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Comparison of Conventional and Glyphosate-Resistant Sugarbeet the Year of Commercial Introduction in Wyoming

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ABSTRACT

In 2007, approximately 800 ha of glyphosate-resistant sugarbeet (*Beta vulgaris*) were planted in Wyoming, representing the largest commercial production of a biotechnology-derived sugar crop at the time. A study was conducted in 2007 to compare the farm-scale economic differences between glyphosate-resistant and conventional (non-glyphosate-resistant) sugarbeet. Twenty-two sugarbeet fields (11 each planted to glyphosate-resistant and conventional cultivars) were selected early in the growing season and all field operations and sugarbeet yields were recorded. Tillage operations and herbicide costs were reduced in the glyphosate-resistant sugarbeet system compared with the conventional sugarbeet system. Sucrose production was over 1,400 kg per ha greater in glyphosate-resistant sugarbeet compared with conventional sugarbeet. The glyphosate-resistant sugarbeet system improved net economic return by $576/ha compared with the conventional sugarbeet system.

Additional Key Words: economic analysis, partial budget, biotechnology, herbicide resistant crops.

Approximately 800 ha of glyphosate-resistant sugarbeet (*Beta vulgaris* L.) were grown in Wyoming in 2007. At the time, this was the largest commercial production of a biotechnology-derived sugar crop in the world. Since then, commercial adoption of glyphosate-resistant sugarbeet has been rapid in the United States, with estimates for 2010 exceeding 95% of total sugarbeet acreage. Glyphosate use in glyphosate-resistant sugarbeet allows greater crop safety, weed control efficacy, and flexibility compared with conventional sugarbeet herbicides (Guza et al. 2002; Kniss et al. 2004; Wilson et al. 2002).

Previous research predicted a strong economic benefit from adoption of glyphosate-resistant technology. Kniss et al. (2004) estimated that growers could afford to pay nearly $480/ha for the technology due to a combined reduction in weed control costs and an increase in sugar production. Now that the glyphosate-resistant sugarbeet seed royalty is known ($106 per unit of 100,000 seeds) the estimate provided by Kniss et al. (2004) would indicate that at a seeding rate of 123,500 seeds/ha, glyphosate-resistant technology would result in a net economic gain to producers of $348/ha. Marlander (2005) predicted average cost savings of 56% in Europe. Marlander (2005) assumed a negligible increase in yield with glyphosate-resistant cultivars (1 to 3%), while others have assumed yield increases of up to 5% (Gianessi et al. 2003). Small-plot research comparing near-equivalent glyphosate-resistant and conventional cultivars demonstrated sucrose yield increases of at least 7% due to the glyphosate-resistant technology (Kniss et al. 2004).

Economic figures published prior to 2007 relied on either small plot research (Kniss et al. 2004) or various assumptions of how the technology would be used following commercial adoption by growers (Gianessi et al. 2003; Marlander 2005). However, no published studies to date document actual differences in production practices, yield differences, or economic factors following adoption of glyphosate-resistant sugarbeet on a farm scale. The objective of this study was to compare the actual economic differences realized by growers between glyphosate-resistant and conventional sugarbeet production systems in 2007, the year of commercial introduction.

MATERIALS AND METHODS

In May of 2007, 11 glyphosate-resistant sugarbeet fields in commercial production were located near Worland, Wyoming and paired with nearby fields of conventional sugarbeet. In order to minimize confounding factors, glyphosate-resistant fields were chosen only if a suitable conventional field could be found that was similar to the glyphosate-resistant field; each pair of fields was managed by the same grower, had similar soil type, slope, irrigation method, and cropping history. In many cases the pairs consisted of a single field where glyphosate-resistant and conventional sugarbeet cultivars were planted side by side. No attempt was made to influence growers' management decisions. All decisions were perceived by the growers to be the best option for their operation, and represent actual farm scale decisions and field operations, rather than researcher estimates of those practices.

For each field, all operations and input costs were recorded and yield data collected. Herbicide and adjuvant costs were derived from Bernards et al. (2009). Herbicide application and in-crop tillage costs were calculated at $9.90/ha and $14.80/ha, respectively. The cost of hauling harvested beets to the pile was calculated at $4.40/Mg of fresh yield. Paired t-tests were utilized to statistically compare yields, field operations, and costs where appropriate.

