ABSTRACT

A Linear Programming model coupled with Monte Carlo simulation compares the profitability of glyphosate-resistant (GR) and conventional sugarbeet systems for a case farm in Southeast Wyoming. The optimal combination of cropping mixtures maximizing total farm profitability is determined based on varying crop and input prices as well as rotational constraints impacting the potential acres of GR sugarbeet. If restrictions on GR sugarbeet occur, producers are better off to grow at least some conventional sugarbeet in their rotation. Profitability reductions would likely not be as great as partial budget analyses might indicate if no sugarbeet were available, although much more variable.

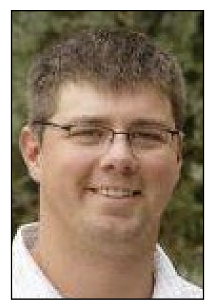
Profitability of Glyphosate-Resistant Sugarbeet Production in Whole Farm Systems

By Brian Lee, John Ritten, Christopher Bastian, and Andrew Kniss

Introduction

Producers are constantly searching for technologies and crops that improve profitability and reduce risk at the farm level. Growing crops resistant to herbicides such as glyphosate (more commonly known by the brand Roundup) has gained wide acceptance among producers. These crops, often named Roundup Ready or glyphosate resistant (GR), allow producers to control weeds with less tillage and/or labor operations than conventionally produced crops.



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Sugarbeet are a very important cash crop for irrigated farmers and GR sugarbeet has become a very popular choice among producers. Sugarbeet are currently grown in eleven states and two provinces in North America. These include the Minnesota, North Dakota, California, Idaho, Oregon, Washington, Colorado, Nebraska, Montana, Wyoming, Alberta Canada, Michigan, and Ontario, Canada (Harveson, 2012). Sugarbeet are well adapted to a wide range of soil types including coarse textured sandy soils to high organic matter, high clay content, silty clay or silty clay loam soils (Cattanach, Dexter and Oplinger, 1991). The USDA National Agricultural Statistics Service estimates that 1.2 million acres of sugarbeet were harvested in 2012 with a value of $2.3 billion, and 1.15 million acres were harvested in 2013 yielding 32.8 million tons (USDA NASS, 2014). It is estimated that GR sugarbeet have seen a 95 percent adoption rate since their introduction in 2007 (Bartlett, 2011).

Despite the importance of Roundup Ready crops to many producers, some groups are concerned about the use of genetically modified (GM) seeds. Legal cases have been filed against use of Roundup Ready crops, including alfalfa and sugarbeet because of risks possibly posed to other producers using different technologies (Congressional Research Service, 2013). Moreover, scientists are also concerned about the potential for weeds to develop resistance to glyphosate and thereby reduce the economic advantage of growing GR sugarbeet. These issues create risks for producers dependent on this crop as this technology could be removed from the market or their economic advantage negated by glyphosate resistance.

A limited number of studies have been conducted using partial budgeting to compare GR and conventional sugarbeet. One such study (Kniss, 2010) uses one year of conventional and GR sugarbeet data and utilizes a partial budget to compare the two systems. It found that in-crop tillage was reduced by 50 percent in glyphosate-resistant sugarbeet and herbicide costs in the conventional sugarbeet were greater than in the GR sugarbeet. It was also found that a significant increase in net economic return can be gained by adopting glyphosate resistant technology in Wyoming. Lee et al., (2014) used stochastic simulation coupled with four different production regimes for both GR and conventional sugarbeet enterprises. They conclude there is generally a profit advantage for GR sugarbeet. Partial budget analyses such as those reported here ignore the potential for producers to alter acres devoted to other crops as a way to mitigate changes in profitability for a certain crop.

Whole-farm Model

There is insufficient research analyzing how overall farm profitability could be affected if GR sugarbeet were removed from the market or the technology lost its economic advantage. The objective of this analysis is to evaluate the effects of GR sugarbeet restrictions coupled with input and output price variability on whole farm profitability using a producer owned case farm in southeast Wyoming.

