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Economic Benefits of Genetically-modified Herbicide-tolerant Canola for Producers

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Genetically-modified herbicide-tolerant (GMHT) canola was introduced in Western Canada in 1995. In 2007, a producer survey elicited answers to 80 questions regarding their experiences, including production practices, tillage and herbicide use, control of volunteer canola, and weed-control practices. The survey revealed that the new technology generated between $1.063 billion CAD and $1.192 billion annual net direct and indirect benefits for producers from 2005-2007; this is partly attributed to lower input costs and partly attributed to better weed control. One major concern in the early years following introduction was the potential for HT traits to outcross with weedy relatives or for GMHT canola to become a pervasive and uncontrollable volunteer in non-canola crops, either of which would offset some producer gains. The survey largely discounts that concern. More than 94% of respondents reported that weed control was the same or had improved, less than one-quarter expressed any concern about herbicide resistance in weed populations, 62% reported no difference in controlling for volunteer GM canola than for regular canola, and only 8% indicated that they viewed volunteer GM canola to be one of the top five weeds they need to control.

Key words: genetically modified, herbicide tolerant, canola, economic impact, land management, herbicide use, benefits.

Introduction

Innovation is pervasive in agriculture, but few single innovations have generated the impacts or controversy of genetic modification. Advocates and critics alike have argued and debated the economic impacts from producer adoption of genetically modified (GM) crop varieties, with a disturbing lack of empirical data. The paucity of direct producer data has had a knock-on effect on diffusion of the technology, as other nations have been unconvinced of the costs and benefits of approving and adopting the technology to their markets.

Herbicide-tolerant (HT) canola has been produced in Western Canada since 1995, which provides the opportunity to undertake an extensive analysis of adoption practices and impacts. HT canola was initially introduced in 1995 through an identity-preserved production and marketing system (Smyth & Phillips, 2001), with unrestricted commercial production beginning in 1997. The subsequent adoption was relatively rapid, reaching 25% in the initial year, 84% by 2002, and 98% by 2007. There are currently three HT systems available to producers—two developed through genetic modification (GMHT) and one through mutagenic breeding. AgrEvo's (now Bayer CropScience) Liberty Link™ and Monsanto's Roundup Ready™ varieties are commonly referred to as GMHT varieties. Pioneer Hybrid's imidazolinone-tolerant Clearfield® system was developed by mutagenesis. These technologies all allow for in-crop spraying of broad-spectrum herbicides, with little or no damage to the HT crop.

This article examines the economic benefits of GMHT canola adoption reported by Western Canadian producers in a survey undertaken in 2007. The next section reviews the previous efforts to document the economic benefits of GMHT canola. Then, we describe the methodological framework for the survey and present the results and analysis of the survey. The article closes with a discussion of the impacts from GMHT canola and some concluding thoughts.

Background

Eighty-one percent of the cultivated land in Canada lies in Alberta, Saskatchewan, and Manitoba, and virtually all of the canola is produced there. Western Canadian farms are relatively large, averaging 1,400 acres. The top three crops from 2002-2007 in terms of seeded acreage were spring wheat, canola, and barley. Total canola acreage significantly increased after the adoption of GMHT varieties in 1995, rising 31% to an average of 13.9 million from 2003-2008, up from an average of 10.5 million acres from 1991-1995 (Statistics Canada, n.d.).

A series of studies have examined the impact of innovation on returns to canola producers. A number of studies between 1977 and 1998 modeled the canola sector to estimate the economic impact of the transition from rapeseed to canola (Nagy & Furtan, 1978; Ulrich & Furtan, 1985; Ulrich, Furtan, & Downey, 1984) and to provide a range of ex-ante estimates of the impact of GMHT on producers, consumers, and the environment (Aulie, 1996; Malla & Gray, 1999; Mayer & Furtan, 1999). All estimated significant returns from those changes, with internal rates of return estimated to be as high as 101%. All of the ex-ante forecasts, however, raised the possibility that the technology could be somewhat self-limiting if the HT traits outcrossed to weedy relatives or if GMHT canola persisted and became an unwelcome volunteer in subsequent crops.

Beginning close to 2000, a number of scholars and practitioners attempted to assess the early prospects for future returns to producers. The bulk of the producer data that was used for these studies was gathered between 1999 and 2002; one study gathered data as late as 2004. The earlier data was gathered at the peak transition period between conventional canola and GMHT canola, and the observances from these studies provide an excellent point of reference for the results of our survey.

Phillips (2003) undertook a four-year retrospective analysis of the economic impact of the introduction of GMHT canola. Using 1995-2000 data, Phillips estimated the broad economic impacts of GMHT canola on the global industry and economy, as well as the direct and indirect effects on producers. Phillips identified the effect of higher seed costs, lower herbicide costs, fewer herbicide applications, lower dockage, and earlier seeding (adjusted for the yield drag in early varieties) as roughly $11.14[1]/acre by 2000. While this generated an estimated $103 million gross producer gain in 2000, farmers did not net the full amount, as lower prices due to increasing supply eliminated $32 million of this figure. Producers were estimated to net $70 million in 2000.

The Canola Council of Canada (CCC, 2001) published a report based on data collected in 1999 that quantified the agronomic and economic impacts associated with GMHT canola. Adoption of GMHT canola by 2001 reached 80%, which allowed for in-field comparisons of transgenic and conventional varieties. The study identified the key producer impacts as improved yield, slightly increased fertilizer usage, increased seed costs, decreased tillage use, improved soil moisture conservation, decreased summer fallow, improved rotation flexibility, lower dockage, and decreased herbicide inputs. Overall, the study reported that direct producer benefits per acre of GMHT canola averaged $10.62 in 2000, yielding a net gain of about $66 million for producers.

