide cost \$417.13 ha^{-1} (at 2010 prices) also was used in this analysis. The high-cost herbicide program uses a herbicide program that is more common in eastern Wyoming and western Nebraska (Kniss et al. 2004), and therefore, it likely more representative of the herbicide program that would be used if GR sugarbeet were not available. The more expensive herbicide program included a preplant application of Nortron(ethofumesate) at roughly \$27.47 ha^{-1} in addition to 2 applications of a phenmedipham + desmedipham (Betamix) + trifusulfuron (Upbeet) + clopyralid (Stinger) at \$194.83 ha^{-1} each. The higher cost system also inlcudes one additional in-crop tillage operation.

Previous studies have documented increases of 5 to 15% in sugarbeet yield when comparing GR with conventional sugarbeet (Guza et al. 2002; May, 2000; Kniss et al. 2004; Kniss 2010; Wilson et al. 2002). The yield difference between GR and conventional sugarbeet reported in previous studies is probably a combined effect of greater weed control and reduced crop injury in GR sugarbeet, but it is unclear how much each of these factors contribute to the operational yield difference. The conventional sugarbeet budgets estimate a 53.8 tonne ha^{-1} yield. Two GR sugarbeet budgets are included; a low-yield budget which assumes the same yield as conventional sugarbeet, and a high-yield budget which assumes yield of 58.3 tonne ha^{-1} for GR sugarbeet to reflect the yield difference observed in previous studies (Table 1). The greater yield of GR sugarbeet also results in increased trucking cost for this system compared to the conventional system. No difference in sucrose content was included in this analysis. Sucrose content

Table 1. Comparison of GR and Conventional sugarbeet input profitability per hectare using 2010 prices.

Sugarbeet Cost and Revenue Estimates ha^{-1}	GR (High Yield, 58.3 t/ha)	GR (Low Yield, 53.8 t/ha)	Conventional (Low Cost, 53.8 t/ha)	Conventional (High Cost, 53.8 t/ha)
Field Operations	**Total**	**Total**	**Total**	**Total**
Disc	$22.97	$22.97	$22.97	$22.97
Spray Liquid Fertilizer	$13.12	$13.12	$13.12	$13.12
Till Plant Beet	$50.59	$50.59	$50.59	$50.59
Row Crop Cultivation	$26.31	$26.31	$26.31	$52.62
Pivot 125' Lift	$390.68	$390.68	$390.68	$390.68
Top Beet	$37.72	$37.72	$37.72	$37.72
Lift Beet	$74.64	$73.61	$73.61	$73.61
Subsoil	$25.47	$25.47	$25.47	$25.47
Total for Field Operations	**$641.50**	**$640.47**	**$640.47**	**$666.78**
Materials and Services				
10-34-0	$123.13	$123.13	$123.13	$123.13
32-0-0	$161.83	$161.83	$161.83	$161.83
Spray Herbicide	$44.46	$44.46	$44.46	$44.46
Glyphosate w/Surf 3 apps.	$45.10	$45.10	$0.00	$0.00
21-0-0-265 3 apps used as an adjuvant	$7.85	$7.85	$0.00	$0.00
Conventional herbicide broadcast spray	$0.00	$0.00	$151.91	$417.13
Sugarbeet Seed	$407.55	$407.55	$222.30	$222.30
Manual weeding	$0.00	$0.00	$37.05	$37.05
Aerial Spray Fungicide	$18.53	$18.53	$18.53	$18.53
Headline	$39.15	$39.15	$39.15	$39.15
Haul Beet	$192.66	$177.84	$177.84	$177.84
Scouting Sugarbeet	$24.70	$24.70	$24.70	$24.70
Sugarbeet Insurance Premium	$74.10	$74.10	$74.10	$74.10
Total Materials and Services	**$1,139.06**	**$1,124.24**	**$1,075.00**	**$1,340.22**