A whole-farm model is used to determine optimal crop mixes based on varying input prices and output prices. Crop budgets were compiled for each crop analyzed in the study for the study area. Crop budgets include all operations (and associated costs) required for each crop, as well as average yields by crop in the study area. Costs include labor, material (including seed, chemicals, fuel and lube), and depreciation. Historical input and output prices were used to generate additional data via Monte Carlo technique. These input and output prices were then used in the crop budgets to analyze how the optimal mix of crops changed with different prices. Several scenarios are analyzed, utilizing restrictions on GR and conventional sugarbeet acreage, to examine changes to profitability under scenarios where a GR sugarbeet restriction may occur. A General Algebraic Modeling System (GAMS) linear programming model is used to determine profitability and optimal crop rotations for each scenario (Rosenthal, 2011). This model used a Monte Carlo random draw technique.

The model determines optimal annual crop rotations to maximize whole-farm returns in response to simulated input and output prices. Crops used in the whole-farm model include conventional and/or GR sugarbeet (with an assumed 2 ton/acre yield increase over conventional sugarbeet), corn, wheat, dry bean and alfalfa. The prices that are randomly drawn in the model include crop prices, fertilizer prices, chemical prices and fuel prices. The model also assumes that sugarbeet acres can be readily changed. This assumption may not always be realistic as sugarbeet are based on shares in the sugarbeet coop. Sugarbeet shares are purchased, which determine your acres of production. If a producer wanted to increase the number of acres they produce they would have to rent shares from another share-holder, and vise-versa if they were looking to decrease acres.

Crop prices are based on historical values taken from either ERS or NASS, depending on the commodity. Sugarbeet prices are reported by NASS, and cover 1975 to 2011, on a national per-ton value (Agricultural Statistics Board, NASS, USDA 2011). Corn prices used are the annual per-bushel historical price received by producers from the year 1975 to 2011 (ERS-USDA, 2011a). Wheat prices used are the historical annual prices received by US wheat producers from 1975 to 2011, on a national per-bushel value (ERS-USDA, 2011b). Dry bean prices were obtained from the United States dry edible bean season average $/cwt price from 1909 to 2010 (USDA-NASS, 2011b). Alfalfa hay per-ton prices come from a NASS report that outlines prices from 1914 to 2011 (USDA-NASS, 2011b). The prices for all crops are based on season ending prices as received by producers and were deflated to 2010 dollars.

Fuel prices were taken from the United States Energy Information Administration (EIS). The data set used contained diesel fuel prices from 1978 to 2011.

The chemical costs included in these budgets are fertilizer mixtures commonly used in the production of these different crops. They include: 10-34-0, 32-0-0, 28-0-0, 11-52-0, 80-0-0, and 10-34-0-1Z mixtures. The use of these fertilizers are represented in the crop budgets, however, not all fertilizers are used in all crops. Only ten years of data for these six fertilizers were available through NASS. However, longer data sets are available for the individual components, so in order to increase the number of observations for fertilizer prices, raw data was used to create a price for the "mixed" fertilizer.

The individual component data used for the creation of fertilizer prices came from NASS (NASS-USDA, 2011). A long term series of nitrogen, phosphorus, and potassium data were available. However, the data reported were not always in the same units applied in the crop budgets, so the data were converted. For example, the 10-34-0 fertilizer was reported in $/ton but applied in gallons. The $/tons price was divided by 2000 to transform it to a pound basis, and was then multiplied by 11.6 (which is the number of gallons in a pound of fertilizer). The 32-0-0 fertilizer was used on a pound of nitrogen basis in the crop budgets. Therefore, the original price reported in $/ton was divided by 640, or the available amount of nitrogen in one ton of 32-0-0 fertilizer, resulting in $/pound of N. The remaining fertilizer blends were "mixed" in the same fashion, based on the individual component prices. The only fertilizer used in the budgets that could not be accurately mixed was 10-34-0-1Z as a price of the zinc micronutrient was not available. However, the University of Nebraska publishes price change of selected fertilizers used in their budgets. It was found that the 10-34-0-1Z fertilizer was on average, about 2.5 percent more expensive than the 10-34-0 fertilizer (University of Nebraska-Lincoln, 2011). This was considered when obtaining prices for the fertilizer to put into the model. All nominal prices were deflated to 2010 dollars using PPI (US Department of Labor: Bureau of Labor Statistics, 2011).