Fulton and Keyowski (1999) noted that the adoption of an innovation depends upon the perceived usefulness and ease of use to adopters; later adopters depend on the opinions and experiences of early adopters. Mauro and McLachlan (2008) conducted a survey in 2003 to assess producer knowledge and perceptions of GM crops and the associated risks. A mixed methodology approach was applied, with 15 producer interviews being used to develop a questionnaire. Mauro and McLachlan found in their survey that 77% of GMHT canola producers were satisfied with the results of GMHT canola. They found that the decision to adopt and to continue to use was not solely an economic decision, as only 47% of producers identified GMHT canola was more profitable than conventional varieties, and only 21% indicated that GMHT canola offered higher yields. Moreover, they found that producers viewed the benefits of GMHT to be decreasing, at least partly due to the 38% of producers who had experienced GMHT volunteer canola on their land. About 80% of these producers concluded the volunteers came mainly from their own production, while 8% reported finding volunteer canola that they suspected originated elsewhere. The authors' concluded that the earlier estimates of the benefits of GMHT canola were suspect, as they did not account for the increasing cost of managing this volunteer canola for producers and their neighbors.

The CCC (2005) released a second report that compiled the results from three different weed surveys conducted between 2001 and 2003, as well as the results from a 2004 producer survey that examined the management of volunteer GMHT canola in subsequent crops. This report provided a comprehensive review of the impact of volunteer canola as a weed and assessed the differences between the various GMHT canola systems. The study discovered little difference between canola systems in regards to management of volunteer canola in subsequent crops. Conventional canola producers were found to make slightly fewer pre-seed passes to apply herbicides yet tilled more than GMHT systems.

Studies by Phillips (2003), the CCC (2005), Beckie et al. (2006) and Kleter et al. (2007) found correlations between adoption of GMHT varieties and adoption of

1. *All monetary figures are expressed in Canadian dollars (CAD).*

zero-tillage systems. The CCC (2005) also that found 60% of GMHT adopters experienced a carry-over benefit of improved weed control, which was judged to be equivalent to the cost of one herbicide application. Volunteer canola was found to be the fourth most common weed targeted by herbicide; while it was not the sole target of herbicide applications, the estimated cost of controlling for volunteer canola was determined to be around $2.00/acre. Overall, the study found the benefits of growing GMHT varieties to be greater than that of conventional varieties.

The data gathered and reported in the majority of these reports and surveys come from the early part of the 21st Century. Since then, the level of adoption has increased substantially and the number of acres seeded to canola has doubled. The results of the two CCC reports and the Phillips paper provide a solid research base on which to build; the survey used in this study was developed from these three pieces of research. Where possible, these results are compared to our own findings.

Theoretical Framework

Measuring the economic value or impact of an innovation is challenging. The myriad of criterion make any modeling efforts of limited value due to the inability of any model to capture all of the relevant economic attributes related to an innovation. In conjunction with this is how much of a specific impact can be directly correlated to the innovation, and how much is an indirect impact, which therefore has to be discounted at some specific rate. So, while modeling the economic impact of innovation is not a simple, nor a perfect process, models do exist that provide us with the best assessment presently available.

Past waves of technological change in the agri-food sector have delivered a relatively straightforward distribution of benefits and costs (see Alston, Wyatt, Pardey, Marra, & Chan-Kang, 2000). As is demonstrated above, past assessments have shown a high rate of return for canola research. In 1970, 83% of research spending was public investment. By 1997, the private sector's share had grown to 80% of the total (Malla, Gray, & Phillips, 2004). This funding shift is evident in the registration of new varieties. Prior to 1973, all varieties were public; in the 1990-98 period, 86% of the varieties were private. This large shift in emphasis from public to private research is due to the large increase in private-sector investment rather than a reduction in public research.

In an earlier study, Smyth and Phillips (2001) estimated that in 2000, the initial two developers—AgrEvo and Monsanto—had recognized a net present value in excess of $100 million. This value was realized five years after the initial commercialization. When economic theory and the literature of returns to research are juxtaposed with the rise of private investment (often for biotechnology-based effort) in the canola sector, Phillips (2002) estimated gains for research to yield an internal rate of return (IRR) between 20% and 95%. This figure may actually be larger for specific biotechnology-based developments because of the reduced cost of the research and the increased array of attributes that can be bred into the seed, which add new value to consumers. Malla et al. (2004) examined the IRR to canola from 1960-1999, concluding that the IRR has declined over time. Their analysis states that early rates of return to the development of canola varieties exceeded 25%, but towards the end of the time period they examined, IRR began to approach rates more consistent with market returns.

Clearly, there are economic benefits from investment in canola variety development, especially the development of HT canola. Numerous accusations have been made against the developers of HT canola, suggesting that the vast majority of these benefits accrue to the developers and that only a limited level of benefits are recognized by producers. In an attempt to assess the distribution of benefits to producers, we build upon the earlier work of Phillips (2003) and have gathered data on the economic benefits at the producer level from the adoption of HT canola in 2006.