Partial Budget Analysis

A partial budget was developed utilizing the data collected from the paired fields. Partial budget analysis allows comparison of two production practices within a farm operation, and is especially useful when comparing a change in one component of a larger operation (Lessley et al. 1991). For the purposes of the partial budget in this analysis, adoption of glyphosate-resistant technology was considered a change in production practice and was compared with the standard production practices used in conventional sugarbeet. Sections within the partial budget include additional income and reduced input costs (which increase the net economic gain from adoption of glyphosate-resistant technology), as well as reduced income and increased costs (which decrease the net economic gain from adoption of glyphosate-resistant technology). Net income was then calculated to determine the economic gain or loss from adoption of glyphosate-resistant sugarbeet.

RESULTS AND DISCUSSION

In-crop tillage was reduced by 50% in glyphosate-resistant sugarbeet compared with conventional sugarbeet (Table 1). The reduction of in-crop tillage in glyphosate-resistant sugarbeet is expected, as glyphosate provides excellent weed control compared with conventional herbicides. Most fields in this study that were tilled during the growing season were furrow-irrigated. At least one tillage operation is required for furrow-irrigated fields to allow water advancement (the furrows were made as part of the in-crop cultivation). All of the conventional fields, except two, utilized one in-crop tillage operation for weed control in addition to a tillage operation to create the furrows.

A marginal reduction in the number of herbicide applications was observed in glyphosate-resistant sugarbeet compared with conventional sugarbeet (P = 0.0816) (Table 1). Two of the 11 glyphosate-resistant sugarbeet fields received three postemergence applications of glyphosate, while the remaining fields received only two glyphosate applications. Five of the conventional fields received three applications of conventional herbicides, and the remaining fields received only two applications. In this study, no herbicides other than glyphosate were applied to glyphosate-resistant sugarbeet, whereas 2 to 5 different herbicide active ingredients were applied to the conventional sugarbeet fields.

Herbicide costs for conventional sugarbeet systems ranged widely from \$57 to \$393/ha, whereas the herbicide costs for glyphosate-resistant sugarbeet systems ranged from \$40 to \$69/ha. The variability in conventional herbicide costs resulted from the choice of herbicides (ranging from 2 to 5 products) and the number of applications made (ranging from 2 to 3). Since only glyphosate was applied to glyphosate-resistant fields, differences in costs were driven by the rate of glyphosate used and number of applications. Overall, herbicide costs were greater in conventional sugarbeet compared with glyphosate-resistant sugarbeet systems (Table 2). Conversely, harvest costs were greater in glyphosate-resistant sugarbeet as a result of higher root yields compared with conventional sugarbeet.

Other input costs that contributed to differences between the glypho-

Table 1. Field operations in conventional and glyphosate-resistant sugarbeet. Worland, Wyoming, 2007.

	Herbicide application	In-crop tillage
	------------ Number per hectare (std. error) ------------	
Conventional	2.45 (0.52)	1.82 (0.40)
Glyphosate-resistant	2.18 (0.40)	0.91 (0.30)
p-value	*0.0816*	*0.0002*

Table 2. Input costs for conventional and glyphosate-resistant sugarbeet. Worland, Wyoming, 2007.

	Seed royalty	Herbicides	Hand labor	Harvest
	--------------------------- $/ha (std. error) ---------------------------			
Conventional	0	153 (104)	235	224 (65)
Glyphosate-resistant	131	49 (10)	0	258 (52)
p-value	*na*†	*0.0067*	*na*†	*0.0076*

† Conventional fields were not assessed a seed royalty, and glyphosate-resistant fields were not hand-weeded, therefore no t-test could be performed on these two variables.