Historical data was used to estimate distributions for each of the variable prices. A Monte Carlo simulation was based on distributions for each of the variable prices (output and input). These simulated prices were referenced by the GAMS model for each iteration analyzed. The objective of the whole-farm Monte Carlo model is to determine optimal annual cropping systems given fluctuating prices to maximize whole-farm profit. A detailed description of the model can be found in appendix A.

Several scenarios were modeled to determine the impact a ban of GR sugarbeet may have on whole-farm profits (Table 1). In Scenarios A, B, and C, sugarbeet had to be grown on exactly one third of the acres on the farm (101 acres), simulating a scenario where a producer holds sugarbeet contracts equal to the maximum production allowed based on agronomic recommendations. In Scenario A, the model could choose between conventional or GR sugarbeet, whereas scenario B forced the farm to grow only GR sugarbeet and scenario C only allowed conventional sugarbeet. In these scenarios, dry bean and sugarbeet will use 202 of the available 303 acres as dry bean are used as a crop preceding sugarbeet in the rotation most common in the study area. The other crops are "competing" for the remaining 101 acres.

Scenarios D, E, and F are similar to the first three except that the producer is allowed to produce less than one third of the total farm acreage to sugarbeet. This allows for greater acres of other crops to be grown in place of sugarbeet if it is more profitable. This would simulate a situation where a producer could adjust the amount of acres of sugarbeet that could be grown each year. As in scenarios A, B, and C, corn cannot be grown on more than half of the remaining acres, and dry bean must again be the same number of acres as sugarbeet for rotation purposes. In scenario D, the producer can choose between conventional and GR sugarbeet, scenario E must be GR sugarbeet, and scenario F must be conventional sugarbeet.

Scenario G simulates a situation where no conventional or GR sugarbeet are available to the producer. This might be a case where GR sugarbeet are regulated and not enough conventional beet seed stock exists to fulfill demand. The producer must choose from other crops, but corn cannot be more than two thirds of the total acreage. While this practice would be discouraged in the long-run, it is expected that if sugarbeet seed was unavailable, producers would likely substitute towards corn until sugarbeet seed could be sourced.

Profitability by crop results

As all scenarios use the same simulated price draws, the distribution of per-acre crop profitability for each scenario is the same. The constraints are the drivers behind different acreages across scenarios. Table 2 illustrates the profitability of the crops used in the model. GR sugarbeet have the highest average profit ($829.31), followed by conventional sugarbeet ($776.48). Dry bean was the next most profitable crop on average ($409.45), followed by established alfalfa ($398.44), corn ($262.47), wheat ($188.18), and initial alfalfa (-$100.69).

Overall, these results suggest a restriction or ban of GR sugarbeet will have a negative impact on producers in sugarbeet producing areas. Our analysis indicates average profitability would decrease while risk for an operation would increase, given our rotation assumptions. The loss of GR sugarbeet create more risk for an operation due to the lower productivity of conventional beets as seen in Table 2. However, GR and conventional sugarbeet have the lowest CV of the crops. Therefore, when no sugarbeet are available to the producer, the profitability of the whole-farm will be more risky, with greater variation in profitability.