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Total Costs for Field Operations, Materials and Services	**$1,780.56**	**$1,764.71**	**$1,715.47**	**$2,007.00**
Interest on Capital	$169.04	$169.33	$169.60	$192.25
Total Operating and Use-Related Ownership Costs	**$1,949.60**	**$1,934.04**	**$1,885.07**	**$2,199.25**
Overhead (accounting, liability insurance, vehicle cost, office expenses)	$12.35	$12.35	$12.35	$12.35
Real Estate opportunity	$195.13	$195.13	$195.13	$195.13
Real Estate tax	$48.78	$48.78	$48.78	$48.78
Total Cost ha^{-1} Including Overhead	**$2,205.86**	**$2,190.30**	**$2,141.33**	**$2,455.51**
Sugarbeet Revenue at $59.19/tonne	$3,457.29	$3,191.47	$3,191.47	$3,191.47
Net Revenue	**$1,251.43**	**$1,001.17**	**$1,050.14**	**$735.96**

of sugarbeet is often a factor in overall sugar price received by producers. There is some evidence that GR sugarbeet can produce increased sucrose content compared with conventional cultivars treated with conventional herbicides (Kniss et al. 2004). However, this has not been consistent with other field research reports (Kniss 2010; Guza 2002; Wilson et al. 2002), and thus, sucrose content was assumed constant between systems in our analysis. 10-34-0 fertilizer is assumed to be applied at the rate of 0.278 tonne ha^{-1} and 32-0-0 fertilizer is assumed to be applied at the rate of 0.5166 tonne ha^{-1}. 10-34-0 fertilizer was included at \$442.08 $tonne^{-1}$, 32-0-0 fertilizer at \$312.57 $tonne^{-1}$. Given the importance of fertilizer costs and variability due to volatility in related energy costs, these prices also were included as stochastic variables in the Monte Carlo analysis. Finally, sugar price is included at 2010 level prices (\$59.19 $tonne^{-1}$), but was also stochastically modeled in the Monte Carlo analysis.

Based on 2010 prices and the assumptions described, our static analysis shows high-yield GR sugarbeet costs to be \$64.53 ha^{-1} greater than the low-cost conventional sugarbeet system. However, high-yield GR sugarbeet was estimated to be \$201.29 ha^{-1} more profitable compared with low-cost conventional sugarbeet due to the predicted yield difference between the two systems. When yield was assumed equal between the systems, the low-cost conventional system was estimated to cost \$48.97 ha^{-1} less and therefore be \$48.97 ha^{-1} more profitable than the low-yield GR system[b]. The high-yield GR system is estimated to cost \$249.65 ha^{-1} less and be \$515.47 ha^{-1} more profitable than the high-cost conventional system, and the low-yield GR system is estimated to cost \$265.21 ha^{-1} less and therefore be \$265.21 ha^{-1} more profitable than the high-cost conventional system, based on the assumptions used in the current study.

Monte Carlo Analysis. Prices are rarely static, and one of the objectives of this study was to determine how profits vary between conventional and GR sugarbeet production when input and output prices fluctuate. For this analysis, profitability of the systems was compared using a simulation process that varied sugar, fuel, and fertilizer prices. Historical price data were compiled and converted to 2010 dollars using the producer price index (PPI). These inputs and outputs were chosen for their relative importance in the costs and revenues of the two systems. Fertilizer prices from 1967 to 2011 were from NASS (NASS, 2011). The historical sugarbeet output prices are from the Agricultural Statistics Board (Agricultural Statistics Board, NASS, USDA, 2011), and these data include the 1975-1976 growing season to the 2010-2011 growing season. Fuel prices for 1978-2011 are from the Energy Information Administration (United States Energy Information Administration, 2011).

[b]*The difference in costs across the GR systems is due to increased harvest costs associated with the higher-yielding GR system.*

Table 2. Price distribution parameters used in Monte Carlo analysis.