sate-resistant and conventional sugarbeet systems included the seed royalty attached to glyphosate-resistant cultivars, and hand-labor for weed removal (Table 2). The seed royalty paid by growers for glyphosate-resistant cultivars was $106 per unit of 100,000 seeds. The average seeding rate for fields in this study was 123,500 seeds/ha, resulting in a seed royalty cost of $131/ha for glyphosate-resistant sugarbeet. All conventional sugarbeet fields required hand-labor for weed control during the growing season whereas none of the glyphosate-resistant sugarbeet fields were hand-weeded. The average cost for hand-labor in this study was $235/ha. This cost is high compared with that observed in other U.S. growing regions due to a shortage of seasonal labor in this region. For example, hand-weeding costs in North Dakota and Minnesota ranged from $67.70/ha to $72.62/ha between the years 2007 and 2009 (Stachler et al. 2009). Similarly, growers in other regions are less likely to utilize hand-labor for weed control in conventional sugarbeet, and will instead make a greater number of herbicide applications, and thus these costs will vary between growing regions.

Although sugar content was similar between the two systems, root yield was 15% greater in glyphosate-resistant sugarbeet compared to conventional sugarbeet (Table 3). Grower payments are typically based on a combination of these two variables. When root yield is multiplied by percent sucrose content to calculate gross sucrose production, the glyphosate-resistant system resulted in over 1,400 kg more sucrose per ha ($P = 0.0228$). This is a 17% increase compared with conventional sugarbeet. An increase in sucrose production due to glyphosate-resistant technology in sugarbeet has been demonstrated by several researchers based on small plot research, and the difference presented here supports previous research at the field scale.

Partial Budget Analysis

For the partial budget analysis (Table 4), estimates for each income and cost category are derived from data collected in this study. Additional income was a result of the increased sucrose production. The

Table 3. Yield, sugar content, and associated standard errors of conventional and glyphosate-resistant sugarbeet. Worland, Wyoming, 2007.

	Root yield	Sugar content	Total sucrose
	--- Mg/ha ---	--- % ---	--- kg/ha ---
Conventional	50.8 (14.7)	16.82 (1.27)	8,586 (2,599)
Glyphosate-resistant	58.6 (11.7)	17.11 (0.94)	10,047 (2,162)
p-value	*0.0076*	*0.5695*	*0.0228*

Wyoming Sugar payment schedule factors in the current net selling price of sugar. Based on a net selling price of $0.60/kg for sugar, the grower payment would be $368/ha greater for the glyphosate-resistant system compared with the conventional sugarbeet system. Cost reductions in the glyphosate-resistant system were observed in several areas, most notably hand-labor and herbicide costs. The glyphosate-resistant system did not result in reduced income compared with conventional practices, but additional costs were incurred through the seed royalty and harvest costs (due to the increased root yield). When taken together, adoption of glyphosate-resistant sugarbeet increased net economic return to the growers by $576/ha compared with conventional sugarbeet. This figure is greater than most previous estimates based on small-plot research or theoretical changes in production practices (Gianessi et al. 2003; Kniss et al. 2004; Marlander 2005).

While this research documents a significant increase in net economic return to sugarbeet growers adopting glyphosate-resistant technology in Wyoming, the results should be interpreted with some caution. This data is based on a single year of production in a small geographical region. An attempt to repeat this study was made in 2008, however, the exceptionally high adoption rate of glyphosate-resistant sugarbeet in Wyoming, prevented the identification of a sufficient number of conventional sugar-

Table 4. Partial budget to analyze the adoption of glyphosate-resistant sugarbeet based on 11 paired fields. Worland, Wyoming, 2007.

	Additional income	Reduced costs	Reduced income	Additional costs
	------------------------ $/ha			------------------------
Seed royalty	-	-	-	131
Herbicide application	-	3	-	-
Herbicide costs	-	103	-	-
In-crop tillage	-	14	-	-
Hand labor	-	235	-	-
Sucrose production†	386	-	-	-
Hauling crop from field to the pile	-	-	-	34
Total	**386**	**355**	**0**	**165**
Net economic benefit of glyphosate resistant sugarbeet			**576**	

† Payment based on Wyoming Sugar payment schedule for a net selling price of sugar on the open market of $0.60/kg.

beet fields for appropriate side-by-side comparisons. Therefore this data encompasses only a small subset of all possible economic and environmental conditions that may influence results. However, the partial budget provided here may provide information that will be useful in making management decisions and designing experiments. This research documents the possible economic advantage of transgenic sugarbeet utilizing infrequently reported farm-scale side-by-side comparisons.

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