The difference in GR sugarbeet and conventional sugarbeet profitability on average is $52.82. Dry bean is the most profitable crop on average after conventional and GR sugarbeet. Corn is a relatively risky crop compared to the other options given its high CV. It is important to remember that established alfalfa and initial alfalfa are combined to represent one crop in our model. The negative profitability of initial alfalfa is due to the high start-up costs and the low return in the first year of alfalfa growth. The individual established alfalfa variable is the least risky before it is combined with initial alfalfa. The combined profitability can be seen in Table 2.

Whole-farm results

Profitability by scenario is shown in Table 3. In this table the 5 percent and 95 percent profit levels are reported, this was done to remove some unrealistic outliers. These were caused by "perfect scenario" data match-ups within the model. Farming systems with at least some sugarbeet (scenarios A, B, C, D, E, and F) are more profitable than those without (scenario G). Moreover, where one third of the acres (scenario C) is restricted to conventional sugarbeet (CSB) is less profitable than those scenarios where the model can choose between sugarbeet type or other crops. Profitability has a wider range in the scenarios with no sugarbeet (G), implying more risk than where the farm can have at least some acres in some type of sugarbeet production. This is further supported by the larger standard deviation and coefficients of variation.

When the whole-farm model was able to choose either GR or conventional sugarbeet, GR sugarbeet were more profitable 100 percent of the time. When the model was forced to grow sugarbeet conventionally, the average profitability of the whole-farm was decreased by 3.2 percent. Scenarios that produced GR sugarbeet were also slightly less risky.

Acreage results by scenario can be seen in Table 4. When sugarbeet acreage is constrained to less than one third of the total acres (as opposed to be equal to 1one third), sugarbeet acreage decreased and supplemental crop acreages increased. Corn acres increase by 18 percent, wheat by 48 percent, and alfalfa by 19 percent. When no sugarbeet are available, over 60 percent of the time at least some acres should be planted to dry bean. It is unsurprising that dry bean was grown on at least part of the farm more often than other crops in this scenario, as they are more profitable on average than all the other available crops with the exception of sugarbeet.

GR sugarbeet are important to producers looking to maximize profits, and based on the assumed increase in yield, it can be concluded that GR sugarbeet should be produced as long as they are available. If a ban or restriction on GR sugarbeet occurs and producers grow conventional sugarbeet, profits would be 3.2 percent lower on average. In situations where GR sugarbeet are not available conventional sugarbeet are still a profitable alternative given producers have the option to grow them. Corn is a risky crop compared to other alternative crops, but can be very profitable. Dry Bean is a very good crop given its profitability potential and its slightly lower risk factor than corn. Flexibility in the crop rotation can increase average profitability of the farm. As expected, scenarios D and E (the scenarios with the least restriction on crop acreage, yet still allowed GR sugarbeet) had the highest average profit, with a relatively similar coefficient of variation as scenarios A and B. Overall these results suggest that if restrictions on GR sugarbeet occur, producers are better off to grow at least some conventional sugarbeet in their rotation.

Management implications

Sugarbeet are an important crop for farm managers that are concerned with risk management as sugarbeet acreage in a crop rotation can reduce variability in profit. High reliance on corn production can be a risky endeavor as the increased potential for higher profits when more acreage is planted to corn is coupled with increased variability in farm profits. Dry bean, on the other hand, tend to be a fairly stable crop. The average profitability of dry bean is higher and less volatile than corn. In the scenario where no sugarbeet are available, most of the available acreage is taken by dry bean. And while wheat and alfalfa don't perform as well as the other crops on average, the fact that they are in the optimal crop mix implies they are also able to stabilize whole-farm profits, and therefore should be included to some degree when making whole-farm plans (our analysis also ignores any nitrogen fixing benefits of alfalfa, which may make it an even more important crop).

One option to increase expected profits would be for producers to negotiate variable shares in sugarbeet. In the scenarios analyzed, where sugarbeet acreage was allowed to be lowered in years with low sugar prices and other crops were more profitable, the farm as a whole became more profitable. However, it would be preferred to keep sugarbeet shares at a fixed level rather than eliminating them entirely as excluding sugarbeet from production does result in significantly increased risk.