The Survey

To gather the data needed for this research project, a four-page, 80-question survey was developed and distributed to agricultural producers. The time required to complete the survey was estimated to be 30-45 minutes. The survey was comprised of six major areas of focus: weed control; volunteer canola control; canola production history; specific weed control measures on canola fields and subsequent crops; crop and liability insurance; and general demographics. Open, closed, and partially open questions were asked in the survey. Space was provided to enable producers to more fully explain changes within the production system in order to facilitate a more complete understanding of producer choices. Where a quantification of producer attitudes was required, a simple three-point scale was used, which allowed for positive, neutral, and negative responses.

Table 1. Distribution of usable survey responses (n=571).

	Low production	High production	Total
Alberta	14%	11%	25%
Manitoba	n/a	16%	16%
Saskatchewan	32%	27%	59%
Total	46%	54%	100%

The University of Saskatchewan's Research Ethics Board approved the survey design (BEH# 06-318).

Forty thousand surveys were distributed across the three Prairie Provinces in March and April 2007. Distribution of the survey was through Canada Post's un-addressed ad-mail service, providing a cluster sampling method. This allowed for a selection of farms as defined by Canada Post within the postal code system. Participant selection was based upon geographic location in five targeted regions separated by provincial boundaries and based on historic canola production levels. A high production and low production region in each of Alberta and Saskatchewan and a high production area in Manitoba were surveyed. The target population was producers having more than 80 acres of cropland. Surveys were randomly distributed through the regions.

A lottery prize was employed to encourage the completion of the survey. The lottery consisted of two draws among eligible survey respondents for consumer electronic goods valued at $250 each. In total, 685 surveys were received, with 571 meeting our population criteria. Outliers within the database were identified and removed utilizing the box plot method as developed by Tukey (1977) and outlined by the National Institute of Standards and Technology (NIST)/SEMATECH (2006). Extreme outliers, or upper outliers, were identified based on the amount of acres treated by the herbicide. Table 1 outlines the distribution of usable responses across the three Prairie Provinces and between areas of low and high canola production. While the number of respondents relative to the number of surveys distributed indicates a low response rate (1.71%), it is important to note that the Canada Post's un-addressed ad-mail service delivers surveys to all mail addresses within the identified region. There is no way to know how many households received surveys that were not farmers or did not produce canola. Therefore, the actual response rate is unknown and is most certainly greater than what can be calculated here. The important point is that the number of valid responses for a survey of this size provides us with a confidence level of 95%.

The demographics of the sample population are similar to the source population as reported in the Statistics Canada Farm Census (2006; Table 2). The average age of farmers is 52 in Saskatchewan and Alberta, and 51 in Manitoba. Our survey population has a substantially higher level of post-secondary education, whereas the census data identifies the percentage of producers with a university degree in Manitoba at 8%, Saskatchewan at 8%, and Alberta at 9%.[2] Average farm size of the sample population was greater than that of census data, which showed that the average Alberta farm size was 1,055 acres, Saskatchewan was 1,450 acres, and Manitoba was 1,000 acres.

Table 2. Producer demographics.

	Alberta	Saskatch.	Manitoba	Total/ Avg.
# of survey respondents	144	335	92	571
Average age				
Sample	45 to 54	45 to 54	45 to 54	45 to 54
Census	52	52	51	52
University degree				
Sample	14%	21%	7%	14%
Census	9%	8%	8%	8%
Average farm size				
Sample	1,652	1,743	1,357	1,656
Census	1,055	1,450	1,000	1,168
Average canola acres	507	476	400	470
Average experience with canola	19.3	20.6	20.8	20.3
First year with GMHT canola	1999	1999	1998	1999

Source: Survey and Statistics Canada 2006 Farm Census.

The respondents to this survey had relatively large operations (1,656 acres), with, on average, more than one-quarter of their operation dedicated to canola (Table 2). The average respondent has farmed for 30 years and belongs to the '45 to 54' age group. These producers

2. *The number of respondents with a university degree is substantially higher in Saskatchewan than is reflected in the census data. A variety of factors contribute to this. The farm size is larger than average and producers are slightly younger than the average, which tend to be correlated with higher levels of education. Moreover, the affiliation of this research with the University of Saskatchewan may have triggered a greater response from graduates than from others.*

Table 3. Attribution of change in weed control after adopting GMHT canola.

Weed control	Change due to adoption (n=242)	Change not due to adoption (n=145)	Total reporting change (n=387)
Weed control less effective	5.4%	7.6%	7.0%
Weed control unchanged	34.3%	42.1%	36.2%
Weed control improved	60.3%	50.3%	56.8%

Table 4. Tillage operations and GMHT canola systems.

Tillage method	Clearfield (n=40)	Liberty Link (n=135)	Roundup Ready (n=154)	Average (n=340)
Zero-till	60.0%	53.3%	50.6%	53.5%
Cultivation	22.5%	20.0%	24.0%	21.8%
Harrow	12.5%	11.9%	9.7%	10.6%
Cultivation and harrow	5.0%	14.8%	15.6%	14.1%

Margin of error: Clearfield® ±15.5%; Liberty Link™ ±8.4%; Roundup Ready™ ±7.9%; Total ±5.3%

reported growing canola for an average 20 years and first adopting GMHT canola in 1999; on average, they reported that they removed conventional canola varieties from their crop rotations by 2000.

For the 2005 and 2006 crop years, farmers reported that 48% of their acreage used Roundup Ready™ varieties, 37% used Liberty Link™, and 10% used Clearfield®. These adoption rates are consistent with the adoption rates provided by the canola industry, which identifies Roundup Ready™ market share at 44%, Liberty Link™ at 40%, and Clearfield® at 11% (C. Anderson [Program Manager, CCC], personal communication, 2008).