Data Series:	Sugarbeet ($/tonne^{-1})	Fuel ($/liter^{-1})	10-34-0 ($/tonne^{-1})	32-0-0 ($/tonne^{-1})
Average:	55.77	0.60	$364.59	$257.78
Distribution:	Max. Ext.	Gamma	Lognormal	Lognormal
SD	12.02	0.18	108.49	75.21

Table 3. Input price correlations used in Monte Carlo analysis.

	10-34-0	32-0-0	Sugarbeet	Fuel
10-34-0	1.00	0.89666234	0.5799911	0.1792674
32-0-0		1.00	0.5817053	0.1469
Fuel			1.00	-0.125703
Sugarbeet				1.00

Using the real (inflation adjusted) values for historical price data, distributions were formed for each input and output price for use in the Monte Carlo analysis (Table 2). Given the nature of the data, the Max Extreme (sugar price), Gamma (Fuel), and Lognormal (fertilizer) distribution fittings were chosen using Crystal Ball simulation software (Oracle, 2012). Crystal Ball was used for the Monte Carlo simulation, where input and output prices were randomly selected based on the distributions and corresponding correlations (Table 3), *i.e.*, a relevant vector of prices were chosen randomly in each draw to control for nonsensical price combinations in the analysis. Results of profitability for the GR and conventional sugarbeet systems were recorded in the Monte Carlo simulation over 10,000 random draws on the input and output prices. The resulting profits were then compared for the GR and conventional sugarbeet systems from the simulation using Statistical Analysis System (SAS). A t-test was used to compare means between the two systems in SAS using PROC TTEST (SAS Institute, 2012).

RESULTS AND DISCUSSION

Simulation results indicate statistically different means in profitability across the four systems analyzed (Table 4). When a 4.4 tonne ha^{-1} (8.3%) yield difference was assumed between GR and conventional sugarbeet, GR sugarbeet were on average $236.36 ha^{-1} more profitable

Table 4. Predicted profit distribution of GR and conventional sugarbeet assuming varying production practices (shown as profit/ha^{-1}).

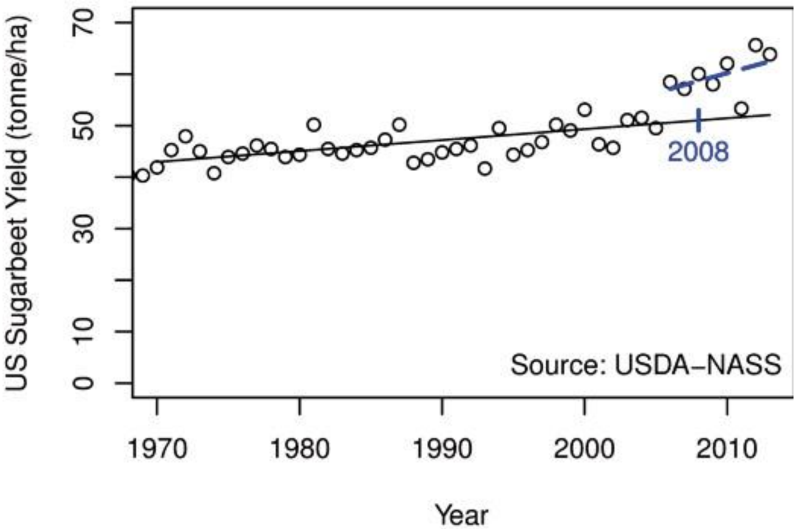
	GR, (58.3 Tonne/ ha^{-1} Yield)	**GR,** (53.8 Tonne/ ha^{-1} Yield)	**Low-Cost Conventional,** (53.8 Tonne/ ha^{-1} Yield)	**High-Cost Conventional,** (53.8 Tonne/ ha-^{1} Yield)
Min	($379.68)	($583.18)	($531.51)	($860.29)
Max	$8,193.03	$7,409.79	$7,461.46	$7,144.89
Mean	$2,011.15A†	$1,723.12C	$1,774.79B	$1,458.29D
CV	0.35	0.38	0.37	0.45
95% CI	13.96	12.9	12.9	12.92