Appendix A

General Model

The general model is represented as follows:

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$$\max \pi = \sum_{\mathrm{i}} [\, (P_i * Y_i * X_i) - (CC_i * CU_i * X_i) - (FP * FU_i * X_i) - (OC_i)]$$

Subject to:

1. $CSB \leq \frac{1}{3}\ or\ RSB \leq \frac{1}{3},or\ CSB + RSB \leq \frac{1}{3}, or\ CSB + RSB = 0$

2. $DB \leq CSB + RSB\ acres\ except\ in\ scenario\ G$

3. $C \leq \frac{1}{2}, C \leq \frac{2}{3} in\ scenario\ G$

4. $IA \times \frac{1}{4} + EA \times \frac{3}{4} = A$

Where X_i = acres of each crop, $X_i \geq 0$

P_i = price received for crop

Y_i = crop yield per acre

CC_i = chemical cost by crop (fertilizer)

CU_i = chemical use by crop per acre

FP = fuel price

FU_i = fuel use by crop per acre

OC_i = other static costs for crop per acre

$i = (CSB, RSB, C, W, DB, IA, EA)$

Where CSB= Conventional Sugarbeet acres planted

Where RSB= GR Sugarbeet acres planted

Where C= Corn acres planted

Where W= Wheat acres planted

Where DB= Dry bean acres planted (DB) = $(X_{RSB}+X_{CSB})$

Where IA =Initial Alfalfa acres planted

Where EA=Established Alfalfa acres planted

Profit (π) is maximized by choosing the number of acres of each crop (X_i)

subject to the constraints discussed below over each of the 10,000 random price draws produced by the Monte Carlo simulation. All variables in the general model as represented above are greater than or equal to zero, implying non-negativity constraint on prices, usage amounts, yields, and acres. Variable (X_i), is acreage by crop and represents the decision variables in the whole-farm model. The variable (P_i), denotes output price by crop, which varies by iteration based on historical distribution as stated above. Variable (Y_i), is yield by crop per acre and is a fixed parameter. The stochastic variable (CC_i), is chemical cost by crop, this variable combines fertilizer costs. (CU_i), is a fixed parameter that describes chemical use by crop in the model. Although fuel price (FP) varies by iteration, it is the same across all crops, therefore it is not subscripted. The fixed parameter (FU_i), is fuel use by crop per acre. Other costs (OC_i), is a fixed parameter that combines all other costs within the budget.

Some other assumptions and constraints were also imposed on the LP model. Due to rotational constraints, sugarbeet can only be produced once in three years. Dry bean acreage is forced to be equal to the total acres of sugarbeet produced. This is based on the need to have a crop before sugarbeet in the rotation that will not leave heavy residue in the field, and dry bean is the most common crop in a typical rotation for SE Wyoming (Miller, 2011). Corn is constrained to ½ of the total acres, discouraging back-to-back corn cropping.

Two enterprise budgets for alfalfa are used in the whole-farm model. One budget is for establishment of alfalfa, which includes drilling and fertilization costs typical in establishing a new stand of alfalfa. The other alfalfa budget displays a cost schedule that is typical of an established stand of alfalfa. These two budgets are used in cooperation to create an alfalfa crop in the whole-farm model. The model assumes alfalfa would be in a common 4-year rotation, therefore one year of the initial alfalfa budget is combined with three years of the established budget. 3.3 tons/acre are produced in the initial alfalfa stand, whereas 6.6 tons/acre produced in the established stand. Equation 4 is used to signify that once alfalfa is established, it will remain in production for four years.