Survey Results and Analysis

The survey asked questions that explored three major economic impacts from the adoption of GMHT canola: cost of weed control, control of volunteer canola, and second-year benefits and costs.

Cost of Weed Control

To determine if a change in weed-control practices of Western Canadian producers has occurred, the two methods of weed control—chemical herbicide use and tillage practices—have to be examined.

Producers were asked if they have changed their chemical herbicide use over the past 10 years, and 68% of respondents reported that a change had occurred. Of those reporting a change, 94% found weed control effectiveness to have improved or remained the same (Table 3). More than 60% of respondents reported that previously difficult-to-control weeds—such as wild mustard, stinkweed, and cleavers—can now be more easily controlled. More than one-third of producers reported that control over difficult weeds in canola fields is unchanged from the situation that existed prior to the commercialization of GMHT canola. Just more than 5% of respondents reported that weed control has become less effective. While the majority of those reporting a change in weed control after adopting GMHT varieties attributed the changes to the new technology, about 36% of the changes in weed control were not related to adoption—other agronomic circumstances (both positive and negative) were at work.

The survey found that many producers have moved to minimum or zero-tillage operations,[3] with more than half of the respondents indicating that they no longer use tillage operations in their cropping system, with very little difference in adoption rates between the three HT technologies (Table 4). Nevertheless, more than 46% of producers reported that they continue to use a mix of cultivation and harrow as part of their seeding practices.

Land management practices added some incremental costs. In 2006, 24.7% of farmers preformed harrow operations at least once, conducting an average of 1.2 passes on 88% of their canola crop. The CCC (2001) estimated that harrowing cost $3.50 per acre. Assuming the costs have not changed, the harrow operations on GMHT canola fields would be about $3.72[4] for each harrowed acre; scaled up to the entire canola production

3. *While there has been a strong movement toward reduced-tillage land-management practices in Western Canada over the past 15-20 years, it is not possible to establish a strong correlation between reduced tillage and GMHT canola adoption. These two technologies have co-evolved and can be said to be mutually beneficial, but there is no strong correlation between the two technologies.*

4. *The cost of $3.72 is determined by: $3.50 harrowing cost × 1.2 passes × 88% of canola acres.*

Table 5. Comparison of harrowing and tillage costs: 1999 to 2006.

	1999 data		2006 data
	Transgenic (n=321)	Conventional (n=316)	All farmers (n=340)
Cultivation operations			
Average number of operations	1.79	2.63	0.48
Average cost per acre cultivated*	$10.74	$15.78	$2.86
Harrowing operations			
Average number of operations	0.94	0.84	0.26
Average cost per acre**	$3.29	$2.94	$0.92
Overall			
Average number of operations	2.73	3.47	0.74
Average cost for all tillage operations	$14.03	$18.72	$3.78
Percent transgenic	67%		95%
Overall cost per acre	$15.58		$4.59
Total acres	13.7 million acres		13.0 million acres
Overall expenditure	$213.5 million		$59.7 million

** assuming $3.50/acre; ** assuming $6/acre*

Source: CCC (2001) for 1999 data. Margin of error at the 95% confidence level on 2006 data: cultivation=9% and harrowing=11%

area, this would add $0.92 to the cost of the average acre seeded to canola.[5] Continuing cultivation similarly adds costs. The survey revealed that 35.9% of farmers preformed cultivation operations on their canola fields, conducting an average of 1.51 passes on 88% of their canola crop. Using the CCC (2001) estimates of $6.00 per cultivated acre, the cost of these sustained operations would add $7.98[6] for each cultivated acre; scaled up to the entire canola acreage, the average cost is $2.86 per acre of canola seeded.

Comparing the CCC (2001) survey of farmer practices in 1999 with our survey of farm practices in 2006, it would appear that the total number of tillage operations for transgenic canola dropped from 2.73 passes to 0.74 passes per acre (Table 5). Assuming the cost of tillage operations have remained constant since 1999 (i.e., $6.00 per acre for cultivation and $3.50 for harrowing), the expected cost of all tillage conducted on canola acres would have been reduced by $10.25 per acre, or 73%. Scaled up for the size of the canola crop in 2006, this saving would translate into $153.8 million (assuming tillage on conventional canola has remained the same).

Tillage is used for both seeding and for weed control. When asked explicitly about weed-control measures conducted on the 2006 canola crop, 77% of producers reported they only used herbicides, while 28% of producers reported they combined the use of herbicides and tillage, and 7% reported they only used tillage for weed control. Use of tillage has markedly decreased since 2000, when 89% of producers reported conducting tillage operations as a form of weed control (CCC, 2000). Perhaps most importantly, weed control had long been one of the main limiting factors in more producers moving both to lower-tillage agriculture and to greater cultivation of canola. The commercialization of GMHT canola and the superior weed control it offers has contributed to the increased utilization of minimum- or zero-tillage operations. The costs of the various weed-control systems are identified in Table 6.

Table 6 shows that the cost of tillage has declined; however, when a comparison of financial costs is undertaken, tillage remains cheaper than herbicide weed-control options. The reported cost for tillage corresponds to the per-pass custom tillage rate in Saskatchewan (Saskatchewan Ministry of Agriculture, 2008). Custom tillage rates vary depending on the size of equipment and hours of annual use. The range of tillage costs in Saskatchewan for 2008-09 was $5.33-$7.79. While the reported cost of one tillage pass in Table 6 is $8.07 (marginally above the provincial range), this cost is for one pass of tillage equipment, and in an average summerfallow year, a field would be tilled 4-6 times.