† Letters denote significant differences between means within a row at the 0.05 level.

than the low-cost conventional system. When no yield difference was assumed between GR and conventional systems, the low-cost conventional sugarbeet were on average $51.67 ha^{-1} more profitable than GR sugarbeet. This result indicates that the GR sugarbeet system would need to yield 0.76 tonne ha^{-1} (or just under 1.5%) greater than the low-cost conventional practice in order to provide the same profit based on the average sugarbeet price used in the analysis. In Nebraska and Wyoming, GR sugarbeet has been documented to produce 15 to 20% greater yield than conventional sugarbeet treated with conventional herbicides (Kniss 2010; Kniss et al. 2004). Therefore, the 1.5% yield difference required to make the GR system more profitable than conventional system is likely to be realized in most years in this growing region. However, data from other growing regions indicate the yield advantage for GR sugarbeet may be inconsistent and of a lesser magnitude (Armstrong et al. 2010; Guza 2002). It is, therefore, unknown how often a 1.5% yield difference would be observed in other U.S. sugarbeet growing regions.

If a producer uses high-cost conventional production practices, the GR system was predicted to be, on average, $264.83 ha^{-1} more profitable, even if no yield increase is realized (Table 4). If the 4.4 tonne ha^{-1} yield increase was assumed, the GR system was $552.86 ha^{-1} more profitable on average than the high-cost conventional system. The simulation results also suggest that variability in input and output prices can cause profits to vary greatly in each of the systems. Even though the magnitude in the range of profitability is similar across the systems analyzed, GR sugarbeet with a yield advantage generally have the least potential for negative returns and lowest variability as measured by the coefficient of variation. Overall, the analysis suggests that, even though there is still a possibility of having a negative profit,

Figure 1. U.S. sugarbeet yield, tonne/ha (1969-2013).



GR sugarbeet are more profitable than even low-cost conventional sugarbeet as long as a 0.76 tonne ha^{-1} yield increase is realized in GR sugarbeet. Conventional sugarbeet is still a relatively profitable crop as shown in this analysis; but it is not likely to be as profitable as the GR counterpart, especially if GR sugarbeet results in increased yields, as expected.

These results indicate that if GR sugarbeet seed were removed from the market, there would likely be a significant economic impact on sugarbeet growers in eastern Wyoming, and possibly elsewhere in the U.S. While sugarbeet yield increased steadily in the U.S. between 1970 and 2005 (Figure 1), since 2006, sugarbeet yield in the U.S. has been much greater than the long-term yield trend, with the exception of 2011, which was only slightly above the long-term yield trend. This relatively dramatic boost in sugarbeet yield does predate widespread adoption of GR sugarbeet in 2008, and this difference cannot, therefore, be attributed to GR sugarbeet. However, this yield boost may still have implications for sugarbeet growers if GR sugarbeet were suddenly removed from the market. Commercial sugarbeet breeding programs have been focused almost exclusively on GR sugarbeet since its commercial introduction in 2007. While our analysis indicates that negative impact of losing the ability to grow GR sugarbeet could be reduced if producers were able to adopt lower cost production practices and inputs such as those represented in Table 1, the lack of conventional seed and labor could make such a transition difficult. Currently, if GR sugarbeet were suddenly removed from the commercial marketplace, conventional seed stocks would likely come from breeding efforts that have not kept up with the greater yield trend observed since 2006. It is likely that conventional cultivars that are currently available would have reduced yield potential compared to the most current GR cultivars due to the >5 year lag in breeding efforts. So even in regions where an obvious yield benefit due to GR sugarbeet has not been observed, yield reductions from planting conventional cultivars may arise if GR sugarbeet suddenly became unavailable. This would not be the case if conventional sugarbeet hectares gradually increased, allowing breeding efforts to anticipate the change.

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