The case farm was modeled around a typical irrigated farm in SE Wyoming. There are 303 acres of available crop-land on the model farm. Profitability of the farm, based on optimal acres of each crop, is determined as crop output prices, fuel price, and multiple fertilizer prices vary. Table 1 shows the various scenarios analyzed. It was assumed that GR sugarbeet, while more expensive to grow, has a 2 ton/acre yield advantage over conventional sugarbeet. This figure might be considered conservative given that related studies have found anywhere from a 5-15% yield increase for GR sugarbeet (Kniss et. al., 2004; Kniss, 2010).

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Table 1. Acreage constraints as a fraction of total acreage by Scenario

<table>
<tr><td>Scenario:</td><td>A</td><td>B</td><td>C</td><td>D</td><td>E</td><td>F</td><td>G</td></tr>
<tr><td>CSB</td><td rowspan="2">1/3</td><td>-</td><td>1/3</td><td rowspan="2">≤ 1/3</td><td>-</td><td>≤ 1/3</td><td>-</td></tr>
<tr><td>GRSB</td><td>1/3</td><td>-</td><td>≤ 1/3</td><td>-</td><td>-</td></tr>
<tr><td>C</td><td>≤ 1/2</td><td>≤ 1/2</td><td>≤ 1/2</td><td>≤ 1/2</td><td>≤ 1/2</td><td>≤ 1/2</td><td>≤ 2/3</td></tr>
<tr><td>DB</td><td>=GRSB or CSB</td><td>1/3</td><td>1/3</td><td>= GRSB or CSB</td><td>= GRSB</td><td>= CSB</td><td>-</td></tr>
</table>

Note: CSB means Conventional Sugarbeet, GRSB means GR Sugarbeet, C means Corn, and DB means Dry Bean

Table 2. Distributions of profitability by scenario in LP model

Scenario	95th Percentile	5th Percentile	Average	95% CI +/-	SD	CV
A	$245,634.40	$102,059.80	$167,185.30[B]	$890.75	$45,447.23	0.27
B	$245,634.40	$102,059.80	$165,184.80[B]	$890.77	$45,448.35	0.27
C	$238,018.00	$99,034.10	$161,849.60[C]	$866.78	$44,224.52	0.27
D	$252,637.60	$105,471.80	$170,911.30[A]	$940.68	$47,995.01	0.28
E	$252,637.60	$105,471.80	$170,911.30[A]	$940.69	$47,995.29	0.28
F	$247,295.10	$102,573.50	$165,998.20[B]	$923.34	$47,110.54	0.28
G	$290,517.20	$75,453.27	$157,106.60[D]	$1,448.61	$73,910.19	0.47

Note: Superscript letters denote significant differences in the means at the 0.05 level

Table 3. Profitability distributions of all crops used in LP model on a per acre basis

	CSB	GRSB	C	W	DB	A
95th Percentile	$1,216.18	$1,305.21	$807.21	$507.201	$883.22	$307.97
5th Percentile	$387.96	$408.30	-$137.53	-$0.30	$54.14	$0.00
Average	$776.49	$829.31	$262.47	$188.18	$409.45	$273.66
95% CI +/-	$4.93	$5.34	$6.08	$3.22	$5.32	$1.97
CV	0.32	0.32	1.18	0.87	0.66	0.37

Note: CSB means Conventional Sugarbeet, GRSB means GR Sugarbeet, C means Corn, W means Wheat, DB means Dry Bean, and A means Alfalfa

Table 4. Average Acreage of crop by Scenario

Scenario	CSB	RSB	Corn	Wheat	Dry Bean	Alfalfa
A	101.00	0.00	37.20	20.05	101.00	43.75
B	0.00	101.00	37.20	20.05	101.00	43.75
C	101.00	0.00	37.20	20.05	101.00	43.75
D	0.06	89.98	43.46	28.61	90.04	50.86
E	0.00	90.04	43.46	28.61	90.04	50.86
F	88.57	0.00	43.97	29.76	88.57	52.14
G	0.00	0.00	47.81	35.32	160.06	59.80