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5. *While not all canola acres are harrowed or tilled anymore, to be able to make a comparison with the CCC study, we have applied the cost to all acres, thus allowing us to determine what changes have occurred.*
6. *The cost of $7.98 is determined by: $6.00 tillage cost × 1.51 passes × 88% of canola acres.*

Table 6. Cost of weed control ($CAD).

Weed-control method	Cost of weed control on canola/acre: Sample size	Cost of weed control on canola/acre: Average cost	Cost of weed control on subsequent crop/acre: Sample size	Cost of weed control on subsequent crop/acre: Average cost	2-year total cost ($/acre)
Herbicide only	77	$19.61	77	$9.28	$28.89
Tillage only	15	$8.07	23	$10.58	$18.68
Herbicide and tillage	105	$13.74	31	$12.54	$26.28

Table 7. Management of herbicide resistance in weed populations.

	Clearfield (n=46)	Liberty Link (n=165)	Roundup Ready (n=209)	Total (n=432)
Harder	28.3%	27.3%	18.7%	23.4%
The same	41.3%	35.2%	50.7%	43.8%
Easier	30.4%	37.6%	30.6%	32.9%
Maximum margin of error at 95% confidence interval	14.4%	7.6%	6.8%	4.7%

Finally, tillage is typically done by the individual producer who will not have added in a cost for their time to till a field. The reality is that when environmental aspects like moisture conservation and soil erosion are factored in, the cost of tillage increases even further. Table 6 confirms that the producer costs drop the year following production of GMHT canola as respondents identify a reduction in herbicide cost for weed control of 52.7%.

Canola production has increased and producers are growing canola more frequently in their crop rotations. A concern with this increase in frequency of canola—and associated herbicides—in the rotation is the potential for the development of herbicide resistance in weed populations. The survey asked producers about their experiences in the management of herbicide resistance in weeds. Twenty-eight percent of producers reported that management of herbicide resistance in weeds has improved, 47% reported it was unchanged, and 24% reported herbicide resistance in weeds was on the rise. Table 7 identifies present survey findings on the issue of weed populations developing herbicide resistance from GMHT platforms. Producers using Clearfield® and Liberty Link™ canola were more likely to report a rise in herbicide resistance in weed populations; 81% of producers using Roundup Ready™ identified that herbicide resistance was the same or weed control had become easier.

Producers were specifically asked about weed control measures taken on their 2006 canola crops. The responses to this question closely reflected the responses to the question on the management of herbicide resistance in weeds, with 17% reporting that no measures had been used to control weeds in their canola fields, 47% reported only using herbicides, 7% reported only using tillage, and 27% reported the use of tillage and herbicide. No significant difference was found between the three HT systems. Producers utilizing tillage and herbicide were found to be more likely (53%) to make only one herbicide application than those only utilizing herbicide to control weeds (39%).

When questioned about herbicide applications to 2006 canola crops (Table 8), 43% of respondents reported a single application, 37% made two applications, and 12% reported three or more applications. Producer applications are consistent for in-crop spraying compared to 10 years ago. Data from 1998 (CCC, 2000) indicates that 47% of producers made more than one pass, 37% made two passes, and 14% made three or more passes.

One additional reference check was to compare the absolute and relative costs of the four potential weed-control systems individually and then as they are combined. Table 9 presents the comparative costs of weed control by the four canola systems: conventional, Clearfield®, Liberty Link™, and Roundup Ready™. Each system is reported in three different ways; first, the average reported cost of weed control of each system; second, the average reported cost of weed control for producers that only grew a single system in 2006; and third, the average reported cost of weed control of producers who used more than one system. While the overall and single-use cost of weed control for producers using Roundup Ready™ varieties was lower than that of other systems, producers who reported using Roundup Ready™ with other systems reported their cost of weed control significantly increased. While the relative costs were higher for Clearfield® users, the pattern was the

Table 8. Herbicide weed-control measures on 2006 canola crops.

	Clearfield (n=33)	Liberty Link (n=112)	Roundup Ready (n=114)	Total (n=259)
One application	51.5%	45.5%	38.6%	43.2%
Two applications	30.3%	34.8%	40.4%	36.7%
Three or more	13.0%	13.5%	11.4%	12.1%
Margin of error at 95% confidence interval	17.1%	9.2%	9.2%	6.1%

Table 9. Mixtures of canola systems and associated cost of weed control ($CAD).

Canola variety	Average	Single system	Multiple systems
Conventional*	$15.40	$15.40	n/a
Clearfield*	$15.18	$14.89	$15.32
Liberty Link*	$18.05	$19.02	$16.68
Roundup Ready*	$13.13	$11.98	$13.82
Total**	$15.64	$15.45	$14.81

** 95% confidence level +/- 10.5% or greater*

*** 95% confidence level +/- 7%*

same. In contrast, producers using the Liberty Link™ system reported their costs were higher if the system was uniquely used but dropped if other systems were combined; this may be at least partly because these producers also reported that they faced a harder time managing herbicide resistance in weed populations.

Control of Volunteer GM Canola

One concern with the increased use of GM agricultural crops—and of GMHT canola in particular—is that volunteer GMHT canola could become a major in-crop weed because those varieties are difficult to control with common broad-spectrum herbicides. Mayer and Furtan (1999) speculated that heavy use of a technology such as GMHT canola could be expected to increase the weedy potential of volunteer canola in the future. Given that producers have demonstrably planted canola with increasing frequency, it would be logical to assume that the challenges of controlling volunteer canola could be increasing. To test this concern, a section of the survey asked producers about the effect of volunteer canola on producer operations and decision-making processes.

When asked an open ended question about the top five weeds targeted by weed-control measures, 92% of producers did not mention volunteer canola; the 8% of producers who did mention volunteer canola listed it as their fourth or fifth most problematic weed. When asked specifically about controlling volunteer canola, 35% responded that it required effort to control. One might conclude from this that volunteer canola is viewed mostly as a nuisance and not a major economic drain on their operations, which coincides with the Canola Council of Canada's 2005 study. These results also support the conclusion by Beckie et al. (2006) that there has been no marked change in volunteer canola as a 'weed' as a result of the transition to GMHT systems.

Advances in control of volunteer canola appear to be keeping pace with the increase in canola acreage. When asked whether they were targeting volunteer canola, 62% of producers identified that they no more focused on volunteer canola than they did 10 years ago. About 74% of respondents reported that they are able to control volunteer canola more easily or about the same as 10 years ago. The 26% that find volunteer canola control to be more difficult than 10 years ago also reported that they are spending more on controlling volunteer canola. Only 9% of producers reported that the loss in yields due to volunteer canola have worsened over the last decade.

The cost of controlling volunteer canola remained constant for 73% of producers over the past decade. Twenty-seven percent of producers reported increased costs, up an average of $4.23/acre. A comparison of responses between ease of control and change in targeting revealed that 77% of those who found volunteer canola more difficult to control were spending more for targeting control measures.

When asked specifically about fields in 2006 that were seeded to canola in 2005, 36% reported that they did not conduct any weed-control measures specifically for volunteer canola. The rest made some investments: 46% sprayed herbicides, 8% conducted tillage operations, and 11% conducted both tillage operations and sprayed herbicide. A range of herbicides were used—58% used a single herbicide application, 29% made two applications, and 13% reported three or more applications. While the average reported cost of these weed-control operations was $12.70/acre, many respondents noted that these weed-control measures were not specifically undertaken to control volunteer canola.

Another concern with the proliferation of GMHT canola is the potential that plants could volunteer on land that was not previously seeded to canola, resulting in a new weed species requiring additional control mea-

Table 10. Field rotations with HT canola.

Rotation	Percent
Every year	0.32%
Once every 2 years	8.83%
Once every 3 years	33.44%
Once every 4 years	48.26%
Once every 5 years or more	7.26%

Significant at the 95% confidence interval with a margin of error of 5.5%

sures. Twenty-two percent of producers indicated that they had conducted control measures for such occurrences, with 13% spraying herbicide, 5% tilling, and 3% both spraying and tilling. Once again, while the average cost reported was $14.30/acre, many producers indicated that this cost was not solely to control volunteer canola but was directed at a number of weeds, which included volunteer canola.

One option many producers exercise is to take preventative measures to limit the potential for GMHT canola to volunteer in their fields. Fifty-two percent of respondents reported that they had undertaken measures to prevent volunteers—64% of these farmers cleaned machinery between fields and 13% restricted use of GMHT canola on their fields through restrictive rotations or other measures. Some larger farms have, however, adopted the practice of growing canola every year. With three different platforms to choose from and weed and insect management enabled, the likelihood of disease is reduced and volunteers are not an issue.

One common practice in Western Canada to control for disease and volunteers has been to limit canola in the crop rotation. Crop insurance agencies in Western Canada recommend that canola be seeded on a field at most once every four years to minimize insect populations and plant diseases from developing. While one might have assumed that the risk of volunteers might encourage farmers to lengthen their rotations, the CCC studies suggest that practice has remained relatively unchanged since 2000 (CCC, 2000, 2005). Producers generally seed canola on the same field every 3.5 years; in 2005 and in 2006 they seeded an average of 450 acres to canola. The survey identified that 41% of producers grow canola in a rotation of less than four years (Table 10). One reason for producers to ignore the crop insurance recommendations could be that the benefits of GMHT canola production are greater than the risk of having to spray an insecticide later in the crop season to control insects. The adoption of GMHT canola seems to have affected crop rotations in two distinct ways. First,

Table 11. Second-year spillover benefits per acre across Western Canada ($CAD).

	Alberta		Saskatchewan			
	Low	High	Low	High	Manitoba	Avg
# of producers	34	25	62	66	22	
Average	17.86	18.93	14.50	13.92	13.05	15.05
Lower value	15.91	16.40	13.29	12.87	11.65	14.40
Upper value	19.81	21.46	15.71	14.97	14.44	15.69

At the 95% confidence interval, margin of error is 8.4% for average and 14.8% or greater for rest.

26% of respondents reported that their crop rotation changed as a result of adoption. Some farmers have removed summerfallow from their rotations, while others are able to grow canola following another crop that previously would not have been an option. Second, in addition to changing rotations, these respondents reported that over the past decade, adoption of GMHT canola directly contributed to an additional 350 acres of their land being seeded to canola.

With canola grown in rotations shorter than four years, one must assume that the abiotic losses of the crop are offset by the increased security or profits from the production of GMHT canola. Use of a GMHT system lessens the risk of biotic losses from competition between the crop and weeds, a highly likely event in this crop in Western Canada, whereas abiotic or extreme environmental conditions such as drought, flooding, and frost are less likely events. Given production costs for GMHT canola are higher than for conventional canola (CCC, 2001), the mitigation of biotic risk and associated damage must be less than the risk and associated damage from potentially more serious—but less likely—abiotic stressors.

Multi-year Benefits

Improvements in weed control from GMHT canola can have a spillover effect on the same field from one year to the next. Producers were asked if they experienced any spillover benefits in terms of fewer weeds or easier weed control on fields that had been previously seeded to GMHT canola. Fifty-four percent reported a second-year benefit from the technology, and 63% of those reporting assigned an economic value to this benefit worth an average of $15.05/acre. Table 11 illustrates the range of benefits that accrue across the Prairie region, divided into benefits to producers with lower-than-average (low) and greater-than-average (high) levels of

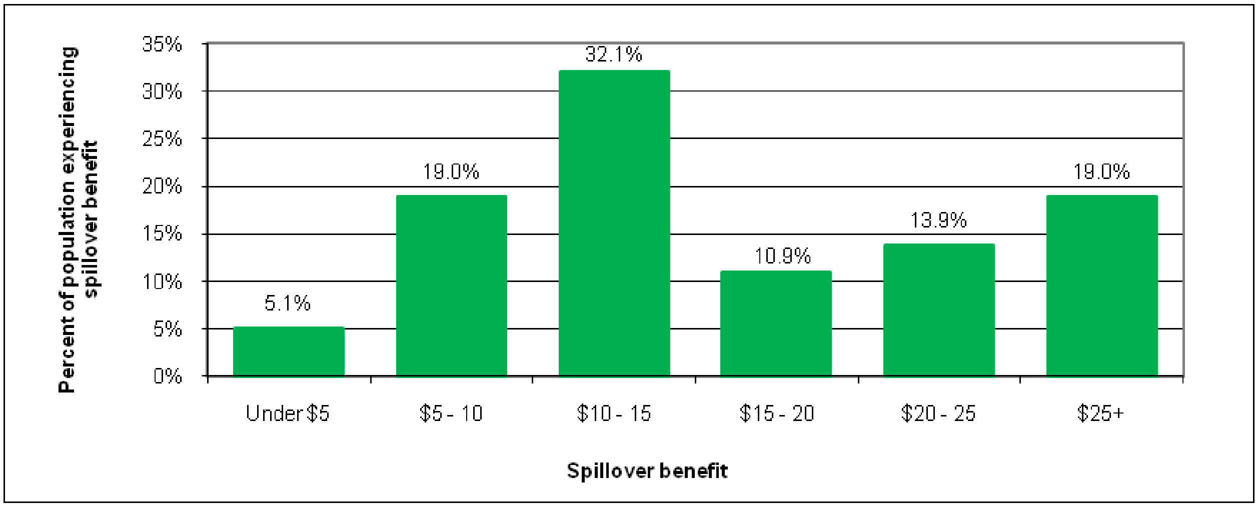

Figure 1. Estimated spillover benefits per acre.

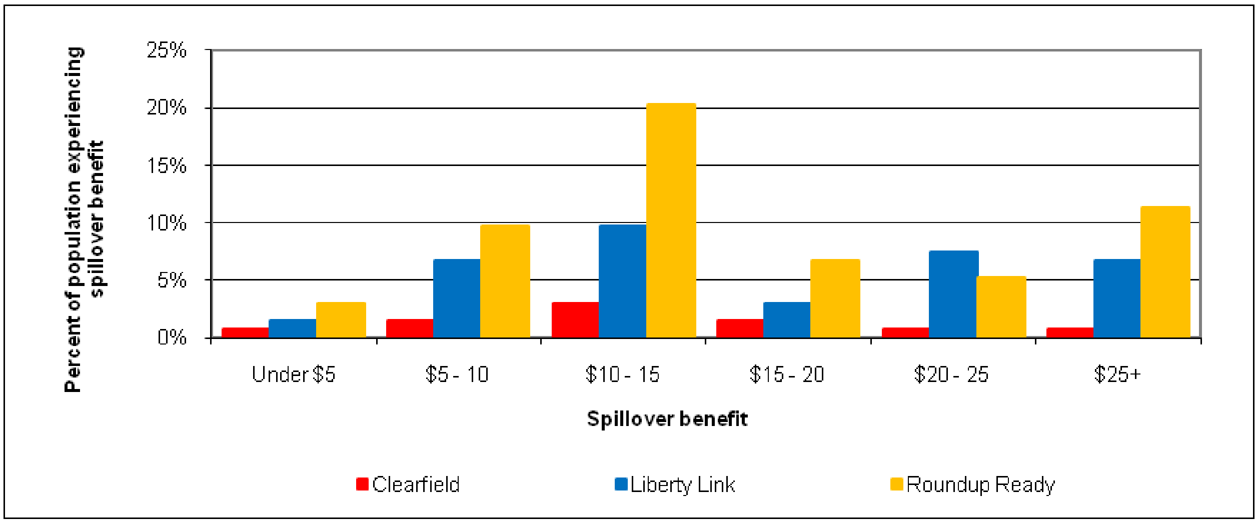

Figure 2. Incidence of spillover benefits by GMHT system used in 2006.

GMHT production. The Alberta low and high, the Saskatchewan low and high, and Manitoba correspond to the previously identified levels of production. The benefits reported by Alberta low and high producers are significantly higher than for the other regions. In Saskatchewan, it is the area identified as low in canola production that realizes the highest level of benefits. This area is along the western and southern areas of the province, areas that had little canola production prior to the commercialization of GMHT canola. Spillover benefits in Manitoba are lower than the other regions on average, but not significantly. These results would tend to suggest that the spillover benefits increase somewhat in the more western regions of the Canadian prairies.

While more than half (54%) of the producers reported spillover benefits between cropping years, the survey data also revealed a distribution of average spillover benefits according to the size of the benefit (Figure 1). While the most frequently reported (32%) benefits were in the $10-15 per acre range, one-fifth of producers identified spillover benefits that were in excess of $25/acre. Over 75% of the producers reporting spillovers estimated the benefit to be greater than $10/acre.

The particular GMHT canola system used by producers also had an influence on the magnitude of the spillover benefit reported by the producer (Figure 2). Producers using Roundup Ready™ canola reported higher spillover benefits compared with other canola systems, which is consistent with the greater level of adoption.

Table 12. Economic benefit of GMHT canola (2005-07; all figures in million $CAD).

Year	Acres	Direct	Spillover Low	Spillover High	Reduced tillage	Cost of volunteer control	Total benefits Low	Total benefits High
2005	12.6M	$141	$63	$103	$153	$14	$343	$383
2006	12.8M	$143	$64	$105	$153	$14	$346	$387
2007	14.8M	$165	$73	$121	$153	$17	$374	$422
Average	13.4M	$150	$67	$110	$153	$15	$354	$397

Summary of Economic Benefits for Producers

Previous surveys (CCC, 2001; Phillips, 2003) put the producer benefit of GMHT canola at $60-70 million in 2000. Neither study, however, attempted to calculate the impact of any spillovers or any increased costs from controlling volunteer canola. With the estimates from this survey, we can now modify those earlier estimates based on more detailed information.

The total producer benefit of GMHT canola can be represented as the direct economic impact of the technology, spillover benefits, and the value of reduced tillage, net of the increased cost for controlling volunteer canola. Phillips (2003) did not include reduced tillage as part of his calculations for direct benefits, hence their inclusion. This survey did not directly estimate the primary economic benefit of the technology to producers, but the data does verify that the benefits likely fall in the range of $10.62 to $11.14 per acre, as calculated by Phillips and the CCC (2001). Using the $11.14/acre benefit as a baseline, we can then consider the potential importance of the spillovers and volunteer control costs.

The direct benefit ($11.14/acre) is applied to the total acres cultivated in 2005, 2006, and 2007. Next, the low and high estimates[7] of the spillover benefits were applied to actual acres cultivated. The value of reduced tillage—$153.8M—can be added to each of the years. Finally, the additional cost of volunteer canola control cost[8] ($1.12/acre) was deducted from the total. Using the actual canola acreage for 2005-2007, we estimate that the total economic benefit from GMHT canola ranged from $343 million to $422 million per year (Table 12). Over the three year period, the average benefit was in the range of $354 million to $397 million per year.

In relative terms, the cost of volunteer canola control has a marginal impact on the technology. The reduction in total benefits is reduced by 4% on average per year. Much more important, however, are the spillover benefits, which account for 19% to 28% of the total net benefits of the new technology.

Conclusion

This study had three objectives: first, to examine weed control in GMHT canola, but more specifically to determine if herbicide resistance was developing; second, to identify if control of volunteer canola had changed following the widespread adoption of GMHT canola; and third, to attempt to quantify any multi-year producer spillover benefits.

Producers have experienced a change in weed pressures following the commercialization of GMHT canola. While not all producers believe that these new weed pressures were due to their adoption of GMHT canola, many did. Of those that believed the changes they faced in weed pressures were due to the adoption of GMHT canola, more than 94% indicated that the ease, cost, and practice of controlling for weeds was either unchanged or had improved. When asked specifically about the management of herbicide resistance in weed populations, a full 76% of respondents indicated that this was either the same or easier following their adoption of GMHT canola.

Nearly two-thirds (62%) of respondents indicated that the measures taken to control volunteer canola are no different than they were prior to the commercialization of GMHT canola. When asked about the difficulty of controlling volunteer canola, almost three-quarters (74%) indicated that this was the same or easier than it was pre-GMHT canola. A mere 8% of respondents indicated that they deemed volunteer canola to be one of the top five weeds that they need to control. Overall, the cost of controlling for volunteers makes only a minor impact on the producer benefits of adoption (i.e., it offsets less than 8% of the benefits of the technology).

7. *The range of low/high spillover estimates were calculated from the 54% of producers that realized some benefits, with 33% assigning a value of $15.05/acre, creating a range of spillover benefits when discounting for proportions of $4.97/acre to $8.19/acre.*
8. *The cost of controlling volunteer canola was reported by 26.6% of producers to average $4.23/acre. Allocating this cost across all cultivated acres results in an average per-acre cost of $1.12 for the entire prairie region.*

The attempt to quantify the reported spillover benefits produced one of the most surprising results. Our survey found that where they are observed, the spillover benefits are actually greater than the direct benefits. The average estimate of spillover benefits was $15 per acre compared to the direct benefit identified by Phillips (2003) of $11 per acre. While some producers did not report any multi-year benefits, the impact of those that did contributed between 19% and 28% of the net benefits to producers in the three years under review.

This under-reported and generally under-valued multi-year benefit may help to explain the reality that GMHT canola was almost fully adopted within six years. Neither the comparative cost of the conventional and GMHT systems nor the estimated direct economic impact of the technology upon adoption could fully explain the unparalleled adoption of this new technology. Producers had to be realizing some substantial economic benefits for which those earlier studies did not fully accounted. This study confirms that substantial economic benefits are recognized at the producer level. In farming, like any other business, operators use technologies that consistently deliver high returns. The sustained rates of adoption and expansion of the canola acreage in Western Canada are strongly correlated to the economic benefits identified by this survey.

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